From: Michael Webb
To: NORRIS, GREGORY P
Date: 1/29/04 7:59AM
Subject: Consultant's preliminary review of RBS request to use GOTHIC

Greg,
For your use, I have attached the preliminary NRC consultant review/report of the River Bend Station request to use GOTHIC to perform high energy line break analyses.

After you and your colleagues have had a chance to evaluate it, we will set up a conference call to discuss the report and determine what additional steps should be taken for this licensing action.

Thanks,
Mike Webb
NRC Project Manager for River Bend Station

CC: Richard Lobel

RIVER BEND STATION
Docket 50-458
PM: Michael Webb

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Preliminary Review of the RBS Request to Use GOTHIC 7 for Sub-compartment Analysis

This review references the following River Bend Station (RBS) submittal requests, RAI responses, along with NAI GOTHIC 7 Qualification and Technical manuals:

1. Entergy letter, RBG-45940 (w attachment), dated 5/14/2002
2. Entergy letter, RBG-45985 (w attachment), dated 6/27/2002
3. Entergy letter, RBG-46124 (w attachment), dated 7/9/2003
4. GOTHIC Containment Analysis Package: Qualification Report, NAI 8907-09 Rev 6, 7/2001
5. GOTHIC Containment Analysis Package: Technical Manual, NAI 8907-06, Rev 12, 7/2001

In partial support of the review, CONTAIN 2.0 calculations for a RBS licensing event have been performed. The event was an 8-in high energy line break in the RWCU Filter/Demineralizer room. CONTAIN 2.0 input decks for this event were supplied by NRR.

Review comments are provided for qualification and acceptance of the "new" methods proposed in the RBS licensing submittal and the calculational results of the specific HELB event involving the Filter/Demineralizer room. Due to the preliminary nature of the report only a few examples that demonstrate the issues and concerns mentioned in the general acceptance review are provided. Additionally, more work on the sub-compartment analysis of the HELB in the Filter/Demineralizer room is needed to confirm the results obtained using the CONTAIN code.

GOTHIC 7 Code for Licensing

The GOTHIC code is of the class of state-of-the-art, "best-estimate" general purpose containment analysis codes that have been developed to predict the containment thermal hydraulic response to a wide range of transient scenarios. The general nature of the code is distinguished by the various levels of details that may be included to describe containment systems and containment phenomena. The code has 1) a history of use in the field of containment behavior predictions, and 2) is currently supported by its developer. These two attributes make the code attractive as a replacement for older, unsupported licensing codes such as the THREED code previous used by RBS.

<u>1. Model Option Limits Qualification:</u>

The GOTHIC code may be run in either a 3D or lumped parameter mode. A choice to restrict usage to one or the other modes can severely affect the qualification. In most high energy injections for sub-compartment analysis the inlet jet will directly impact a stationary structure. Often to protect test facilities (HDR, etc.) an impaction plate is placed a few jet diameters in front of the jet nozzle. It is known from general experience with impact plate experiments that direct impaction can have a significant effect on the entrainment/de-entrainment of liquid droplets during the flashing process. The ability to model adequately the phenomena associated with direct jet impaction is limited to a 3D sub-nodalization of the break compartment.[1] Although, impaction within the jet can be simulated in the lumped parameter mode by adjustment through a bend parameter, the physical significance is absent, and the "bend" parameter is used simply as a tuning parameter. Therefore, when the GOTHIC code is restricted to the lumped parameter mode, there can be a severe reduction of applicable models in the qualification area.

