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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 80 - Containment Systems - RAI Number 6.2-138**

Enclosure 1 contains GEH's response to the subject NRC RAI transmitted via the Reference 1 letter.

If you have any questions or require additional information, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

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NRO

Reference:

1. MFN 06-419, Letter from U.S. Nuclear Regulatory Commission to David Hines, *Request for Additional Information Letter No. 80 Related to ESBWR Design Certification Application*, November 2, 2006

Enclosure:

1. MFN 07-383 - Response to Portion of NRC Request for Additional Information Letter No. 80 - Related to ESBWR Design Certification Application - Containment Systems - RAI Number 6.2-138

cc:	AE Cubbage	USNRC (with enclosures)
	BE Brown	GEH/Wilmington (with enclosures)
	GB Stramback	GEH/San Jose (with enclosures)
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Enclosure 1

MFN 07-383

Response to Portion of NRC Request for

Additional Information Letter No. 80

Related to ESBWR Design Certification Application

Containment Systems

RAI Number 6.2-138

NRC RAI 6.2-138:

Describe and justify capability for ensuring a mixed containment atmosphere.

10 CFR 50.44(c)(1) states:

> *Mixed atmosphere. All containments must have a capability for ensuring a mixed atmosphere during design-basis and significant beyond design-basis accidents.*

The following is the complete text of DCD, Tier 2, Revision 1, Section 6.2.5.3.4, "Containment Atmosphere Mixing":

> *The ESBWR design provides protection from localized combustible gas deflagrations including the capability to mix the steam and non-condensable gases throughout the containment atmosphere and minimize the accumulation of high concentrations of combustible gases in local areas. The containment design features that will reduce the likelihood of combustible gas deflagrations resulting from localized buildup of combustible gases during degraded core accidents are listed in Section 19.3.*

It appears that Section 19.3.2.1, "Hydrogen Generation and Control," is the only part of Section 19.3 that mentions containment atmosphere mixing. The problem is that the only mention of it is a statement that the analysis of post-accident oxygen concentration assumes "Adequate gas mixing throughout containment."

Insofar as an assumption is not an explanation or justification, add an appropriate discussion to the DCD which explains and justifies ESBWR's capability for ensuring a mixed atmosphere during design-basis and significant beyond design-basis accidents. The discussion should address: passive features of the design, including containment/subcompartment layout, elevations, and openings between compartments that impact mixing; active features of the design, including ventilation systems, cooling systems, and spray systems; and the effectiveness of the passive and active features in providing a mixed atmosphere in the design-basis and significant beyond design-basis events. If non-safety related systems are relied upon for mixing, the availability of these systems in the frequency-dominant beyond design-basis events and any "special treatment" requirements for these systems should also be addressed.

GEH Response:

The cited DCD Tier 2, Revision 1, Subsection 6.2.5.3.4 states that "The ESBWR design provides protection from localized combustible gas deflagrations including the capability to mix the steam and non-condensable gases throughout the containment atmosphere and minimize the accumulation of high concentrations of combustible gases in local areas. The containment design features that will reduce the likelihood of combustible gas deflagrations resulting from localized buildup of combustible gases during degraded core accidents are listed in Section 19.3." DCD Tier 2, Revision 1, Section 19.3 simply assumes "Adequate gas mixing throughout containment."

Based on the configuration of the ESBWR containment coupled with the dynamics of the design basis loss-of-coolant accident (LOCA) and the mitigating components within the containment volume, adequate mixing within the ESBWR containment system is assured. The containment volumes' atmospheres (drywell and wetwell) are inerted with nitrogen as required by

10 CFR 50.44. At the start of an accident, normal drywell ventilation can be assumed to be in operation, therefore the atmosphere is thoroughly mixed at that point in time. Although the normal drywell ventilation system will cease to operate at the onset of the accident, the accident itself (LOCA) will create a highly turbulent condition in which mixing is assured. Steam expansion will also serve to create large mixing flows. Molecular diffusion and natural convection will continue the mixing process providing reasonable assurance that adequate mixing exists throughout the accident coping period. Natural convection is promoted by temperature gradients existing in the drywell and the cascading effect of the water exiting through the break. It should also be noted that because the ESBWR core remains covered during Design Basis Accidents, only a minimal amount of hydrogen is generated by radiolysis. This is based on the fuel temperature remaining below the metal-water reaction initiation temperature.

Containment Volume

It should be noted that the ESBWR containment structure is one of the larger of the BWR line in free volume, equal to that of the ABWR and larger than the earlier Mark I and II containments. This increase in open volume enhances the structure's ability for continued mixing. In consideration of the differential component temperatures inside containment, local convection around these components coupled with the natural chimney effect of the open shafts in the containment volume will provide substantial motive force furthering the mixing process.

