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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 144 - Related to ESBWR Design Certification Application – RAI Number 21.6-69 Supplement 1**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by the Reference 1 NRC letter. GEH response to RAI Number 21.6-69 Supplement 1 is addressed in Enclosure 1.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. MFN 08-043, Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, *Request for Additional Information Letter No. 144 Related to the ESBWR Design Certification Application*, dated January 17, 2008.

Enclosure:

1. MFN 08-631 – Response to Portion of NRC Request for Additional Information Letter No. 144 - Related to ESBWR Design Certification Application – RAI Number 21.6-69 S01

cc:	AE Cubbage	USNRC (with enclosure)
	RE Brown	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
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Enclosure 1

MFN 08-631

Response to Portion of NRC Request for

Additional Information Letter No. 144

Related to ESBWR Design Certification Application

RAI Number 21.6-69 S01

NRC RAI 21.6-69 S01

The focus of the RAI is on the sensitivity of the MSLB / FWLB results to the PIRT multipliers, and the underlying phenomena, such as, radiolysis, and droplet entrainment into the PCCS condensers.

Concerning GEH's response to RAI 21.6-69, Part (b), it is necessary for the staff to validate the sensitivity of the phenomena identification and ranking table (PIRT) multipliers. In this regard, please address the following:

A. Provide a discussion of the dominant phenomena driving the predicted pressure profiles. Please include phenomena, such as the water droplets entrainment into the PCCS condenser, likely to significantly affect the containment pressure, considering the available margin to the containment design pressure at 72 hours. In more recent long term peak containment pressure calculations, core radiolysis appears to be an important process, and yet it was not identified in any PIRT or discussion within NEDC-33083P-A. Please include this process, or explain why this process should not be included in the containment PIRT.

B. Perform a sensitivity study to determine the limiting PIRT multipliers set for both feed water line break (FWLB) and main steam line break (MSLB); or provide the basis as to why a single multiplier set is applicable to both breaks.

C. DCD, Tier 2, Revision 4, Appendix 6B documents the Main Steam Line Break (MSLB) results, but it does not document the Main Feed Water Line Break (FWLB) results. Please include the corresponding FWLB results and their sensitivity to nodalization in the DCD or NEDE-32176P, TRACG Model Description, as background information for the short and long-term containment analyses. This documentation is necessary due to the design and modeling changes, such as the removal of the T-component in the lower DW (Figure 7-43, NEDE-32176P, Rev.3), and using the wider interconnecting pathways between the lower and upper dry well.

D. The staff also recommends the following editorial corrections to be made to NEDE-32176P, Rev.3, page 6-142, in Steam Condensation in Containment section.

> *The second line of the first paragraph should read ....designed for vertical plate condensation, in the viscous region., instead of ....designed for vertical plate condensation.*
>
> *The expression gcos(0o) = 0 is incorrect.*
>
> *The statement starting on the fourth line of the second paragraph (A comparison of the.....) is incomplete.*

GEH Response

(A) The following paragraphs provide the discussions of the dominant phenomena driving the predicted pressure profiles.

(A1) Key parameters affecting the long-term containment pressures

The key parameters that dominate the long-term containment pressures following a postulated Loss-of-Coolant Accident (LOCA) in the ESBWR design are: the suppression pool surface temperature, the wetwell (WW) gas temperature, and the total amount of non-condensable (NC) gases transferred into the WW.

The total pressure inside the WW is the sum of the partial steam pressure and the NC gas pressure. The WW partial steam pressure depends on the suppression pool surface temperature. The NC gas pressure in the WW, based on the perfect gas law, is proportional to the gas temperature and the total amount of NC gases in the WW. For long-term transient, the drywell (DW) pressure is slightly greater than the sum of WW pressure and the passive Containment Cooling System (PCCS) vent line submergence.

