BWR OWNERS' GROUP

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Washington, DC 20555

Subject: BWR Owners' Group Actions in Response to Pipe Ruptures in Non-U.S. BWRs
BWROG Project Number 691

Enclosures:
1. BWR Piping and Component Susceptibility to Hydrogen Detonation, Proprietary version
2. BWR Piping and Component Susceptibility to Hydrogen Detonation, Non-Proprietary version
3. Affidavit of proprietary information

Attention: Chief, Information Management Branch
Policy Management, Policy Development and Analysis Staff

The BWROG has taken the following actions relative to the two NSSS pipe rupture events late last year at non-U.S. BWRs. Both events are believed to be the result of ignition of radiolytic hydrogen-oxygen mixtures.

The BWROG participated in the GE task force to study the events. The task force concluded that the risk of future event was small, but not zero. Accordingly, the BWROG received and examined Service Information Letter (SIL) 643, "Potential for Radiolytic Gas Detonation," which identifies top-level plant characteristics for potential detonation risk and top-level remedial actions/modifications to reduce or eliminate risk of future events.

One risk characteristic is the presence of RHR steam condensing mode valves and piping. Table 1 shows that many of the plants were not provided with RHR steam condensing mode (SCM) piping and RHR steam isolation valves. Many of plants with SCM piping have eliminated it. RHR steam isolation valve leakage has either not been a problem or has been corrected or mitigated. Additionally, a number of plants have begun reviewing their piping for points of hydrogen accumulation.

The BWROG formed the Hydrogen Accumulation Committee to provide detailed guidance to the BWR utilities for identification, disposition, and mitigation of potential radiolytic hydrogen and oxygen in plant piping and equipment. The committee sought input from GE and the Chubu

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Electric Company, as well as the benefit of the experience of its members. The Committee work product included:

1. Identifying the most significant generic plant equipment that could be subject to rapid hydrogen accumulation and informing BWROG members via executive letter.
2. Surveying its members relative to plant areas with the greatest potential for hydrogen/oxygen accumulation, and actions taken to address this configuration.
3. Reviewing GL 91-18 recommendations to ensure that operability with hydrogen accumulations is properly addressed.
4. Developing the guidance document "BWR Piping and Component Susceptibility to Hydrogen Detonation." This report provides detailed guidance for identifying equipment subject to hydrogen accumulation and potential rupture and identifies short-term and long-term mitigation strategies for such equipment.

The proprietary and non-proprietary versions of the guidance document are enclosed, as well as the original affidavit of proprietary information. This report has been transmitted to all the utilities through the BWROG Executive Committee strongly urging that all plants perform detailed evaluations and implement mitigating actions as appropriate.

It should be noted that while the enclosed document has been endorsed by a substantial number of the members of the BWROG, it should not be interpreted as a commitment of any individual member to a specific course of action. Each BWROG member utility must formally endorse the BWROG position in order for that position to become the member's position.

If you have any questions regarding the BWR Owners' Group activities in response to NSSS pipe ruptures, please contact the undersigned at 914-272-3372.

Sincerely,

Original signed by JA Gray

J. A. Gray, Jr., Chairman
BWR Owners' Group

cc: S. Collins, USNRC
B. Sheron, USNRC
A. Wang, USNRC (with 8 copies)
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T.G. Hurst, GE Nuclear Energy
C.B. Kincaid, GE Nuclear Energy

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
			1. Has SCM been eliminated and how?	2a. Have there been leakage problem with RHR steam isolation valves?	2b. If yes, how was the leakage problem addressed?	3. Water accumulated upstream of RHR steam isolation valves?	4. What actions have been taken as a result of information to date?
Plant 1	N	NA	NA	NA	NA	NA	A preliminary review has been performed of systems with a potential for hydrogen accumulation. Recommendations have been made to the Operations department on operation of systems where appropriate.

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Plant 2	N	NA	NA	NA	NA	NA	Personnel participated in BWROG H_2 Accumulation Task Force and briefed System Engineering on H_2 accumulation considerations to be made during normal outage walk-downs. Reviews complete.
Plants 3 & 4	N	NA	NA	NA	NA	NA	Personnel participated in BWROG H_2 Accumulation Task Force and briefed System Engineering on H_2 accumulation considerations to be made during normal outage walk-downs. Reviews complete.

