February 7, 2007

TSTF-07-07
PROJ0753

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

SUBJECT: Response to NRC Request for Additional Information Regarding TSTF-478, Revision 0, "BWR Technical Specification Changes that Implement the Revised Rule for Combustible Gas Control," dated November 9, 2006

REFERENCE: Letter from T. J. Kobetz (NRC) to the Technical Specifications Task Force, "Request for Additional Information Regarding TSTF-478, Revision 0, 'BWR Technical Specification Changes that Implement the Revised Rule for Combustible Gas Control'," dated November 9, 2006.

Dear Sir or Madam:

In the referenced letter, the NRC provided a Request for Additional Information (RAI) regarding TSTF-478, Revision 0, "BWR Technical Specification Changes that Implement the Revised Rule for Combustible Gas Control." This letter responds to the NRC's referenced request.

The TSTF is developing a revision to TSTF-478 that reflects the changes described in this response. We will submit the revised Traveler by March 1, 2007.

The TSTF requests a meeting with the NRC within 3 weeks of the receipt of this letter to discuss the RAI responses and the status of the review of TSTF-478.

Any NRC review fees associated with the review of TSTF-478 should continue to be billed to the Boiling Water Reactors Owners Group.

The TSTF requests that the Traveler be made available under the Consolidated Line Item Improvement Process.

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Should you have any questions, please do not hesitate to contact us.

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Enclosure
Attachments 1 and 2

cc: Tim Kobetz, Technical Specifications Branch, NRC
Ross Telson, Technical Specifications Branch, NRC

Response to NRC Request for Additional Information Regarding TSTF-478, Revision 0, "BWR Technical Specification Changes that Implement the Revised Rule for Combustible Gas Control," dated November 9, 2006

The following are the Technical Specification Task Force (TSTF) responses to the NRC's November 9, 2006, Request for Additional Information (RAI) on TSTF-478, Revision 0.

Extending the Period of Deinerted Operation from 24 Hours to 72 Hours

RAI #1

1. *Provide the following information to better understand the rationale and benefits associated with extending the period of deinerted operation from 24 hours to 72 hours:*

    a. *a general description of operational experience with the 24 hour completion time, including:*

        - *a typical timeline or sequence of events for a plant startup and a plant shutdown, with the times at which inerting/de-inerting is initiated and completed, the times in each operating mode, and the times at which the LCO is entered/exited,*

        - *typical frequency/occurrences of startups and shutdowns in which inerting/de-inerting: caused a trip, became a critical path activity, or was perceived to have placed the plant in a less-safe state,*

        - *a description of typical control room staffing during the startup and shutdown periods, whether the control room staffing is supplemented to address inerting and de-inerting, and how the responsibilities for inerting and de-inerting are typically distributed among the control staff, and*

        - *any known current plant-specific technical specifications that permit a completion time greater than 24 hours, or prior NRC approvals of a completion time greater than 24 hours.*

    b. *an anticipated typical timeline or sequence of events for a plant startup and a plant shutdown assuming a 72 hour completion time, with the times at which inerting/de-inerting is initiated and completed, the times in each operating mode, and the times at which the LCO is entered/exited.*

    c. *an explanation why inerting/de-inerting would have a lower likelihood of causing a trip, becoming a critical path activity, or placing the plant in a less-safe state if the completion time is extended from 24 hours to 72 hours*

Response to RAI #1a

TSTF-478, Revision 0, was transmitted to the NRC on April 25, 2005. The justification for TSTF-478 stated that our request to extend the allowable time for de-inerted operation from the existing 24 hour limit to the proposed 72 hour limit is to provide additional operational flexibility during startup and shutdown should unplanned events occur. The proposed 72 hour limit will allow sufficient time to complete numerous startup test activities, including Surveillance Requirements, and to achieve stable conditions before inerting operations are begun. As demonstrated in our response to RAI #2 (below), this change will have negligible impact on plant risk.

Some older plant-specific Technical Specifications required the containment to be inerted on entry into Mode 1. If the containment was not inerted, Reactor Coolant System pressure had to be reduced to 100 psig. This presented significant operational difficulties which were corrected in the standard Technical Specifications, which provided 24 hours after exceeding 15% power to inert containment. This allowed the NSSS to be brought to pressure and temperature and completion of tests and Surveillance Requirements prior to inerting containment. The 24 hour period was selected as a suitable balance between the need for operational flexibility and the conditions under which a design basis accident involving hydrogen production was risk significant.

The existing requirement that primary containment be inerted within 24 hours after achieving 15% power results in the work activities necessary to achieve an inerted state being performed in parallel with other required activities. This is a challenge for the plant operation staff to perform the manual activities required to inert the containment and continue with other required activities to achieve full power operation. In order to assure compliance with the existing requirement to inert the containment within 24 hours, plants will commence inerting when they close the containment or at 15% power. Often, pre-inerting activities will commence earlier, such as containment closure or when the plant enters Mode 1 operation. Some plants will start their preparations for inerting the containment earlier because in the past equipment problems have resulted in a delay of startup in order to ensure the containment can be inerted within 24 hours after exceeding 15% power.

Challenges imposed by the existing Technical Specification provision are:

- Twenty-four hours is a short period of time to inert containment given the complexities and limitations of the plant systems required;

- Inerting containment within 24 hours after exceeding 15% power significantly complicates the repair of equipment problems found during power ascension that require containment entry; and

- Repair of identified or unidentified system leakage found after the start of inerting that requires containment entry can result in de-inerting containment to facilitate containment entry, substantially extending the repair and plant startup.

During ascension to Mode 1, the plant has performed multiple tests, control rod drive manipulations, and Nuclear Steam Supply System (NSSS) tests to ensure operability criteria are met. When power reaches 15%, the existing 24 hour limit clock for containment inerting begins. At 15% power and above, most of the startup activities are focused on balance of plant systems. However, a substantial amount of testing remains to confirm proper system operation for power ascension, including verification of the reactor recirculation system requirements and control rod drive scram testing. (Note that TSTF-484, "Use of TS 3.10.1 for Scram Time Testing Activities," approved by the NRC on October 27, 2006, eliminates the need for control rod testing performed at 20-40% power, but other power ascension activities required to be completed will remain.)

Unexpected problems can occur as power is increased above 15% and systems are placed in service (including the systems needed for containment inerting). When such problems occur, corrective actions may be challenging, especially if containment entry is needed to complete the identified corrective actions. Entry into containment without a breathing apparatus is prevented at most plants when the plant is inerted. Most plants would choose to suspend the startup, reduce power below 15%, and totally de-inert the containment if entry is required. This enables the plant to reset the existing 24 hour limit to inert the containment, but at a significant cost associated with prolonging the time to start up the plant, burden on plant staff, and consumption of nitrogen.

The proposed 72 hour limit will allow plants to perform required startup tests, identify unexpected equipment problems found during startup, enter the containment without de-inerting, and make appropriate repairs, without incurring the problems described above. If the proposed 72-hour limit is adopted, containment inerting will likely begin at 60% power and will have limited impact on the actual time the plant operates de-inerted unless unexpected problems occur. At 60% power, all systems required to achieve full power operation should be in service. If a problem is detected, and trouble shooting indicates entry to containment is needed, the risk of having to de-inert and drop power below 15% to effect corrective actions would be avoided.

During the planning for a plant startup, the existing 24 hour time limit to inert containment is not critical path. However, unexpected problems can result in containment inerting becoming critical path. Plants have experienced equipment-related problems that have resulted in the need to de-inert the primary containment during startup, such as problems with drywell sump pumps, reactor recirculation pump motors, drywell temperature indicators, and acoustic monitors. Problems have also occurred with the equipment needed to supply nitrogen to inert the containment. The frequency of occurrence of equipment-related problems varies within the boiling water reactor (BWR) fleet, but all Mark I and II plants have experienced extended startup times to address need to de-inert for containment entry. Leakage from the RCS or other systems within containment (e.g., gasket failure, pipe flanges insufficiently tightened, etc.) can also result in the need to de-inert in order to affect repairs. When such events occur, the need to de-inert and reduce power becomes critical path

We have no evidence that any plant has initiated a plant trip or been placed in a less safe condition as a result of the existing Technical Specification provisions. However, any time a carefully constructed startup or shutdown plan is altered or operator duties are increased, the possibility for error is increased. The introduction of this operator distraction must be balanced against the safety benefit of the activity that caused the disruption. The proposed change will avoid many of the issues and operator distractions that occur under the existing 24 hour limit.

A consistent challenge to address these events involves the systems and components needed to inert and de-inert the containment. It is possible for personnel to enter the containment when it is inerted using breathing apparatus, but most utilities choose to de-inert the containment to assure personnel safety. Multiple operational activities are needed to align plant valves and start equipment to supply the nitrogen for inerted operation, assuming a sufficient quantity of nitrogen is on hand. Large quantities of nitrogen are needed (18,000 gallons) to inert containment and plants are challenged to inert the drywell and the suppression chamber due to limited in-plant system capabilities. Some plants have limited storage capacity onsite and can provide enough nitrogen for only one containment inerting. Should additional nitrogen be needed, time-consuming arrangements must be made to obtain nitrogen from offsite suppliers. In addition, the nitrogen inerting systems at some plants require a great deal of maintenance which must be performed more frequently when multiple inerting and de-inerting activities are required.

Attachment A depicts a generic startup timeline highlighting key events. It is used for training purposes at some plants and reflects the anticipated sequence of events if problems are not encountered. Attachment A does not include all testing and Surveillance Requirements that may be required during plant startup. For example, control rod drive scram time testing is not included but is a time-consuming test performed at 20-40% power. Scram time testing can identify system problems that may require containment entry. The existing 24 hour limit for inerting containment begins when the plant exceeds 15% power. Note that above 60% power, full power operation is achieved using control rod withdrawal and reactor recirculation flow increases, and no additional systems are placed in service or Surveillance Requirements required in order for the plant to achieve full power operation.

Attachment A indicates approximately 7 hours is needed to raise power from 15% to 60%. However, balance of plant problems often extend this time. The time to perform the steps necessary to inert the containment vary depending on the size of the containment and inerting system capabilities, but can be completed within 4 to 6 hours with an experienced plant staff and assuming no problems are encountered with the inerting equipment. Thus, it can be expected that if containment inerting is started at 60% power, it would be completed within the existing 24 hour limit. The proposed 72 hour limit to inert containment is requested to provide time to respond to unexpected problems during startup.

Relevant log entries for a BWR startup in 2006 are listed below:

Day 1

14:47	Entered Mode 1
14:54	Under vessel leak from CRD found and corrected
20:04	Reactor power @13%
20:42	Started Standby Gas Treatment (SBGT) System in preparation for inerting
20:54	Stopped ventilating primary containment
21:27	Reactor power at 15% with rods
21:27	Entered Tech Spec Action on O2 not within limit
21:55	Started venting the drywell in prep for inerting
23:05	Stopped venting the drywell
23:40	Rolled the main turbine

Day 2

16:30	Met the LCO with O2 at 2.5 % and 60% power
17:27	Purge complete

The plant was in the Condition for containment oxygen concentration not within limit for approximately 19 hours of the existing 24 hour Completion Time. The plant was in compliance with the LCO in less than the indicated 19 hours because the Technical Specification oxygen concentration is limit 3.5% at this plant and the record indicates oxygen concentration at 2.5% when exiting the Action. Had the plant identified the need for a containment entry during the startup, power would have been reduced to at least 15% and the containment de-inerted for investigation of the problem. Manual actions would have required 4 to 6 hours to reduce power and de-inert the containment with a corresponding startup delay. This particular plant has onsite nitrogen capacity to perform only one containment inerting, so additional nitrogen from a supplier would be needed.

For a typical plant shutdown for a refueling outage, the shutdown timeline must include allowances for compliance with the existing 24 hour limit on de-inerting the containment prior to reducing power below 15%.

Relevant log entries for a BWR shutdown are listed below:

Day 1

17:13	Started de-inerting (Mode 1)
17:22	Entered the LCO Action for Primary Containment O2 concentration above 4%

Day 2

16:22	Shutdown (Mode 3)

It is reported that approximately 4 to 6 hours are needed to raise oxygen concentration from an inerted condition to 19%. Similar to a plant startup, the problems associated with meeting the existing 24 hour time limit from de-inerting the containment to being below 15% power during a plant shutdown are unexpected problems with plant systems required for shutdown. However, as few systems are started during shutdown, these types of problems are much less likely than during startup and the primary reason for the requested change is for flexibility during plant startup.

