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Subject: PWR Owners Group
For Information Only – LTR-LIS-08-627, "PWROG Position Paper on Non-condensable Gas Voids in ECCS Piping; Qualitative Engineering Judgment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events, Task 3 of PA-SEE-450"

This letter transmits four (4) copies of LTR-LIS-08-627, "PWROG Position Paper on Non-condensable Gas Voids in ECCS Piping; Qualitative Engineering Judgment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events, Task 3 of PA-SEE-450". This document is being submitted for information only, in response to NRC staff request associated with review of NRC Generic Letter 2008-01: Managing Gas Accumulation in Emergency Core Cooling, Decay Heat Removal, and Containment Spray Systems Licensee submittals. As such, no review fee or separate Safety Evaluation (SE) is expected.

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If you have any questions, please do not hesitate to contact me at 254-897-5851 or Mr. Anthony Nowinowski of the Owners Group Program Management Office at 412-374-6855.

Add'l copies sent to PM.

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NRR

Sincerely yours,

K. Nemit Approving for D. Buschbaum

Dennis E. Buschbaum, Chairman
PWROG Owners Group

Enclosure: Four (4) copies of LTR-LIS-08-627, "PWROG Position Paper on Non-condensable Gas Voids in ECCS Piping; Qualitative Engineering Judgment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events, Task 3 of PA-SEE-450" (Non-Proprietary)

cc: PWROG Management Committee
PWROG Steering Committee
PWROG Systems & Equipment Engineering Subcommittee
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Date: September 4, 2008

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Subject: **PWROG Position Paper on Non-condensable Gas Voids in ECCS Piping; Qualitative Engineering Judgment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events, Task 3 of PA-SEE-450**

References: 1. LTR-LIS-08-543, "PWROG Position Paper on Non-condensable Gas Voids in ECCS Piping; Qualitative Engineering Judgment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events, Task 3 of PA-SEE-450," August 19, 2008.

Attachments: 1. Text for Transmittal to PWROG on Task 3 of PA-SEE-450

This document is a re-issue of Reference 1 with updates to proprietary classification. In order to meet the contractual requirements of PA-SEE-450, it is being re-classified as Non-Proprietary Class 3, in lieu of Proprietary Class 2.

Please direct any questions/comments to the undersigned.

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**Electronically approved records are authenticated in the electronic document management system.*

Attachment 1 to LTR-LIS-08-627

Non-condensable Gas Voids in ECCS Piping; Assessment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events

Non-condensable Gas Voids in ECCS Piping; Assessment of Potential Effects on Reactor Coolant System Transients Including Chapter 15 Events

1. Introduction:

The purpose of this document is to qualitatively evaluate through engineering judgment the impact on the reactor coolant system (RCS) of a small amount of non-condensable gas in emergency core cooling system (ECCS) piping in pressurized water reactor designs during accident conditions. The focus is on certain points in the system where non-condensable gases can collect. This includes portions related to charging/safety injection, high pressure safety injection and residual heat removal system/low pressure safety injection piping down-stream of the ECCS pumps. This evaluation assumes that the amount of gas present in the ECCS will not impact ECCS flow or time of delivery. Because of this, the amount of gas volume present in the suction side of the pump(s) is assumed to be very small.

The following tables list the sizes of gas voids which have been considered in this evaluation. These have been broken down for both the high pressure (high head) and low pressure (low head/RHR) portions of the emergency core cooling systems. For the high pressure system piping, an initial sum total of 5 ft^3 of gas at a system pressure of 400 psia and ambient temperature of 68° F is assumed. For the low pressure system piping, an initial sum total of 5 ft^3 of gas at a system pressure of 100 psia and ambient temperature of 68° F is assumed. The initial condition pressure assumptions are based on hot shut-down conditions with the ECCS pressurized to that of the RCS, and/or what could be tolerated in those portions of the ECCS without adverse effects on flow delivery or performance. Because these volumes are somewhat arbitrary, any void volumes observed in the ECCS piping can be adjusted accordingly to accommodate for pressure and temperature as long as they do not exceed the equivalents at the specified conditions. For example, as long as the total observed gas voids in a particular high pressure portion of an ECCS do not exceed the equivalent of 5 ft^3 at 400 psia, 68° F, this evaluation applies. With these volumes as a starting point, the following volumes result under variations in pressure and temperature assuming ideal gas behavior.

