HCVS Guidance Inquiry Form

A. TOPIC: Radiological Evaluations on Plant Actions Prior to HCVS Initial Use Inq. No.: HCVS-FAQ-12

Source document: NEI 13-02 Revision 1 Section: 4.2.5, 5.1.1.3.1, Appendices F and G

B. DESCRIPTION:

HCVS-WP-02 addresses how to determine expected radiological dose from the HCVS vent line under assumed severe accident conditions but does not provide specific guidance details for determining feasibility of operator actions in the reactor building prior to the initial use of the HCVS vent line under severe accident conditions. This FAQ provides guidance for evaluating operator actions within the reactor building during the initial phases of core melt progression prior to ex-vessel core debris or first HCVS vent use after core damage.

C. PROPOSED ANSWER: (Include additional pages if necessary. Total pages: 4)

This response provides a graded approach for performing feasibility evaluations of operator actions within the Reactor Building that addresses the need for some actions to be performed during the early phases of accident progression. This approach is only valid from T=1 hour when it is assumed that core damage begins for the early RCIC failure case and T=8 hours when it is assumed that either the HCVS vent line is first used under severe accident conditions or the accident progresses to ex-vessel core debris. From previous evaluations supporting NEI 13-02 Revision 1, it has been shown that the HCVS vent line is first used to vent containment about the time of Reactor Pressure Vessel (RPV) breach. For the purpose of the evaluation methodologies described in this FAQ, it is not intended to perform plant specific evaluations of RPV breach time or initial HCVS vent line use. The assumed times of T=1 hour and T=8 hours to establish the bounds of applicability of these evaluation methods should be reduced to T=1 hour to T=7 hours in order to provide sufficient margin to inform operator action feasibility evaluations and will be further informed by emergency response dose assessment activities during an actual event. (Reference NRC SECY-15-0085, EPRI Technical Report 3002003301 and NEI-13-02 OIP Template Attachment 2)

Assumptions:

1. The primary and secondary containment boundary provides substantial shielding such that the performance of actions outside the reactor building does not need to consider radiological dose from containment shine.
2. Existing shielding components remain in place and intact following the initiating event that leads to severe accident conditions.
3. Radiological conditions will not adversely impact any actions taken within the Reactor Building until core damage occurs (T=1 hour from start of ELAP where RCIC is assumed to fail at T=0).
4. When core damage begins, radiological conditions within the Reactor Building degrade due to the release of noble gas (gap release and early in vessel release). The noble gas will migrate to the wetwell air space through the open Safety Relief Valves (SRVs)/Electromatic Relief Valves (ERVs).
5. Noble gas released to the primary containment wetwell may migrate to the drywell airspace over time due to leakage/actuation of wetwell to drywell vacuum breakers. It is assumed for the purposes of radiological evaluation that a maximum of 20% of the total noble gas inventory migrates to the drywell airspace.
6. Containment shine from non-gaseous core debris within the RPV or early in-vessel release aerosols released to the wetwell via the SRVs/ERVs will not be a significant contributor to dose rates from the containment until the RPV is breached by core debris (T=8 hours from start of ELAP)

Particulate aerosols leaving the RPV via the SRVs/ERVs will be mostly scrubbed by the wetwell water volume and are not expected to be a significant contributor to dose rates from the wetwell or drywell air spaces until the RPV is breached by core debris (T=8 hours from start of ELAP).

<u>Method 1</u>

From T=0 until T=1, there should be no adverse radiological conditions within the Reactor Building because this is the pre-core damage phase of the event.

From T=1 until either the RPV is breached by core debris, or the HCVS vent line is first placed in service following core damage, the radiological conditions within the Reactor Building will be governed by the gap and early in vessel release noble gas source term. It is expected that the noble gases associated with the gap and early in vessel release will accumulate in the wetwell air space due to the transport from the RPV to the wetwell via the SRVs/ERVs. Some fission product aerosols will also be transported to the wetwell via the SRVs/ERVs but these are expected to be significantly scrubbed by the water in the wetwell early in the accident sequence because the wetwell will remain subcooled in the early phases of the accident where RCIC is assumed to fail at T=0. As evidenced by Mark I and II MAAP runs, it is expected that the suppression pool temperature will be near 200°F and at 20-24 psig at the time of RPV breach for an early RCIC failure scenario, thus the subcooled assumption for the suppression pool is valid. As such, the majority of the radiological dose to be considered for operator actions within the Reactor Building will be from the wetwell air space. The generically accepted RPV breach time is T=8 hours as documented in NEI 13-02 Revision 1 and the initial use of the HCVS vent line is expected to occur at about the same time as RPV breach. For the purpose of this evaluation, T=7 may be used as a generically accepted value for defining the applicability of this method of evaluation of operator actions within the Reactor Building in order to provide margin to the start of venting.