The inerting process adds to operational staffing requirements at some plants because of the complexity of the inerting systems and the need to perform the activity in sequence with other startup activities. The system alignments and operation of systems needed to inert the containment are manual operations. At a plant with a complex inerting system, a minimum of three individuals will be involved in the process: a dedicated equipment operator for nitrogen systems, another operator, and a licensed reactor operator (RO) to supervise the activities. For other plants, additional personnel are not needed and the inerting activities can be performed by the existing control room staff, which includes one Shift Manager, two senior reactor operators (SROs) and 4 to 5 ROs .

We are not aware of any plant-specific Technical Specification that permit a Completion Time greater than 24 hours or of prior NRC approvals of a Completion Time greater than 24 hours.

Response to RAI #1b

An anticipated plant startup while operating with the proposed 72 hour limit on containment inerting will not defer a plant startup under the existing 24 hour limit, but will avoid issues such as the need to compensate for xenon reactivity effects while holding power stable at 15%. The plant will enter the Action with a 72 hour Completion Time when Mode 1 is entered, not at 15% power. Although likely to vary somewhat among the plants, containment inerting activities (such as starting SBGT and venting the drywell) would likely start at approximately 50-60% power. At this power level, the plant has achieved stable operating conditions and the majority of system testing and control rod manipulations have been essentially completed. Containment inerting could then be accomplished in approximately 6 hours. Based on the startup timeline shown in the response to RAI 1.a, relevant events would proceed as follows:

Day 1

14:47	Enter Mode 1
14:47	Enter Tech Spec Action for O2 limit not met
21:27	Reactor power @15% with rods

Day 2

16:30	Reactor power @ 60%, start SBGT and drywell venting in preparation for inerting
17:30	Stop venting drywell and start inerting
23:00	Meet the LCO on 02 concentration and exit the Action

In comparison to the previous example startup (see log entries in the response to RAI 1.a), the above sequence would add a maximum of 90 minutes to the length of time the plant is operating outside the O2 limit. Note that the example given above assumes significantly more time to reach 60% power than the timeline in Attachment A and the plant will probably meet the LCO prior to the actual log entry. The Attachment A timeline specifies approximately 7 hours to raise power from 15% to 60% instead of the 18 hours shown in the simulated log entries. This reflects the fact that the balance of plant activities typically take more time than assumed in an "ideal" startup. If the Attachment A timeline is assumed to be representative, the containment would be inerted long before the existing 24 hour limit.

Neither the Attachment A timeline nor the example startup log assumed the need for a containment entry. As described in the response to RAI #1a, a containment entry will add significant time to the plant startup due to the need to initiate activities to de-inert the containment. Manual valves would need to be aligned to vent the containment and release the nitrogen blanket. After the containment is de-inerted to assure oxygen concentration is at 19%, containment entries can be authorized. As it is difficult to forecast the time required to investigate and repair a problem, some plants choose to enter shutdown (Mode 4) rather than risk violation of the existing 24 hour limit.

<u>Response to RAI #1c</u>

We have not identified any plant trips that have resulted from the existing 24 hour limit. However, plants have chosen to shut down or delay startup or shutdown if there was a risk of not complying with the existing provisions. As an example, one plant had problems with their balance of plant auxiliary boiler system which resulted in a delay of a plant shutdown because of concerns with meeting the 24 hour limit for containment inerting. We have no evidence that any plants have been placed in a less safe condition as a result of the existing Technical Specification provisions. However, any time a carefully constructed startup or shutdown plan is altered or operator duties are increased, the possibility for error is increased. The introduction of this operator distraction must be balanced against the safety benefit of the activity that caused the disruption. The proposed change will avoid the operator distractions that occur when inerting is begun under the existing 24 hour limit and allow inerting to proceed when the plant startup and shutdown activities have been reduced. This would be an operational improvement.

<u>RAI #2</u>

2. *Based on a scoping assessment performed by the NRC staff, the ΔLERF for the proposed extension would exceed the 1E-7 per year value associated with a "very small change" in RG 1.174. Provide an assessment of the approximate level of the risk increase associated with extending the completion time from 24 hours to 72 hours. This assessment should address the factors identified below.*

    a. *the likelihood of either an internally-initiated or an externally-initiated core damage event occurring during the additional 96 hour period (i.e., 48 additional hours during startup and 48 additional hours during shutdown),*

    b. *the potentially higher core damage frequency associated with transition risk during startup and shutdown, when the containment might be de-inerted, and*

    c. *the increase in the conditional containment failure probability for a de-inerted containment (essentially 1.0) versus an inerted containment.*

<u>Response to RAI #2 - General</u>

The guidance of Regulatory Guide (RG) 1.174 was used to calculate a ΔLERF (Large Early Release Frequency) for the extension of the Completion Time from 24 hours to 72 hours. The time that the primary containment is not inerted does not change the calculated Core Damage Frequency (CDF).

Historically, the containment is not inerted approximately 1-2% of the time the plant is in Mode 1, 2, or 3. For calculation purposes, that equates to approximately 90 hours per year (approximately 1% of 8,766 hours in a year) that the containment is not inerted in Mode 1, 2, or 3. The 90 hours represents the operational history over the last 10 years of operation with the existing 24 hour requirement when plants had more frequent startup and shutdowns due to shorter operational cycles (12 or 18 months versus 24 months) and more forced shutdowns. The 90 hours equates roughly to one refueling outage startup and shutdown with one or two forced outage shutdowns and startups per year averaged over the BWR fleet. Operation under the proposed 72 hour Completion Time is assumed to result in a total of 144 hours per year of operation with the containment not inerted. We have simply assumed one startup and shutdown time of 72 hours to arrive at 144 hours, which we consider to be conservative. As noted in our response to RAI#1, we expect little or no actual change in the time being de-inerted during a startup unless there are unexpected problems. We expect no change in the time being de-inerted during shutdown. Current operational performance supports less than one forced shutdown on a yearly basis for the BWR fleet and most plants are operating with 24 month operating cycles. In the Level 2 PRA models, credit is provided for steam inerting of containment and combustible gas venting precluding a hydrogen deflagration event.

The Level 2 LERF values were recalculated for a representative sample of BWR plants assuming the containment was not inerted 144 hours per year. The BWRs in the representative sample included 5 of the 23 domestic operating BWRs with Mark I containments and 2 of the 5 domestic operating BWRs with Mark II containment designs. The resulting ΔLERF values for internal events varied from 1.7E-9 to 5.4E-8 per year. These values satisfy the RG 1.174 criterion for a very small change.

The contribution of external events to ΔLERF was addressed as follows. As with the internal events analysis, the proposed 72 hour limit does not affect the CDF resulting from external (fire and seismic) events. Very little work has been performed on LERF calculations for fire and seismic risk. Therefore, a CDF estimate for fire and seismic events is derived and then the internal events LERF analysis was used to infer the associated external event ΔLERF, as shown below:

> An average seismic CDF was derived from NUREG-1742[1] by summing the BWR plant values using the Lawrence Livermore National Laboratory seismic hazard curves. The resulting CDF is 6.58E-6 per year. The average fire-induced CDF was similarly derived with a value of 2.42E-5 per year.
>
> The LERF analysis used the following time frames for the base case: 720 hours in shutdown per year, 90 hours of de-inerted operation during startups and shutdowns, and 7,950 hours of inerted operation. The analysis was modified to accommodate the proposed 72 hour Completion Time as follows: the de-inerted time was raised to 144 hours and the inerted time reduced to 7,950 – (144 – 90) = 7,896 hours. Based on example plant internal events Level 2 PRA analyses, a representative conditional LERF value of 0.1 was obtained. This indicates that 10% of the CDF events lead to large early release during inerted operation. The conditional LERF value for de-inerted operation was assumed to be 1.0. If the initiators are applied without any consideration for unique issues, the resultant ΔLERF value is 2.2E-07 per year, which is or slightly above the RG 1.174 criterion for very small changes.
>
> If one reviews fire PRA evaluations, loss of decay heat removal and long term station blackout (SBO) sequences tend to dominate the results. These are long term issues that fall

[1] NUREG-1742, Perspectives Gained from the Individual Plant Examination of External Events (IPEEE) Program, April 2002.

outside the time frame associated with LERF. In NUREG/CR-4550[2], Volume 4, Part 3, these events form 65% of the CDF. Thus, it may be assumed that only the remaining portion of the fire CDF (35%) needs to be considered in this analysis. For seismic risk, NUREG/CR-4550 Volume 4, Part 3, shows that 62.5% of the CDF already results in LERF. Thus, it may be assumed that only the remaining 37.5% of the seismic CDF needs to be considered in this analysis. Similarly, the internal events results indicate that 66% of the CDF is from non-LERF sequences such as of loss of decay heat removal and long term SBO.

If the above refinements for CDF are applied, the resulting ΔLERF value is 7.8 E-8 per year. This uses the industry current average (base case) of 90 hours of de-inerted operation per year and the assumed bound of 144 hours per year representing the proposed 72 hour Completion Time to calculate the ΔLERF.

A sensitivity evaluation was performed assuming one full containment inerting / de-inerting cycle per year and using the full value of allowed time (2 x 24 hours for the base case and 2 x 72 hours for the proposed change). A ΔLERF of 1.4 E-7 per year was calculated, which is approximately equal to the RG 1.174 criterion for very small changes.

[2] NUREG/CR-4550, "Results of Core Damage Frequency Analysis for the Reference Plants," January 1986.

Response to RAI #2a

Based on NUREG/CR-5750[3], the total initiating event frequency for a BWR is 1.8 per critical year. This would translate to 0.026 for the indicated 96 hour period given the 75% capacity factor used in the NUREG. This is the frequency of an initiating event only and would have to proceed to core damage for the de-inerted state of the Primary Containment to have an effect. Seismic and fire initiating events have a much lower base frequency and would thus have a very minor contribution to the 96 hour time frame.

Response to RAI #2b

During the transition from power operation to shutdown or from startup to power operation, it is possible that both the frequency of events and the mitigation available during the event are affected.

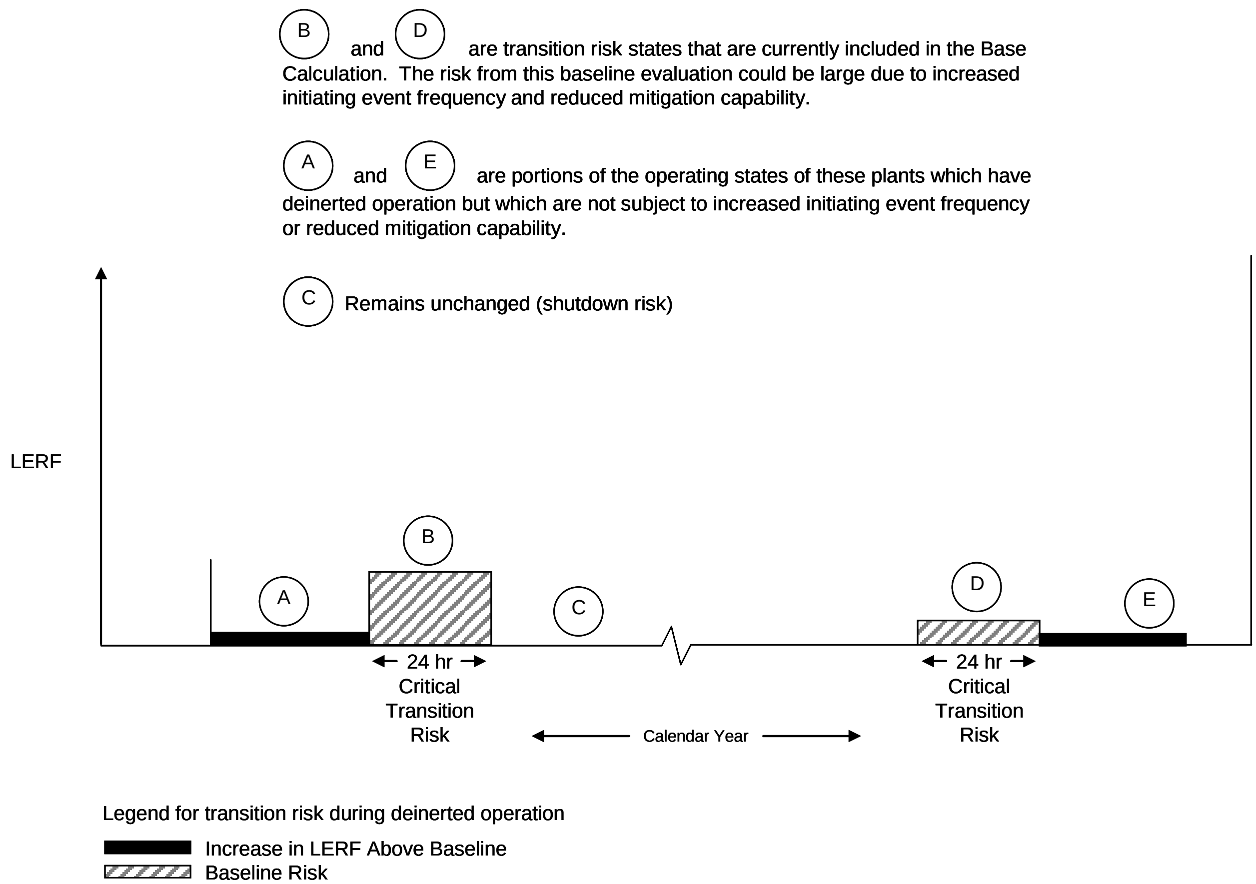
The critical transition risk occurs over a time frame of approximately 24 hours. This critical risk is included in the base risk of the plant within this 24 hour period during the currently allowed time when the containment is not inerted during startup and shutdown. The transition risk contribution over this time period remains the same between the base case and the proposed change, i.e.; the startup and shutdown transition periods do not change.