Table 1

Maximum Expected Gas Void Size in High Pressure ECCS piping Evaluated for Cold Leg Injection under Transient Conditions

Pressure (psia)	Temperature (°F)	Volume (ft^3)
1800	621	2.3
1000	545	3.8
400*	350*	7.7
14.7	212	173.2

* Corresponds to approximate residual heat removal/shut-down cooling system in-service conditions

Table 2

Maximum Expected Gas Void Size in Low Pressure ECCS piping Evaluated for Cold Leg Injection under Transient Conditions

Pressure (psia)	Temperature (°F)	Volume (ft^3)
400*	350*	1.9
200	380	4.0
100	328	7.5
14.7	212	43.3

* Corresponds to approximate residual heat removal/shut-down cooling system in-service

The gas volumes chosen in the tables above are based on gas void quantities which are larger than the anticipated gas volume in the ECCS system under any circumstance. There are several considerations which would limit the void size in ECCS piping to values much less than those provided in the tables. For instance, if the gas voids are located in the suction of the ECCS pumps, stringent criteria regarding the allowable gas volume fractions at the pump inlet will restrict the void sizes to much lower values than what is listed here. Allowable gas volume fractions at the inlet of emergency core cooling pumps and the transport of gas to the pump through system suction piping are addressed in separate PWROG project authorizations. In addition, if the gas voids are located in the pump discharge, water hammer concerns in the cold leg discharge piping may also restrict the allowable gas void quantities to lower values than what has been considered. The water hammer evaluations in cold leg discharge piping are currently being addressed on a plant specific basis. Like treatment of voids upstream of the ECCS pumps, a methodology for predicting the resulting pressure pulsations and pipe loads is being developed in separate PWROG authorizations. However, the application of these methodologies to demonstrate that relief valves do not lift and piping loads are acceptable will limit the void size to values lower than what is identified in Tables 1 and 2.

2. Impact on ECCS Flow:

Again, the purpose of this evaluation is to demonstrate that these voids have no adverse impact on the post-accident RCS thermal hydraulic performance. A critical assumption inherent to this evaluation is that there will be no delay or reduction in ECCS flows beyond the point assumed in the safety analyses of record. Because of the plant specific aspects of potential void locations, piping layouts, pipe diameters and anticipated flow rates, demonstrating this on a generic basis is not practical. Each postulated void would have to be evaluated on a case by case basis. As such the evaluation to determine the ultimate conclusion that ECCS flows are not less than the values assumed in the safety analyses of record would have to be performed on a plant specific basis.

3. LOCA Analyses:

The impacts of the identified gas voids listed in Tables 1 and 2 on the LOCA analyses are evaluated: There are four general areas of LOCA analyses which are considered: Large Break LOCA (LBLOCA), Small Break LOCA (SBLOCA), Long Term Core Cooling (LTCC), and LOCA Forces.

3.1 Large Break LOCA – All designs:

For LBLOCA, the initial gas void volumes of interest are those listed in Tables 1 and 2, which would be injected during cold leg injection. Note for the purposes here LBLOCA is defined as a LOCA in which the break flow area is greater than $1 ft^2$.

During a LBLOCA, the RCS depressurizes completely and the vast majority of initial primary side mass is expelled into containment. In these cases, the accumulators inject their entire liquid mass as well as the nitrogen driving gas, which is on the order of thousands of cubic feet once expanded to containment back pressure. The addition of the extra gas volume to the RCS will have no impact in the short term in this regard. Gas that is injected prior to accumulator empty time is either ejected through the break via ECCS bypass or will have negligible effects on core heat transfer since a large amount of vapor may already be present in the core region at that time. In the longer term, the majority of these gases either migrate to the upper spaces of the RCS or out into containment where they have no bearing on core cooling response because the core is in a stratified, boiling mode of heat transfer with the mixture level residing in the area of the hot/cold leg penetrations.

3.2 Small Break LOCA (SBLOCA) – Westinghouse and Combustion Engineering Design NSSS with Recirculating Steam Generators:

For SBLOCA, the gas void volumes of interest are those listed in Table 1, which would be injected during cold leg injection.