2. Model Selection Criteria Ambiguous:

Benchmarking the GOTHIC code to previous THREED results have been completed using the GOTHIC code under the model restrictions that the GOTHIC code models are forced to simulate THREED. Although not clearly stated these "important" THREED models would be homogeneous equilibrium modeling for fluid in the nodes and vent paths and 100% entrainment within the nodes. It would appear that the GOTHIC code was actually run in the benchmarking with the droplet conversion model invoked (See Table "SRP compliance of the THREED and GOTHIC models," in RBG-45940). Since the pressure increases were minimal in the selected benchmarking, one could infer that the importance of entrainment modeling (i.e. drop-liquid conversion) is low. Additionally, because the benchmarking cases are selected for cases that have a substantial degree of safety margin (design limit – calculation), they may not represent a true test of the importance of the drop-liquid conversion model option.

A more severe case that emphasizes the importance of the drop-liquid conversion model option occurs when the water injection is significantly subcooled, the breakroom volume is small, and the vent path area exiting the room is also small (e.g., 8 inch RWCU break in Filter/Deminerlizer room). In this case, selection of the drop-liquid conversion option results in significant variation in the sub-compartment pressure differential such that the safety margin may reduce to zero if the drop-liquid option is not selected. Because of this outcome, clearly noted in response to RAI #3 and #18 (RBG-46124), the question concerning the criteria used to include the drop-liquid conversion option for sub-compartment analysis becomes an issue. RBS addresses the question of the use of the drop-liquid conversion model in response to RAI #3. The reasons that RBS offers are listed here in summary form:

- general inspection of the physical conditions of the injected water flashing potential;
- other conservatisms beyond the issue of entrainment/de-entrainment;
- reduced safety margin if drop-liquid option is not used;
- cost of increasing safety margin by re-analyzing the design limit; and,
- only the Filter/Deminerlizer room is affected by the analysis (no effect on downstream pressurization).

[1] See Section 6.7 of the GOTHIC Qualification report, and Section 8.7.5 of the GOTHIC Technical manual.

Clearly, a reviewer would expect to see experimental data to address the phenomena involved with the conversion process during conditions of the accident. Further discussion of this limiting sub-compartment case is included later in this report.

3. Appropriate experimental data for drop-liquid conversion modeling:

The applicant that requests the use of a new method is the one who has the responsibility to communicate the qualification of the new method (i.e. GOTHIC models). RBS responsibility in this respect is affirmed in the letter RBG-45940.[2] The only qualification performed at RBS however, as communicated, is a limited benchmarking to THREED as described above for relatively benign cases with minimal pressurization. Other qualifications sighted, yet not performed at RBS, are those model assessments contained in the referenced NAI qualification report. A key example is discussed here to show the deficiency of the NAI qualification report for a specific licensing application.

Section 6 of the GOTHIC qualification report is the section that addresses qualification of the drop behavior models. The models covered are (by subsection) jet breakup, entrainment, settling deposition, drop heat and mass transfer, combine effects testing. The phenomenon of drop removal due to direct impaction is only covered in the combined effects testing. Direct drop impaction in a jet for lump parameter nodes (Section 8.7.5 of GOTHIC technical manual) during high energy line breaks is not addressed as discussed in 1. above. Tests that deal with both jet breakout, direct impaction, and wall entrainment/de-entrainment are tests discussed in the subsection labeled "combined effects testing" based on the WALE test series.

The WALE tests were funded by Canadian utilities, and were designed to address the effects of water aerosols on containment conditions during severe accidents conditions (not DBA or HELB conditions). The phenomenon of concern in these tests was the transport of released fission products within and leaked from the containment. The tests were therefore tailored to a specific accident scenario (severe accident) having a relatively low energy break flow rate. The tests were run in a steady state manner with minimal pressurization in the break compartment (containment). The suspended water aerosol concentrations were extremely low (< 10g/m3). These tests are not directly applicable to high energy line breaks in small rooms that result in significant transient pressurization resulting in substantial pressure differentials (8-inch RWCU beak in the Filter/Deminerlizer room). Furthermore, only the drop-liquid conversion model in the code's 3D mode is validated in the WALE integral tests.

