# A Probabilistic Methodology for Assessing the Effectiveness of the Containment Filtered Venting Systems

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## 1. Introduction

Containment Filtered Venting Systems (CFVS) are being installed in order to preserve the containment building during severe accidents as part of the Post Fukushima Measures. Avoiding a breach of the reactor containment due to overpressure and consequently significant releases of radioactive products into the environment during an accident is the point of using CFVS. But it should be used only as the last possible because release of the fission product using the facility resulted in offsite risk [1].

After the Chernobyl nuclear accident, mainly in Sweden, Germany, France, Switzerland, the Netherlands and other European countries have installed CFVS. In the US, some Boiling Water Reactor type only the voluntary installation of CFVS was required. But until now it has not been installed for pressurized water reactors. In Korea, CFVS is currently installed on Wolseong Unit 1 and preferentially applied to Heavy Water Reactor. Later it plans to apply for the Light Water Reactor [1, 2].

In this study, a safety improvement of installing the CFVS was assessed by the tool of Probabilistic Safety Assessment (PSA) for a reference plant [3].

## 2. Methods and Results

The internal event model of the reference plant was used as an example for assessing the safety improvement for the assessment [3]. CFVS heading was added on CF-LATE Decomposition Event Tree (DET), corresponds to the Late Containment Failure (LCF), and an unavailability of CFVS was calculated by constructing a separate fault tree. Considering the CFVS, a new logic diagram for source term category (STC) was drawn up. STC was quantified by applying a new release fraction. It was quantified by using SAREX code and MACCS2 code. The large release frequency and early fatality and cancer fatality rate was used as evaluation index. [5,6].

### *2.1 Logical Tree Models*

An unavailability of CFVS was calculated by constructing a separate fault tree. The failure rate of the rupture disk to be installed in the piping connected to the filter vessel through the containment penetration was assumed to be 1.0E-06. Other probability and frequency of CFVS fault tree were based on Level 1 PSA reliability data [3, 4].

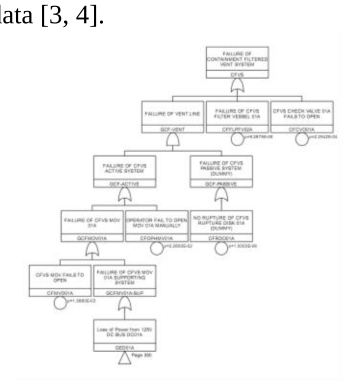

Fig. 1. Fault tree of CFVS

Containment Safety Systems, such as CFVS, are generally analyzed by adding a heading to the Plant Damage State ET. But since CFVS is a passive system and has no dependency with other systems, this was reflected directly as shown in Fig.2 [4].

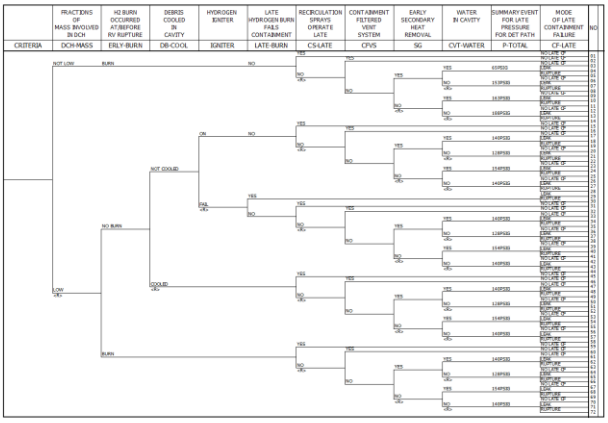

Fig. 2. DET of LCF

### *2.2 Source term category and release fraction*

The CFVS is in charge for venting the containment building in case of the accident sequence of gradual pressurization. At this time, the different release fraction should be considered since the fission product release through the filtration system. CFVS heading was added up on the existing logic diagram for grouping STC. And accident sequences that CFVS works branch off to separated STCs. Each frequency of STC was calculated from the difference between the existing STC frequency and it's frequency in case that CFVS was added.

The release fraction was set the same as for the conventional fraction of inert species. In the case of iodine, chemical forms (elemental, particulate and organic form) of iodine and filtration efficiency of each type of chemical form were considered in this study. For the other elements, the filtration efficiency for particles of CFVS was applied. [7].

