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Your ref: Docket No. 52-006
Our ref: DCP/NRC1582

April 28, 2003

SUBJECT: Transmittal of Westinghouse Responses to US NRC Requests for Additional Information on the AP1000 Application for Design Certification

This letter transmits the Westinghouse responses to NRC Requests for Additional Information (RAI) regarding our application for Design Certification of the AP1000 Standard Plant. A list of the RAI responses that are transmitted with this letter is provided in Attachment 1. Attachment 2 provides the RAI responses.

Please contact me if you have questions regarding this submittal.

Very truly yours,

M. M. Corletti
Passive Plant Projects & Development
AP600 & AP1000 Projects

/Attachments

1. Table 1, "List of Westinghouse's Responses to RAIs Transmitted in DCP/NRC1582"
2. Westinghouse Non-Proprietary Response to US Nuclear Regulatory Commission Requests for Additional Information dated April 2003

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DCP/NRC1582

April 28, 2003

Attachment 1

"List of Westinghouse's Responses to RAIs Transmitted in DCP/NRC1582"

Attachment 1

Table 1 **"List of Westinghouse's Responses to RAIs Transmitted in DCP/NRC1582"**
440.173, Rev. 2

DCP/NRC1582

April 28, 2003

Attachment 2

Westinghouse Non-Proprietary Response to US Nuclear Regulatory Commission Requests for Additional Information dated April 2003

AP1000 DESIGN CERTIFICATION REVIEW

Response to Request For Additional Information

RAI Number: 440.173 (Response Revision 2)

Question:

Please provide additional information on the simulations reported in Section A.4 on sensitivity studies on upper plenum entrainment rate and interfacial drag. In particular, show:

(a) Axial continuous liquid and steam flow rates into the upper plenum cell(s).

(b) Void fraction in each of the upper plenum cell(s).

(c) Collapsed liquid level in the upper plenum.

(d) Lateral flows (WLM, WEM, and WGM) into each hot leg from the upper plenum.

(e) Axial continuous and entrained liquid flows, and steam flow in the upper plenum at the bottom of the hot legs, and also the entrained drop size.

NRC Additional Comment on Revision 0 Response:

The original transmittal was missing Figures identified as items 2 through 6 below. These are included in Revision 1 response.

Westinghouse Response: (Revision 1)

The requested plots are provided for the sensitivity study cases in this order:

1. Base Case upper plenum model (Figures 440.173-1 through 20)
2. 1.3 * upper plenum interfacial drag (Figures 440.173-1a through 20a)
3. 0.65 * upper plenum interfacial drag (Figures 440.173-1b through 20b)
4. 0.5 * upper plenum entrainment rate (Figures 440.173-1c through 20c)
5. 2.0 * upper plenum entrainment rate (Figures 440.173-1d through 20d)
6. 4.0 * upper plenum entrainment rate (Figures 440.173-1e through 20e)

The sequence of the plots for each case follows the order listed in the question. The time scales correspond to the scale of the WCAP-15833 Section A.4 figures, and the Base Case model is the three vertical cell upper plenum representation case from Section A.4.

In interpreting the plots, please recall that there are [

]^{a,c} the bottom elevation of the hot legs. The entrained droplet size is provided in the top cells of Channels 15 and 47 and also the bottom cell 2 of Channel 20.

Each of these cases exhibits a liquid circulation pattern in the upper plenum, but the magnitude varies. Both the continuous and entrained liquid fields show a positive flow upward at the hot leg elevation in Channel 15, together with a downward flow of continuous and entrained liquid fields in the Channel 47 junction. In all cases, the magnitude of these liquid flows is greatest at the opening of the first ADS-4 valve, and diminishes thereafter.

NRC Additional Comment on Revision 1 Response:

The original transmittal was missing Figures identified as items 2 through 6 below. In the most recent Westinghouse response, dated February 14, 2003, a complete series of figures were provided for the simulations reported in Section A.4 of WCAP-15833. They show the effect of varying the entrainment rate in WCOBRA/TRAC simulations of AP1000 for an Inadvertent ADS Actuation transient. The February 14, 2003 response satisfies the original request; however, a review of this new information leads to some new questions.

Provide additional details and explain the calculations affecting de-entrainment and circulation patterns in the upper plenum and other regions of the vessel, if necessary. For example, consider the Base Case. After about 130 seconds, the collapsed liquid level in the upper plenum stabilizes at a nominal level of about 1.0 ft. Most of the upper plenum liquid appears to reside in the outer global Channel 47. Water that is entrained in Channel 15 flows through Gaps 21 and 24 to the hot legs. De-entrainment occurs along this path, as evidenced by the fact that the Gap flows consist of both continuous and entrained liquid. After 130 seconds, there is effectively no continuous liquid flow at the top of Channel 47. That is, de-entrainment has little effect on the upper plenum inventory in this case, as liquid entrained in Channel 15 finds its way to the hot legs.

In the 4.0*Entrainment case however, de-entrainment plays a more important role in maintaining a level in the upper plenum. The Gap flows to the hot legs consist mainly of entrained drops. The continuous liquid flow is small with several "spikes." At least periodically, liquid now falls back into Channel 47 as entrained drops. (With the scale in Figure 440.173-18e, it is difficult to determine if the flow rate is zero or a small negative value for t > 130 seconds.)