Therefore, the extension of time when the containment is not inerted is evaluated to determine the increased risk of large early release, but does not materially change the frequency of challenges, the CDF, or mitigation capability. In addition, the transition risk is controlled by the plant configuration risk management program. This limits the possibility of significant increases in risk during the transition period.

Figure 1, below, illustrates that while the duration of the time the containment is not inerted increases, which may influence the ΔLERF calculation, that the transition risk remains concentrated within a 24 hour period and that there is essentially no change in the transition risk between the two conditions, baseline (24 hours allowed de-inerted) and proposed change (72 hours de-inerted).

[3] NUREG/CR-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants 1987-1995," February 1999.

Figure 1



Response to RAI #2c

As noted in the general portion of the response, the analysis used 1.0 as the conditional containment failure probability for de-inerted operation. This is conservative given the capability of BWRs to mitigate hydrogen buildup by combustible gas venting and steam inerting.

Steam inerting of the containment atmosphere during a severe accident may prevent or delay a deflagration, and implementation of BWR severe accident management guidelines (SAMG) strategies may control combustible gas concentrations and limit containment pressurization (and the consequent peak pressure if a deflagration in containment were to occur).

Extending the Completion Time for Restoring Systems

RAI# 1

1. *Provide an assessment of the approximate level of the risk increase associated with extending the completion time for restoring the following systems to 7 days, when all systems/divisions are inoperable:*

   - *the drywell cooling system fans (for Mark I and II containments),*

   - *the drywell purge system (for Mark III containments), and*

   - *the hydrogen igniters (for Mark III containments).*

   A separate assessment for each affected system appears necessary. This assessment should address the factors identified below.

   a. *the likelihood of either an internally-initiated or an externally-initiated core damage event occurring during the additional period (i.e., 7 days) when the system may be inoperable, and*

   b. *the increase in the conditional containment failure probability with the affected system inoperable.*

Response to RAI #1

For plants with Mark I containments, the drywell cooling fans are not included in the NRC evaluation of combustible gas mitigation in NUREG-1150[4] because they are deemed ineffective, with or without recombiners, in preventing a challenge to containment due to combustible gas accumulation in an inerted containment. The supporting analysis for the Final Rule for 10 CFR 50.44 concluded that combustible gases produced by beyond design-basis accidents, involving both fuel-cladding oxidation and core-concrete interaction, would be risk significant for plants with Mark I and II containments if not for the inerted containment atmosphere. Given the relatively small volume and large zirconium inventory, these containments, without inerting, would have a high likelihood of failure from hydrogen combustion due to the large concentration of hydrogen that a severe accident could cause. Neither NUREG-1150 nor Reference 5 credits the drywell (DW) fans as effective in mitigation of combustible gases from causing a hydrogen deflagration. In fact, the DW cooling fans isolate on a high DW pressure signal and drywell coolers and recombiners are severely restricted in use by the BWROG Emergency Procedure and Severe Accident Guidelines (EPGs/SAGs) for high DW temperatures and high H2 concentration, respectively.

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[4] NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," December 1990.
[5] Drouin, Mary, et al., Feasibility Study for a Risk-Informed Alternative to 10 CFR 50.44: "Standards for Combustible Gas Control System in Light-water-cooled Power Reactors," Office of Nuclear Regulatory Research, August 2000.

In fact, most DW cooling systems automatically isolate on high drywell pressure due to equipment operability limitations and recombiner use is avoided if they would become the ignition source for a hydrogen deflagration.

For Mark III plants, a similar situation exists in that only the igniters are credited as an adequate mitigation measure for combustible gases over the severe accident spectrum. In fact, without igniters and a severe accident in progress, the Hydrogen Deflagration Overpressure Limit (HDOL) would be reached and the Purge System (or Mixer System) is directed to be shut down. Therefore, for potential LERF contributors, the Purge System (or Mixer System) is procedurally disabled because it is viewed to have little benefit but a large negative impact as an ignition source.

I. MARK I AND II DRYWELL COOLING FANS

For the smaller volume containments, i.e., the BWRs with Mark I and Mark II containments, the NRC has determined[6]:

- Inerting is an effective hydrogen control system for all risk-significant degraded core and full core melt accidents in these containments. Therefore, because of the inerted nature of these containments, the risk-significance of keeping the atmosphere mixed to prevent hydrogen combustion is actually quite low. The risk significance of the systems used to meet the post-LOCA combustible gas requirements of (the previous) 50.44 is low.

- Risk analyses performed for plants with Mark I and II containment designs model the containment atmospheres as inert. Containment failure due to combustion is therefore found to be not significant in most PRAs.

- NUREG-1150 and industry Level 2 PRA evaluations have determined that DW cooling fans have no risk significance as measured by the LERF risk metric.

II. MARK III DRYWELL PURGE SYSTEM

The significant risk contributors in Mark III containments related to combustible gas control are sequences in which igniters are unavailable and the deflagration occurs in the outer containment. This hydrogen deflagration pressure rise causes both failure of the containment and buckling failure of the drywell. The Drywell Purge System does not reduce the possibility of this failure mode of the containment that could lead to a LERF.

III. MARK III IGNITERS

The hydrogen igniters cause hydrogen in containment to burn in a controlled manner as it accumulates following a degraded core accident. Burning occurs at the lower flammability concentration, at which the resulting temperatures and pressures are relatively benign. Without

[6] Drouin, Mary, et al., Feasibility Study for a Risk-Informed Alternative to 10 CFR 50.44: "Standards for Combustible Gas Control System in Light-water-cooled Power Reactors," Office of Nuclear Regulatory Research, August 2000.

the system, hydrogen could build up to higher concentrations that could result in an energetic reaction if ignited by a random ignition source.

The hydrogen igniters have been shown by probabilistic risk analysis to be significant in limiting the severity of accident sequences that are commonly found to dominate risk for units with a Mark III containment.

The currently standard Technical Specifications allow both divisions of igniters to be unavailable and provides a 7 day Completion Time if the hydrogen control function (i.e., the DBA hydrogen control with purge system and recombiner) is available. However, this hydrogen control function is designed for response to a design basis accident (DBA) Loss of Coolant Accident (LOCA) and is not capable of coping with the assumed hydrogen generation rates caused by severe accidents. In addition, the DBA LOCA hydrogen control function has been removed from the standard Technical Specifications following the approval of the revised 10 CFR 50.44 rule. Therefore, the current standard Technical Specifications allow the hydrogen igniters to be unavailable for 7 days with no mandated backup for hydrogen control sufficient for response to severe accident hydrogen generation rates.

The requested change in the Technical Specifications does not materially alter the risk that existed with the Purge System and Recombiner System available and in the Technical Specifications. Nevertheless, the following assessment of the risk significance is associated with the proposed from the existing requirement to be in Mode 3 within 12 hours when the hydrogen control is not available to 7 days to restore the system to Operable status before requiring a shutdown.

Generic analysis can be performed using average estimates of the risk profiles. The operation of BWR plants with Mark III containments, with or without igniters operational, has been found to not result in changes in the Core Damage Frequency (CDF) risk metric.

A full Level 2 PRA evaluation of a BWR with a Mark III containment was used as an example to assess the risk associated with internal events. The base case LERF is 1.57E-7 per year.

The calculated LERF with a 7 day Completion Time is 5.93E-7per year and ICLERP = 8.36E-09. This result indicates that based on the internal events evaluation, the 7 day Completion Time hydrogen igniters meets the acceptance guideline from RG 1.177. Using a conservative assumption of one event per ten years, this equates to a ΔLERF of 1.1E-9 per year.

The contribution of external events to ΔLERF was addressed as follows. As with the internal events analysis, the extended Completion Time does not affect the CDF from external events. Very little work has been performed on LERF calculations for fire and seismic risk. Therefore a CDF estimate for fire and seismic is derived and then the internal events LERF analysis was used to infer the effected on associated external event LERF, as shown below:

> An average seismic CDF was derived from NUREG-1742, by summing the values for BWR plants using the Lawrence Livermore National Laboratory seismic hazard curves. The resulting CDF is 6.58E-6 per year.

The average fire induced CDF for BWR plants with Mark III containments was similarly derived from NUREG-1742 with a value of 1.69E-05 per year.

If one reviews fire PRA results, loss of decay heat removal and long term station blackout sequences tend to dominated the results. These are longer term issues that fall outside the time frame associated with LERF. In NUREG/CR-4550, Volume 4, Part 3, these form 65% of the CDF. Thus, it may be assumed that only the remaining portion of the fire CDF (35%) needs to be considered in this analysis. For seismic risk, NUREG /CR-4550, Volume 4, Part 3, shows that 62.5% of the CDF already results in LERF Thus is may be assumed that only the remaining 37.5% of the seismic CDF needs to be considered in this analysis. Similarly the internal events results may be reviewed to indicate that 66% of the CDF is from non-LERF sequences of loss of decay heat removal and long tem SBO. The resulting ΔLERF is 5.2E-9 per year and ICLERP is 3.8E-8. These values satisfy the RG 1.174 criterion for very small changes.

RAI #2

2. *Provide a more detailed description of the severe accident management strategies for controlling hydrogen concentrations and lowering containment pressure as alluded to in "Insert 2" on page 12 of the TSTF, and the associated equipment/systems on which these actions would rely. Address the availability of these equipment/systems given the removal of the recombiner and CAD systems.*

Response to RAI #2

The requested detailed description of severe accident management strategies for controlling hydrogen concentrations and lowering containment pressure are described in Attachment B. The Severe Accident Management Guidelines (SAMGs) vary depending on BWR containment design (Mark I, II, or III) but in all cases the guidelines are symptom-based, not event-based.

All Mark I and Mark II primary containments are inerted with nitrogen. Some Mark I and II primary containments were designed or modified with hydrogen recombiners and drywell hydrogen mixing systems to help mix the containment atmosphere. BWRs with Mark I or Mark II containments not equipped with recombiners or mixing systems have a Containment Atmosphere Dilution (CAD) system. All BWRs with Mark III containments were originally designed with hydrogen recombiners, igniters, and mixing systems for beyond design basis accident hydrogen control.

As noted above and illustrated by the strategies described in Attachment B, there is a low risk consequence for operating up to seven days without the combustible gas control systems referenced in Technical Specifications. Should those systems not be available, the SAMGs define appropriate actions with due consideration of the impact of such actions on the protection of fission product barriers (containment) and on the impact to the health and safety of the public and plant personnel. If recombiners and the CAD system are abandoned after implementation of the amended Combustible Gas Control Rule, plants with Mark I or Mark II containments continue to have alternatives available to assure successful protection of barriers and protection on the public, such as the use of nitrogen inerting. An inerted containment atmosphere ensures there is insufficient oxygen to burn with any hydrogen in the containment. BWR plants with Mark III containments have the hydrogen igniter system, as well as the drywell hydrogen mixing system, to keep hydrogen concentrations as low as practicable.

When these systems are unavailable or incapable of controlling combustible gas concentrations, the decisions and actions governing operation of drywell and suppression pool sprays provide a strategy to mitigate the consequences of a hydrogen generation event. Spray operation:

- Reduces containment pressure.
- Reduces the flammability of combustible gases through the addition of water vapor to the gas mixture.
- Suppresses the temperature and pressure increase following combustion if a deflagration does occur.
- Scrubs the containment atmosphere in anticipation of radioactivity release.
- Mixes the containment atmosphere to reduce localized buildup of combustible gases.