During a SBLOCA, the reactor coolant system (RCS) pressure can remain at elevated values for extended periods, which precludes accumulator injection and injection of the nitrogen cover gas which occurs during a LBLOCA. Regardless, the injection of the non-condensable gas void volume of interest during cold leg injection is not expected to impact the core cooling response during a SBLOCA. When considering the pressures and temperatures expected during a SBLOCA transient, the gas void volumes of interest in Table 1 are small relative to the primary system volume. Further, the RCS flow path would influence the migration of this gas. For example, the gas would enter the cold legs where the bubbles would tend to migrate towards the top of the pipe. For the short term where the reactor coolant pumps (RCPs) would be running, it is likely that some, if not the majority, of the bubble population would migrate to the top of the downcomer once this gaseous phase enters the vessel nozzles. This gas would ultimately travel to the top of the downcomer. In reactor vessels equipped with spray nozzles the gas would travel to upper head. In either case, its ultimate residing place would have a negligible impact on the core cooling response. Should the gas make its way through the downcomer and core, the next separation zone would be the upper plenum. The impact of the gas voids on heat transfer in the core region under this unlikely circumstance is expected to have a negligible impact as discussed in the Non-LOCA Steamline Break section. Like the downcomer and upper head, the location would have a negligible impact on the RCS/core cooling response. Any gas phase that separates out in the upper plenum would also more than likely end up in the vessel head too. There is a chance that during pressurization of the ECCS piping upon pump start, some of the gases present may go into solution. Because of this, there is also a chance these gases may come out of solution once introduced into the RCS under lower pressure/higher temperature circumstances. As such, in the unlikely event the non-condensable gas ends up in the steam generator tubes, the impact of the gas presence is still considered to be insignificant. In Westinghouse designs, small break transients of the size that normally result in clad heat up rely little on steam generator (SG) heat transfer since the break is the dominant energy sink. In SBLOCAs for CE designs, there is more reliance on SG heat transfer beyond the points of two-phase natural circulation and reflux condensation. However, the amount of non-condensable gases present is not expected to significantly impact this because of the large amount of SG heat transfer area that is available. Tests conducted for natural circulation situations indicative of SBLOCAs show that neither of these processes nor SG heat transfer is adversely affected when larger amounts of non-condensable gases were present. These are discussed in the paragraphs below. In addition, Post-LOCA cooldown and depressurization using the SGs would not be adversely affected either, again because of the noted small impacts on SG heat transfer.

In smaller breaks where natural circulation is not lost (and other transients as well, such as feedwater line break and steam generator tube rupture, etc), it is considered that any gas coming out of solution would occur before it enters the steam generators. As such, the downcomer and/or upper plenum are still the most likely places the gas phase would tend to separate from the liquid velocity field. If this mechanism of separation doesn't occur, the bubble sizes would tend to be small and therefore would stay at the same relative velocity as that of the liquid phase. In this case, it is unlikely that the gas would accumulate at the top of the steam generator tubes under this flow regime. If larger bubble formation were to occur in the hot legs in significant amounts, it is judged that upon entering the SG inlet plenum(s), they would tend to migrate towards the outer periphery tubes and thus not interrupt the natural circulation process as a whole. Also, if the gas phase is present in the hot legs, some of it may enter the pressurizer, depending on the orientation of the surge line. However, the presence of these gases in the amounts specified in Table 1 would not reduce the effectiveness of either the pressure communication through the surge line or the pressurizer itself for pressure reduction scenarios such as auxiliary spray, PORVs, etc.

The FLECHT Test 6 described in Reference 1 supports the argument that natural circulation will not be interrupted. In this test, a series of non-condensable gas injections were made into the facility hot legs while the system was in a natural circulation mode of core cooling. This was done to test the effects of the gas on the coolant flow and heat transfer through the steam generator tubes. Note that the standard volume of non-condensable gas injected in the reference FLECHT test was on the order of 22% of total test facility volume, significantly larger than the volume of gas injection assumptions specified herein at the expected pressures and temperatures during a SBLOCA. As such, the Reference 1 test is an extreme example of the effect of non-condensable presence in a reactor coolant system.