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Plant 5	N	NA	NA	NA	NA	NA	Plant initiated a reviewed of systems to find other systems susceptible to the issue.

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Plant 6	N	NA	NA	NA	NA	NA	Personnel participated in BWROG H_2 Accumulation Task Force and briefed System Engineering on H_2 accumulation considerations to be made during normal outage walk-downs. Reviews complete.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
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Plant 7	N	NA	NA	NA	NA	NA	Initial OE review of GE SIL 643 found no inherent system design susceptibility to radiolytic gas accumulation. A detailed review of piping isometrics is now being done to find smaller high point traps or "dead legs". Also the Reactor Water Level Condensing Chambers will be modified in next RFO to a vented configuration to eliminate H2/O2 buildup that has been causing level "notching" problems.

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Plants 8 & 9	N	NA	NA	NA	NA	NA	A preliminary review has been performed of systems with a potential for hydrogen accumulation. No potentially susceptible H2 accumulation issues found, as yet.
Plants 10 & 11	Y	HPCI	Yes - w/ blank plates at tee with HPCI (1' off HPCI steam line) and at HX	Yes	Valves were eliminated	Valves were eliminated	Survey conducted based on limited knowledge; awaiting BWROG guidance for further evaluations.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
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Plant 12	Y	HPCI	No. Components associated with the Steam Condensing Mode have been operationally abandoned-in-place and station procedures have been modified to leave the components in a safe position (closed) and eliminate their operation.	Yes. Only on one loop.	This was corrected by an extensive rework of the valve seat.	No. All piping upstream of the RHR steam isolation valves is sloped down allowing any condensation that may develop to drain downward to a drip leg condensate drain.	Reviewed isometric drawings for the Steam condensing mode of the RHR system for slope and possible high point traps or dead legs.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
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Plant 13	Y	HPCI	Yes - w/ 10" pipe cap close to steam supply line.	No (even before the mod).	NA	No, very little piping remains upstream of flange and location/orientation/volume does not allow accumulation.	Preliminary review of systems compared to BWROG and SIL recommendations. Operations personnel briefed on foreign plant experience with hydrogen detonations.
Plant 14	N	NA	NA	NA	NA	NA	Reviewed safety-related piping and found no unusual vulnerabilities. Changed design verification procedure regarding increasing the potential for accumulation and detonation of radiolytic gas.