Successful spray operation may prevent containment venting at rates beyond allowable offsite radioactivity release rate limits for combustible gas control or delay its requirement until systems designed to control combustible gas concentrations can be restored to service.

Removal of the hydrogen recombiners and CAD system will have no adverse affect on the availability of other systems included in plant-specific SAMGs for combustible gas control.

RAI #3

3. *Provide the technical analyses that support the claim that post-accident natural circulation forces will promote sufficient mixing to avoid the accumulation of combustible gases at concentrations that could challenge containment structure integrity due to either detonations or large deflagrations.*

Response to RAI #3

The justification in TSTF-478 does not claim that natural circulation alone will be sufficient for all BWR containment designs to avoid accumulation of combustible gases. The basis for our request that drywell purge systems for Mark III containments and drywell fans for certain Mark II plants can be inoperable for up to 7 days is based on the low probability of sufficient post-accident hydrogen accumulation that could challenge containment integrity as supported by the amended Combustible Gas Rule. In addition, we note that natural circulation inherent in the BWR Mark II and III containment designs coupled with severe accident management strategies, including the use of containment sprays, will be sufficient to support mixing.

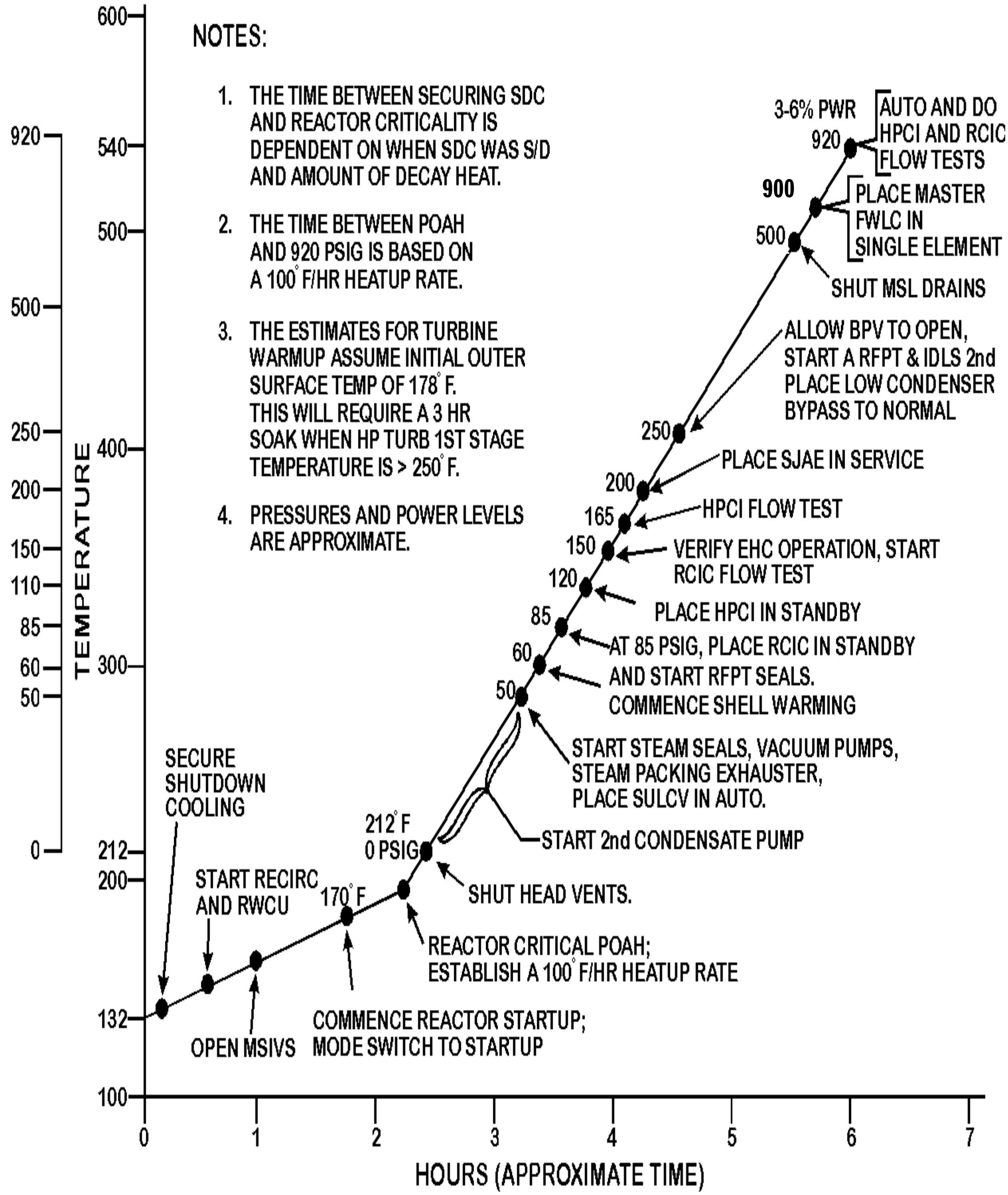
Certain Mark II containments rely on drywell fans with natural circulation to support mixing. The existing Technical Specifications for those plants require the use of a recombiner should both of their drywell fans be inoperable. As noted in the revised Combustible Gas Rule and in the statements of consideration concerning the Rule, hydrogen recombiners contribute little benefit in the control of hydrogen following an accident and the same conclusion can be made for the hydrogen recombiner contribution to assuring a mixed atmosphere.

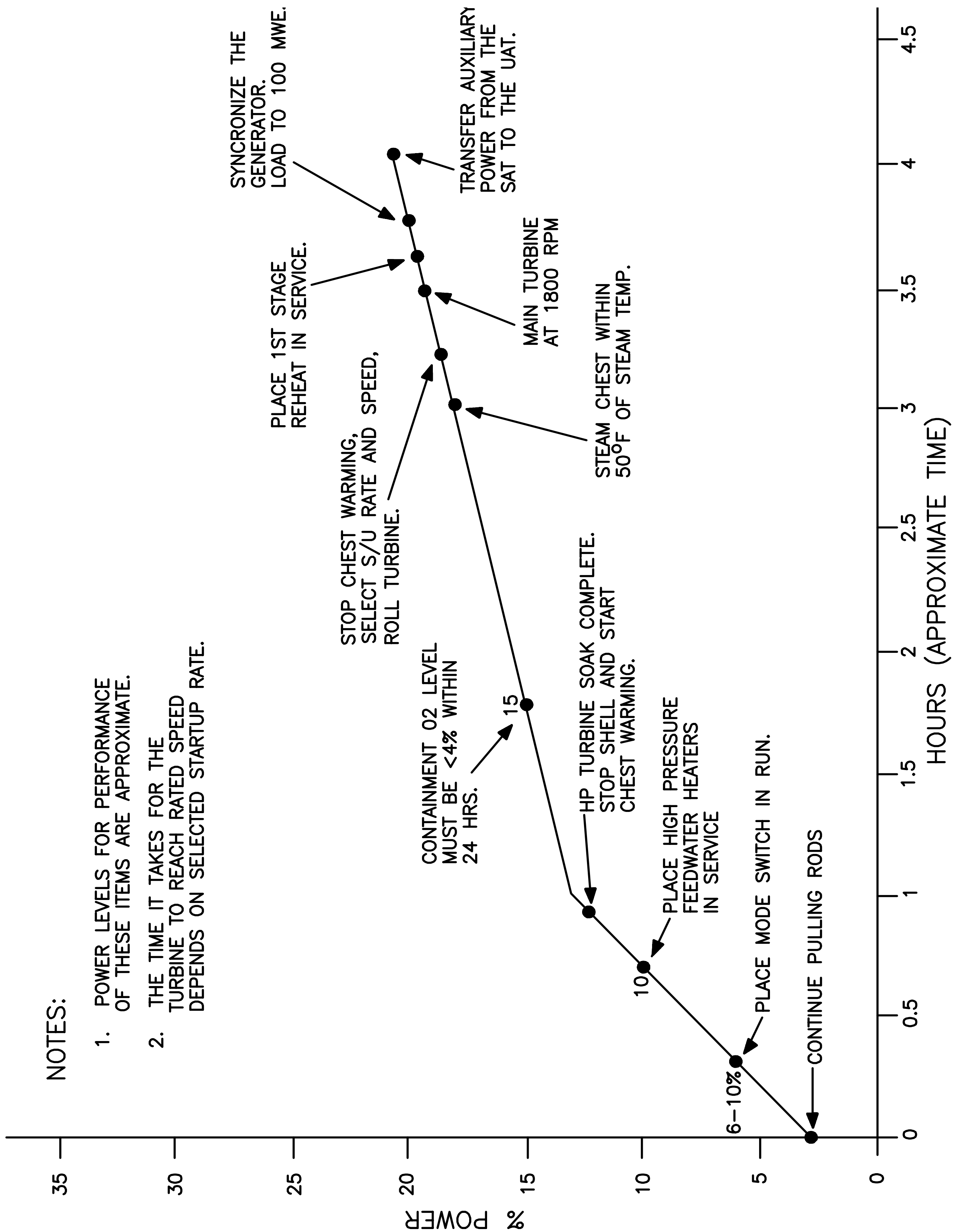
As noted on the discussion on SAMGs (RAI 2, above), the use of drywell and suppression pool sprays can be used to assure proper mixing for Mark II containments. Support and analysis for this conclusion can be found in RG 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors," which concludes that containment sprays will provide mixing. The NRC has previously reviewed and accepted the use of drywell sprays as the appropriate action for loss of drywell fans at a BWR plants with Mark II containments with supporting analysis. We believe this is the appropriate action for loss of drywell fans for all BWR plants with Mark II containments.

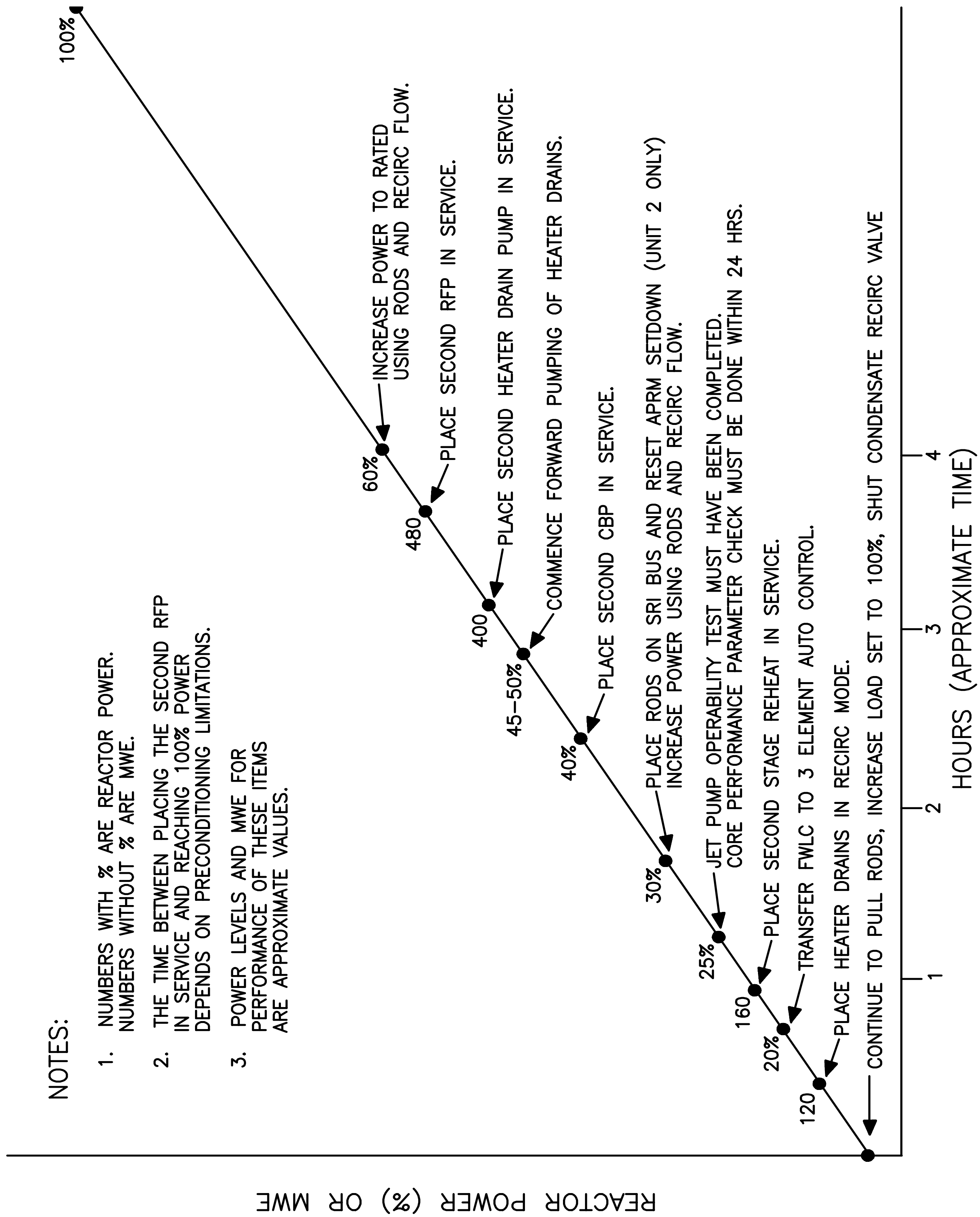
Mark III containments rely on both natural circulation and the drywell purge system for post-accident mixing. Similar to plants with Mark II containments, the SAMGs will direct use of suppression pool sprays to assist in post-accident mixing as the plants with Mark III containments do not have drywell sprays. Regulatory Guide 1.183 provides the technical analysis supporting use of containment sprays for mixing.