The processes and phenomena during a LOCA that affect these key parameters are discussed in the following paragraphs. To facilitate the discussions in Paragraphs A2 through A8, the results from the bounding case of Main Steam Line Break (MSLB) with 1 Depressurization Valve (DPV) failure and 2 cm^2 leakage area are used. The results of the MSLB and Feedwater Line Break (FWLB) are compared and discussed in Paragraph A9.

(A2) Overall LOCA sequence

The overall LOCA sequence can be divided into three periods: Blowdown period, Gravity Driven Cooling System (GDCS) period and the Long-term cooling PCCS period. These periods are shown in Figure 2.2-2 in NEDC-33083P. The sequence of events is similar for all the LOCA events, particularly after initiation of the GDCS flows, when the vessel and containment transients are coupled.

The Blowdown period is characterized by a rapid depressurization of the vessel through the break, Safety Relief Valves (SRVs) and DPVs. The steam blowdown from the break and DPVs pressurizes the DW, clearing the main containment vents and the PCCS vents. First, NC gases and then steam flow through the vents and into the suppression pool. The steam is condensed in the pool and the NC gases collect in the WW gas space above the pool. At about 650 s, the pressure difference between the vessel and the wetwell is small enough to enable flow from the GDCS pools to enter the vessel. This marks the beginning of the GDCS period.

During the GDCS period, the GDCS pools drain their inventory. The GDCS flow fills the vessel to the elevation of the break, after which the excess GDCS flow spills over into the drywell annulus. The GDCS period is characterized by condensation of steam in the vessel and drywell, depressurization of the vessel and DW and possible openings of the vacuum breakers, which returns small amount of NC gases from the WW gas space to the DW. The decay heat eventually overcomes the subcooling in the GDCS water added to the vessel and boiloff resumes. The DW pressure rises until flow is reestablished through the PCCS. This marks the beginning of the Long-term PCCS cooling period.

During the Long-term PCCS cooling period, the steam generated by the decay heat in the vessel enters into the DW and mixes with the NC gases in the DW. This mixture enters into the PCCS, where the steam is condensed and the decay heat is rejected to the IC/PCCS pool. Condensate from the PCCS is recycled back into the vessel through the PCCS drain lines. The NC gases are purged into the WW.

(A3) Short-term responses

Figure 6.2-14a3 (DCD Rev. 5) shows the short-term pressures for the bounding MSLB with 1 DPV failure. The blowdown phase determines the initial pressurization. During the GDCS phase the pressure levels off and decreases as the GDCS temporarily stops inventory boil off from the vessel and eventually spills over into the DW, condensing steam in the DW. At the end of GDCS period, the steaming resumes. The PCCS takes up the decay heat load and purges the remaining NC gases from the DW into the WW.

The blowdown phase also determines the initial heatup of the suppression pool water (Figure 6.2-14b1, DCD Rev. 5). After the blowdown and GDCS period, the water temperature at the pool surface remains relatively flat through out the rest of the transient.

(A4) Long-term responses

Shortly after the GDCS period, the PCCS resumes the function of decay heat removal and purges the remaining NC gases from the DW to the WW. The remaining NC gases in the DW include those returned from the WW during the vacuum breakers openings, the remaining amount of NC gases not purged during the blowdown period, NC gases hiding out in the DW head gas space and GDCS pool gas space, and the radiolytic gases generated in the core.

Figures 6.2-14d1 and 6.2-14a1 (DCD Rev. 5) show the NC gases pressures in different DW regions and the containment pressures, for the bounding MSLB with 1 DPV failure. Most of the NC gases in the DW annulus are purged into the WW in about 3 hours (Figure 6.2-14d1). As a result, the DW and WW pressures show a large increase due the addition of NC gases in the WW (Figure 6.2-14a1). From 4 to 72 hrs, the containment pressures increase linearly (more or less) with time. This increase is due to two factors; (1) the continued purging of NC gases (the radiolytic gases and the hide-out gases) from the DW into the WW, leading to continued and gradual increase of total NC gas mass inside the WW, and (2) the continued increase of gas temperature in the WW (See discussion in Paragraph A7). During this time period, the DW pressure is higher than the WW pressure by the amount corresponding to the PCCS vent submergence (Figure 6.2-14a1). This pressure differential indicates the continued process of purging NC gases from the DW to the WW.

