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# 8.2 ANALYSIS OF CONTAINMENT VENTING FOLLOWING A CORE DAMAGE AT A BWR MARK I USING THALES-2

Surip WIDODO
Nuclear Safety Technology Development Center,
National Nuclear Energy Agency (BATAN),
Puspiptek, Serpong, Tangerang, INDONESIA 15310
Ph.: 62-21-7560912 Fax.: 62-21-7560913
E-mail: suripw@batan.go.id

Jun ISHIKAWA, Ken MURAMATSU
Japan Atomic Energy Research Institute
2-4 Shirakata Shirane Tokai-mura, Naka-gun, Ibaraki-ken, 319-11, JAPAN

Toru SAKAMOTO
Toshiba Advanced System Co.
1-2-4 Isogo, Kawasaki-ku, Kawasaki-shi, Kanagawa-ken, 210, JAPAN

**ABSTRACT**

Analysis of containment venting following a core damage at a boiling water reactor (BWR) Mark I using THALES-2 was performed. In this analysis, the effect of various parameters, namely,

- the areas of the vent path,
- containment venting pressure, and
- accident sequences

on the containment thermodynamic response, and radionuclide transport and release in the containment venting at a BWR was examined. The code THALES-2B developed by the Japan Atomic Energy Research Institute (JAERI) was used in this analysis. The model plant in this analysis was the Browns Ferry plant. From this analysis was found that the 4-inch pipe of containment venting flow path is sufficient to maintain the containment pressure in the specified range if the containment was pressurized by the decay heat power. The entrainment by the pool swelling as well as by the flashing was not occurred during the containment venting. The source terms are not sensitive to the variation of containment venting flow path area. The containment venting pressure operation setting point has important rule in the containment venting. In the containment venting, the source terms are not sensitive to the accident sequence, except for Sr source term. In order to get better understanding on the containment venting strategy, the following analyses are necessary. Analyses of accident sequence which has a high power such as anticipated transient without scram are necessary, as well as analyses of accident sequence which pressurize the containment before the core damage.

## 1. Introduction

Containment venting has been recognized as an important accident management tool for Boiling Water Reactor (BWR) Mark I containments[1]. It is used to prevent uncontrolled containment failure by providing a controlled release of containment atmosphere if the containment pressure equals or exceeds a specified limit. After core damage, venting via a path through the suppression pool will provide considerable radionuclide scrubbing and reduce release. Important issues for containment venting are the containment venting pressure, the areas and flow capacities of the vent paths, and the structural capability of vent paths.

Ishikawa, et al.[2] performed analyses of containment venting at a BWR using THALES-2 code[3]. The purposes of analyses were aiming at obtaining better understanding on the controlling factors of the source terms of containment venting and demonstrating the usefulness of THALES-2 code for planning or reviewing of containment venting strategies. Further study on the THALES-2 code applications to examine effect of various parameters (i.e. set point pressure for opening, set point pressure for closing, accident sequences) on the containment venting at a BWR was recommended by them.

Based on above circumstances it is necessary to study furthermore on the containment venting at a BWR.

The objective of this analysis is to examine effect of various parameters, namely,

- the areas of the vent path,
- containment venting pressure, and
- accident sequences

on the containment thermodynamic response, and radionuclide transport and release in the containment venting at a BWR using THALES-2 code.

## 2. Analytical Method

The THALES-2B code, a BWR version of THALES-2, was used in this analysis. The integrated severe accident analysis code THALES-2 code, was originally developed by JAERI under the cooperation of Japan N.U.S. Co. Ltd. and Toshiba Advanced System Co. The code covers major physical phenomena that would occur in the severe accident condition. Figure 2.1 and 2.2 show the control volume model in the THALES-2B and the fission product transport model of the ART module, respectively.

The Browns Ferry plant[4] was used as a reference plant in this analysis. This plant is a General Electric BWR4 Mark I, with thermal power 3,440 MWt. Since this study is not intended to provide a plant-specific analysis, various assumptions were made because sufficiently detailed information was not obtained from the Final Safety Analysis Report

The input data was prepared by JAERI.

The analytical assumptions were as follows:

- venting from wetwell using hardened vent paths,
- successful closure of vent line after depressurization,
- pool scrubbing model by Kaneko et al.,
- revaporation of deposited aerosol was considered

The calculation cases in the analyses were as follows:

for the area of the vent path sensitivity study

Case 1 (base case) : TQUV sequence (loss of feed water + no injection to core + no containment spray), flow path area 16" pipe, open at 1.5x design pressure, close at design pressure.

Case 2 : same as case 1 except use flow path area 8" pipe.