Aside from the drywell and wetwell, there are only two other subcompartments within the containment, the Drywell Head Region and the Reactor Shield Annulus. The Drywell Head Region contains no high energy piping. As such, and based on the location of this region above the drywell proper, in the unlikely event that hydrogen migrated toward this area it would be quickly displaced by the rising steam from the break. There is reasonable assurance that it would not be possible for hydrogen to collect in this region. The Reactor Shield Annulus volume is that area between the reactor shield wall and the reactor vessel. In the unlikely event that the LOCA occurs at the nozzle of any of the vessel's high energy piping (which does pass through this region), any non-condensable effluent from the break would quickly be dispersed by the escaping steam and swept down into the wetwell by steam along with the rest of the drywell non-condensable gases.

Passive Autocatalytic Recombiners (PARs)

Another consideration with respect to the mixing process is the incorporation of PARs into both the ESBWR drywell and wetwell. PARs are passive devices that operate when the surrounding atmosphere contains a stoichiometric mix of hydrogen and oxygen. The PARS contain a catalyst that facilitates the recombination of the hydrogen and oxygen gases into water vapor. In addition to the advantage of reducing combustible gases in containment, PARs also create convective air currents (recombination is an exothermic reaction), which further serves to drive both the recombination process along with mixing both in the drywell and wetwell atmospheres.

Wetwell

The dynamic effects of a LOCA in the ESBWR containment will serve to drive the non-condensable gases from the drywell into the wetwell. This initial blowdown is due to pressurization of the drywell atmosphere by steam exiting the vessel. This steam will force (blowdown) non-condensable gases through (under) the wetwell water volume. This will be a

quite dynamic evolution that will thoroughly mix the wetwell atmosphere, albeit an atmosphere much richer in hydrogen and oxygen than that remaining in the drywell.

Subsequent to the reactor depressurization, the Passive Containment Cooling System (PCCS) condensers will continue to operate. The PCCS condensers vent non-condensable gas to the wetwell (suppression pool), so the concentration of hydrogen will be higher in the wetwell than in the drywell. This increase in the hydrogen and oxygen levels in the wetwell atmosphere will result in the recombination action and subsequent convective currents brought on by the PARs.

DCD Impact:

DCD Tier 2, Subsection 6.2.5.3.4 and Subsection 19.3.2.1.1, will be revised as shown in the attached markup.

6.2.5.3.4 Containment Atmosphere Mixing

The ESBWR design provides protection from localized combustible gas deflagrations including the capability to mix the steam and non-condensable gases throughout the containment atmosphere and minimize the accumulation of high concentrations of combustible gases in local areas.

Adequate mixing within the ESBWR containment system is assured based on the configuration of the ESBWR containment coupled with the dynamics of the design basis loss-of-coolant accident (LOCA) and the mitigating components within the containment volume. The containment atmospheres (drywell and wetwell) are inerted with nitrogen. At the start of an accident normal drywell ventilation can be assumed to be in operation, therefore the inerted atmosphere is thoroughly mixed at that point in time. Although the normal drywell ventilation system will cease to operate at the onset of the accident, the accident itself (LOCA) will create a highly turbulent condition in which mixing is assured. Steam expansion will also serve to create large mixing flows. Molecular diffusion and natural convection will continue the mixing process providing reasonable assurance that adequate mixing exists throughout the accident coping period. Natural convection is promoted by temperature gradients existing in the drywell and the cascading effect of the water exiting through the break. Because the ESBWR core remains covered during Design Basis Accidents, only a minimal amount of hydrogen is generated by radiolysis. This is based on the fuel temperature remaining below the metal-water reaction initiation temperature.

The relatively large open volume of the ESBWR containment enhances the structure's ability for continued mixing. In consideration of the differential component temperatures inside containment (coupled with the relative low temperatures of the outer drywell walls), local convection around these components coupled with the natural chimney effect of the open shafts in the containment volume will provide substantial motive force furthering the mixing process.

Aside from the drywell and wetwell, there are only two other subcompartments within the containment, the Drywell Head Region and the Reactor Shield Annulus. The Drywell Head Region contains no high energy piping. As such, and based on the location of this region above the drywell proper, in the unlikely event that hydrogen migrates toward this area it would be quickly displaced by the rising steam from the break. There is reasonable assurance that it would not be possible for it to collect in this region. The Reactor Shield Annulus volume is that area between the reactor shield wall and the reactor vessel. In the unlikely event that the LOCA occurs at the nozzle of any of the vessel's high energy piping (which does pass through this region), any non-condensable effluent from the break would quickly be dispersed by the escaping steam and swept down into the Wetwell by steam along with the Drywell non-condensable gases.