The NUREG-1434 (BWR/6 plants), Specification 3.6.3.2, "Drywell Purge System," Action for loss of both drywell purge subsystems requires verification that the hydrogen control function is maintained. The Bases for the Required Action state that the hydrogen igniters provide the hydrogen control function, but provide the option to use other mechanisms. TSTF-478 proposed a change to NUREG-1434, Specification 3.6.3.2, to delete the Required Action to verify the hydrogen control function is maintained. On further review, we have concluded that retaining this Required Action is appropriate. While this Required Action does not address mixing, it does provide assurance that both the drywell purge and the alternate hydrogen control function would not be out of service at the same time. The change to this specification was proposed because some plant-specific Technical Specification Bases define the alternate hydrogen control function as including a hydrogen recombiner as well as an igniter. Hydrogen recombiners were removed from the Technical Specifications, consistent with the change to 10 CFR 50.46. However, we have determined that the preferable change is for those plants is to revise the Technical Specification Bases under the Technical Specifications Bases Control Program to remove the reference to the hydrogen recombiners and to indicate that one division of igniters will be their alternate hydrogen control function. Therefore, the proposed change to NUREG-1434, Specification 3.6.3.2, is not needed and will be removed in a revision to TSTF-478.

ATTACHMENT A




NOTES:
1. POWER LEVELS FOR PERFORMANCE OF THESE ITEMS ARE APPROXIMATE.
2. THE TIME IT TAKES FOR THE TURBINE TO REACH RATED SPEED DEPENDS ON SELECTED STARTUP RATE.
SYNCRONIZE THE GENERATOR. LOAD TO 100 MWE.
TRANSFER AUXILIARY POWER FROM THE SAT TO THE UAT.
PLACE 1ST STAGE REHEAT IN SERVICE.
MAIN TURBINE AT 1800 RPM
STOP CHEST WARMING, SELECT S/U RATE AND SPEED, ROLL TURBINE.
STEAM CHEST WITHIN 50°F OF STEAM TEMP.
CONTAINMENT 02 LEVEL MUST BE <4% WITHIN 24 HRS.
15
HP TURBINE SOAK COMPLETE. STOP SHELL AND START CHEST WARMING.
PLACE HIGH PRESSURE FEEDWATER HEATERS IN SERVICE
10
PLACE MODE SWITCH IN RUN.
6-10%
CONTINUE PULLING RODS
% POWER
0
5
10
15
20
25
30
35
HOURS (APPROXIMATE TIME)
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5


NOTES:
1. NUMBERS WITH % ARE REACTOR POWER. NUMBERS WITHOUT % ARE MWE.
2. THE TIME BETWEEN PLACING THE SECOND RFP IN SERVICE AND REACHING 100% POWER DEPENDS ON PRECONDITIONING LIMITATIONS.
3. POWER LEVELS AND MWE FOR PERFORMANCE OF THESE ITEMS ARE APPROXIMATE VALUES.
REACTOR POWER (%) OR MWE
HOURS (APPROXIMATE TIME)
1
2
3
4
100%
60%
480
400
45-50%
40%
30%
25%
160
20%
120
INCREASE POWER TO RATED USING RODS AND RECIRC FLOW.
PLACE SECOND RFP IN SERVICE.
PLACE SECOND HEATER DRAIN PUMP IN SERVICE.
COMMENCE FORWARD PUMPING OF HEATER DRAINS.
PLACE SECOND CBP IN SERVICE.
PLACE RODS ON SRI BUS AND RESET APRM SETDOWN (UNIT 2 ONLY) INCREASE POWER USING RODS AND RECIRC FLOW.
JET PUMP OPERABILITY TEST MUST HAVE BEEN COMPLETED. CORE PERFORMANCE PARAMETER CHECK MUST BE DONE WITHIN 24 HRS.
PLACE SECOND STAGE REHEAT IN SERVICE.
TRANSFER FWLC TO 3 ELEMENT AUTO CONTROL.
PLACE HEATER DRAINS IN RECIRC MODE.
CONTINUE TO PULL RODS, INCREASE LOAD SET TO 100%, SHUT CONDENSATE RECIRC VALVE

Attachment B
Response to RAI #1
Extending the Completion Time for Restoring Systems

1. Introduction

This Attachment describes the severe accident management strategies for controlling hydrogen concentration and lowering containment pressure as prescribed by generically applicable BWROG Severe Accident Management Guidelines (SAMGs) and related implementing documentation. The current BWROG SAMG revision assumed BWRs were equipped with the following combustible gas control equipment as it existed prior to implementation of the amended Combustible Gas Control Rule (Reference 1):

- For all Mark I/II containment designs, this included nitrogen inerting the containment atmosphere and drywell/suppression pool sprays for mixing the atmosphere. Some Mark I/II containments were designed or backfitted with hydrogen recombiners and the drywell hydrogen mixing system. Mark I/II BWRs not equipped with recombiners/mixing systems have a Containment Atmosphere Dilution (CAD) system.
- For all Mark III containment designs, combustible gas control equipment consisted of hydrogen recombiners, hydrogen igniters, and drywell purge (mixing system) and containment (suppression pool) sprays for mixing the atmosphere. (Mark III containments are not nitrogen inerted and do not have drywell sprays.)

The severe accident management strategies are discussed within the context of a postulated severe accident and carried out by a typical BWR Emergency Response Organization (ERO). For Mark I/II containment designs, events are managed without the operability of the hydrogen recombiners, the drywell hydrogen mixing system and the CAD system. For Mark III containment designs, events are managed without the operability of hydrogen recombiners. In addition, either the hydrogen igniters are out of service while the drywell hydrogen mixing system remains operable or the mixing system is out of service while the hydrogen igniters remain operable. The strategies demonstrate management of containment combustible gas concentrations (hydrogen and oxygen). They allow for successful initiation and operation of containment sprays and, thereby, help prevent containment venting at rates beyond allowable offsite radioactivity release rate limits or delay its requirement until the inoperable combustible gas control equipment can be restored to service. Systems and equipment needed to carry out the strategies are described in the discussion of the strategies.

The remaining sections of this Attachment address the following topics:

Section 2 provides background information concerning the source of the severe accident management strategies.

Section 3 lists assumptions and initial conditions that are associated with a sequence of events involving core uncovery, hydrogen generation and elevated primary containment pressure and are applied in the discussion of ERO decisions/actions in Sections 4 and 5.

Section 4 discusses combustible gas control strategies that the ERO implements in a severe accident to effect control of primary containment hydrogen concentrations.

Section 5 discusses strategies for lowering primary containment pressure during a severe accident with use of drywell and suppression pool sprays, in preference to containment venting.

Section 6 contains a list of references cited in this Attachment.

2. Background

BWR utilities have implemented plant-specific guidance for severe accident management that was derived from generic documents applicable to all BWR models and containment designs. The primary sources were the BWROG Accident Management Guidelines Overview Document (Reference 2) and the BWROG Emergency Procedure and Severe Accident Guidelines (EPGs/SAGs) (Reference 3). The EPGs/SAGs provide comprehensive technical direction for the operation of BWR nuclear power plants during emergencies and severe accidents. The EPGs/SAGs were first published in June 1996 and were revised in July 1997 and March 2001. Revision 2 is the most current revision of the EPGs/SAGs, and all BWR utilities have implemented or are in the process of implementing this guideline revision. EPG/SAG Revision 2 retains reference to combustible gas control equipment that eventually may be removed as a result of implementation of the amended Combustible Gas Control Rule. Presently, not all BWRs have abandoned the hydrogen recombiners. Ultimately, the BWROG may revise the EPGs/SAGs for this change in equipment status but only if all BWRs remove the recombiners.

<u>Overview Document</u>
The Overview Document describes the BWR utility response to the industry initiative to enhance severe accident management capabilities (Reference 4) and identifies methods utilities can use to integrate the EPG/SAG strategies into the Emergency Response Organization (ERO). To this end (and of interest to the control of primary containment pressure and hydrogen concentration), the Overview Document prescribes the development and implementation of Technical Support Guidelines (TSGs). TSGs are a set of guidelines that describe enhancements to technical support activities that may be undertaken by the ERO to assist in the execution of mitigation actions developed from the EPGs, SAGs, and plant specific strategies developed from utility specific IPE and IPEEE assessments.

During severe accident management development, BWR utilities opted to implement TSGs in a number of different ways based on the physical arrangement of ERO facilities, ERO locations, and the ERO command structures; all of which vary considerably from plant to plant. Typically, a team of ERO members in the Technical Support Center is responsible for conducting TSG assessments and providing decision-making support to ERO decision-makers (e.g., Shift Manager, ERO facility coordinators, Emergency Director, etc.). The team is identified by different names among the plant EROs but in later sections of this Attachment the team is entitled the "Accident Assessment Team."

<u>EPGs/SAGs</u>

The SAG portion of the EPGs/SAGs prescribes the symptom-based guidance for controlling plant parameters to mitigate the consequences of a severe accident. A severe accident is defined to begin at the onset of core damage. Core damage in this context is the consequence of a loss of adequate core cooling. When RPV water level can be determined, entry to the SAGs from the EPGs occurs if RPV water level cannot be restored and maintained above the Minimum Steam Cooling RPV Water Level (MSCRWL). The MSCRWL is the lowest RPV water level at which the covered portion of the reactor core will generate sufficient steam to prevent any clad temperature in the uncovered part of the core from exceeding 1500°F. All sections of the EPGs are exited when the SAGs are entered. Two guidelines comprise the SAGs:

- RPV and Primary Containment Flooding

  Of interest to this discussion is Section RC/F, which defines an integrated strategy for flooding the RPV and the primary containment. Five functions are performed to achieve the flooding objectives—RPV injection, primary containment injection, RPV venting, primary containment venting, and containment (drywell and suppression pool) spray.

- Containment and Radioactivity Release Control

  Of interest to this discussion are the decisions and actions associated with control of drywell temperature, containment temperature (Mark III plants only), primary containment pressure, primary containment radiation, and combustible gas concentrations.

Explicit direction to control containment combustible gas concentrations appears only in the Primary Containment Combustible Gas Control (PC/G) sections of the Containment and Radioactivity Release Control guideline. Due to differences in containment design, there is one PC/G section for Mark I and Mark II containments and one PC/G section for the Mark III containment. The combustible gases of concern are hydrogen and oxygen. Instructions to control primary containment pressure involve operation of suppression pool and drywell sprays, controlling primary containment water level and, if necessary, venting the primary containment to areas outside the primary containment. These instructions are given in several SAG sections because the equipment needed to control primary containment pressure may also be needed to perform other SAG functions (such as injecting water into the RPV or raising primary containment water level, etc.).

3. Assumptions / Initial Conditions

A severe accident is postulated to examine ERO response to control containment combustible gas concentrations and pressure while using the SAGs and TSGs. RPV water level has dropped below the MSCRWL, the reactor was successfully scrammed, and operators have fully depressurized the RPV. Core resubmergence cannot be achieved due to unspecified RPV injection system failures; RPV water level continues to lower due to boil off and an unisolable break in the RCS. ERO facilities are activated and the Accident Assessment Team in the TSC is conducting decision-making support activities in accordance with the TSGs. Since the current revision of the EPGs/SAGs provides guidance based on equipment available prior to implementation of the amended Combustible Gas Control Rule, the following equipment status is assumed to reflect possible equipment configurations after implementation of the Rule:

- For Mark I/II containment designs, hydrogen recombiners, the drywell hydrogen mixing system and CAD system are inoperable.
- For Mark III containment designs, two cases are considered:
    1. Hydrogen igniters are operable while hydrogen recombiners and the drywell hydrogen mixing system are out of service.
    2. The drywell hydrogen mixing system is operable while hydrogen recombiners and hydrogen igniters are out of service.