At 72 hrs, there is a small amount of NC gases hiding out in the DW head and GDCS gas spaces (Figure 6.2-14d1). The maximum DW pressure at 72 hrs is estimated by assuming that all residue NC gas mass in the DW regions is purged completely into the WW (see footnote in Table 6.2-5, DCD Rev. 5).

(A5) Long-term PCCS operation

The total heat removal capacity for the PCCS at rated condition is 66 MW (Table 6.2-10, DCD Rev. 5). The capacity could be degraded depending on the NC gas mass fraction in the mixture entering into the PCCS. For the MSLB case, most of the NC gases in the DW annulus are purged into the WW in about 3 hrs (Figure 6.2-14d1, DCD Rev. 5), and the NC gas mass fraction entering into the PCCS is very low after that time. A comparison to the decay heat (Figure 6.2-14c1, DCD Rev. 5) shows that the PCCS is over capacity starting at about 3 hrs. Under this over capacity condition, the PCCS regulates the heat removal rate to match decay heat by accumulating NC gases in the lower part of the PCCS tubes.

The primary parameters that drive the self-regulation process are the DW pressure, the incoming NC gases, and the decay heat. For example, a small increase in NC gas accumulation (from the incoming mixture) will reduce the PCCS condensation capacity, leading to lesser DW steam being condensed and higher DW pressure. A small increase in the DW pressure will cause some NC gases in the lower part to be pushed through the PCCS vent into the WW. This increases the PCCS heat removal, condenses more DW steam and equilibrium is reestablished with the DW conditions.

It should be noted that the total PCCS tubes volume is ~ 11 m^3, which is very small comparing to the total DW volume (~7210 m^3). And, it takes an equally small amount of NC gas mass to conduct the self-regulation process in the PCCS.

It should be also noted that, during the time period with over capacity in the PCCS, only the NC gases are purged into the suppression pool and WW. There is no bypass of uncondensed steam (of any significant amount) to the suppression pool.

(A6) Radiolytic Gases

The ESBWR analysis considers the contribution of radiolytic gases (Section 6.2.1.1.3.2, DCD Rev. 5). Appendix A of SRP Subsection 6.2.5 provides a conservative methodology for calculation of radiolytic gases generation. The generation rate used in the analysis was developed in a manner that is consistent with the guidance provided in SRP 6.2.5 and RG 1.7. The generation rate depends on the reactor decay power profile that decreases rapidly over time.

The core radiolysis provides a continuous, added source of NC gases to the DW. The radiolytic gases mix with steam and the NC gases in the DW (mostly from the hideout regions), enters into the PCCS and transfers into the WW. Because the PCCS is over capacity during that time period, this addition does not affect the long-term PCCS performance.

Since the generation rate is already conservative and the radiolytic gases do not affect the long-term PCCS performance, the process of radiolytic gas generation does not need to be included in the containment Phenomena Identification and Ranking Tables (PIRT).

(A7) WW Gas Temperature

Figure 6.2-14b1 (DCD Rev. 5) shows the WW gas temperature at the ceiling location. The gas temperature increases gradually over time. At 72 hrs, the WW gas temperature reaches 126 C. The key factor that causes the WW temperature increase is the bypass leakage from the DW to the WW.

In the calculation, it is assumed that there exists a leakage path between the DW and the WW. This leakage path allows DW hot steam/NC gases mixture to leak from the DW to the top of WW. The diaphragm floor is supported by array of I-beams (of 1 m in height), located at the top of WW. The model conservatively assumes that the hot gas mixture stays at the top of WW (in the gas space between the I-beams) and does not mix with the gases in the lower part of the WW. Furthermore, no credit is taken for the heat sink effect through the diaphragm floor.