The dynamic effects of a LOCA in the ESBWR containment will serve to drive the non-condensable gases from the drywell into the wetwell. This initial blowdown is due to pressurization of the drywell atmosphere by steam exiting the vessel. This steam will force (blowdown) non-condensable gases through (under) the wetwell water volume. This will be a quite dynamic evolution that will thoroughly mix the wetwell atmosphere, albeit an atmosphere much richer in hydrogen and oxygen than that remaining in the drywell.

Subsequent to the reactor depressurization, the Passive Containment Cooling System (PCCS) condensers will continue to operate. The PCCS condensers vent non-condensable gas to the wetwell (suppression pool), so the concentration of hydrogen will be higher in the wetwell than in the drywell.

Another consideration with respect to the mixing process is the incorporation of Passive Autocatalytic Recombiners (PARS) into both the drywell and wetwell. PARS create convective air currents, which further serves to drive both the recombination process along with mixing both in the drywell and wetwell atmospheres. A description of PARS is given in Section 6.2.5

The containment design features that will reduce the likelihood of combustible gas deflagrations resulting from localized buildup of combustible gases during degraded core accidents are listed in Section 19.3.

19.3.2.1.1 Introduction to Hydrogen Generation and Control

The potential for containment failure due to hydrogen generation is addressed by considering physical characteristics of the containment, notably the inerted condition and containment structural capability, as well as the reliability of passive systems engineered to perform the containment functions of isolation, vapor suppression, and heat removal. Containment failure due to combustible gas deflagration is shown to be negligible considering the inerted containment and time period required to generate enough oxygen to create a combustible gas mixture.

Because the ESBWR containment is inerted, the prevention of a combustible gas deflagration is assured in the short term following a severe accident. In the longer term, there is an increase in the oxygen concentration resulting from the continued radiolytic decomposition of the water in the containment. Because the possibility of a combustible gas condition is oxygen-limited for an inerted containment, it is important to evaluate the containment oxygen concentration versus time following a severe accident to assure that there will be sufficient time to implement recovery actions. It is desirable to have at least a 24-hour period following an accident to allow for actions with a high likelihood of success. This subsection discusses the rate at which post-accident oxygen will be generated by radiolysis in the ESBWR containment following a severe accident, and establishes the period of time that would be required for the oxygen concentration in containment to increase to a value that would constitute a combustible gas condition (5% oxygen by volume) in the presence of a large hydrogen release.

The rate of gas production from radiolysis depends upon the power decay profile and the amount of fission products released to the coolant. Analysis results have been developed in a manner consistent with the guidance provided in SRP 6.2.5 and Regulatory Guide 1.7. There are unique design features of the ESBWR that are important with respect to the determination of post-accident radiolytic gas concentrations. In the post-accident period, the ESBWR does not utilize active systems for core cooling and decay heat removal. For a design-basis LOCA, ADS depressurizes the reactor vessel and GDCS provides gravity-driven flow into the vessel for emergency core cooling. The core coolant is subcooled initially and then it is saturated, resulting in steam flow out of the vessel and into the containment. The PCCS heat exchangers remove the energy by condensing the steam.

A similar situation exists for a severe accident that results in core melt followed by reactor vessel failure. In this case, the GDCS coolant covers the melted core material in the lower drywell, with an initial period of subcooling followed by steaming. The PCCS heat exchangers remove the energy in the same manner as described above for a design basis LOCA.

Each PCCS heat exchanger has a vent line that transfers non-condensable gases to the suppression pool vapor space, driven by the drywell to suppression pool pressure differential. In this way, the majority of the non-condensable gases will be in the suppression pool.

The calculation of post-accident radiolytic oxygen generation accounts for this movement of non-condensable gases to the suppression pool after they are formed in the drywell. In addition, the effect of the core coolant boiling, which strips dissolved gases out of the liquid phase resulting in a higher level of radiolytic decomposition, is accounted for in the analysis.

Analysis Assumptions

The analysis of the radiolytic oxygen concentration in containment is performed consistent with the methodology of Appendix A to SRP 6.2.5 and Regulatory Guide 1.7. Some of the key assumptions are as follows:

- Reactor power is 102% of rated;
- G(O2) = 0.25 molecules/100eV;
- Initial containment O2 concentration = 4%;
- Allowed containment O2 concentration = 5%;
- Stripping of drywell non-condensable gases to wet-well vapor space;
- Fuel clad-coolant reaction up to 100%;
- Iodine release up 100%; and
- Adequate gas mixing throughout containment (reference Subsection 6.2.5.3.4 for further discussion).