The GOTHIC technical manual comments that the empirical room impaction formula used for drop deposition in a lumped parameter node agrees well with the *functional form* of the formula based on comparisons to HDR and Marviken tests. However, the basis for the comparison is not stated, but implied to be observed ability to maintain the saturation temperature when the drops are modeled. In fact, a review of the GOTHIC HDR

[2] Section 4.0 Technical Analysis of RBG-45940 statement: "The new RBS HELB models use the GOTHIC code, which has been qualified at RBS."

qualification test report explicitly states that drop deposition data were not available for these tests. So it is speculation to assume that the HDR (or Marviken tests) tests are representative of tests that validate *quantitatively* the drop behavior models in GOTHIC.

In short, there appears to no qualification data to support quantitatively the drop removal by impaction of wetted surface on the walls of a lumped parameter node. Additionally, as stated above there are no data to support quantitative assessment of drop removal by direct jet impaction. Qualification of the conversion model for the licensing cases such as the HELB in the Filter/Demineralizer room is not present in the documentation thus far transmitted to the NRC by RBS.

Acceptance: (8 inch RWCU break in the Filter/Demineralizer Room)

Since the 8-inch RWCU line break in the Filter/Demineralizer room represents a limiting case for sub-compartment analysis, this event is reviewed in some detail. Shown in Figure 5 is the mass rate and specific enthalpy profiles for the SAR and the new sources used for the updated SAR. The horizontal line that divides the two-phase and liquid jet regimes for the blowdown is based on the level of liquid enthalpy for flashing at atmospheric pressure. What this figure shows is that for the first ~ 10 seconds the break flow is liquid water that will not flash. The water is relatively cold and we would expect that most of water would go directly to the room sump. In fact, ~ 50% of the total water injected into the room is in the form of unflashed liquid during the first 10 seconds of the blowdown. Basically, this condition is identical for both the SAR and updated SAR sources.

Guidance in SRP 6.2.1.2 specifically addresses only the conditions within the vent flows (homogeneous equilibrium model, with 100% entrainment). The guidance does not address conditions within the sub-compartment with respect to injected liquid water that becomes suspended. It has been past practice to consider 100% entrainment of injected water to maximize break compartment pressure for subsonic as well as supersonic flows. However, this practice is only empirically established for primary system line ruptures (HDR rupture line tests for PWRs / Waltz Mill tests for Ice condenser PWRs). Low pressure / temperature lines such as the RWCU lines should be considered a special case. Shown in Figure 6 is the break room pressure and pressure differential calculated with CONTAIN (homogeneous frozen model for critical flow, with 100% water entrainment within the break room and vent path). In this case, the homogeneous frozen model is multiplied by a factor to convert the critical flow model to a nonadiabatic, homogenous equilibrium model. The comparison with the THREED calculation is good.

In the original RB SAR, the Filter/Demineralizer room analysis was performed assuming 100% entrainment of the total water injected into the break compartment. Not only does the entrainment assumption affect vent flows, but also the pressurization of the break compartment due to the imposed condition of thermal equilibrium between suspended liquid and gas. Large amounts of suspended liquid can act as a heat sink thereby suppressing the break room pressure and therefore reducing the pressure differential between the break and adjoining compartments. The thermal equilibrium effect is in part offset by the added resistance in the vent paths as a result of suspended liquid. It is not clear that an assumption of 100% entrainment will always result in the maximum pressure differential. For example, shown in Figure 7 are the pressure differential for the Filter/Demineralizer room assuming no entrainment of the initial liquid water ($t < 10$ seconds) followed by various assumed entrainment percentages of the unflashed liquid ($t > 10$ seconds). Clearly, the assumption of 100% entrainment (for liquid and flashed water) for this specific scenario is not the most conservative assumption for estimating safety margins.