Is the sensitivity to entrainment small because the net effect is negated by additional de-entrainment? If not, please provide justification that the de-entrainment fractions observed in these sensitivities is adequate. In addition, please provide information on flow from the core to the upper plenum. The flow has considerable oscillation, and conditions in the upper plenum may depend more on the process of continuous liquid flow at the top of Channel 10 rather than on the upper plenum region calculations. Include a figure of the collapsed liquid level in the core, in your response.

Westinghouse Response: (Revision 2)

The original transmittal was missing the requested Figures identified as items 2 through 6 below. These were included in the Revision 1 response and are not repeated in the Revision 2 response. As discussed in the NRC additional comments, the Revision 1 response satisfies the original request. The following discussion addresses the new questions contained in the NRC Additional Comments on Revision 1 Response.

The WCOBRA/TRAC cases investigating the sensitivity to entrainment in WCAP-15833 show only small changes in results from increasing the calculated entrainment rate in the upper plenum to 4.0* the base code-calculated value. Through 125 seconds the reactor vessel mass inventories of the base case and the [4 x rate] case are approximately the same, as shown in Figure 440.173R2-1. It is between 125 and 140 seconds that a difference in reactor vessel mass inventory appears, and it occurs in the upper plenum. Figure 440.173R2-2 compares the upper plenum collapsed liquid levels and indicates that the mass inventory differential occurs there at that time. Figures 440.173R2-3 and -4, the core and downcomer collapsed level plots for the two cases, exhibit very similar decreases / increases in inventory overall for the two entrainment rates during the ADS-4 IRWST initiation phase transient until IRWST injection is established at 170 seconds. Shortly after 140 seconds, the core collapsed liquid level is slightly higher for the [4 x rate] case than the base case for a while. Figure 440.173R2-2 indicates that during this same time period the upper plenum inventory is a bit lower in the [4 x rate] case than in the base case. This slight inner vessel mass redistribution is due to a spurt of increased steam flow from the lower half of the core in the base case.

The impact of the calculated upper plenum entrainment rate upon these two cases is small because up until 125 seconds, the total liquid mass flow rates out the hot legs are approximately equal. The integrated flows of the entrained fields from the two cases are shown in Figure 440.173R2-5. Figure 440.173R2-6 shows that up to 70 seconds the higher entrained flow into the hot legs in the [4 x rate] case results in increased back flow of continuous liquid to the upper plenum. Up until 125 seconds, the higher entrained flow in the [4 x rate] case is offset by the greater continuous liquid field flow into the hot legs in the base case (Figure 440.173R2-6), so the total liquid flow rates into the hot legs are approximately the same. The upper plenum masses are also about the same at 125 seconds. The liquid present in the lower two cells of upper plenum channel 15 is primarily continuous liquid (Figure 440.173R2-7) in the base case, whereas in the [4 x rate] case the liquid content of the lower two cells of channel 15 is mostly entrained droplets (Figure 440.173R2-8). The same condition exists in upper plenum Channel 47 at 125 seconds (Figures 440.173R2-9 and -10). Over the next 15 seconds, the same behaviors occur in both cases in these channels; continuous liquid fractions remain constant or even increase a bit, while the entrained droplet mass decreases markedly. The continuous liquid flow exiting Channel 15 is about zero in both cases (Figure 440.173-14 and Figure 440.173-14e) but the entrained liquid flow continues (Figure 440.173-15 and Figure 440.173-15e). Therefore, as a consequence of which liquid field is present, the base case retains most of its upper plenum liquid over the 125-140 second time span, but the [4 x rate] case upper plenum liquid inventory is reduced somewhat. Flow through gaps 21 and 24 into the hot legs is

taken from channel 20 of the WCOBRA/TRAC model, located in the section immediately above Channels 15 and 47. The flow of entrained liquid at the top of the upper plenum global channel 47 in the [4 x rate] case (shown in Figure 440.173-18e as cited in the NRC staff comments) occurs simply because more entrained drops are present in the Channel 20 cell adjacent to Channel 47 (Figure 440.173R2-11). Figure 440.173R2-12 shows the Channel 20 overall de-entrainment rates for the two cases during the ADS-4 IRWST initiation phase transient. The de-entrainment rate is notably higher prior to 125 seconds in the [4 x rate] case, as expected. However, during the 125-140 second time interval, the net de-entrainment rate in Channel 20 is about the same for each of these cases.

The prediction of de-entrainment in the upper plenum has been minimized via input in both of these cases. The de-entrainment prediction in the upper plenum is not particularly important prior to 125 seconds because the liquid flow into the hot legs occurs as both entrained and continuous liquid fields. The vessel mass inventory effect at 125-140 seconds occurs because the upper plenum liquid inventory is primarily entrained liquid droplets in the [4 x rate] case, which are depleted through the hot legs; in contrast, the continuous liquid present in the upper plenum in the base case is unaffected. De-entrainment in Channel 20 in both the base case and the [4 x rate] case between 125-140 seconds occurs at about the same rate and does not have a large effect on the entrained flow into the hot legs. It appears that the small pressure differential that exists between the vessel and the containment after 125 seconds is more able to discharge entrained droplets from the upper plenum than the continuous liquid field.