4. Combustible Gas Control Strategies

When SAGs are entered, the ERO is required to monitor and control plant parameters by following concurrently the guidance in the RPV and Primary Containment Flooding guideline and in the Containment and Radioactivity Release Control guideline. The discussion of key combustible gas concentration control steps of SAG Section PC/G for each type of containment design during the postulated severe accident is given below. BWROG SAG steps appear in italic print followed by discussion of guideline decisions and actions in regular print. Additional discussion of these guideline sections can be obtained from EPG/SAG Appendix B (Reference 5).

<u>Mark I/I Containments</u>
PC/G Monitor and control primary containment hydrogen and oxygen concentrations.
Since core uncovery has occurred, RPV water level is decreasing and hydrogen concentration has been detected in the drywell and suppression chamber, it is appropriate for the ERO to enter Section PC/G of the SAGs and continue monitoring and controlling these concentrations. Elevated concentrations of oxygen are not expected in Mark I/II containments during normal power operations except during brief periods of time at startup and shutdown of the plant when the containment atmosphere is being inerted and de-inerted. In the postulated severe accident, oxygen concentration is assumed to be well below the combustible level.

Control hydrogen and oxygen concentrations in the drywell as follows:

<table>
<tr><td colspan="2" rowspan="4"></td><td colspan="4">Drywell Oxygen Concentration</td></tr>
<tr><td rowspan="3">< 5%</td><td colspan="3">≥ 5% or cannot be determined to be below 5%</td></tr>
<tr><td colspan="3">Suppression Chamber Hydrogen Concentration</td></tr>
<tr><td>None Detected</td><td>< 6%</td><td>≥ 6% or cannot be determined to be below 6%</td></tr>
<tr><td rowspan="3">Drywell Hydrogen Concentration</td><td>None Detected</td><td>No action required</td><td>No action required</td><td rowspan="2">[PC/G-2]</td><td rowspan="3">[PC/G-3]</td></tr>
<tr><td>< 6%</td><td rowspan="2">[PC/G-1]</td><td></td></tr>
<tr><td>≥ 6% or cannot be determined to be below 6%</td><td colspan="2"></td></tr>
</table>

Control hydrogen and oxygen concentrations in the suppression chamber as follows:

<table>
<tr><td colspan="2" rowspan="4"></td><td colspan="4">Suppression Chamber Oxygen Concentration</td></tr>
<tr><td rowspan="3">< 5%</td><td colspan="3">≥ 5% or cannot be determined to be below 5%</td></tr>
<tr><td colspan="3">Drywell Hydrogen Concentration</td></tr>
<tr><td>None Detected</td><td>< 6%</td><td>≥ 6% or cannot be determined to be below 6%</td></tr>
<tr><td rowspan="3">Suppression Chamber Hydrogen Concentration</td><td>None Detected</td><td>No action required</td><td>No action required</td><td rowspan="2">[PC/G-5]</td><td rowspan="3">[PC/G-6]</td></tr>
<tr><td>< 6%</td><td rowspan="2">[PC/G-4]</td><td></td></tr>
<tr><td>≥ 6% or cannot be determined to be below 6%</td><td colspan="2"></td></tr>
</table>

Steps PC/G-1, PC/G-2, and PC/G-3 provide directions for monitoring and controlling hydrogen and oxygen concentrations in the drywell, while Steps PC/G-4, PC/G-5, and PC/G-6 provide directions for monitoring and controlling concentrations in the suppression chamber. The decisions and actions for controlling drywell combustible gas concentrations are essentially the same as those for the suppression chamber. The remaining discussion of the Mark I/II strategy will focus on controlling drywell combustible gas concentration only.

These decision tables identify the steps to be performed based on the hydrogen and oxygen concentrations in each volume. The ERO continuously evaluates the tables while the Containment and Radioactivity Release Control guideline is in effect to ensure that the appropriate strategies are implemented as the gas concentrations change. A maximum of two steps, one for the drywell and one for the suppression chamber, are performed concurrently.

In the postulated severe accident, however, core uncovery has occurred with detectable levels of hydrogen throughout the primary containment. If monitoring capability were to be lost, the Accident Assessment Team would consider the hydrogen concentration trend and project a time at which the combustible hydrogen concentration would likely be exceeded. The ERO would also maintain a heightened awareness for any equipment status change that could introduce oxygen to the containment atmosphere. At this point in the postulated severe accident, the primary containment remains inerted. Since hydrogen is detected in both volumes, the decision tables require performance of Steps PC/G-1 (for drywell hydrogen concentration) and PC/G-4 (for suppression chamber oxygen concentration).

PC/G-1 Reduce drywell hydrogen and oxygen concentrations by one or both of the following methods:

- *If the offsite radioactivity release rate is expected to remain below the offsite release rate specified in [Technical Specifications], vent and purge the drywell as follows, defeating isolation interlocks (except high radiation interlocks) if necessary:*

  > *If while executing the following steps the offsite radioactivity release rate reaches the offsite release rate specified in [Technical Specifications], secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].*

  (1) Refer to [sampling procedure].

  (2) Vent the drywell.

  (3) If the drywell can be vented, purge the drywell by injecting nitrogen into the drywell.

  (4) When hydrogen is no longer detected in the drywell, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

- *If drywell [and suppression chamber] hydrogen and oxygen concentrations are within the limits for recombiner operation:*

  (1) Place hydrogen recombiners in service taking suction on the drywell and operate the drywell hydrogen mixing system.

  (2) When [either] drywell [or suppression chamber] hydrogen and oxygen concentrations are no longer within the limits for recombiner operation, secure all hydrogen recombiners taking suction on the drywell.

…

Two methods of controlling combustible gas concentrations are specified: vent/purge and recombiner/mixing system operation. Recombiner/mixing system operation is not available for the purpose of this discussion. Thus, no action can be performed in the second bullet of these steps.

For Mark I plants not equipped with recombiner/mixing systems following implementation of the amended Combustible Gas Control Rule, the second bullet of these steps is not implemented. For plants that retain the drywell hydrogen mixing system, the second bullet of Step PC/G-1 retains only the action to operate the mixing system.

Plants equipped with a CAD system would actuate CAD in this portion of these steps but only if the containment can be vented to areas outside the primary containment. Purging without an open vent path will result in repressurizing the volume without lowering the partial pressure or mass of hydrogen. Although this will reduce the relative hydrogen concentration somewhat, it will raise containment pressure and significantly increase the peak pressure which will result if hydrogen generation continues and a deflagration subsequently occurs. Therefore, CAD systems are not operated so as to repressurize the containment. In the postulated severe accident, CAD systems are inoperable. Since it is desirable to maintain containment pressure reasonably low during events that result in hydrogen generation to mitigate the consequences of a deflagration (should it occur), SAG guidance for this purpose given in other sections would be performed concurrently with Section PC/G. Section 5 of this Attachment discusses strategies associated with primary containment pressure control.

Purge flow is established to provide the driving force for "pushing" hydrogen out of the drywell. Since drywell oxygen concentration is below 5% in this step, a nitrogen purge is specified to maintain an inerted atmosphere.

Detailed instructions for selecting and establishing the appropriate vent and purge lineups are typically provided in plant-specific EOP/SAG support procedures. The Accident Assessment Team is equipped with TSGs that help determine the risks and benefits associated with the timing of primary containment venting, vent path selection and vent duration. The Accident Assessment Team would evaluate factors such as those listed in Table 4-1 to determine the appropriate timing and duration of primary containment venting. The following factors are considered in the development of the plant-specific TSG instructions and venting procedures:

- Radioactivity release. If the containment atmosphere may be contaminated, vent lineups should be selected so as to minimize the amount of radioactivity released while still achieving the objective of the venting requirement.
- Pressure capability of the vent paths
- Vent flowrate
- If hydrogen and oxygen concentrations are rapidly approaching the deflagration limits (6% hydrogen and 5% oxygen)
- Purge supply pressure

- Purge flowrate
- Vent control capability
- System interrelationships
- Vent piping location and access requirements to secondary containment
- Vent path radiation monitoring capability
- Primary containment water level. Suppression pool water level affects the availability of vent and purge paths, the pressure required to clear the downcomers, and the availability of the suppression chamber to drywell vacuum breakers.

The extended core uncovery condition in the postulated severe accident has not only generated detectable levels of hydrogen but also discharged radioactivity into the containment atmosphere. The ERO would make the determination at this point in the event that offsite radioactivity release rates would be exceeded if venting were to proceed. Recognizing the importance of maintaining the primary containment inerted, the ERO would monitor oxygen concentrations and avoid to the extent possible any actions that would cause introduction of air to the containment atmosphere. No further actions are then required by the Mark I/I Section PC/G.

For the purpose of examining the remaining steps of the Mark I/II Section PC/G of the SAGs, however, it is assumed that hydrogen concentration is detected and still remains below the deflagration concentration (6%) but, for unknown reasons, the drywell and suppression chamber oxygen concentrations have exceeded 5%. Evaluation of the decision tables preceding Step PC/G-1 indicates that Step PC/G-2 (for the drywell) and PC/G-5 (for the suppression chamber) would be performed.

Table 4-1: Containment Vent Timing and Duration Considerations

CONSIDERATIONS	YES	NO	NA
Can venting be performed without exceeding applicable off-site radioactivity release rate limits?			
Can venting be performed using a filtered release path? Scrubbed through the suppression pool?			
Can venting prevent further degradation of plant conditions?			
Can venting be coordinated with evacuation procedures?			
Can venting be performed during favorable meteorological conditions?			
Can venting be performed without interfering with key operator actions in the Reactor Building?			
Has operation of containment sprays been unsuccessful in avoiding the need to vent the containment? Is it unlikely that containment sprays can be placed in service before venting must be performed?			
If the containment atmosphere is contaminated, can venting be controlled such that the volume released would be that required to just maintain drywell pressure below the Primary Containment Pressure Limit (PCPL)?			
If the primary containment is being flooded, would early or extended venting be appropriate while the suppression chamber vent path is still available to take advantage of suppression pool scrubbing?			
If significant fuel damage is anticipated or RPV breach by core debris is anticipated, would early or extended venting be appropriate while the primary containment atmosphere is still relatively clean?			
If primary containment integrity has been lost, would venting through a filtered or elevated release point reduce the total off-site dose?			
If venting is being performed to increase the injection rate, is the existing injection rate insufficient? Would injection rate be increased significantly (e.g., > 25%)?			
Will the time required to submerge core debris be significantly reduced?			
Will venting reduce containment overpressure but not cause pumps taking suction from the suppression pool to exceed NPSH limits?			
YES responses are considered benefits; NO responses, drawbacks. Do benefits outweigh drawbacks?			

PC/G-2 Reduce drywell hydrogen and oxygen concentrations by one or both of the following methods:

- If RPV water level cannot be maintained above [-164 in. (top of active fuel)] or the offsite radioactivity release rate is expected to remain below the offsite radioactivity release rate which requires a General Emergency, vent and purge the drywell as follows, defeating isolation interlocks if necessary:

  > If while executing the following RPV water level can be maintained above [-164 in. (top of active fuel)] and it has been determined that the offsite radioactivity release rate has reached the offsite radioactivity release rate which requires a General Emergency, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

  (1) Vent the drywell.

  (2) If the drywell can be vented, purge the drywell by injecting nitrogen into the drywell at the maximum rate.

  (3) When no hydrogen is detected in the drywell and either drywell oxygen concentration is below 5% or no hydrogen is detected in the suppression chamber, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

- If drywell [and suppression chamber] hydrogen and oxygen concentrations are within the limits for recombiner operation:

  (1) Place hydrogen recombiners in service taking suction on the drywell and operate the drywell hydrogen mixing system.

  (2) When [either] drywell [or suppression chamber] hydrogen and oxygen concentrations are no longer within the limits for recombiner operation, secure all hydrogen recombiners taking suction on the drywell.

Similar to Step PC/G-1, the ERO is directed to vent/purge and operate recombiner/mixing systems. Equipment inoperability in the postulated severe accident prevents the use of any recombiner/mixing systems and, again, the guidance in the second bullet of this PC/G step cannot be carried out.

For Mark I plants not equipped with recombiner/mixing systems following implementation of the amended Combustible Gas Control Rule, the second bullet of this step is not implemented. For plants that retain the drywell hydrogen mixing system, the second bullet of Step PC/G-2 retains only the action to operate the mixing system.