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Plant 15	Y	HPCI	No	There have been periodic pressurizations of the RHR system above the values maintained by the keep-full system, the source is not positively identified (i.e., SCM blocking valve vs. LPCI injection valves).	Procedures are in place to vent the RHR heat exchangers (periodically or continuously) to control header pressure.	Piping is sloped downward to HPCI steam line to preclude water accumulation.	SCM piping geometry has been reviewed in detail and estimates have been made of heat transfer / steam condensation / non-condensable gas accumulation rates in the piping.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
			1. Has SCM been eliminated and how?	2a. Have there been leakage problem with RHR steam isolation valves?	2b. If yes, how was the leakage problem addressed?	3. Water accumulated upstream of RHR steam isolation valves?	4. What actions have been taken as a result of information to date?
Plant 16 & 17	Y	HPCI	Yes. Capped associated line on the steam side.	N/A	N/A	N/A	Walked down Unit 1 drywell to identify piping configurations where gas accumulation is possible. Concluded that correct system alignment and maintaining designed vent paths and orifices are key to preventing detonation.
Plant 18	Y	HPCI	Yes - w/ blank plates installed.	None Noted	NA	Unknown, not monitored.	Evaluation completed of SCM piping. Potential problem areas identified in accordance with GENE Pipe Rupture Task Force report and draft susceptibility report. Preparation of design change is underway.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
			1. Has SCM been eliminated and how?	2a. Have there been leakage problem with RHR steam isolation valves?	2b. If yes, how was the leakage problem addressed?	3. Water accumulated upstream of RHR steam isolation valves?	4. What actions have been taken as a result of information to date?
Plants 19 & 20	Y	HPCI	Yes. Steam supply valve is isolated. Valve is located physically close to HPCI steam supply pipe on horizontal pipe sloped down toward valve. Hydrogen would rise to HPCI steam supply line. Cold side of isolation valve is sloped to a low point and then rises to a blind flange. Periodic draining is possible via low point drains.	To Be Determined	To Be Determined	To Be Determined	Personnel participated in BWROG H_2 Accumulation Task Force and briefed System Engineering on H_2 accumulation considerations to be made during normal outage walk-downs. Reviews ongoing.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
			1. Has SCM been eliminated and how?	2a. Have there been leakage problem with RHR steam isolation valves?	2b. If yes, how was the leakage problem addressed?	3. Water accumulated upstream of RHR steam isolation valves?	4. What actions have been taken as a result of information to date?
Plants 21 & 22	N	NA	NA	NA	NA	NA	Personnel participated in BWROG H_2 Accumulation Task Force and briefed System Engineering on H_2 accumulation considerations to be made during normal outage walk-downs. Reviews complete.
Plants 23 & 24	Y	HPCI	Yes - w/ elbow replacing the tee	No (even before the mod?)	NA	NA	Systems attached to the NSSS were reviewed using the guidance of SIL 643. No areas of concern were found. Currently monitoring industry for any new information.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
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Plant 25	N	NA	NA	NA	NA	NA	Personnel participated in BWROG H2 Accumulation Task Force and briefed System Engineering on H2 accumulation considerations to be made during normal outage walk-downs.
Plant 26	Y	RCIC	Never completed during construction (Steam line deactivated w/ isolation valve de-energized and locked closed	No	NA	No.	Remedial Corrective Action is to following BWROG recommendations.

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Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
			1. Has SCM been eliminated and how?	2a. Have there been leakage problem with RHR steam isolation valves?	2b. If yes, how was the leakage problem addressed?	3. Water accumulated upstream of RHR steam isolation valves?	4. What actions have been taken as a result of information to date?
Plants 27 & 28	Y	RCIC	Yes - w/ Blind flange at steam line	No steam leak through the valve Jack – no answer about the parenthetical comment, I've removed it.	NA	Short stub (~1 ft) before blank, so potential for small accumulation.	Personnel participated in BWROG H_2 Accumulation Task Force and briefed System Engineering on H_2 accumulation considerations to be made during normal outage walk-downs. Reviews ongoing.
Plant 29	Y	RCIC	No	Both valves leaked (one w/ damaged seat)	Valve seat extensively reworked, leak stopped	No	Personnel performed a limited evaluation earlier this year. No immediate actions were deemed necessary, additional reviews will be performed when the final committee reports are issued.

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Plant 30	Y	RCIC	Yes - w/ Blind flange ~6 feet above RCIC steam junction	Only packing leak, no steam leak through the open valve	Adjusted or replaced w/ Chesterton packing	Not possible	Personnel participated in BWROG H_2 Accumulation Task Force and briefed System Engineering on H_2 accumulation considerations to be made during normal outage walk-downs. Reviews ongoing.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
			1. Has SCM been eliminated and how?	2a. Have there been leakage problem with RHR steam isolation valves?	2b. If yes, how was the leakage problem addressed?	3. Water accumulated upstream of RHR steam isolation valves?	4. What actions have been taken as a result of information to date?
Plant 31	Y	RCIC	Yes. Blind flanges have installed in the RHR piping just upstream of the cross connect valve to the RCIC System, making SCM mode impossible to use. However, some piping remains installed.	Due to the installation of the blind flanges, the there is no isolation valve leakage. However, small leakage has been experienced through abandoned SCM system valves.	However, leakage in abandoned SCM system valves has been corrected by manual closure.	Installation of blind flanges has resulted in a potential area of piping that could be exposed to water accumulation. However, that piping has at least one active steam trap that should minimize the potential for water accumulation and protect the affected piping.	Plant personnel have reviewed available OE and other sources of information and the existing plant design to ensure existing designs were adequate. As of this date, no known corrective actions or redesigns have been proposed or have been considered necessary.