A comparison of Figures 6.2-14b1 (2 cm^2 leakage area, DCD Rev. 5) and Figure 6I-1b1 (1 cm^2 leakage area, DCD Rev. 5) shows the effect of leakage area on the WW gas temperature. Larger leakage area leads to higher WW temperature and higher containment pressure.

Results of parametric study (Appendix 6H, DCD Rev. 5) show that the containment pressure margin would improve about 3% if the gases were allowed to mix between the top layer and the lower part in the WW.

Other factors that affect the WW gas temperature are the heat transfer to the vertical walls (the vertical wall between the DW and WW, and the vertical outer wall) and the diaphragm floor (WW ceiling). Results of parametric study (Appendix 6H, DCD Rev. 5) show that the heat transfer to the vertical walls has secondary effect on the long-term pressure. The heat transfer to the diaphragm, however, is expected to have some reasonable reduction on the WW gas temperature and pressure. Since the WW gas temperature is higher than 100 C for a large period of time (Figure 6.2-14b1, DCD Rev. 5), and the diaphragm floor is in contact with the GDCS pool water, which is below or at around 100 C.

(A8) Water droplets entrainment into the PCCS

The calculated results show that there are no significant water droplets at the PCCS inlet location during the LOCA transient. Paragraphs A1.6 and A2.8 in MFN 08-011, Response to RAI 6.2-98 S01 provide more discussions and figures related to this item.

(A9) Comparison of MSLB and FWLB

The results of the bounding MSLB and FWLB (with 1 DPV failure and 2 cm2 leakage area) are presented in Figures 6.2-14a1 to 6.2-14d3 and Figures 6.2-13a1 to 6.2-13d3 (DCD Rev. 5), respectively. The DW pressures, suppression pool surface and WW gas temperatures from these two cases are compared and discussed in the following paragraphs.

The key factors that affect the long-term DW pressure are the suppression pool surface temperature, the total amount of NC gases transferred into the WW and the WW gas temperature. The suppression pool surface temperature affects the partial steam pressure in the WW, and consequently the WW and DW pressures. Figures 21.6-69S01-1 to 21.6-69S01-4 compare the DW pressures, suppression pool surface and WW gas temperatures, and the total NC gas mass in the WW from these two cases.

During the blowdown period, steam from the break and DPVs blows down first into the DW and then through the main containment vents and PCCS vents into the suppression pool. The heatup in the suppression pool water for the MSLB case is higher than that for the FWLB case (Figure 21.6-69S01-2). The same temperature difference between these two cases is maintained (more or less) for the rest of the 72 hours transient.

Figure 21.6-69S01-3 compares the WW gas temperatures from these two cases. As a result of higher suppression pool surface temperature, the WW gas temperature is a few degrees higher in the MSLB case than that in the FWLB case. Higher WW gas temperature and suppression pool surface temperature lead to higher WW and DW pressures for the MSLB case.

Figure 21.6-69S01-4 compares the total NC gas mass in the WW from these two cases. For both cases a significant amount of NC gases initially in the DW is transferred into the WW during the blowdown period. During the GDCS period, the GDCS pools drain their inventory. The volume created by GDCS draining creates a hideout volume for the remaining NC gas in the DW. This volume for the FWLB case is larger and deeper than that for the MSLB case. As a result, more NC gases can hide in the drain down volume for longer time period in the FWLB case. Figure 21.6-69S01-4 shows that the total NC gas masses in the WW for both cases increase gradually over the long-term PCCS cooling period, and the NC gas mass for the MSLB case is slightly larger than that for the FWLB case, due to lesser amount of NC gases hiding out in the GDCS drain down volume.

Figure 21.6-69S01-1 compares the DW pressures from these two cases. This figure shows that the pressure responses are similar in these cases, i.e., increase gradually over time during the long-term PCCS cooling period. The DW pressure for the MSLB case is higher than that for the FWLB. This is the result of higher suppression pool surface temperature, higher WW gas temperature, and larger amount of total NC gas mass in the WW.