Actions outside the Reactor Building may be assumed acceptable from a radiological perspective until the first use of the HCVS vent line under severe accident conditions. The secondary containment boundary provides substantial shielding in addition to other shielding provided by the primary and secondary containment structures such that the evaluation of dose from source term within the containment need not be considered. After the first HCVS vent line use under severe accident conditions, then actions outside the Reactor Building must be evaluated for impact of the vent line dose per HCVS-WP-02.

This method of evaluation uses a time, distance and shielding toolbox approach to managing operator actions that may occur within the Reactor Building during the limited time in which this method of evaluation applies (i.e., between T=1 and T=7).

Actions performed above and substantially shielded from the wetwell (e.g., grade level and above) may be determined acceptable from a radiological perspective without further evaluation provided the following conditions are met:

a. The dose received will be monitored in accordance with established plant procedures and practices acceptable under extreme event response.

b. A qualitative evaluation of substantial structural shielding that is assumed to remain in place and intact following the initiating event that leads to severe accident conditions is determined to provide a significant dose reduction factor for the actions to be performed. This may include consideration of the location of the action with respect to the biological shield wall, containment boundary, concrete floors and walls and large intervening pieces of equipment between radiation sources and the action to be performed. This evaluation should consider potential streaming paths from stairwells and containment penetrations.

c. Appropriate traverse paths to and from the location where the actions is to be performed are pre-determined, and where appropriate, are captured in procedures as guidance for performing the action.

d. The location where the action is to be performed has been evaluated and determined appropriate as to location and distance from radiation sources and the time and resources needed to perform the action have been minimized (e.g., quick connect fittings or simple threaded connections, transfer switches or disconnects).

If there are actions within the Reactor Building to be performed between T=1 and T=8 that cannot be determined acceptable using Method 1, then additional quantitative methods of evaluation may be performed to determine the feasibility of operator actions as described in Method 2.

Method 2

Discussion:

As described in Section 5.1.1.3 of NEI 13-02 Revision 1, the expected conditions following an ELAP initiated severe accident should be consistent with the expected conditions assumed in the plant's current licensing basis for a major accident. This provides important insights for estimating the expected dose rates in areas where HCVS/SAWA actions are to be performed, particularly when considering the source term inventory, distance and shielding dose reduction factors. What may differ significantly is the release timing and location of the source term and the potential impact to the timing and quantification of expected dose rates at the locations of interest. For example, most license basis major radiological accidents are major Loss of Coolant Accident (LOCA) based, in which a large break in the reactor coolant system allows for a release of fission product inventory into the drywell airspace early in the event sequence. This produces a large source term inventory that can produce high dose rates in the Reactor Building at elevations above that which would be expected in an ELAP driven severe accident sequence where the Reactor Coolant pressure boundary remains largely intact until the RPV is breached by core debris. While HCVS-WP-02 uses NUREG-1465 to establish bounding time-dependent airborne radioactivity used for vent pipe dose, application of the same to determine impact on operator actions prior to RPV breach is significantly over-conservative. To provide the best estimate dose rates in areas of the Reactor Building where HCVS/SAWA actions are to be performed requires identification of when the action will be performed and where the significant contributors of radiological dose will be within the primary containment and are expected to be consistent with Assumptions 2 through 6 above. The following guidance for performing radiological evaluations for actions in the Reactor Building necessary to support HCVS/SAWA is provided:

Timeline of Source Term Applicability

NOTE: This timeline, from T=0 to T=8 is based on the generically accepted 8 hour breach time described in NEI 13-02 Revision 1. As in Method 1, one hour margin is provided in which to perform actions within the Reactor Building.

0 Hours ≤ T ≤ 1 Hours

ELAP initiating event. Reactor Building access to perform HCVS/SAWA actions is unlimited from a radiological perspective. HCVS/SAWA actions outside the Reactor Building are also unlimited from a radiological perspective.

1 Hours < T < 7 Hours

Onset of core damage for early RCIC failure case, start of gap and early in vessel release. Reactor Building access becomes limited from a radiological perspective based on location. Radiological evaluation to consider containment shine caused by gap and early in vessel release (noble gases) and using assumptions and clarifications in this FAQ. Radiological dose from the HCVS vent line is not considered because the vent line has not yet been opened under severe accident conditions. HCVS/SAWA actions outside the Reactor Building are unlimited from a radiological perspective.

7 Hours < T < 8 Hours

Margin to venting start or RPV breach.