Case 3 : same as case 1 except use flow path area 4" pipe.

for the containment venting pressure sensitivity study

Case 4 : same as case 1 except open at containment failure pressure

Case 5 : same as case 4 except close at (failure pressure - 0.5 design pressure)

for the accident sequence sensitivity study

Case 6 : same as case 1 except for S2E sequence (small break at loop B + no containment spray).
Case 7 : TQUV sequence, no containment venting, containment fails in the drywell.

## 3. Analytical Result

### 3.1 Containment Thermodynamic Response

Sequence of events and their timing of occurrence for both TQUV and S2E accident sequences are summarized in Table 3. The Figure 3.1 shows the containment pressurization prior to the containment was vented. It was found that both accident sequences pressurized the containment significantly after the core was damage. In the S2E accident sequence, it was found a pressure spike in the containment just following the vessel breach.

Figure 3.2 shows containment pressures for cases 1, 2, and 3. We found that in all cases the containment pressure can be maintained in the specified pressure range.

Figure 3.3 shows the wetwell temperature of cases 1, 4 and 5. It found that the liquid temperature was remaining in the sub cooled until the end of simulation, therefore the flashing was not happen. The Figure 3.4 shows the wetwell mixture level for cases 1, 4 and 5. It found that the pool swelling due to the containment venting was not enough to produce entrainment through containment venting line.

### 3.2 Radionuclide Transport and Release

Figure 3.5 shows the CsI mass in the wetwell (WW) gas space for both TQUV and S2E accident sequences. This figure indicates that both accident sequence give a difference CsI mass before the containment venting started to operate. The higher containment venting setting pressure operation has more time to remove CsI naturally from the WW gas space than the lower containment venting setting pressure operation has.

The comparison for other species of fission product released to the environment is depicted in the Figure 3.6 in the form of normalized for case 1. The percentage in the parentheses in the figure 3.6 represents source terms for case 1. It was found that the high setting pressure of opening containment venting could extend time for fission product to be removed from WW gas space naturally. Therefore the high setting pressure of opening containment venting will produce a smaller fission product released to the environment than the low setting pressure of opening containment venting has. However the wide range of containment venting operation pressure will produce a higher fission product released to the environment than the narrow range of containment venting operation pressure has. It also was found that the only the Sr was sensitive to the accident sequence.

## 4. Conclusions and recommendation

### 4.1 Conclusions

1. The 4-inch pipe of containment venting flow path is sufficient to maintain the containment pressure in the specified range if the containment was pressurized by the decay heat power.
2. The entrainment by the pool swelling as well as by the flashing was not occurred during the containment venting.
3. The source terms are not sensitive to the variation of containment venting flow path area.
4. The containment venting pressure operation setting point has important rule in the containment venting.
5. The source terms are not sensitive to the accident sequence, except for Sr source term.

## 4.2 Recommendation

The various analyses described in this paper not only confirmed to the conclusions described in the previous section but also identified several areas where additional analyses would give better understanding on the containment venting strategy. It is recommended that analyses of accident sequences which has high power such as anticipated transient without scram are necessary as well as accident sequence which pressurized the containment before the core damage to investigate the capability of venting flow path area for maintaining containment pressure. There is a pressure spike in the containment due to vessel breach. Therefore, this pressure spike is necessary to be considered in the decision on the determination of the starting point of containment venting pressure operation.

## Acknowledgement

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## References

1. US. Nuclear Regulatory Commission “Individual Plant Examination Program: Perspectives on reactor Safety and Plant Performance”, NUREG-1560 Volume 2, Parts2-5, December 1997.
2. J. Ishikawa, et al., “A scooping analysis of containment venting at a BWR using THALES-2”, Proceedings of the workshop on severe accident research held in Japan (SARJ-97), JAERI-Conf-98-009 513 pp. 389-394/ May 1998
3. M. Kajimoto, et al., Private Communication, 1994.
4. TENNESSE VALLEY AUTHORITY, “Browns Ferry Nuclear Power Plant, FSAR”, DOCKET 50259, 1970.

**Table 3 Sequence of Events and its Timings of Occurrence**

| EVENTS | TQUV | S2E |
|---|---|---|
| | Time (min.) | Time (min.) |
| Accident | 0 | 0 |
| Automatic Depressurization System (ADS) open | 8.25 | NA[a)] |
| Core Uncovery | 14.82 | 17.55 |
| Core Melt Initiation and Relocation | 44.67 | 63.65 |
| Core Support Failure | 61.05 | 87.25 |
| Core Collapse | 88.95 | 88.92 |
| Vessel Failure | 101.92 | 124.53 |
| Containment Pressure reaches the design pressure (4.97E4 $kg_f/m^2$) | 215.4 | 277.5 |
| Containment Pressure reaches 6.94E4 $kg_f/m^2$ | 303.0 | 369.0 |
| Containment Pressure reaches the limit pressure (9.2594E4 $kg_f/m^2$) | 398.0 | NA[b)] |

Notes
a) : It was not modeled in this analysis.
b) : It was not simulated in this analysis.