Shown in Figure 8 are the break room pressures for the new sources and new vent paths used in the updated SAR submittal. The assumptions that maximize the break room compartment pressure above for the original SAR mass and energy source (Old_ME/Paths) also apply for this case (New_ME/Paths). Because the Filter/Demineralizer room has been calculated with pressures that would exceed pressure differentials allowed by structure analysis, it is recommended that the RB analysis both from previous and current analysis be review indepth. Updated calculations by RBS show break room pressure and pressure differentials below the SAR values previously calculated with THREED. As indicated in Figure 8, the GOTHIC calculations without the drop-liquid conversion model are equivalent to the CONTAIN calculation with 100% total entrainment. The observation that the drop-liquid conversion model reduces the break room pressure below the case with partial entrainment suggests that the GOTHIC calculation with the drop-liquid conversion model includes an effect other than entrainment/de-entrainment. It is possible that the separate flow field equations are simulating significant slip between the fields in the vent paths. A simulation of nonhomogeneous flow in the vents needs validation.

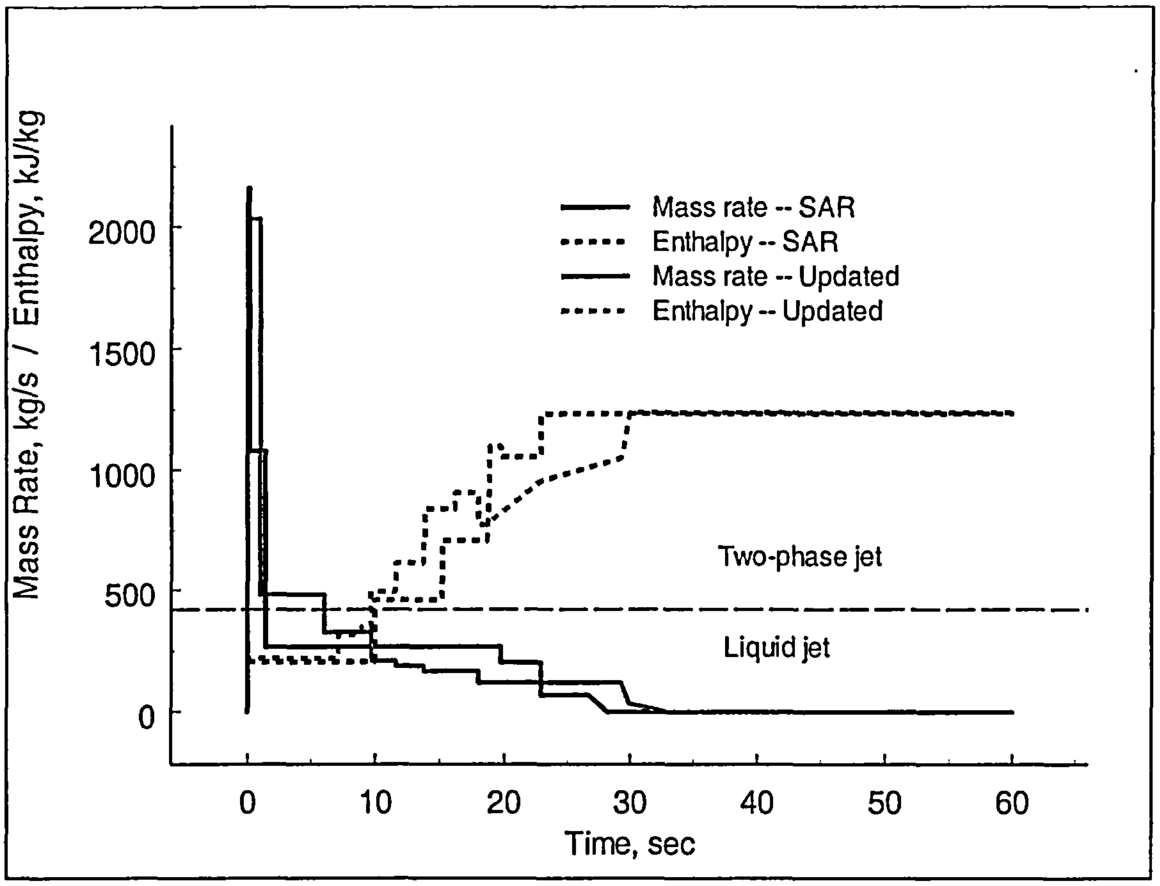

Figure 1 Water mass rate and enthalpy profiles for the 8 inch RWCU break in the Filter/Demineralizer room.