Page 5-83 of Reference 1 states: "Test 6 was designed to examine the effects of non-condensable gas on single-phase natural circulation. During the test, a total of 11.5 moles (2.53 x 10-2 lb_m-moles) of helium were injected into the primary system in a series of nine injections. The primary system responded to the addition of non-condensable gas by reducing the single-phase flow from 0.0015 to 0.0011 m^3 / sec (24 to 18 gal/min) during the first three injections. The six subsequent injections of helium had no impact on the system. It is believed that the flow decrease observed during the first three non-condensable gas injections was the result of helium accumulation at the top of selected steam generator U-tubes. The helium consequently formed a vapor plug at the top of the U-tubes, which blocked flow through these tubes. As a result of the tube blockage, the effective flow area through the steam generators was reduced. This translated into an increase in frictional flow resistance through the steam generators and the system responded by reducing flow. It is postulated that flow was not reduced during the last six helium injections because this helium found its way to previously plugged tubes rather than plugging additional steam generator U-tubes. The manner in which the helium was injected (at the top of the hot leg) may have caused the helium to flow preferentially into selected tubes in the generator."

There is no significance between the inner and outer tubes with regard to the natural circulation conditions of focus here. Because of the possible bubble dynamics, it is judged that the gas bubbles would preferentially travel to the outer periphery tubes. Again, it should be emphasized that the FLECHT test injected the gas in the hot legs which therefore ensured that the non-condensable gas would end up in the steam generators. Ultimately, under this test of extreme conditions, core cooling was maintained. For an operating plant, this situation is considered unlikely since the majority of this gas should migrate to the vessel head because of the RCS flow path as previously stated.

Additional tests were performed to characterize the effects of non-condensable gases in the RCS at the Idaho National Engineering Laboratory's Semi-Scale test facility. Specifically, tests S-NC-5 and S-NC-6 represented two-phase natural circulation and reflux cooling situations, respectively with non-condensable gases present in the steam generators. In both cases, the scaled amount of gases injected far exceeds that of the gas volumes being considered here. Both tests showed the presence of non-condensable gases "did not preclude effective rejection of core heat through the steam generator." Like the FLECHT test cited above, Test S-NC-5 showed that although some of the SG tubes became blocked with the gas, there was sufficient flow through the tubes to remove core heat. Again, the scaled amount of gas present was in excess of that under consideration. Summaries of these tests can found in Reference 2.

Further, in natural circulation situations, one or more steam generators (SGs) can be out of service without adverse effects on core cooling for several reasons which includes a) the amount of flow reduction is outweighed by the excessive amount of heat transfer area that exists in the functioning SGs and b) the flow reduction is also compensated for by a natural increase in the temperature differentials across the core and the functioning SGs. Also, any small amounts of gas bubbles in the flow stream are not expected to interfere with the primary fluid to SG tube wall convective heat transfer. Again, this would be for scenarios where gas bubbles do find their way into the SGs, which is not expected to be the case, especially under natural circulation conditions.

It should be noted that all of the above arguments provided for LOCAs are considered applicable to gas volumes larger than those identified in Table 1.

Therefore, the injection of the non-condensable gas void volume of interest during cold leg injection is not expected to impact the core cooling response during a SBLOCA.

3.3 Small Break LOCA (SBLOCA) – Babcock and Wilcox NSSS Design with Once-through Steam Generators:

For SBLOCA and post-transient natural circulation situations in the B&W NSSS design, the expected RCS response with or without the gas is similar for the limiting cold leg pump discharge (CLPD) breaks. That is, the gas bubbles would separate out and either be discharged out of the break with the steam from the internals reactor vessel vent valves (RVVVs), or separate out in the upper downcomer. Since the B&W plants trip the RCPs immediately on a loss of adequate subcooling margin, the pumps may be coasting down before the gas is discharged into the RCS. This timing makes it less likely that the injected gases will be carried down the downcomer and into the core. If they are, they can flow upward into the upper head or if they are near the periphery of the core, they could pass through the holes in the upper plenum cylinder and out of the RVVVs and back into the upper downcomer. The plenum cylinder is an efficient separator for any gasses creating levels that can form loop seals for certain scenarios when the hot leg is full of water or the water level is in the riser section of piping. In the unlikely event that the gas could migrate into the hot legs, it is possible for the gas to accumulate at the top of the hot leg U-bends. However, for the volumes identified in Table 1, the hot leg U-bends would not be voided to the point where natural circulation would be adversely effected and core cooling is not maintained. That is, for the hot leg pipe size (3 ft diameter) and U-bend radius (5 ft), the small fraction of the gas volume from Table 1 that could possibly enter the hot legs can be accommodated without occupying a significant flow area in the U-bend region. It is also noted that the RV upper head and hot leg U-bend regions have high point vents that the operators can open to vent any small quantity of gas should it accumulate in those locations.