RPV water level cannot be maintained above the top of active fuel in the postulated severe accident and significant amounts of hydrogen could be generated. With drywell oxygen concentration above 5%, a potential for deflagration is developing. A vent and nitrogen purge is established to reduce oxygen concentration below the deflagration limit, thereby precluding deflagration. The potential risk to the containment from the presence of a deflagrable mixture of hydrogen and oxygen warrants this action even if the offsite radioactivity release rate may exceed the offsite radioactivity release rate which requires a General Emergency. The Accident Assessment Team is equipped with TSG instructions that assist ERO decision-makers in determining if the offsite radioactivity release rate would remain within acceptable limits. Factors influencing the timing, vent path selection and vent duration are as described in Step PC/G-1.

For the purpose of discussion of the remaining steps of the Mark I/II Section PC/G, it is assumed that the drywell and suppression chamber are deinerted and hydrogen concentrations in both volumes have reached and exceeded 6%. Evaluation of the decision tables preceding Step PC/G-1 indicates that Step PC/G-3 (for the drywell) and PC/G-6 (for the suppression chamber) must be performed.

PC/G-3 Secure the drywell hydrogen mixing system and all recombiners taking suction on the drywell and vent and purge the drywell as follows, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary:

PC/G-3.1 Vent the drywell.

PC/G-3.2 If the drywell can be vented, purge the drywell by injecting air or nitrogen, whichever will more rapidly return hydrogen concentrations to below 6% or oxygen concentration to below 5%, into the drywell at the maximum rate.

PC/G-3.3 DRYWELL SPRAY IS REQUIRED.

For Mark I plants not equipped with recombiner/mixing systems following implementation of the amended Combustible Gas Control Rule, the portion of the step pertaining to recombiners/mixing systems is not implemented. For plants that retain the drywell hydrogen mixing system, the first paragraph of Step PC/G-3 would retain only the action to secure the drywell hydrogen mixing system.

The potential for hydrogen deflagration warrants exceeding normal radioactivity release rate limits if necessary and defeating any isolation interlocks that interfere with the vent lineup. The consequences of not venting could include primary containment damage resulting in larger, uncontrolled releases of radioactivity. Venting is not performed indiscriminately, however. The Accident Assessment Team weighs the anticipated benefits of the action against the possible radiological consequences using the guidance discussed under Step PC/G-1 and makes appropriate recommendations to the ERO decision-makers concerning vent timing, vent path selection and vent duration. Controlled releases, if necessary, would be performed in a manner that minimizes the total dose to the public while accomplishing the objectives of the SAGs.

Since these steps are performed only when the containment is de-inerted, either an air or nitrogen purge may be used. The lineup which will most rapidly return containment gas concentrations to below the deflagration limits would be selected.

Operation of sprays mitigates the consequences of a deflagration should one occur. Sprays are initiated to:

- Reduce the flammability of combustible gases through the addition of water vapor to the gas mixture.
- Suppress the temperature and pressure increase following combustion.
- Scrub the containment atmosphere in anticipation of radioactivity release.
- Mix the containment atmosphere to reduce localized buildup of combustible gases.

These steps establish a spray requirement; the actual direction to initiate sprays and applicable restrictions on their use are provided in the overrides at the beginning of Steps RC/F-1 through RC/F-6 of the RPV and Containment Flooding guideline. These steps are discussed in Section 5 of this Attachment.

Mark III Containments

PC/G Monitor and control drywell and containment hydrogen concentrations.

Core uncovery has occurred in the postulated severe accident, RPV water level is decreasing and hydrogen concentration has been detected in the drywell and suppression chamber. It is appropriate for the ERO to enter Section PC/G of the SAGs and continue monitoring and controlling these concentrations. Oxygen concentration is not specifically monitored because the Mark III containment is not deliberately inerted.

PC/G override:

If while executing the following steps:

- *The hydrogen monitoring system is or becomes unavailable, sample the drywell and containment for hydrogen in accordance with [sampling procedure].*
- *The igniters are deenergized and either containment hydrogen concentration cannot be determined to be below the containment Hydrogen Deflagration Overpressure Limit or drywell hydrogen concentration cannot be determined to be below [9% (drywell Hydrogen Deflagration Overpressure Limit)], prevent operation of the igniters until containment hydrogen concentration can be determined to be below*

the Containment Hydrogen Deflagration Overpressure Limit and drywell hydrogen concentration can be determined to be below [9% (drywell Hydrogen Deflagration Overpressure Limit)].

- *The igniters are deenergized and containment hydrogen concentration cannot be determined to be below the containment Hydrogen Deflagration Overpressure Limit, secure and prevent operation of the drywell hydrogen mixing systems and recombiners and vent and purge the containment in accordance with [Steps PC/G-5.1 through PC/G-5.4], defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary, until the containment hydrogen concentration can be determined to be below the containment Hydrogen Deflagration Overpressure Limit.*

First bullet:
When the monitoring systems for hydrogen become unavailable, the concentration of this gas must be determined by sample and analysis. In the postulated severe accident, hydrogen monitoring equipment has been in service and operable. There is no need to employ alternate methods of determining gas concentrations.

Second bullet:
If hydrogen concentration in the containment or drywell cannot be determined by any means, and the hydrogen igniters are de-energized, it must be assumed that levels in excess of HDOL are present. Since energizing the igniter system results in the simultaneous actuation of igniters in both the drywell and the containment, this action must be based on the ability to determine hydrogen concentration in either volume.

The containment Hydrogen Deflagration Overpressure Limit (HDOL, Figure 4-1) is the highest containment hydrogen concentration at which a deflagration will not generate pressures in excess of the structural capability of the containment.

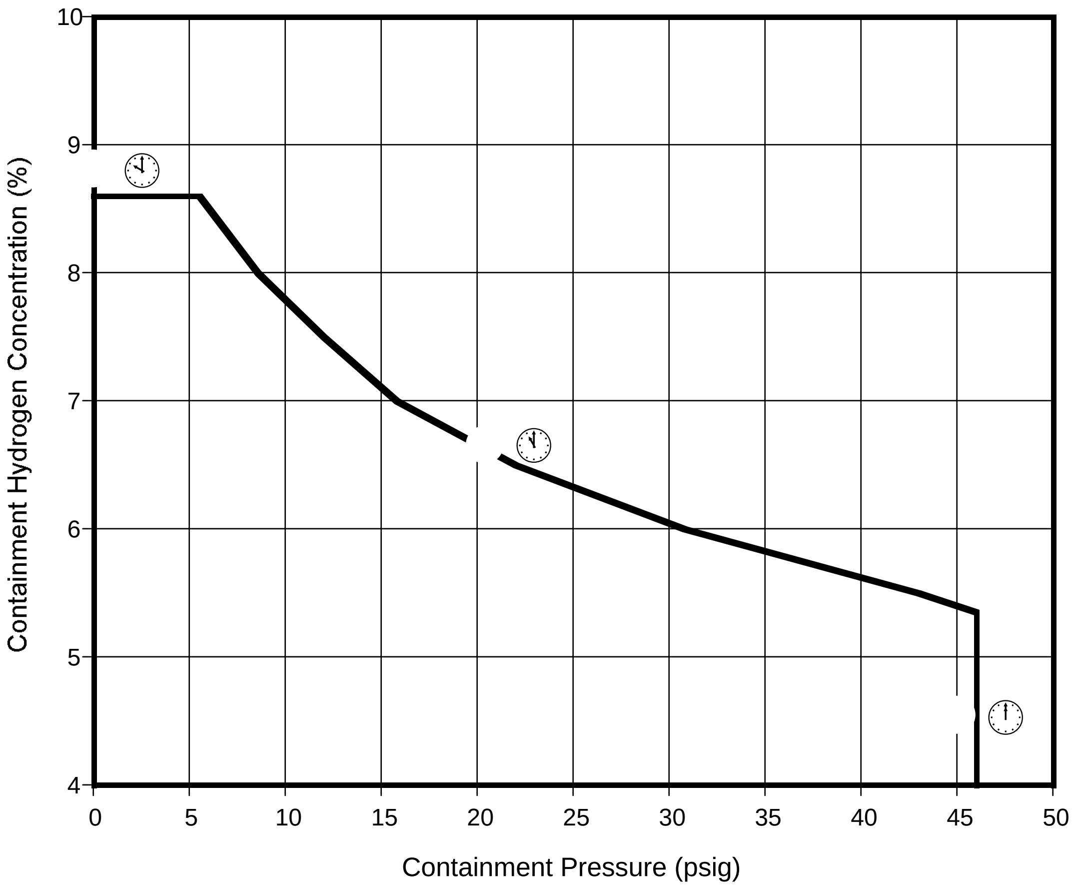
The drywell Hydrogen Deflagration Overpressure Limit (HDOL) of 9% is the lesser of:

- The highest drywell hydrogen concentration at which the peak differential pressure between the drywell and containment resulting from a deflagration will not exceed the peak differential pressure resulting from a main steam line or recirculation line break in the drywell.
- The highest drywell hydrogen concentration at which the rate of change of drywell pressure resulting from a deflagration will not exceed the maximum rate of change resulting from a main steam line or recirculation line break in the drywell.

In the postulated severe accident, no action is taken for the case in which igniters are inoperable. For the case in which igniters are operable, containment hydrogen concentration can be determined to be below the containment HDOL and drywell hydrogen concentration can be determined to be below 9% and no action is required by this override.

Third bullet:
The drywell hydrogen mixing system and recombiners are secured to eliminate potential ignition sources. In the postulated severe accident, no action is taken for the case in which hydrogen igniters are energized (operable). For the case in which igniters are deenergized, containment hydrogen concentration can be determined to be below the containment HDOL and no action is required by this override. Following implementation of the amended Combustible Gas Control Rule, Mark III plants that have abandoned recombiners would delete the action of this override that secures and prevents operation of the recombiners.

Figure 4-1: Example Containment Hydrogen Deflagration Overpressure Limit



PC/G-1 If containment hydrogen concentration is below the containment Hydrogen Deflagration Overpressure Limit and drywell hydrogen concentration is below [9% (drywell Hydrogen Deflagration Overpressure Limit)], energize the hydrogen igniters.

Execute [Steps PC/G-2, PC/G-3 and PC/G-4] concurrently.

Initially in the postulated severe accident, containment hydrogen concentration is well below the HDOL. For the case in which hydrogen igniters are inoperable, no action can be taken in this step. For the case in which igniters are operable, the igniters would be energized with a resultant decrease in drywell and containment hydrogen concentrations. Deflagration concentrations would not be reached and further actions in this section of the guidelines unnecessary. In the case in which igniters are inoperable in the postulated severe accident, hydrogen concentration remains above the minimum detectable level in the drywell and containment but has not yet reached the HDOL. For this case, the ERO would attempt to perform Steps PC/G-2, PC/G-3 and PC/G-4.

PC/G-2 When hydrogen is detected in the containment or drywell, but only if the offsite radioactivity release rate is expected to remain below the offsite release rate specified in [Technical Specifications], vent and purge the containment as follows, defeating isolation interlocks (except high radiation interlocks) if necessary:

If while executing the following steps the offsite radioactivity release rate reaches the offsite release rate specified in [Technical Specifications], secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

PC/G-2.1 Refer to [sampling procedure].

PC/G-2.2 Vent the containment.

PC/G 2.3 If the containment can be vented, initiate and maximize the containment purge.

PC/G-2.4 When hydrogen is no longer detected in the containment or drywell, secure vent and purge not required by other steps in the [procedures developed from the Severe Accident Guidelines].

For the second case of the Mark III postulated severe accident, the existence of a detectable amount of hydrogen in the containment or drywell warrants corrective action so that a hydrogen-free atmosphere can be restored as soon as possible. Venting and purging are methods normally used to control primary containment atmosphere conditions.

The containment vent is aligned prior to initiating the purge because it is desirable to maintain containment pressure reasonably low during events that result in hydrogen generation to mitigate the consequences of a deflagration (should it occur). SAG guidance given in other sections would be performed concurrently with Section PC/G for this purpose. Section 5 of this Attachment discusses the strategies associated with primary containment pressure control.

The containment must be vented, even if hydrogen is only detected in the drywell, because the drywell in a Mark III containment cannot be vented directly to atmosphere. Venting through the containment also scrubs the drywell atmosphere, thus minimizing the amount of radioactivity released. Detailed instructions for selecting and establishing the appropriate lineups are typically provided in plant-specific EOP/SAG support procedures. The Accident Assessment Team is equipped with TSGs that help determine the risks and benefits associated with the timing of primary containment venting, vent path selection and vent duration. The Accident Assessment Team would evaluate factors such as those listed in Table 4-1 to determine the appropriate timing and duration of primary containment venting. Factors considered in the development of plant-specific Mark III containment TSG instructions and venting procedures are similar to those described in the discussion of Mark I/II containment Step PC/G-1, above.