T ≥ 8 Hours

RPV breach by core debris. First expected HCVS vent line usage to maintain containment pressure below Primary Containment Pressure Limit (PCPL). Reactor Building access becomes very restricted or inaccessible from a radiological perspective because of increasing dose rates from the gap and early in vessel release, particulate release to drywell airspace resulting from breach of the RPV and radiological dose from the HCVS vent line from those portions of the HCVS vent line inside the Reactor Building. HCVS/SAWA actions outside the Reactor Building may become limited due to dose from the HCVS vent line and should be evaluated using the guidance in HCVS-WP-02.

Method 2 Evaluation:

For the ELAP scenario, EOPs/SAPs will direct depressurizing the RPV through SRVs/ERVs upon sustained loss of adequate core cooling and prior to the onset of core damage, thereby directing radionuclides through the open SRVs/ERVs to the Suppression Pool (wetwell) starting with the gap and early in vessel release phase of core damage progression. Directing radionuclides into the wetwell via SRVs has three dominant effects:

- Substantially limits dose from the Drywell (very little airborne) having a net positive impact for most plants with HCVS/SAWA actions at grade elevation or higher in the Reactor Building early in the severe accident sequence, between T=1 hour and T=8 hours.

- Substantially reduces the overall peak dose values by ~70% due to scrubbing of aerosols (Figure 4 of HCVS-WP-02), between T=1 hour and T=8 hours.
- Since the primary contributors to dose prior to RPV breach are noble gases, dose values will lower rapidly due to decay after Reactor Shutdown (Figure 2 in HCVS-WP-02). This will have an impact for all event timing sequences considered, but a more pronounced impact to the late RCIC failure timing sequence.

A method for evaluating dose from the Torus/Suppression Chamber is to scale the following activity levels (shown in units of micro curies) using Scaling Factor SF1 from HCVS-WP-02, and placing the source term in the Wetwell airspace, then calculate dose (e.g., using a suitable calculation code such as Microshield). The scaling method is for evaluating dose from noble gases in the Suppression Chamber/Torus/Drywell and is applicable to the period before RPV breach with margin (T=1 to T=7).

The following table includes 5% noble gas inventory at T=0.5 hours from start of core damage as defined by clad temperature exceeding 1800°F (gap release phase) and an additional 95% noble gas inventory at T=2 hours from the start of core damage (early in vessel release phase). The table also accounts for radioactive decay.

Total activity	0.5 hr	1 hr	2 hr	4 hr	8 hr
Kr-83m	5.5191E+05	3.3593E+06	6.3115E+06	2.9953E+06	6.7461E+05
Kr-85m	1.2836E+06	8.7124E+06	2.0355E+07	1.4937E+07	8.0443E+06
Kr-85	7.9917E+04	5.8605E+05	1.5983E+06	1.5984E+06	1.5984E+06
Kr-87	2.0129E+06	1.1240E+07	1.7774E+07	5.9749E+06	6.7521E+05
Kr-88	3.2938E+06	2.1380E+07	4.5681E+07	2.8037E+07	1.0562E+07
Rb-88	3.2938E+06	2.1380E+07	4.5681E+07	2.8037E+07	1.0562E+07
Xe-133	1.0700E+07	7.8445E+07	2.1340E+08	2.1113E+08	2.0666E+08
Xe-133m	3.3019E+05	2.4187E+06	6.5529E+06	6.3853E+06	6.0628E+06
Xe-135	3.9320E+06	3.0113E+07	8.3245E+07	7.1625E+07	5.2796E+07
Xe-135m	9.6841E+05	5.6591E+06	6.3278E+06	2.7557E+04	5.2261E-01
Xe-138	2.1158E+06	3.5876E+06	5.2308E+05	1.4950E+03	1.2213E-02

As pressure in the Wetwell increases, vacuum breakers may open and some of the noble gases will be transferred from the wetwell to the drywell airspace. While the total fraction that is transferred is dependent on scenario, plant layout and time, the assumption of a 20% transfer of noble gases from the wetwell to drywell airspace from T=start of core damage and that 20% being uniformly mixed through the entire drywell airspace volume is judged reasonable for the purpose of this assessment. 20% applies to the values in the above table. As an alternative to the 20% transfer generic assumption, licensees may perform a plant specific evaluation to perform a best estimate percentage transfer from the wetwell to the drywell during the time of interest.

D. RESOLUTION: (Include additional pages if necessary. Total pages: 4)

Licensees should use the information in this FAQ for estimating source term contributions to Reactor Building dose rates for operator actions from the start of core damage until the RPV is breached by core debris or the HCVS vent line is first used under severe accident conditions, which can be assumed to be from T=0 to T=7 hours

Applies to both Phase 1 and Phase 2.

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