These figures show that the containment responses for these two cases are very similar in nature during the blowdown period, the GDCS period, and the long-term PCCS cooling period. It should be noted that the impact of hideout NC gases on the DW pressure is accounted for as follow. The maximum DW pressure at 72 hrs is estimated by assuming that all residue NC gas mass in the DW regions is purged completely into the WW (see footnote in Table 6.2-5, DCD Rev. 5).

(B) The Phenomena Identification and Ranking Tables (PIRTs) are discussed in Section 3.2 in NEDC-33083P. The PIRT development is based on the review of the scenarios of various LOCA events, including large and small breaks. The scenarios stress on the phenomenological evolution of the transients, such as the short-term blowdown period and GDCS period, and long-term PCCS cooling period. Interdisciplinary teams review the scenarios, identify PIRTs, and rank the PIRTs with respect to their impact on the critical safety parameters (i.e., containment pressure). For example, the WW pressure is determined by the blowdown flow, NC gases transport from the DW, suppression pool stratification, and PCCS heat removal.

Since the development of PIRTs covers the scenarios of both large and small breaks, and the containment responses for the MSLB and FWLB cases are very similar in nature during the blowdown period, the GDCS period, and the long-term PCCS cooling period (Paragraph A9). As a result, the single multiplier set of PIRT is applicable to both the MSLB and FWLB breaks.

(C) Appendix 6B (DCD Rev. 4) provides the justification for the use of the DCD nodalization (DCD Rev. 5, Figures 6.2-6 and 6.2-7), including the results of the tie-back calculations using the DCD nodalization and the nodalizations presented in the TRACG Application Report (NEDC-33083P). The main steam line break is used in the tie-back calculations. The major change in the containment nodalization is the use of more VSSL cells to model the lower DW, replacing the TEE-component. The results show that: (1) modeling the lower DW with VSSL cells leads to a shorter time period for the NC gases initially stored in the DW to purge, and (2) the effect of purging time period on the long-term DW pressure is small because the PCCS is over capacity in a few hours after the LOCA.

This conclusion is applicable to both the MSLB and FWLB breaks, since the containment responses for the MSLB and FWLB cases are very similar in nature during the blowdown period, the GDCS period, and the long-term PCCS cooling period (Paragraph A9). The impact of the hideout NC gases in different DW regions on the DW pressure is accounted for in the estimated maximum DW pressure at 72 hours.

(D) The editorial comments to NEDE-32176P, Rev. 3, page 6-142 (also applied to NEDE-32176P, Rev. 4) will be considered in the next update to the report.

DCD Impact

No DCD changes will be made in response to this RAI.