The core continuous liquid flow rates into the upper plenum are compared in Figure 440.173R2-13, and an integral comparison plot of these flow rates is shown as Figure 440.173R2-14. The values from the base case and the [4 x rate] case are very similar over the course of the ADS-4 IRWST initiation phase transient until IRWST injection is established at 170 seconds. It does not appear that the entry flow from the core is dictating the predicted mass inventory behavior in the upper plenum in these cases.

Design Control Document (DCD) Revision:

None

PRA Revision:

None

WCAP Revision:

Westinghouse will update WCAP-15833 to include an Appendix containing the RAI responses related to WCAP-15833. Therefore the additional figures contained in the Revision 1 and Revision 2 responses will be included in the WCAP-15833.

Figure 440.173R2 -1

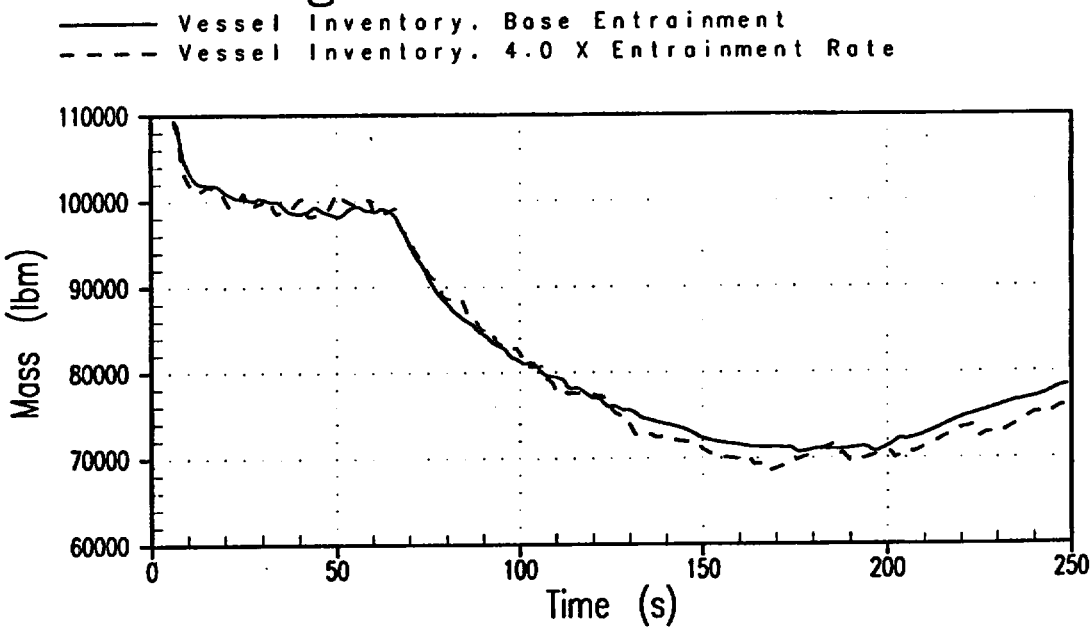

Figure 440.173R2 -2

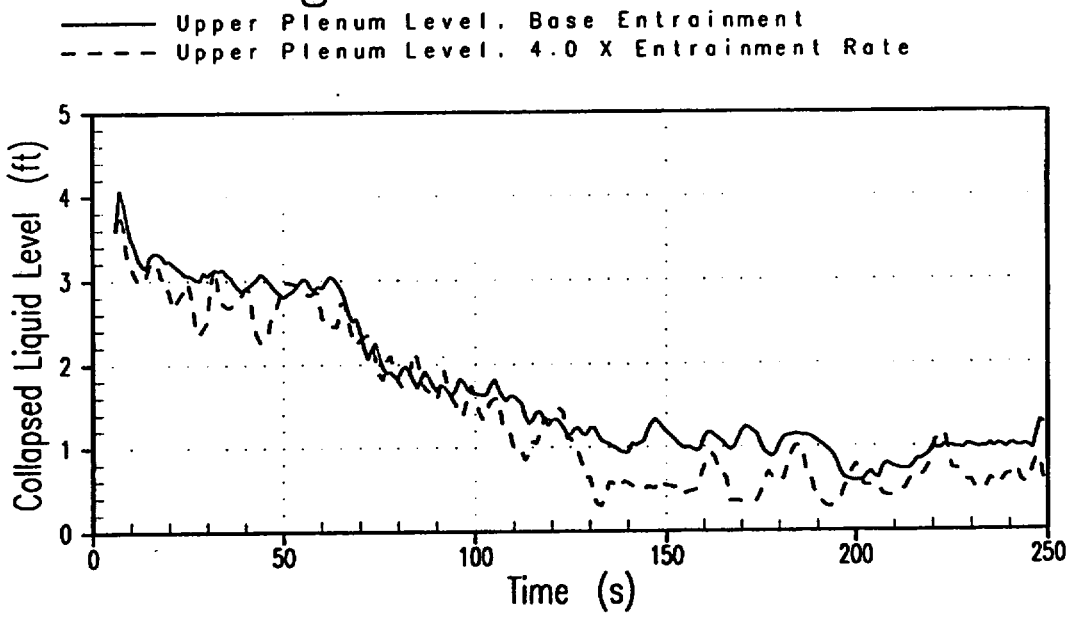

Figure 440.173R2 -3

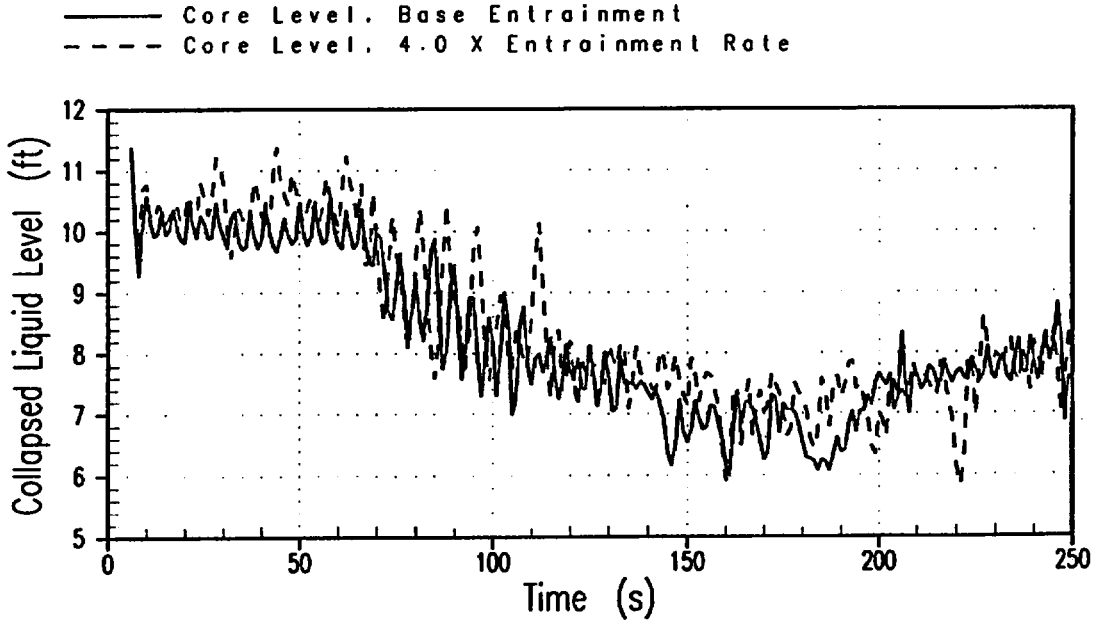

Figure 440.173R2 -4

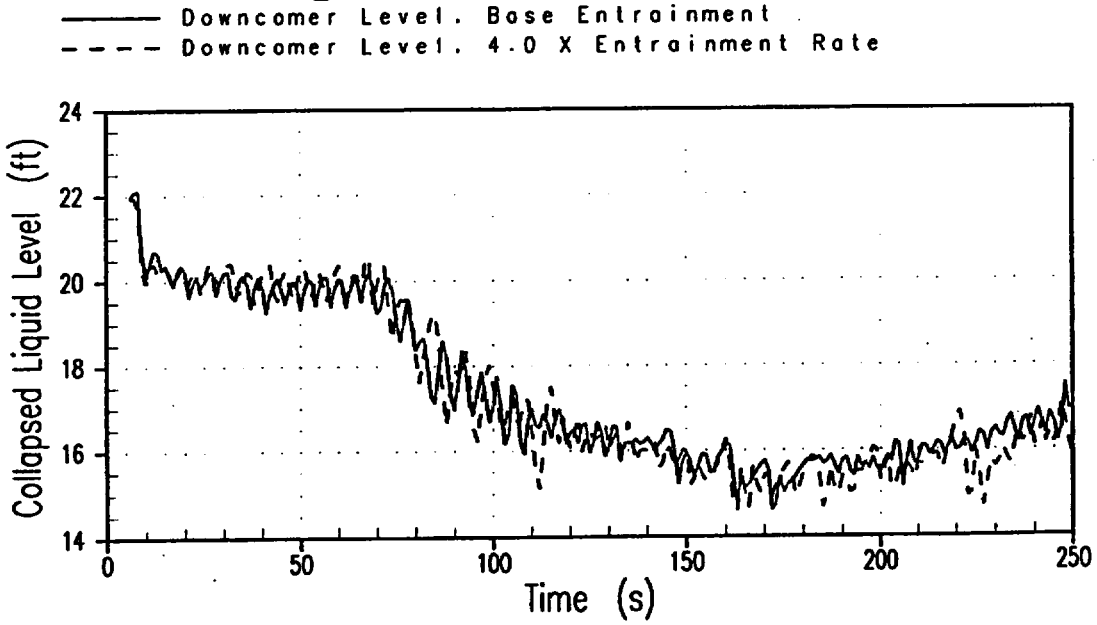

Figure 440.173R2 -5