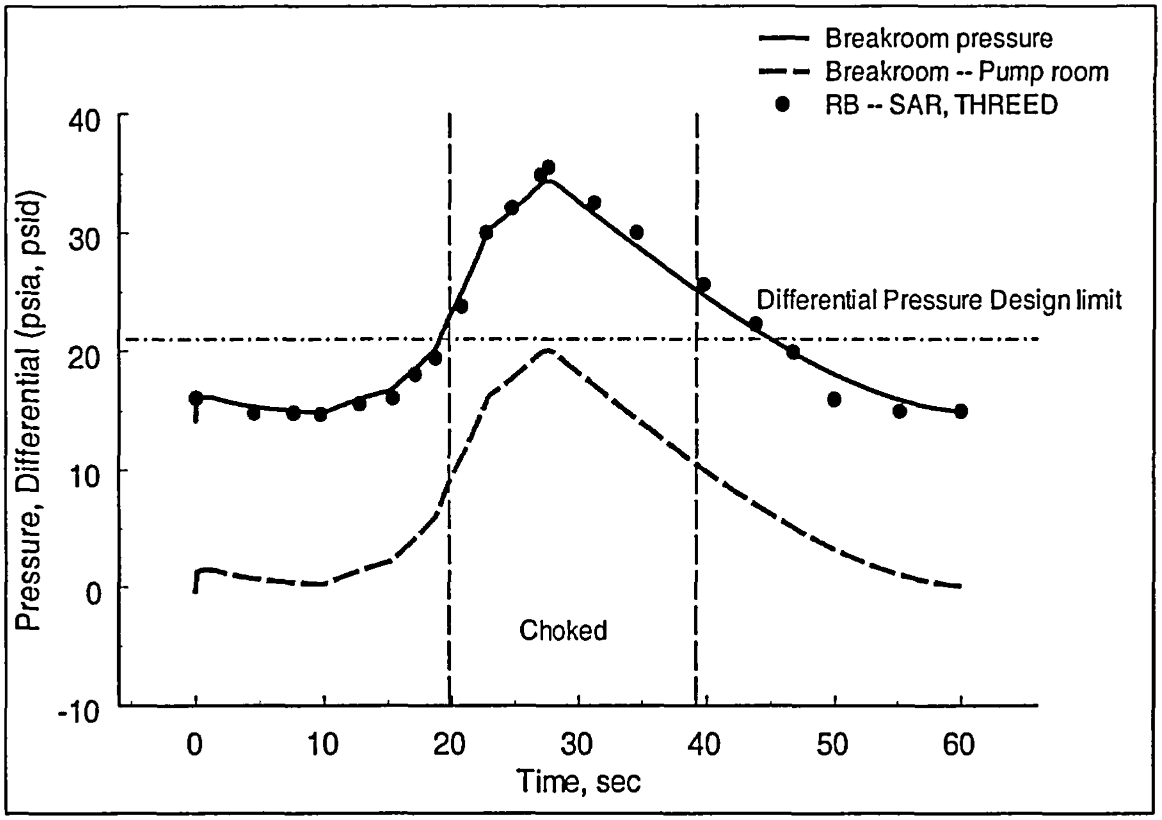

Figure 2 Comparison of CONTAIN and THREED Filter/Demineralizer room sub-compartment pressure and differential profiles for 8 inch RWCU line break (100% entrainment of water injection).