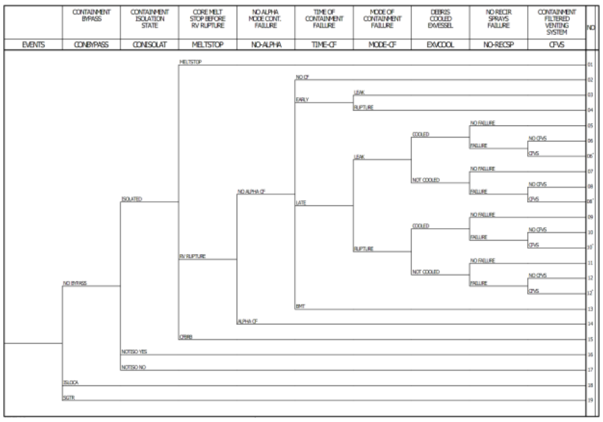

Fig. 3. Logic diagram for grouping STC

Table I: Frequency of STC with/without CFVS

| STC | Frequency(/year) | Frequency with CFVS(/year) |
|---|---|---|
| 1 | 1.63E-06 | 1.63E-06 |
| 2 | 2.35E-06 | 2.35E-06 |
| 3 | 1.47E-08 | 1.47E-08 |
| 4 | 1.16E-08 | 1.16E-08 |
| 5 | 0.00E+00 | 0.00E+00 |
| 6 | 1.85E-07 | 4.35E-11 |
| 6* | - | 1.85E-07 |
| 7 | 3.39E-10 | 3.39E-10 |
| 8 | 1.56E-07 | 2.06E-08 |
| 8* | - | 1.35E-07 |
| 9 | 0.00E+00 | 0.00E+00 |
| 10 | 2.13E-07 | 5.00E-11 |
| 10* | - | 2.13E-07 |
| 11 | 1.13E-10 | 1.13E-10 |
| 12 | 1.66E-07 | 6.91E-09 |
| 12* | - | 1.59E-07 |
| 13 | 2.18E-07 | 2.71E-07 |
| 14 | 4.26E-09 | 4.26E-09 |
| 15 | 3.37E-07 | 3.37E-07 |
| 16 | 1.68E-08 | 1.68E-08 |
| 17 | 1.78E-08 | 1.78E-08 |
| 18 | 1.77E-09 | 1.77E-09 |
| 19 | 5.29E-07 | 5.29E-07 |

Table II: Release fraction of each STC

| STC | Xe/Kr | I | Cs | Te | Sr | Ru | La | Ce | Ba |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.11E-04 | 8.27E-10 | 8.18E-10 | 1.38E-12 | 6.44E-12 | 1.17E-10 | 1.53E-14 | 4.59E-19 | 2.04E-11 |
| 2 | 2.22E-03 | 2.12E-06 | 1.48E-06 | 1.26E-06 | 8.06E-09 | 2.09E-07 | 1.87E-09 | 5.83E-12 | 1.44E-07 |
| 3 | 9.85E-01 | 2.18E-02 | 1.01E-02 | 5.54E-03 | 1.63E-04 | 4.46E-03 | 6.06E-06 | 7.75E-08 | 1.50E-03 |
| 4 | 9.97E-01 | 9.69E-02 | 3.86E-02 | 2.62E-02 | 2.92E-03 | 3.19E-02 | 1.31E-04 | 1.07E-06 | 1.68E-02 |
| 6 | 9.71E-01 | 1.37E-02 | 7.53E-03 | 2.24E-03 | 2.07E-05 | 1.96E-04 | 3.16E-07 | 1.07E-08 | 7.83E-05 |
| 6* | 9.71E-01 | 2.17E-05 | 7.53E-06 | 2.24E-06 | 2.07E-08 | 1.96E-07 | 3.16E-10 | 1.07E-11 | 7.83E-08 |
| 7 | 9.88E-01 | 1.04E-02 | 3.07E-03 | 3.66E-04 | 3.44E-04 | 6.40E-04 | 7.37E-07 | 1.85E-08 | 6.13E-04 |
| 8 | 9.72E-01 | 9.46E-03 | 5.61E-03 | 7.59E-04 | 1.56E-05 | 1.79E-04 | 2.82E-07 | 2.89E-08 | 6.71E-05 |
| 8* | 9.72E-01 | 1.50E-05 | 5.61E-06 | 7.59E-07 | 1.56E-08 | 1.79E-07 | 2.82E-10 | 2.89E-11 | 6.71E-08 |
| 10 | 9.56E-01 | 1.08E-02 | 5.78E-03 | 2.53E-03 | 2.22E-05 | 1.43E-04 | 6.67E-07 | 2.83E-08 | 7.32E-05 |
| 10* | 9.56E-01 | 1.71E-05 | 5.78E-06 | 2.53E-06 | 2.22E-08 | 1.43E-07 | 6.67E-10 | 2.83E-11 | 7.32E-08 |
| 11 | 1.00E+00 | 1.03E-02 | 4.86E-03 | 9.81E-04 | 1.59E-04 | 6.56E-05 | 3.04E-07 | 7.93E-09 | 2.61E-04 |
| 12 | 9.62E-01 | 8.37E-03 | 4.66E-03 | 7.55E-04 | 1.34E-05 | 1.42E-04 | 6.59E-07 | 5.82E-08 | 6.66E-05 |
| 12* | 9.62E-01 | 1.33E-05 | 4.66E-06 | 7.55E-07 | 1.34E-08 | 1.42E-07 | 6.59E-10 | 5.82E-11 | 6.66E-08 |
| 13 | 9.90E-01 | 1.50E-02 | 6.69E-03 | 1.64E-03 | 4.29E-05 | 1.16E-04 | 7.99E-07 | 1.06E-07 | 5.57E-05 |
| 14 | 9.79E-01 | 9.71E-01 | 9.71E-01 | 9.59E-01 | 4.20E-03 | 9.06E-02 | 3.00E-04 | 1.77E-06 | 3.34E-02 |
| 15 | 1.00E+00 | 4.35E-01 | 4.29E-01 | 2.49E-01 | 1.36E-02 | 2.50E-02 | 3.10E-04 | 5.68E-06 | 2.49E-02 |
| 16 | 3.87E-01 | 6.68E-03 | 3.27E-03 | 2.50E-03 | 6.99E-05 | 3.88E-03 | 4.12E-06 | 2.40E-08 | 6.68E-04 |
| 17 | 9.98E-01 | 6.13E-02 | 3.60E-02 | 1.58E-02 | 1.38E-03 | 1.14E-02 | 1.85E-05 | 3.79E-07 | 4.86E-03 |
| 18 | 1.00E+00 | 5.61E-01 | 5.06E-01 | 2.60E-01 | 2.70E-02 | 1.42E-02 | 6.74E-04 | 2.17E-05 | 3.41E-02 |
| 19 | 9.84E-01 | 3.40E-01 | 2.25E-01 | 1.51E-01 | 2.68E-03 | 1.06E-01 | 3.13E-04 | 2.05E-06 | 3.13E-02 |