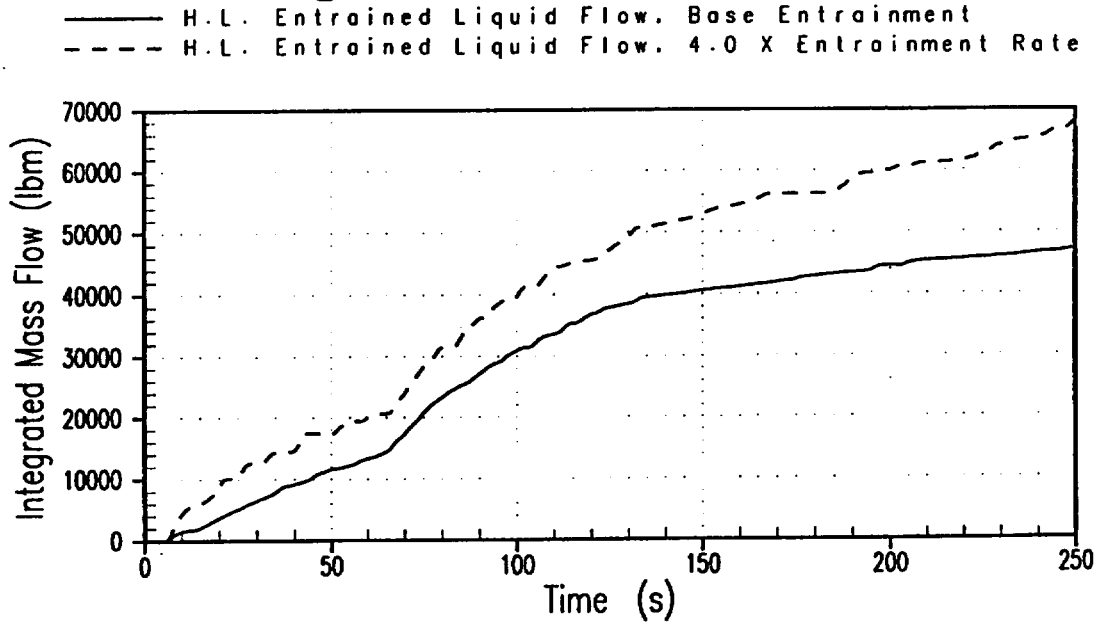

Figure 440.173R2 -6

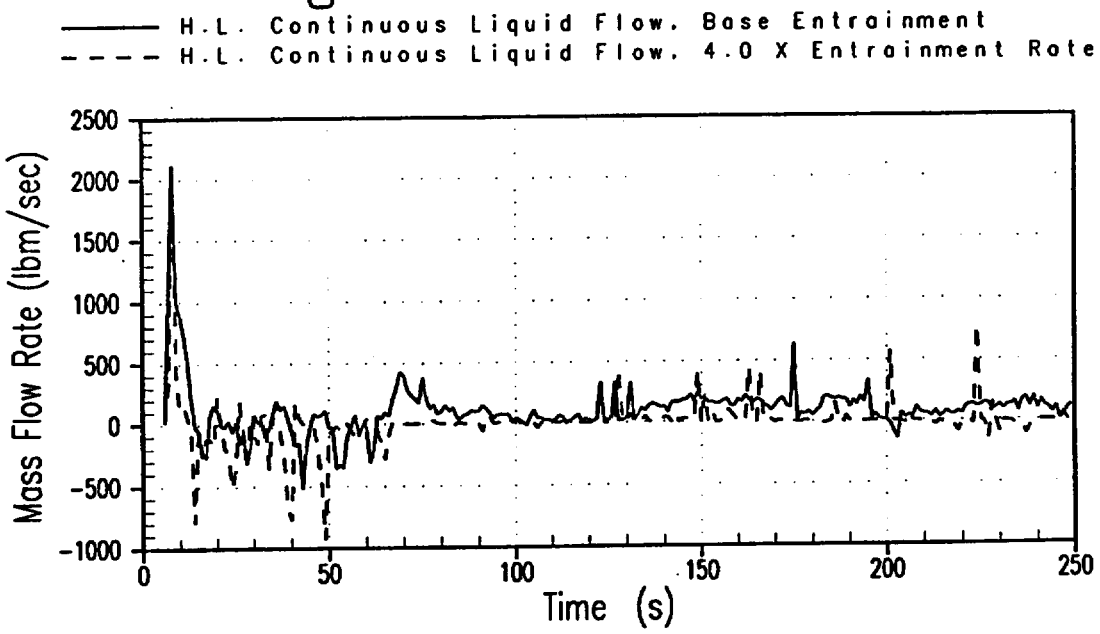

Figure 440.173R2 -7

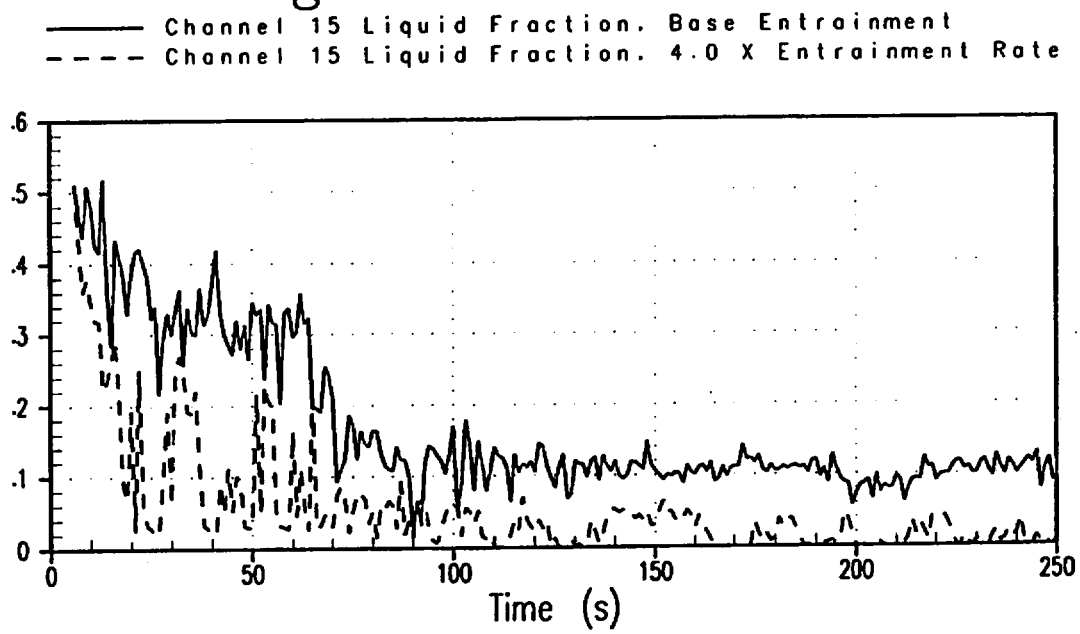

Figure 440.173R2-8

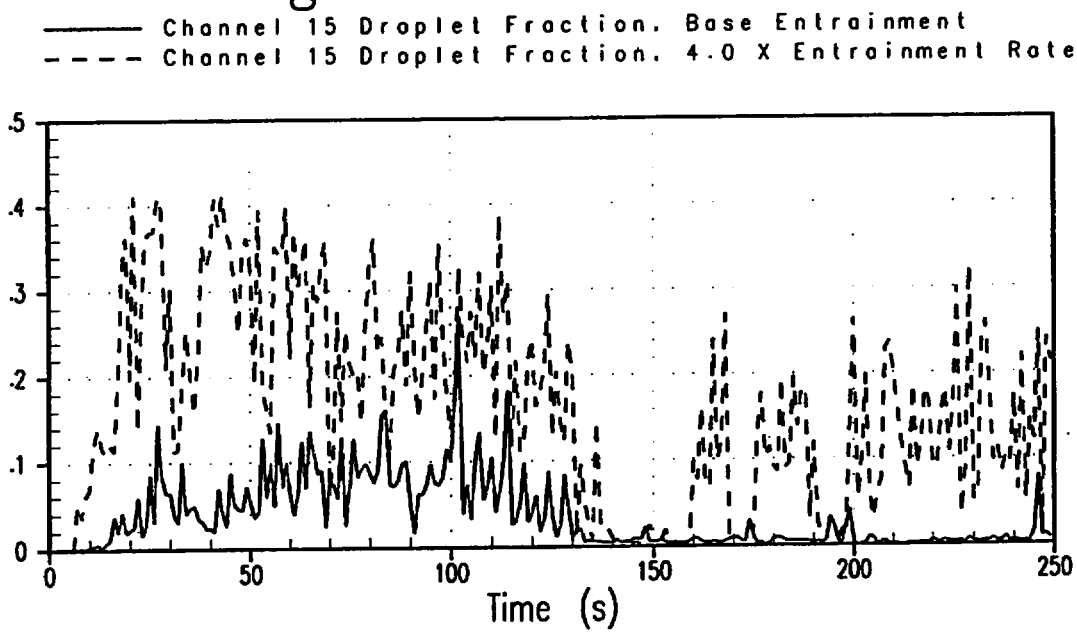

Figure440.173R2-9

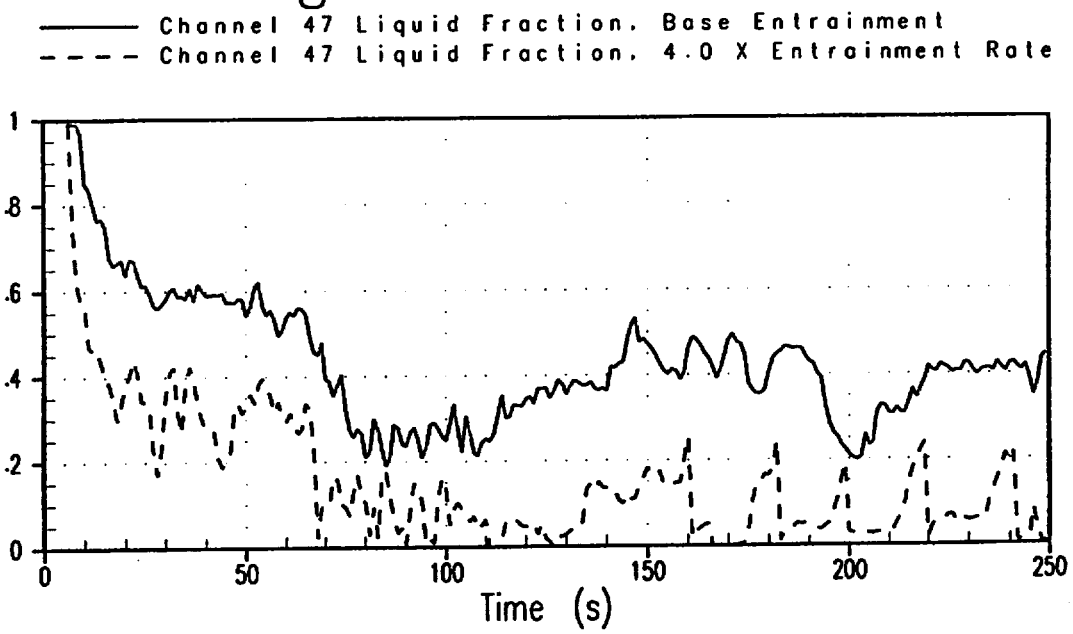