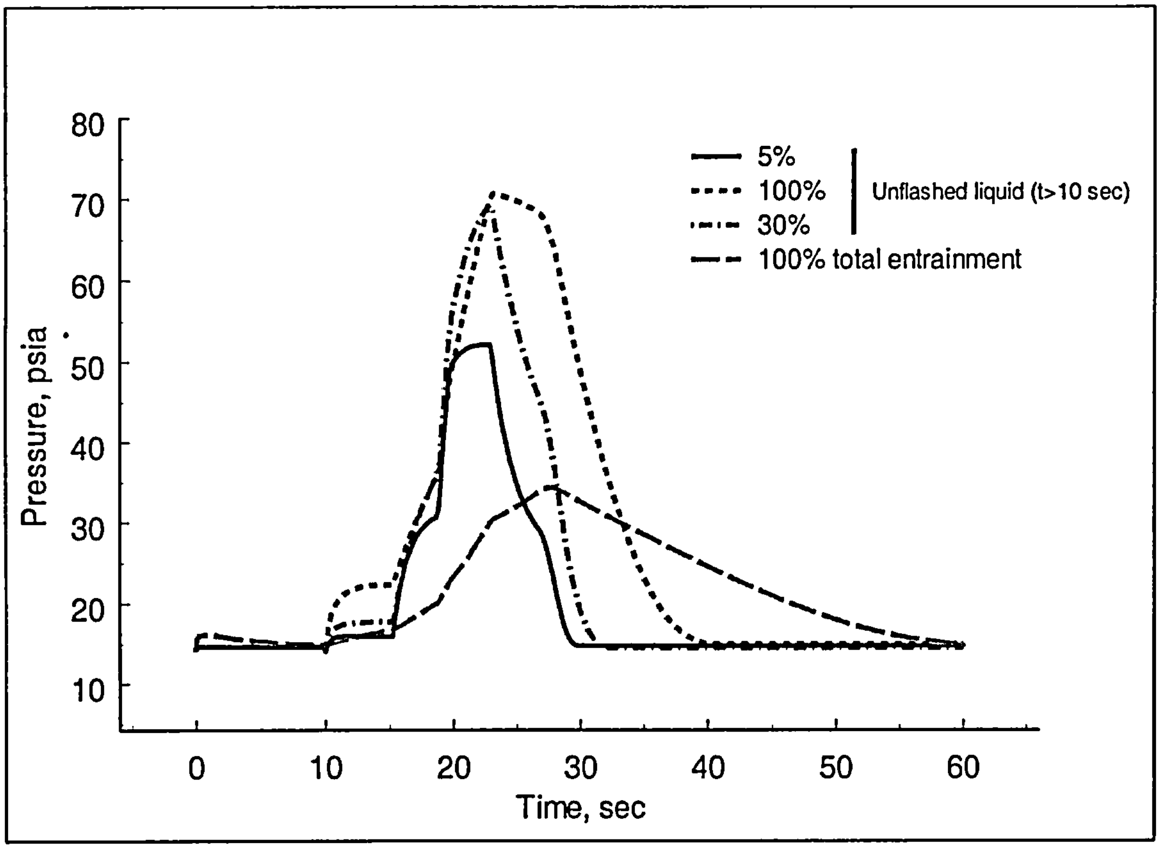

Figure 3 CONTAIN calculated Filter/Demineralizer room pressure for 8 inch RWCU line break. In the case of 5-100% unflashed liquid calculations, the water injection prior to 10 seconds was assumed to be transferred directly to the room sump. The case for 100% total entrainment includes suspension of the entire inventory of injected water, similar to the method used in the RBS SAR.