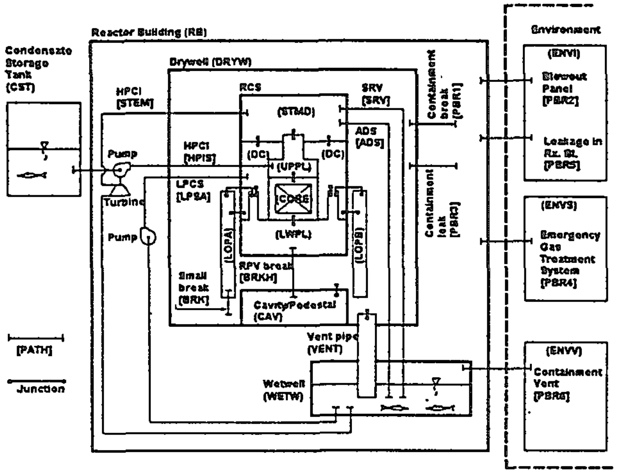


Figure 2.1 Control Volume Model in THALES-2B

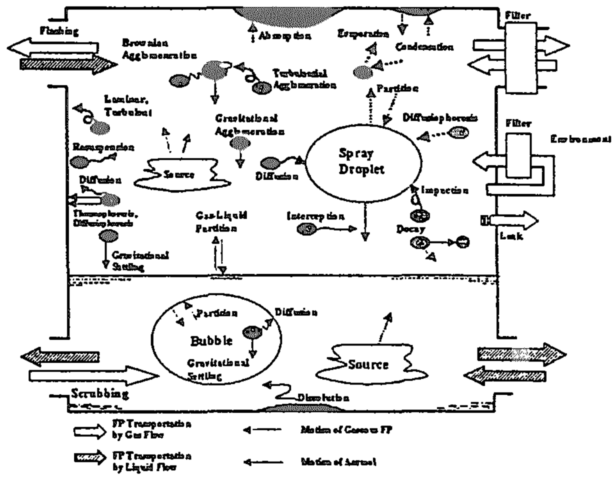


Figure 2.2 Fission Product Transport Model of the ART Module

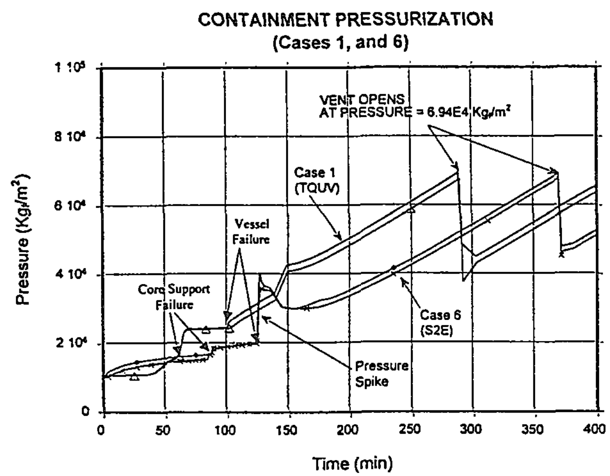


Figure 3.1 The containment pressurization prior to the containment was vented

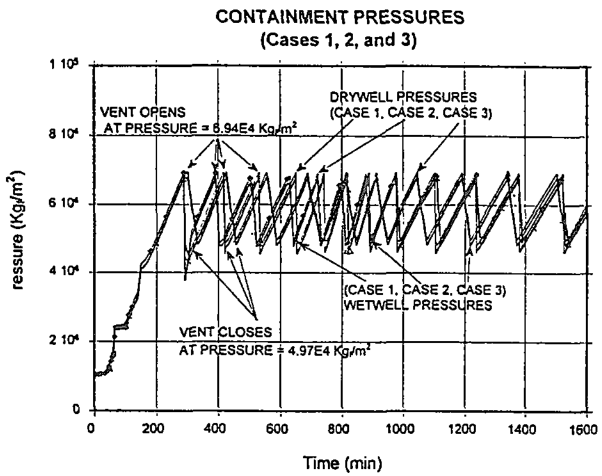


Figure 3.2 Containment pressures for cases 1,2 and 3

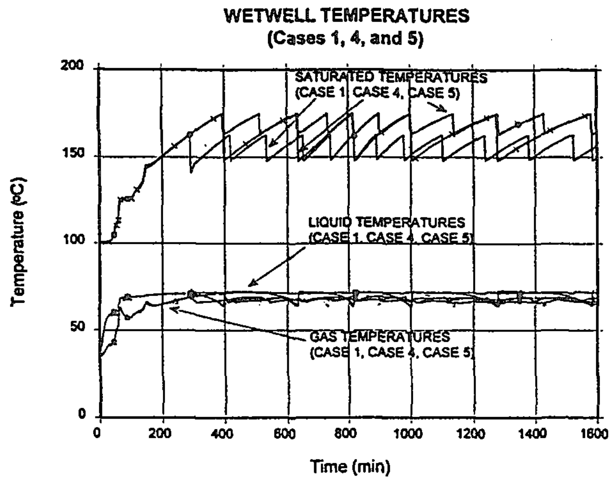



Figure 3.3 Wetwell temperatures for cases 1, 4 and 5

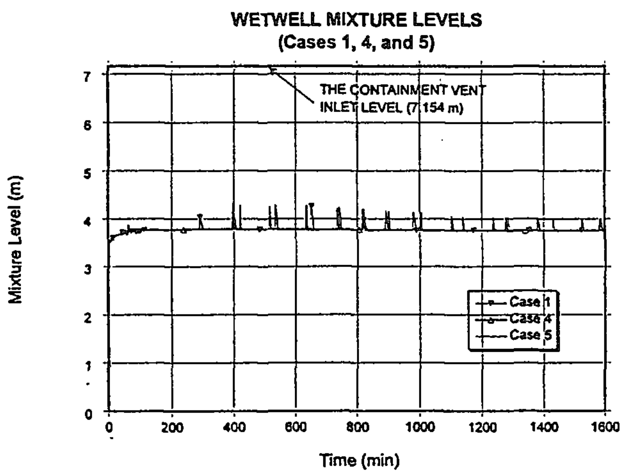



Figure 3.4 Wetwell mixture level for cases 1, 4, and 5

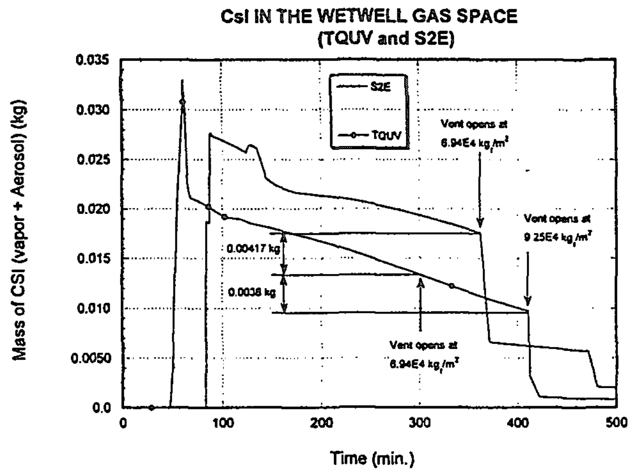
