Basis for Venting Capacity in Order EA-13-109, "Order to Modify Licenses with Regard to Reliable Hardened Containment Vents Capable of Operation Under Severe Accident Conditions"

This summary and related references have been compiled in order to document the basis for the requirements included in Order EA-13-109 for the capacity of severe accident capable vents for boiling water reactors (BWRs) with Mark I and Mark II containments. Specifically, technical requirement 1.21 in the order states:

> 1.2.1 The HCVS shall have the capacity to vent the steam/energy equivalent of one (1) percent of licensed/rated thermal power (unless a lower value is justified by analyses), and be able to restore and then maintain containment pressure below the primary containment design pressure and the primary containment pressure limit.

This capacity requirement is the same as that included in Order EA-12-050 for reliable hardened containment vents issued in March 2012 to address reactor conditions prior to significant core damage. Order EA-13-109 revised the previous order (EA-12-050) to require licensees to ensure that the containment vents are capable of operation under severe accident conditions at their facilities. Severe accident conditions include the elevated temperatures, pressures, radiation levels, and combustible gas concentrations, such as hydrogen and carbon monoxide, associated with accidents involving extensive core damage, including accidents involving a breach of the reactor vessel by molten core debris.

Over the years a number of studies have been completed related to generation of energy within the reactor core and subsequent decay heat once the reactor has shutdown. The American Nuclear Society Standard (ANS) 5.1 (Reference 1) which was approved by the ANS standards committee in August 1979 provides a method to calculate decay heat power in light water reactors. In 1980's, the NRC sponsored further studies under a program known as Severe Accident Consequences Mitigation. In one of the reports, NUREG/CR-3908 (Reference 2), Figure 2-1 provides decay heat rate and heat accumulation curve with time. It shows that after 3 hours, the decay heat is about 1 % (values shown in that figure were based on 3440 MWT BWR plant at 80 % power, but they show power at or below the 1% of thermal power history value at 3 hours). Generic Letter 89-16 (Reference 3) related to installation of hardened wetwell vents was issued in September 1989 and stated that the system installed by Boston Edison Company at the Pilgrim Nuclear Power Station and associated analysis was acceptable. The design analysis included a vent design objective of venting approximately 1 % of decay heat for a 56 psi saturated steam conditions in the torus. In July 1996, in Information Notice (IN) 96-39 (Reference 4), the NRC staff provided additional clarification in selecting input parameters for estimating decay heat using methodology provided in ANS 5.1. The IN also included results using various available computer codes (MELCOR, RELAP, TRAC, etc...). On the international level, Swiss standard HSK-R-40/d (Reference 5) issued in March 1993 noted in Section 3.2 that the design capacity should be based on a guiding value for steam production of 1% of the thermal reactor power. References 6 and 7 provide additional information on decay heat estimates and compares different methods and results.

Further support for selecting a value corresponding to the decay heat generation rate at 3 hours after shutdown is that suppression pool water mass relative to reactor licensed power provides at least 3 hours of decay heat absorption capacity before reaching saturation temperature (at atmospheric pressure). When a suppression pool reaches saturation, some alternate means of removing additional decay heat energy from containment is needed to avoid further containment pressure increase. Since the decay heat level after the pool reached saturation would be less than 1% of licensed thermal power, a vent capable of discharging the equivalent steam flow from a containment at design pressure to the atmosphere is considered adequate for the pressure control (heat removal) needed to preserve the ability to return containment to a leak tight configuration when normal or other reliable closed loop means of decay heat removal subsequently became available.

The progression of an accident up to and including significant core damage would likely include the need to vent the containment multiple times to prevent a failure of Mark I or Mark II containments due to overpressure conditions. The initial venting operations would likely be performed prior to core damage and the presence of significant amounts of hydrogen and other noncondensible gases and the venting capacity requirements in EA-12-050 were therefore maintained in the revised order, EA-13-109. In addition, the sizing and design of the venting path would not change significantly for severe accident conditions since the credible hydrogen production rates would require a few percent of the capacity of a system designed for 1% steam flow at design pressure. The presence of hydrogen and other noncondensible gases could result in higher containment pressures for some scenarios but would unlikely challenge the structural integrity of the containment given the design margin available. References 8, 9, and 10 provide good information on hydrogen generation and mitigation related issues.

The primary change in the design of the venting system to address hydrogen generation during a severe accident is the additional of technical requirements 1.2.10, 1.211 and 1.2.12. These requirements read as follows:

1.2.10 The HCVS shall be designed to withstand and remain functional during severe accident conditions, including containment pressure, temperature, and radiation while venting steam, hydrogen, and other non-condensable gases and aerosols. The design is not required to exceed the current capability of the limiting containment components.

1.2.11 The HCVS shall be designed and operated to ensure the flammability limits of gases passing through the system are not reached; otherwise, the system shall be designed to withstand dynamic loading resulting from hydrogen deflagration and detonation.

1.2.12 The HCVS shall be designed to minimize the potential for hydrogen gas migration and ingress into the reactor building or other buildings.

References:

1. "American National Standard for Decay Heat Power in Light Water Reactors." American Nuclear Society Standards Committee Working Group ANS 5.1. Approved August 29, 1979.
2. NUREG/CR-3908, "Survey of the State of the Art in Mitigation Systems." January 1988.
3. Generic Letter 89-16, "Installation of a Hardened Wetwell Vent." September 1, 1989.
4. Information Notice 9639, "Estimates of Decay Heat using ANS 5.1 Decay Heat Standard may very significantly." July 5, 1996.
5. HSK-R-40/d, "Filtered Venting for Containment Vessels of Light Water Reactors (LWR): Design Requirements." March 1993.
6. Technical Report 1998-03, "Decay Heat Estimates for MNR." February 23, 1999. http://www.nuceng.ca/papers/decayhe1b.pdf
7. Decay heat illustration2.PNG. http://enm.wikipedia.org/wiki/File:Decay heat illustration2.PNG.
8. IAEA-TECDOC-1661, "Mitigation of Hydrogen Hazards in Severe Accidents in Nuclear Power Plants." July 2011.
9. NUREG/CR-5597, "In-Vessel Zircaloy Oxidation/Hydrogen Generation Behavior during Severe Accident." September 1990.
10. NUREG/CR-2726 SAND82-1137R3, "Light Water Reactor Hydrogen Manual." August 1983.

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