### *2.3 Results*

The quantification was carried out for each PDS using the SAREX code, and each failure mode results are shown in Table 3. The quantified results using the MACCS code based on the new logic diagram for grouping STC and release fraction are shown in Table 4. The individual risk of early and cancer fatality are calculated with respect to the distance 1, 3, 5, 10 miles, respectively [6].

Table III: Containment failure frequency with and w/o CFVS

| Category | No CFVS | | CFVS | |
|---|---|---|---|---|
| | fraction | frequency(/year) | fraction | frequency(/year) |
| NO CF | 68.0% | 3.97E-06 | 79.0% | 4.61E-06 |
| ECF | 0.5% | 3.05E-08 | 0.5% | 3.05E-08 |
| LCF+BMT | 16.0% | 7.42E-07 | 5.1% | 2.99E-07 |
| NOT ISO | 6.4% | 3.72E-07 | 6.4% | 3.72E-07 |
| BYPASS | 9.1% | 5.31E-07 | 9.1% | 5.31E-07 |
| Sum | 100.0% | 5.84E-06 | 100.0% | 5.84E-06 |

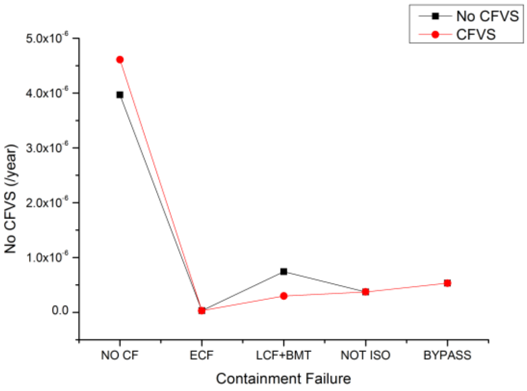


Fig. 4. Containment failure frequency with and w/o CFVS

Table IV: Fatalities with and w/o CFVS

| Category | Distance (km) | No CFVS | CFVS | Redution ratio |
|---|---|---|---|---|
| Individual risk of early fatality | ~1.6 | 7.49E-08 | 7.40E-08 | 1.3% |
| | ~8.0 | 1.19E-08 | 1.18E-08 | 0.6% |
| | ~16.0 | 5.18E-09 | 5.15E-09 | 0.6% |
| | ~48.0 | 8.77E-10 | 8.72E-10 | 0.6% |
| | ~80.0 | 2.94E-10 | 2.92E-10 | 0.6% |
| Individual risk of cancer fatality | ~1.6 | 7.72E-08 | 7.62E-08 | 1.3% |
| | ~8.0 | 3.20E-08 | 3.14E-08 | 2.0% |
| | ~16.0 | 2.05E-08 | 2.01E-08 | 2.3% |
| | ~48.0 | 5.09E-09 | 4.86E-09 | 4.5% |
| | ~80.0 | 1.94E-09 | 1.85E-09 | 4.8% |

## 3. Conclusions

The CFVS is under installment in CANDU reactor for preventing the containment failure during severe accidents. But it has been evaluated that the effectiveness is negligible because of adverse effects of radioactive nuclides releases. Now the CFVS has not been installed yet in the LWR. The results can vary greatly depending on the detailed assessment. It is shown that this methodology might contribute to assessing the accident management strategy such as the implementation of the CFVS quantitatively. It can be used for improving EOPs and SAMGs.

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