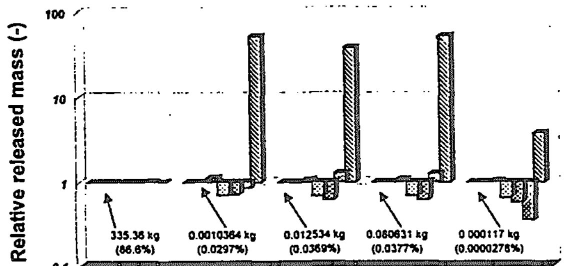



Figure 3.5The CsI mass in the wetwell gas space for both TQUV and S2E accident sequences




| | Xe | Te | CsI | CsOH | Sr |
|---|---|---|---|---|---|
| Case 1 | 1 | 1 | 1 | 1 | 1 |
| Case 2 | 1 | 1 | 0.98 | 0.99 | 0.99 |
| Case 3 | 1 | 1.13 | 1.06 | 1.07 | 1.03 |
| Case 4 | 0.99 | 0.7 | 0.68 | 0.69 | 0.65 |
| Case 5 | 0.99 | 0.71 | 0.61 | 0.61 | 0.57 |
| Case 6 | 1.02 | 0.85 | 1.27 | 1.25 | 0.35 |
| Case 7 | 1 | 51.44 | 38.22 | 52.36 | 3.82 |

**Figure 3.6 Relative Fission Product released mass to the Environment for Case 1 (base case) at 1600 minutes into the accident**