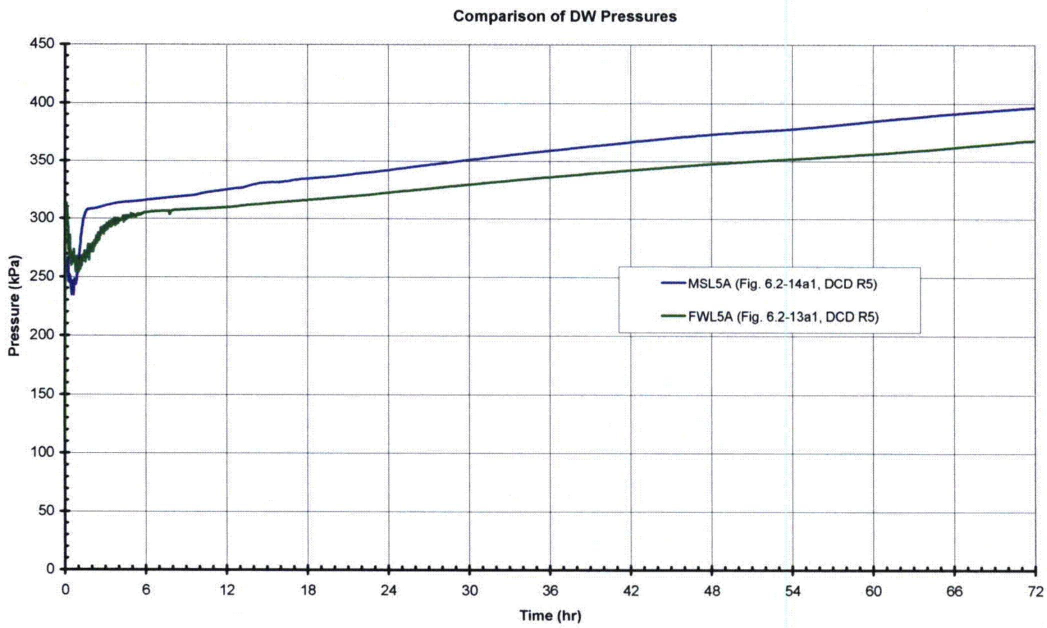

Figure 21.6-69S01-1. Comparison of DW Pressures

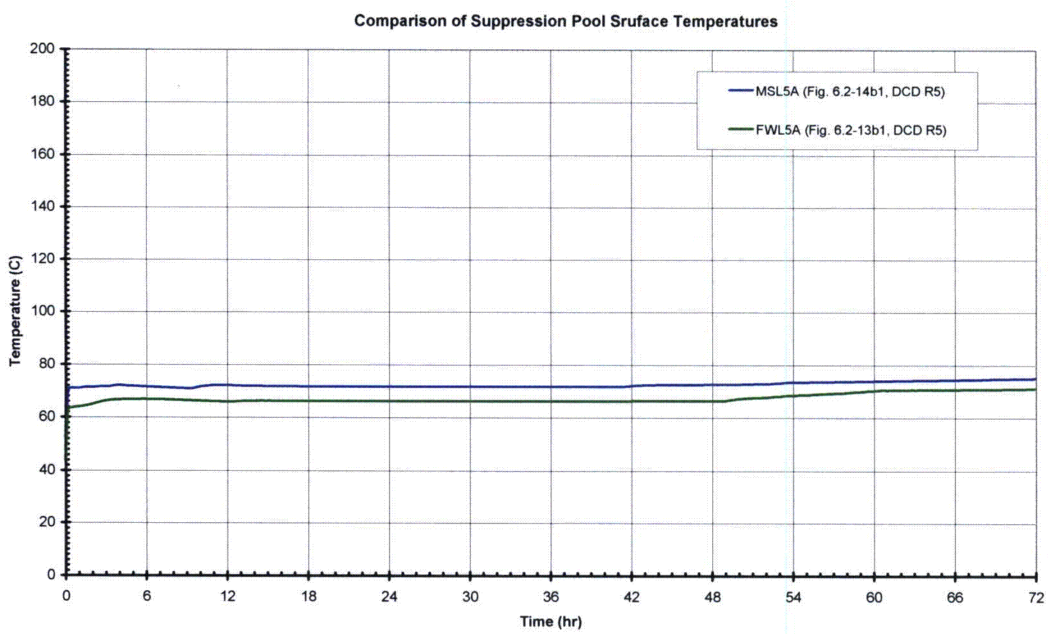

Figure 21.6-69S01-2. Comparison of Suppression Pool Surface Temperatures