Figure440.173R2-10

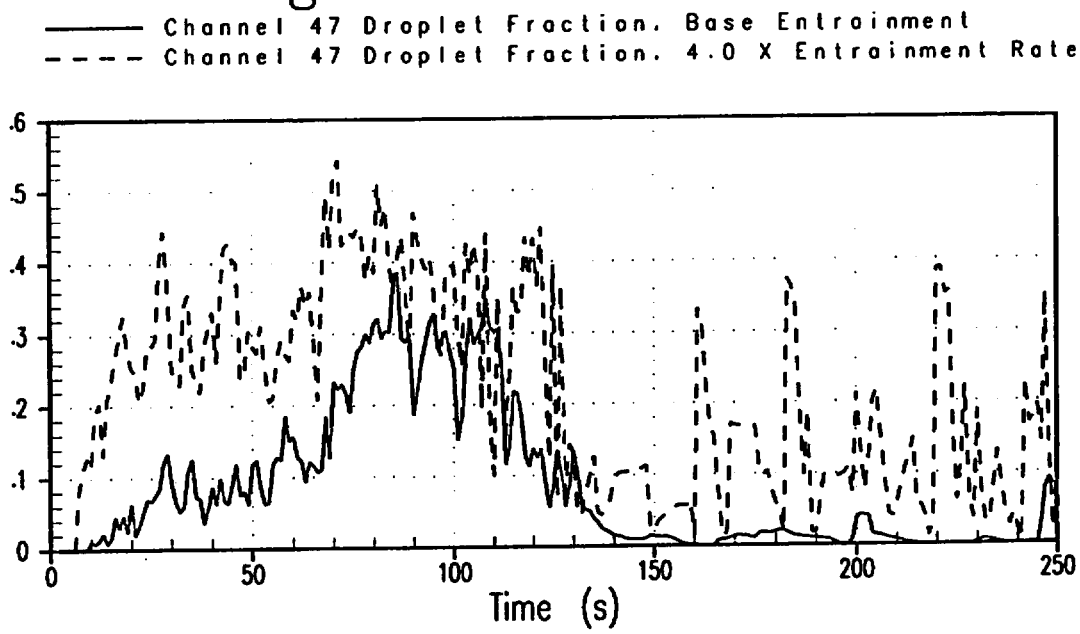

Figure440.173R2-11

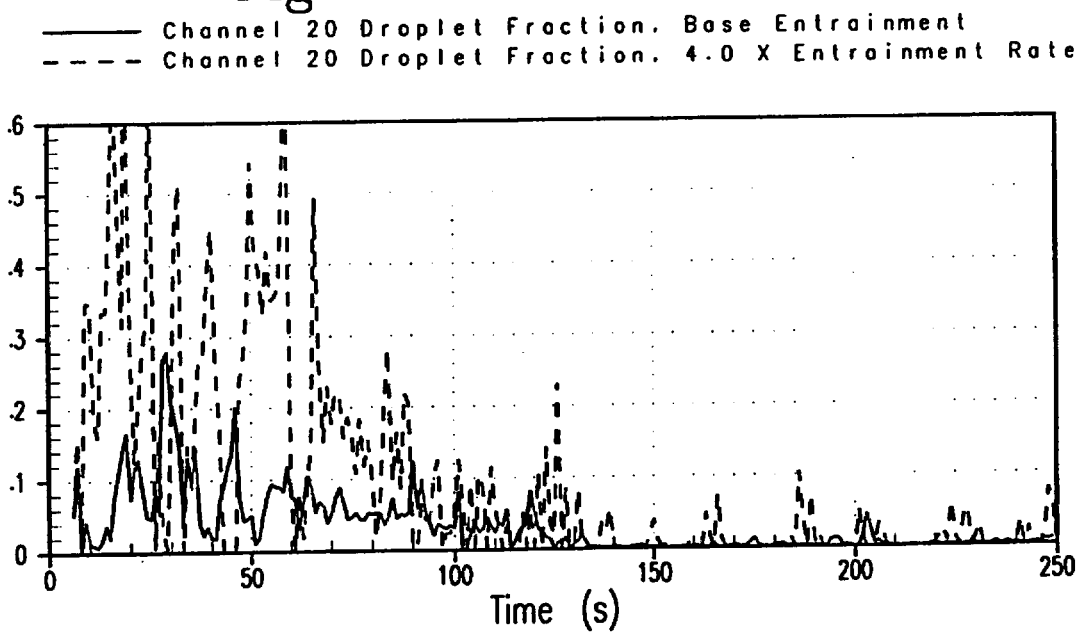

Figure440.173R2-12

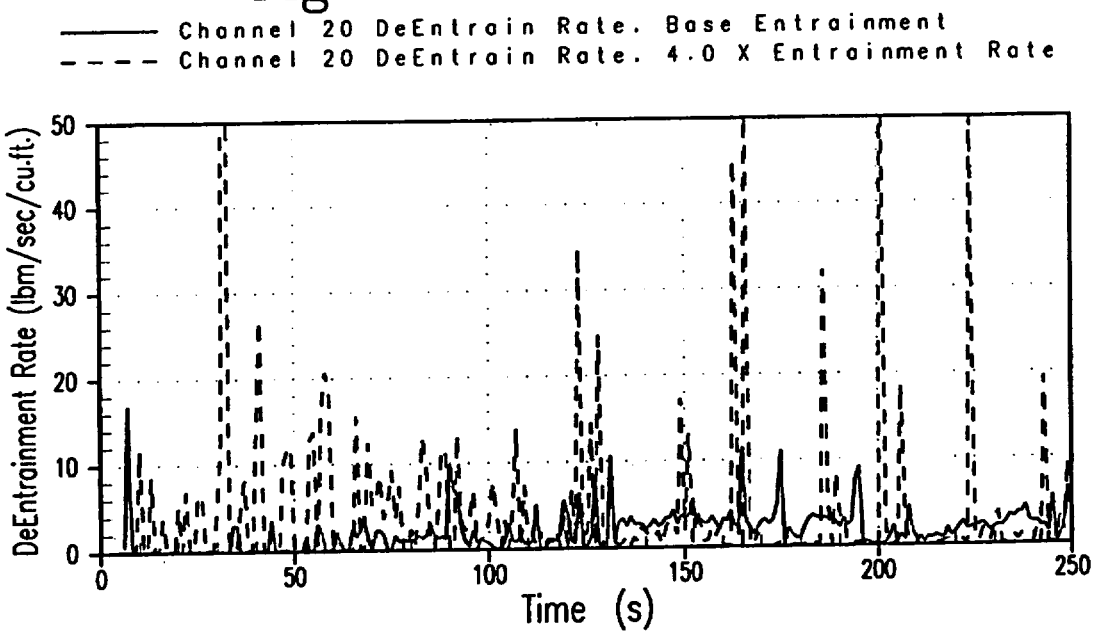

Figure 440.173R2-13

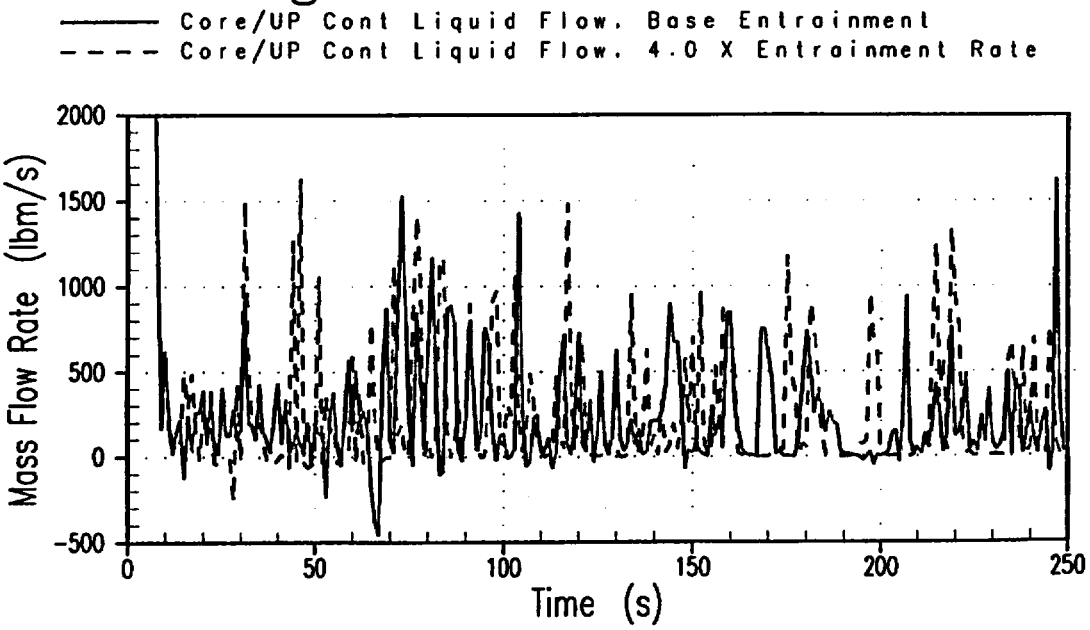

Figure 440.173R2-14