4.0 Long Term Core Cooling (LTCC)- All designs:

For LTCC, the initial gas void volumes of interest are those listed in Tables 1 and 2, which would be introduced during cold leg injection or possibly under switch-over to ECCS sump recirculation (cold and/or hot leg).

LOCA Long Term Cooling (LTC) analyses consist of calculations performed to ensure that the core remains subcritical in sump recirculation mode, calculations to support actions that prevent boric acid precipitation in the core after a LOCA, and calculations to confirm the capability for long term decay heat removal.

Post-LOCA subcriticality analyses performed for the Westinghouse fleet include ECCS piping volume as a dilution source to the sump water volume, and typically, generic values for ECCS piping volume are used. Since the total sump water volume is typically several hundred thousand gallons or more, the identified potential voids in the ECCS piping would have an insignificant effect on the analysis results. Post-LOCA subcriticality analyses performed for the Combustion Engineering fleet do not include the ECCS piping volume as a dilution source to the sump water, and therefore, there would be no impact on these analyses.

The post-LOCA LTC analyses are performed to support actions that prevent boric acid precipitation in the core. For Westinghouse and CE plants, this is also referred to as the Hot Leg Switchover (HLSO) analysis. For the B&W-designed plants boric acid concentrations are managed through combinations of dump-to-sump via the decay heat drop line, auxiliary pressurizer spray injection, or dump-to-containment. The calculations that predict the buildup of boric acid in the core are primarily impacted by the vessel mixing volume and boron concentration assumptions from various sources of water that drain to the containment sump. The boric acid precipitation analyses do not include ECCS piping volume as a boration source to the sump water volume since the volume is small when compared to the total sump water volume. Therefore, these analyses are not impacted by potential voids in the ECCS piping.

LTC analyses also include calculations that ensure adequate core flushing flow (before and after switchover to hot leg recirculation) and long term decay heat removal. These calculations confirm the adequacy of the post-LOCA safety injection flow in both cold and hot leg recirculation modes. Since pumped ECCS flow during recirculation is not affected by potential voids in the ECCS piping, the calculations that confirm the ability to flush the core and remove decay heat are not impacted.

In summary, the impact of injecting the identified volume of non-condensable gases in the ECCS piping has been evaluated for LOCA Long Term Cooling analyses. It is concluded that there would be no impact on current licensing basis analyses.

5.0 LOCA Forces:

The identified gas voids do not impact the LOCA Forces analyses. The LOCA Forces transients are of extremely short duration and are over in less than one second; safety injection is not modeled because the conditions to actuate safety injection will not exist until after the LOCA Forces transient is over.

6.0 Non-LOCA Analyses:

There are three non-LOCA events potentially impacted by the introduction of gas voids into the reactor coolant system (RCS): steamline rupture, feedwater line rupture and steam generator tube rupture.

There are three scenarios associated with the introduction of gas voids into the reactor coolant system (RCS) described: 1) Cold Leg Injection, 2) Cold Leg Recirculation and 3) Hot Leg Recirculation. In the non-LOCA events discussed here, the significance of the ECCS occurs very early in the transient. That is, the transient is essentially over by the time ECCS sump recirculation is required (if needed). As such, only the cold leg injection has potential impact on the non-LOCA analyses. These scenarios are addressed as follows:

6.1 Non-LOCA Events – Westinghouse and Combustion Engineering Design NSSS with Recirculating Steam Generators

6.1.1 Steamline Rupture and Feedwater line Rupture:

In general, the Steamline Rupture and Feedline Rupture events are potentially impacted because they rely on ECCS injection for event mitigation. As identified in introduction of this evaluation, there is no anticipated change in ECCS flows. There is no impact on the steamline rupture and feedline rupture analyses related to ECCS (SI) flow degradation and injection delay since there is no change in the RCS and ECCS flows. Even if a delay in the ECCS flow was postulated, the impact is reduced since both the Feedline Rupture and Steamline Rupture events conservatively model a 0 ppm boron concentration while the lines are being swept (prior to injection of the borated water from the RWST).