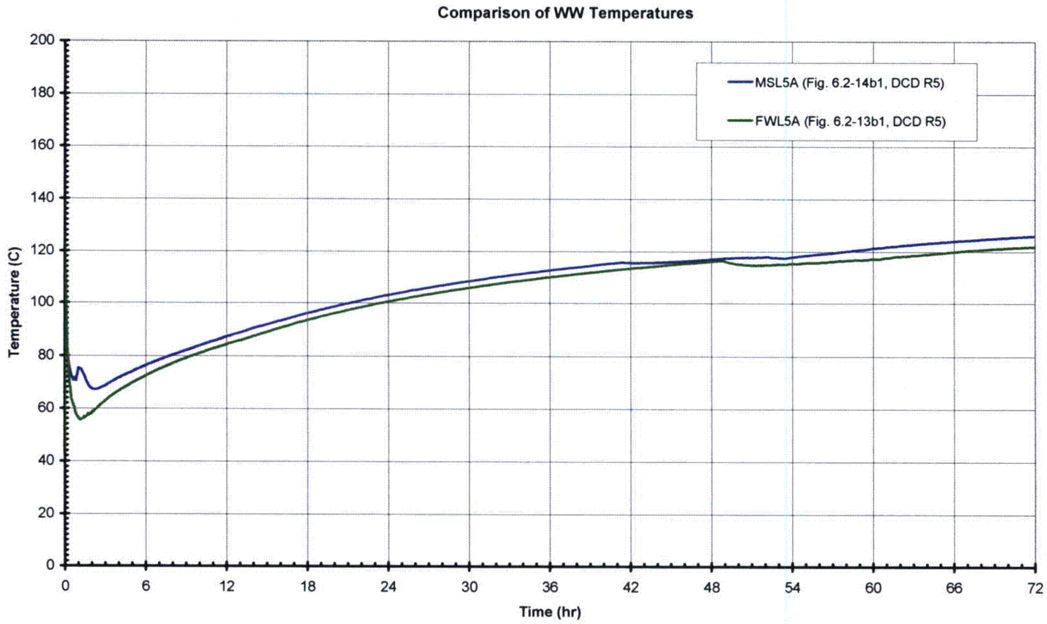

Figure 21.6-69S01-3. Comparison of WW Gas Temperatures

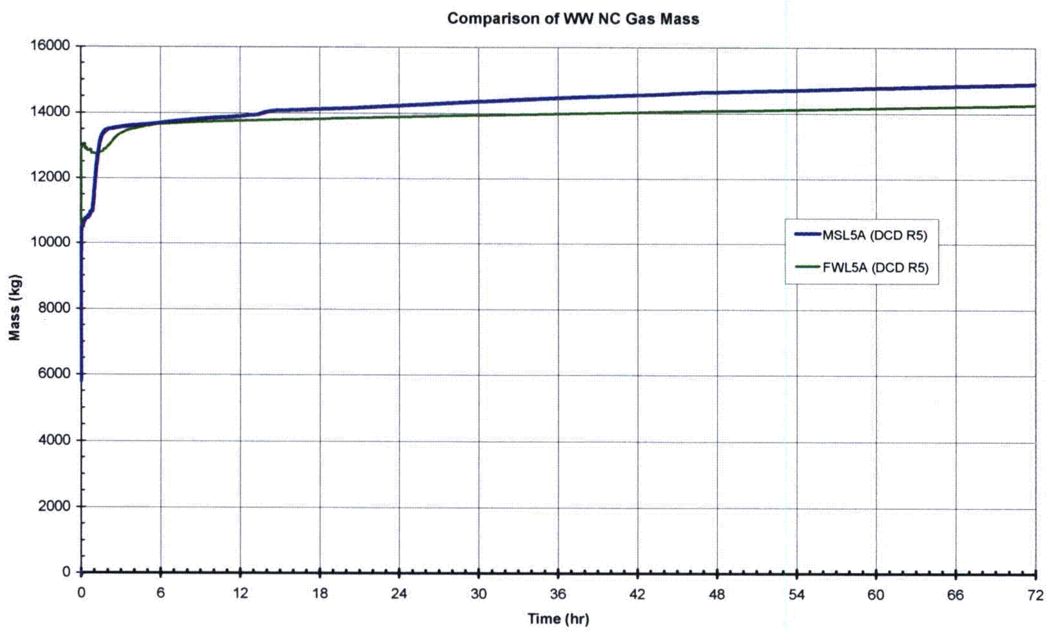

Figure 21.6-69S01-4. Comparison of WW NC Gas Mass