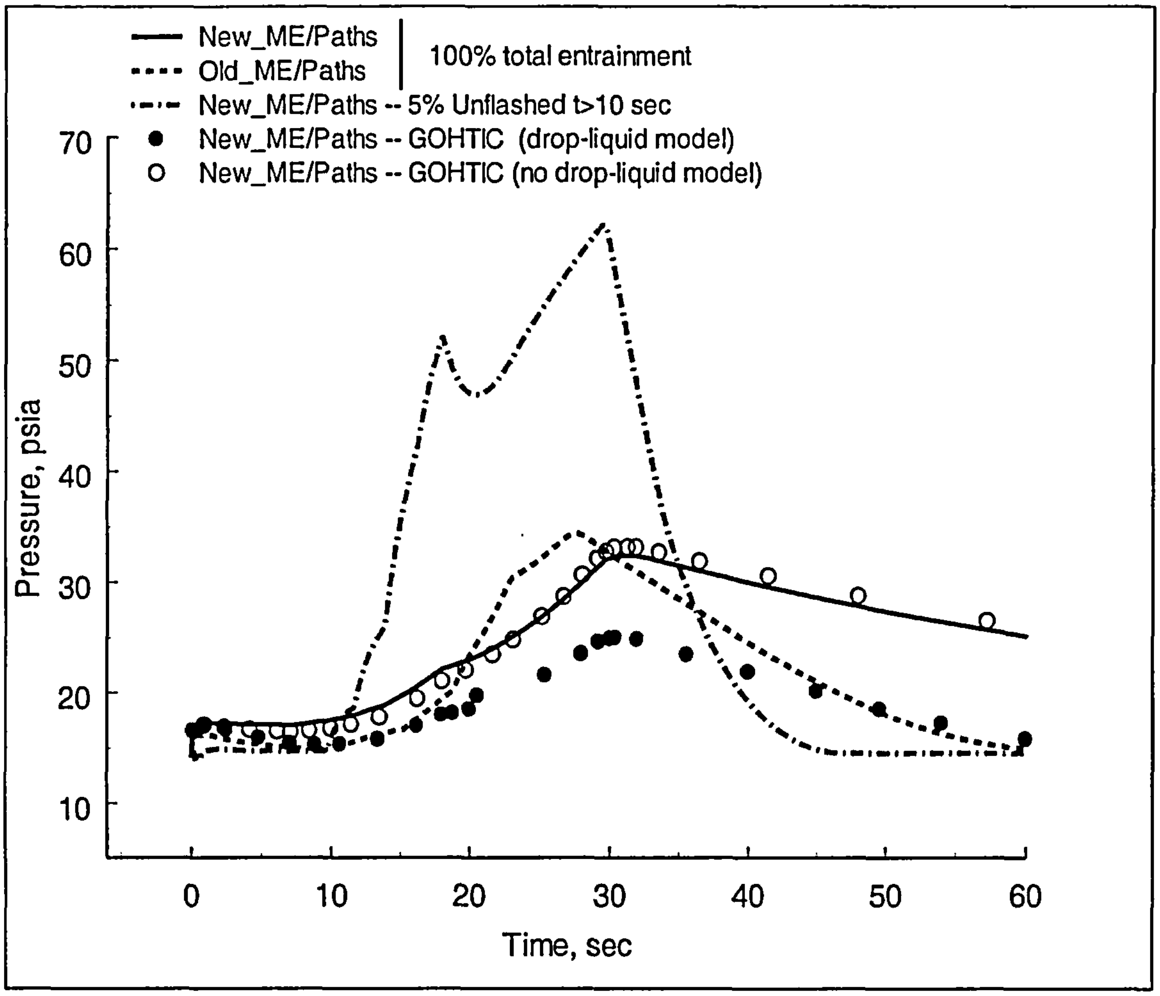

Figure 4 CONTAIN calculated pressure profiles for the 8 inch RWCU line break in the Filter/Demineralizer room. The cases with 100% entrainment correspond to the method of entrainment used in the RBS SAR. The GOHTIC calculation without the drop-liquid model corresponds to the CONTAIN calculation (New_ME/Paths) with 100% total entrainment.