With respect to the heat transfer degradation, for the steamline break event, it is conservative to assume maximum heat transfer capabilities across the steam generator tubes to maximize the RCS cooldown and associated reactivity insertion resulting from the break. As such, any potential heat transfer degradation in the steam generators has no significant impact. There is a chance under RCPs running conditions that the gas bubbles would remain very small in which case the liquid phase drag force could dominate over the bubble buoyancy forces. Because of this, in the unlikely event that some non-condensable gas does not separate out of the flow in the downcomer and makes its way into the core, the small amount present would not have an appreciable effect on fuel rod heat transfer. That is, the impact is considered to be either insignificant or possibly beneficial for two reasons; 1) the voiding will reduce moderator density and thus drop local nuclear power and the corresponding rod surface heat flux, 2) bubble formation can induce rod surface convective heat transfer due to turbulent mixing. Once through the core, the gas phase will tend to separate out either into the upper plenum or the downcomer and thus would only be of possibility in one pass through the core. Therefore, this event is unaffected by the potential heat transfer degradation.

The feedline rupture analysis assumes minimum heat transfer capabilities across the steam generator tubes to minimize the ability of the intact steam generators to remove decay heat via the auxiliary feedwater system, in the post-trip phase of the transient. This transient is modeled both with and without the RCPs running. Typically, more limiting results occur with the RCPs in operation because of the added heat to the RCS. In this case, the presence of non-condensable gas volumes on the order of those identified in Table 1 do not pose any real significance since the gas void fraction is small. In addition, system velocities are too high for phase separation to occur. Without the RCPs running, the same arguments for SBLOCA natural circulation listed above would apply here as well.

6.1.2 Steam Generator Tube Rupture:

For Westinghouse-design plants, there are multiple steam generator tube rupture (SGTR) methodologies.

For all SGTR methodologies, since there is no change in the initial RCS conditions and no change to ECCS flow, there is no impact on the SGTR analysis. However, it is noted that degradation in ECCS flow would actually be a benefit for the SGTR event due to reduced break flow even though that is not assumed to be the case.

Some licensing basis SGTR analyses use a conservative mass and energy balance (referred to as the hand calculation method) to provide the primary to secondary break flow and secondary releases (i.e. flashed break flow and steam releases) to the atmosphere. In these cases, releases from the ruptured and intact steam generators for the initial 30 minutes of the transient assume maximum SG heat transfer in order to maximize secondary releases. This would not be impacted by a gas intrusion entering with the safety injection flow.

For plants whose analysis models operator actions and plant responses using a detailed thermal-hydraulic code, it is conservative to assume minimum heat transfer capabilities across the steam generator tubes for the SGTR margin to overfill analyses since this delays break flow termination. While the heat transfer degradation could result in reduced margin to overfill, it is likely the non-condensable gas voids will take the path identified for SBLOCA natural circulation (i.e. collecting in the downcomer and/or upper plenum) and therefore would not present a problem.

For plants whose analysis models operator actions and plant responses using a detailed thermal-hydraulic code, it is conservative to assume maximum heat transfer capabilities across the steam generator tubes for the input to dose SGTR analyses since this maximizes secondary releases. The SGTR input to dose analyses model minimum tube plugging to maximize heat transfer which bounds the effect of a gas intrusion.

It should be noted that for these events, the gaseous phase flow path in the RCS is considered to be the same as that described for the SBLOCA event discussed above.

6.2 Non-LOCA Events – Babcock and Wilcox NSSS Design with Once-through Steam Generators

6.2.1 Steamline Rupture and Feedwater Line Rupture:

The feedwater line break is an overheating event for the B&W-designed plants and the ECCS is not actuated. Therefore, the transient would not be affected.

With the reactor coolant pumps operating, the only location that the fluid velocity is low enough for gases to accumulate is in the upper downcomer or reactor vessel upper head region. The available volume in these RV high points is adequate to accommodate the gas volume with no appreciable affect. Any degradation in heat transfer between the primary and secondary would reduce the severity of the event. If offsite power is lost, the severity of the transient, with or without non-condensable gases, would not be changed. The cooling potential (reactivity addition) of the ECCS fluid is nearly offset by the boron addition such that any reduction or delay in flow would have a negligible affect on the transient. Therefore, the transient results would not be affected.