The extended core uncovery condition in the postulated severe accident has not only generated detectable levels of hydrogen but also discharged radioactivity into the containment atmosphere. The ERO would make the determination at this point in the event that offsite radioactivity release rates would be exceeded if venting were to proceed. Due to the inoperable equipment and radioactivity in the containment atmosphere, no action can be taken in this step. For the purpose of discussion of Step PC/G-5, it is assumed that hydrogen concentrations in the containment and drywell exceed the HDOL.

PC/G-3 Monitor and control hydrogen concentration in the drywell.

PC/G-3.1 When hydrogen is detected in the drywell, but only if containment hydrogen concentration is below the containment Hydrogen Deflagration Overpressure Limit [and RPV pressure is below Primary Containment Pressure Limit A], operate the drywell hydrogen mixing system.

PC/G-3.2 Continue in this procedure at [Step PC/G-5].

Drywell hydrogen mixing system operation is designed to transfer hydrogen from the drywell to the containment. Operation of the mixing system serves to redistribute the hydrogen throughout the containment and drywell, thereby diluting localized regions of high hydrogen concentrations. When containment hydrogen concentration is less than drywell hydrogen concentration, drywell hydrogen mixing system operation effects a reduction in drywell hydrogen concentration.

In the case in which hydrogen igniters are operable in the postulated severe accident, the drywell hydrogen mixing system is inoperable and no action is taken in this step. In the case in which the drywell hydrogen mixing system is operable and igniters inoperable, the system is placed in service and drywell hydrogen concentration is reduced as the drywell atmosphere is diluted by the containment atmosphere. For the purpose of discussion of Step PC/G-5, however, it is assumed that hydrogen concentrations in the containment and drywell exceed the HDOL.

PC/G-4 Monitor and control hydrogen concentration in the containment.

PC/G-4.1 When containment hydrogen concentration reaches [1% (minimum hydrogen concentration for recombiner operation)], but only if containment hydrogen concentration is below [6% (maximum hydrogen concentration for recombiner operation)] and the containment Hydrogen Deflagration Overpressure Limit, place hydrogen recombiners in service.

PC/G-4.2 When containment hydrogen concentration reaches [6% (maximum hydrogen concentration for recombiner operation)] or the containment Hydrogen Deflagration Overpressure Limit, secure hydrogen recombiners.

Prior to implementation of the amended Combustible Gas Control Rule, hydrogen recombiners would be placed in service in accordance with the vendor limitations on recombiner operation and the indicated levels of hydrogen concentration in the containment. Hydrogen recombiners are inoperable in the postulated severe accident and no action can be taken in this step. After implementation of the amended Combustible Gas Control Rule, Step PC/G-4 would be deleted from plant-specific SAGs for BWRs in which the recombiners are abandoned. For the purpose of discussion of Step PC/G-5, it is assumed that hydrogen concentrations in the containment and drywell exceed the HDOL.

PC/G-5 When containment hydrogen concentration reaches the containment Hydrogen Deflagration Overpressure Limit, vent and purge the containment as follows, defeating isolation interlocks and exceeding offsite radioactivity release rate limits if necessary, to restore and maintain containment hydrogen concentration below the containment Hydrogen Deflagration Overpressure Limit:

PC/G-5.1 SUPPRESSION POOL SPRAY IS REQUIRED.

PC/G-5.2 If the igniters are de-energized, secure the drywell hydrogen mixing system.

PC/G-5.3 Vent the containment.

PC/G 5.4 If the containment can be vented, initiate and maximize containment purge.

PC/G-6 When containment hydrogen concentration can be maintained below the containment Hydrogen Deflagration Overpressure Limit, return to Step PC/G-1.

If containment hydrogen concentration reaches the containment Hydrogen Deflagration Overpressure Limit (HDOL) with igniters deenergized, a deflagration could occur. Normal radioactivity release rate limits may therefore be exceeded if necessary and any isolation interlocks that interfere with the vent lineup may be defeated. The consequences of not venting could include primary containment damage resulting in larger, uncontrolled releases of radioactivity. Venting is not performed indiscriminately, however. The Accident Assessment Team weighs the anticipated benefits of the action against the possible radiological consequences using the guidance discussed under Step PC/G-2 and makes appropriate recommendations to the ERO decision-makers concerning vent timing, vent path selection and vent duration. Controlled releases, if necessary, would be performed in a manner that minimizes the total dose to the public while accomplishing the objectives of the SAGs.

Suppression pool spray operation is required in order to:

- Reduce containment pressure below the containment HDOL.
- Reduce the flammability of combustible gases through the addition of water vapor to the gas mixture.
- Suppress the temperature and pressure increase following combustion if a deflagration does occur.
- Scrub the containment atmosphere in anticipation of radioactivity release.
- Mix the containment atmosphere and thereby reduce localized buildup of combustible gases.

Step PC/G-5.1 establishes a spray requirement; the actual direction to initiate sprays and applicable restrictions on their use are provided in the overrides at the beginning of Steps RC/F-1 through RC/F-6 of the RPV and Containment Flooding guideline.

5. Primary Containment Pressure Control Strategies

Core uncovery and hydrogen generation in the postulated severe accident has increased all key primary containment parameters controlled in the SAGs. The methods employed for reducing containment pressure in the SAGs involve venting the atmosphere to areas outside the containment and spraying the containment airspace.

<u>Containment Venting</u>
Containment venting is beneficial because it can remove combustible gases from the containment atmosphere while reducing containment pressure. Pressure reduction in a hydrogen generation event is helpful because it suppresses the peak containment pressure that results should a deflagration occur. Containment venting, however, is the least desirable choice when the containment atmosphere is highly radioactive because of the potential for an offsite radioactivity release in excess of allowable limits and the consequent adverse affect on the health and safety of the public and plant personnel.

In addition to combustible gas concentration reduction in Section PC/G, containment venting may be prescribed within the RPV and Primary Containment Flooding SAG to maintain primary containment integrity, to facilitate RPV injection and primary containment flooding, and to preserve pressure suppression capability. The decisions and actions associated with placing the containment vent in service are described in Section 4 of this Attachment and are similar no matter which SAG step specifies containment venting. The ERO must weigh numerous considerations before initiating the containment vent. Indeed, one consideration questions if operation of containment sprays has been unsuccessful in avoiding the need to vent the containment (Table 4-1). Clearly, the ERO foresees operation of drywell and suppression pool sprays as the preferred method to effect a reduction in containment pressure and would endeavor to place them in service if at all possible before taking action to vent the containment. When performed solely for the purpose of containment pressure control, SAG Step PC/P mandates initiation of sprays at a pressure well below the pressure at which containment venting is permitted.

<u>Spray Operation</u>
The requirement for initiation of drywell and suppression pool sprays is given in several locations in the SAGs and can be identified by the phrase "DRYWELL SPRAY IS REQUIRED" and "SUPPRESSION POOL SPRAY IS REQUIRED." In addition to the spray initiation requirements in Section PC/G, spray initiation is also required in the following steps of the Containment and Radioactivity Release Control guideline to assist in control of other containment parameters:

DW/T Monitor and control drywell temperature.

….

Before drywell temperature reaches [340°F (maximum temperature at which ADS is qualified or drywell design temperature, whichever is lower)], DRYWELL SPRAY IS REQUIRED.

CN/T Monitor and control containment temperature.

….

Before containment temperature reaches [185°F (containment design temperature)], SUPPRESSION POOL SPRAY IS REQUIRED.

PC/P Monitor and control primary containment pressure.

Before suppression chamber pressure reaches [the Pressure Suppression Pressure] [13.8 psig (Suppression Chamber Spray Initiation Pressure)], SUPPRESSION POOL SPRAY IS REQUIRED.

When suppression chamber pressure exceeds [13.8 psig (Suppression Chamber Spray Initiation Pressure)] DRYWELL SPRAY IS REQUIRED.

….

PC/R Monitor and control [drywell] [suppression chamber] radiation level.

Before [drywell] [suppression chamber] radiation level reaches [14,000 R/hr (drywell or suppression chamber radiation level which requires a General Emergency)], SUPPRESSION POOL SPRAY IS REQUIRED and DRYWELL SPRAY IS REQUIRED.

Unlike the spray requirements in Section PC/G in which the requirement is only reached when combustible gas concentrations are above the deflagration limit or cannot be determined, the Containment and Radioactivity Release Control guideline steps offer significant flexibility in determining when to initiate sprays. The logic term "before" that introduces the conditions of the Containment and Radioactivity Release Control guideline steps listed above means "anytime prior to reaching the specified parameter action level." In the postulated severe accident, the ERO decision-makers have the latitude to initiate sprays as soon as entry to the SAGs is made. The ERO would quickly recognize the limited combustible gas control capability because of the inoperability of the igniters, the drywell hydrogen mixing system and the CAD system. In addition to effecting repairs on the disabled equipment, the ERO would identify the need to initiate drywell and suppression pool sprays as soon as possible. This action, if successful, could prevent the need for containment venting at rates beyond allowable offsite radioactivity release rate limits or delay its requirement until the combustible gas control systems are returned to service. The Accident Assessment Team is equipped with TSG instructions that help determine the timing of spray initiation and the duration of spray operation. The Accident Assessment Team would likely make the recommendation for early spray initiation and the spray function would become a high priority action assuming other limitations on spray initiation are satisfied. The Accident Assessment Team would assess factors such as those listed in Table 5-1 to reach the conclusion that drywell spray initiation is a high priority, beneficial action. Factors influencing suppression pool spray initiation are similar to those in Table 5-1.

The SAG steps in which drywell and suppression pool sprays are actually initiated and operated are given in the overrides of SAG Steps RC/F-1 through RC/F-6. In the postulated severe accident, the actions to initiate and operate drywell and suppression pool sprays would be dependent, therefore, on the Section RC/F step being performed. For plants at which containment sprays are supplied by pumps capable of injecting into the RPV, spray operation must be coordinated with RPV injection.

- If core debris can be adequately cooled (Steps RC/F-2, RC/F-3, and RC/F-4), RPV injection takes precedence over the use of containment sprays since catastrophic failure of the primary containment is not expected under the conditions for which spray is required. Each of these RC/F steps specifies the minimum requirements to maintain core debris cooled (e.g., Minimum Debris Retention Injection Rate, etc.), and any excess pumping capacity could then be directed to spray operation.
- If adequate cooling of core debris cannot be ensured but it has not yet been determined that core debris has breached the RPV (Steps RC/F-5 and RC/F-6), the prioritization of sprays and injection depends upon whether pressure suppression capability exists. Spray operation is a high priority action for restoring and maintaining containment pressure suppression capability.
- If it has been determined that core debris has breached the RPV (Step RC/F-1), drywell sprays are operated irrespective of the effect upon RPV and primary containment injection.

Table 5-1: Drywell Spray Timing Considerations

CONSIDERATIONS	YES	NO	NA
Is the risk to electrical equipment in the drywell, that may be needed after sprays are operated, acceptable?			
Is the water needed for drywell sprays *not* needed for core cooling?			
Has suppression chamber pressure exceeded 10 psig?			
Is drywell temperature increasing rapidly and expected to exceed design temperature? Has drywell temperature exceeded design temperature?			
Is drywell spray initiation possible now, but may not be at a later time?			
Has primary containment integrity been lost?			
Is primary containment venting anticipated? In progress?			
Is the water needed for drywell sprays *not* needed for other SAG priorities?			
Is RPV breach by core debris anticipated? Has it occurred?			
Are drywell or suppression chamber radiation levels high or increasing?			
Will spray operation neither de-inert the containment or challenge the negative containment design pressure?			
Will spray operation reduce containment overpressure, but not cause pumps taking suction on the suppression chamber to exceed NPSH limits?			
YES responses are considered benefits; NO responses, drawbacks. Do benefits outweigh drawbacks?			

6. References

1. 10 CFR 50.44, "Combustible Gas Control in Containment," October 16, 2003.

2. *BWR Owners' Group Accident Management Guidelines Overview Document*, Revision 1, June 1996.

3. *BWR Owners' Group Emergency Procedure and Severe Accident Guidelines*, Revision 2, March 2001.

4. NEI 91-04, "*Severe Accident Issue Closure Guidelines*," Revision 1, December 1994.

5. *BWR Owners' Group Emergency Procedure and Severe Accident Guidelines, Appendix B: Technical Basis*, Revision 2, March 2001.