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Computational Aid of CANDU Reactor Severe Accident Management Strategies for Containment Integrity

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1. Introduction

Six computational aids (CA) have developed for the severe accident management strategies, plant specific features and behaviors must be studied by detailed analysis works. These computational aids (CA) are one of the tools that can be used to assess the hydrogen generation and challenges that may occur. This paper shows hydrogen related CA. The purpose of this CA is to define whether the hydrogen in the reactor building atmosphere is flammable, and to estimate the hydrogen concentration in the reactor building atmosphere based on an estimated oxidation percentage.

2. Methods and Results

In this section, analysis techniques used to model the CANDU plants and Results are described.

2.1 CA Development Methodology

Basically the same methodology used for PWRs is applied to CANDU plants for specific strategies from results of Level 1 PSA analyses are grouped into plant damage states (PDSs).

In the development of this CA, the following assumptions have been made.

- The reactor building environment is assumed to be a homogeneous mixture of air, steam and hydrogen for which the ideal gas law applies.
- Hydrogen igniters have not been used, and there have been no previous hydrogen burns.
- The reactor building environment is assumed to be at a 100% humidity. This is expected to be a valid assumption for most severe accident scenarios, with the exception of scenarios with a superheated reactor building atmosphere.

Review process of analysis results from GOTHIC or ISAAC

-Quantification of H2 concentration in containment

-Drive preventive procedure for event oriented characteristics

To explain the general usage of this CA, it is helpful to consider it in relation to the other tools that are available to address hydrogen concerns [2]. Therefore, for some hydrogen questions, there are multiple tools that could be referenced to find an answer. Generally, this CA is the tool referenced when the focus is on the current condition, when the zircaloy reaction lines are needed to estimate the current or future hydrogen percentage, or when the question is flammability versus non-flammability.

2.2 CA Development of Hydrogen burn for Plant Specific Failure

The input needed for this CA is the reactor building pressure and the reactor building hydrogen concentration. If the reactor building hydrogen concentration cannot be measured, the 50% or 75% zirconium reaction curves within the CA can be used as a means to estimate the hydrogen concentration. In addition, the guidelines refer to adding a hydrogen equivalent of a 25% zirc reaction to the current measurement, and therefore this curve is also provided. There are several sets of figures within this CA to address different major assumptions. For each set of conditions illustrated, there are two figures: one for the wet hydrogen percentage and one for the dry hydrogen percentage. Both the wet percentage and the dry percentage figures represent the same physical scenario, only the presentation of the data differs. The wet hydrogen percentage is the actual moles of hydrogen when compared to the total moles of steam, air and hydrogen. The dry hydrogen percentage does not include the presence of steam, and it is only a comparison of the hydrogen to dry air and hydrogen. The use of the wet versus dry figures differs, since a fixed amount (moles) of hydrogen appears as a constant horizontal line in the dry figure, while it appears as a curved line in the wet figure. Therefore the user must understand that as the reactor building depressurizes, the hydrogen percentage will remain the same on a dry measurement basis, but it will increase on a wet measurement basis.

It is also important that the user refers to the appropriate set of figures. For the Wolsong 2 this CA, four sets of hydrogen figures were developed:

- No venting, no core/concrete interaction
- 15% venting, no core/concrete interaction
- 30% venting, no core/concrete interaction
- No venting, core/concrete interaction for 24 hours resulting in 114°F superheat and addition of non-condensable gases.

If a venting has occurred, there are two sets of figures which illustrate the shift in the flammability regions. For the Wolsong 2 CA, ventings of 15% and 30% have been illustrated such as Figure 1. Venting is defined as a decrease in the absolute pressure during a venting, divided by the pressure before a venting was initiated. The venting figures should be referred to any time after a reactor building venting has been done. For the figures which address a core/concrete interaction, 50°F of superheat and non-condensable gases from 24 hours of a core/concrete interaction have been illustrated. Also, another line representing a 100% zirc-water reaction has been added. Although 75% has been accepted as a reasonable upper limit, the 100% line is a reminder that additional hydrogen is produced during a core/concrete interaction. If a core/concrete interaction is occurring, the reactor building is generally predicted to become superheated. Therefore, elevated reactor building atmosphere temperatures can be a method of diagnosing that a CCI is occurring. Figure 2 provides information on the temperature/pressure relationship expected for a saturated steam-air mixture, and for a superheated/CCI scenario. The temperature /pressure information should be used in conjunction with other plant data which could indicate a CCI, such as the PHTS at the same pressure as the reactor building, and a limited amount of water in the reactor cavity. At the early stages of an accident, it would also be a good idea to continually compare the actual temperature data to the predicted saturated steam/air mixture temperature, since the actual conditions may vary from the assumed conditions. In this manner, a CCI could be detected based on relative temperature increases. Plant- specific input for Wolsong 2 is represented at reference [2].

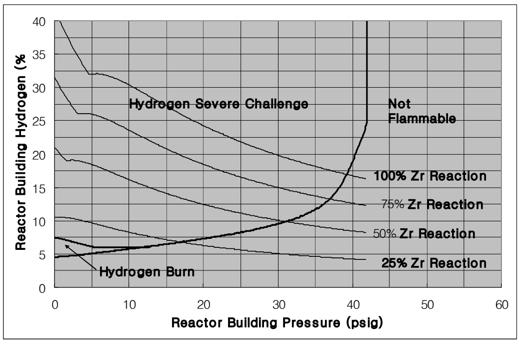

Figure 1 Potential for a Hydrogen Combustion Based on the Wet Hydrogen Measurement (The Reactor Building has been vented 30%)

For development of accident management strategies, various initiating scenarios are selected by logical category schemes for Wolsong units 2, 3, 4 as typical CANDU plant.

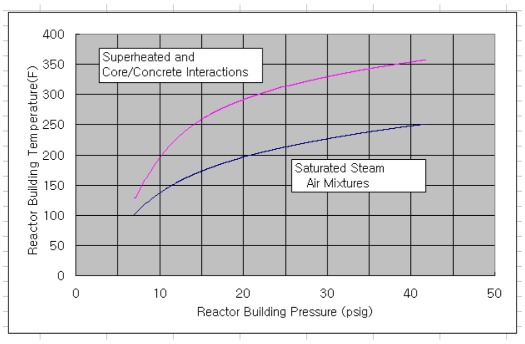

Figure 2 Reactor building Temperature and Pressure Correlation

3. Conclusions

In order to select the useful severe accident management strategies, plant specific features must be identified by logical schemes using detailed studies for the characteristics of CANDU plants. The hydrogen concentration, temperature, pressure and source term information should be used in conjunction with other plant data. This computational aid (CA) is one of the very useful tools that can be used to assess the symptom (e.g. hydrogen generation) and challenges that may occur.

Acknowledgements

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[2] KAERI/RR-2533/2004. “Development of Optimal Severe Accident Management Strategy and Engineered Safety Features”, April, 2005.