6.2.2 Steam Generator Tube Rupture:

Similar to the discussion presented for Recirculating SG plants, there is no impact on the SGTR analysis related to ECCS flow degradation and injection delay.

7.0 Post Non-LOCA Event Use of the RHR System:

The presence of non-condensable gases in the RCS must also be considered from a post-transient perspective. That is, Non-LOCA events which receive an S-signal must also consider the longer term effects of non-condensable gases. In any of these situations, the ultimate goal is to get the plant to hot shut-down conditions and shift the mode of core cooling from the steam generators (with or without forced circulation) to the residual heat removal (RHR) system. As stated in Table 1, the maximum possible amount of gas that could be present is 173 ft^3. This volume is conservatively high since it is based on saturation conditions at one atmosphere. However, the RHR system typically operates with a high level of sub-cooling and therefore, the bulk RCS temperatures will be lower. With a lower temperature the accumulated volume of non-condensable gases will also be lower. Recall that the position for SBLOCA (and Non-LOCA events as well) is that most, if not all non-condensable gases, will ultimately end up in the vessel head region. The typical volume of the various PWR vessel head designs are on this order or larger. As such, this volume is capable of accommodating the worst case assumed gas volume in a post-transient state of conditions and will not interfere with RHR operation. With some CE vessels, the communication path between the downcomer and vessel head is extremely small. In these instances, gas trapped in the downcomer may not travel into the head. The downcomer volume to the top of cold legs in these designs is approximately 150 ft^3. Gases trapped in this area would only exceed this volume in the final stages of depressurization/cooldown. Should the downcomer be unable to accommodate this, the gas could then start to propagate into the tops of the cold legs and hot legs (via the hot leg nozzle gaps) and possibly into the steam generators.

However, there is sufficient volume in these areas of the RCS to accommodate these gas excesses without adversely affecting RHR operation since the excess volume here is small.

Unlike the arguments made with regard to transient effects directly related to the ECCS, the RCS can tolerate a delay or degradation in RHR flow under these conditions. This is because the steam generators are left in service both during and after start-up of the RHR system. Provided that it can be assured no mechanical damage will occur to the RHR system components under these conditions, a RHR system flow delay or degradation will not have any adverse effects to core cooling under these circumstances.

8.0 Effects on RCP Integrity:

Because some of the SBLOCA (early stages) and non-LOCA events may have the reactor coolant pumps in operation, there is the potential for the gas voids to come in contact with the pump impellers for an extended period. While localized damage to the impellers cannot be ruled out, the pressure boundary of the RCPs and seal packages will remain intact under these faulted conditions. In Westinghouse NSSS designs with safety grade charging pumps, the seal packages are not considered subject to air introduction through the seal cooling circuits. This is because the tap-off to this portion of the charging system is immediately downstream of the charging pumps and is separate from the ECCS headers. The normal charging path for seal cooling will be in operation prior to any transient discussed here, therefore, no air will be present in those lines. Again, the charging pump suction side void fractions are considered to be very small in this evaluation. With all this considered, there will be no appreciable amounts of gas introduced into the seal packages and their integrity will be maintained. As such, no adverse complications to the transients are expected with regard to presence of the non-condensable gases in this regard.

9.0 Conclusions:

A qualitative evaluation has been performed to consider the potential impact on the RCS safety analyses related to injection of small quantities of non-condensable gas assumed to be located in ECCS pump discharge piping. It is concluded that the LOCA or Non-LOCA analyses are not impacted so long as a plant specific evaluation of the gas volumes detected were less than those identified in Tables 1 and 2. The evaluation assumes that the timing of ECCS delivery is not greater than what was assumed in the safety analysis of record. In addition, it also assumes that resultant ECCS flow rates, considering the gas volume found in the ECCS piping, would not be less than those used in the analyses of record. Other plant specific evaluations, such as water hammer loading or ECCS pump performance, may need to be addressed separately.

10.0 References:

1. WCAP-10415, NUREG/CR-3654, "PWR FLECHT SEASET System Effects Natural Circulation and Reflux Condensation Data Evaluation and Analysis Report," February 1985.
2. EGG-SEMI-5591, Quick Look Report for Semi-Scale Mod-2A Tests S-NC-5 and S-NC-6, September 1981.