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Plant 32	Y	RCIC	Yes – w/ two blind fittings in each supply line.	Yes	Run ESW through RHR HX to collapse the steam bubbles.	None (Drained to RCIC steam supply condensate pot).	Reviewed isometric drawing – RHR steam line is insulated and slopes down toward blind fitting/condensate drain. Updated Design Interface Checklist to include review for increased potential for radiolytic hydrogen gas accumulation.

Table 1. U.S. BWR Inspection Results in Response to hydrogen Accumulation Issue							
Plant Name	SCM provided originally	Interfacing system for steam supply	Survey Questions				
			1. Has SCM been eliminated and how?	2a. Have there been leakage problem with RHR steam isolation valves?	2b. If yes, how was the leakage problem addressed?	3. Water accumulated upstream of RHR steam isolation valves?	4. What actions have been taken as a result of information to date?
Plant 33	Y	RCIC	Steam condensing mode lines have been cut and capped.	No. The valves have been deleted with a blind flange.	NA	NA.	Steam condensing mode lines have been cut and capped. Plant personnel performed a review of piping systems based on information provided in SIL No. 643. Neither modifications nor mitigating actions have been identified at this time. Plant personnel continue to monitor industry information related to this issue.

General Electric Company

AFFIDAVIT

I, George B. Stramback, state as follows:

(1) I am Project Manager, Regulatory Services, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in the GE proprietary report GE-NE-0000-0007-4008-01, *BWR Piping and Component Susceptibility to Hydrogen Detonation,* Revision 0, Class III (GE Proprietary Information), dated November 2002. The proprietary information is delineated by bars marked in the margin adjacent to the specific material.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), 2.790(a)(4), and 2.790(d)(1) for "trade secrets and commercial or financial information obtained from a person and privileged or confidential" (Exemption 4). The material for which exemption from disclosure is here sought is all "confidential commercial information", and some portions also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals cost or price information, production capacities, budget levels, or commercial strategies of General Electric, its customers, or its suppliers;

d. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, of potential commercial value to General Electric;

e. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in both paragraphs (4)a. and (4)b., above.

(5) The information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

8) The information identified in paragraph (2), above, is classified as proprietary because it contains responses containing or based on detailed results of analytical models, methods and processes, including computer codes for BWRs.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GE asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 20th day of December 2002.

George B. Stramback
General Electric Company

GE Nuclear Energy

GE-NE-0000-0007-4008-01
Revision 0
Class I
November 2002

BWROG Hydrogen Accumulation Committee

BWR Piping and Component Susceptibility to Hydrogen Detonation

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IMPORTANT NOTICE REGARDING THE CONTENTS OF THIS REPORT

Please Read Carefully

A. Disclaimer

The only undertakings of the General Electric Company (GE) respecting information in this document are contained in the contract between the Boiling Water Reactor Owners' Group (BWROG) and GE, as identified in the respective utilities' BWROG Standing Purchase Order for the performance of the work described herein, and nothing in this document shall be construed as changing those individual contracts. The use of this information, except as defined by said contracts, or for any purpose other than that for which it is intended, is not authorized; and with respect to any unauthorized use, GE, nor any of the contributors to this document, makes any representation or warranty, express or implied, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

PARTICIPATING UTILITIES

The utilities listed below contributed to the development of this report. However, while this report has been endorsed by a substantial number of the members of the BWR Owners' Group, it should not be interpreted as a commitment of any individual member to a specific course of action. Each member must formally endorse the BWROG position in order for that position to become the member's position.

AmerGen-Clinton
AmerGen-Oyster Creek
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Progress Energy-Brunswick
PPL-Susquehanna
PSEG Nuclear-Hope Creek
Southern Nuclear Operating Company-Hatch
Tennessee Valley Authority-Browns Ferry

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The authors wish to acknowledge the contributions of the following members of the BWROG Hydrogen Accumulation Committee in the completion of this report.

Matt Antony (NMC)

Jeff Drowley (Exelon)

Bruce Kincaid (GENE) – Project Manager

Mike Metell (Entergy Nuclear – VY)) - Chairman

Greg Morrison (PSE&G)

Surjit Pabby (Nine Mile Point Nuclear)

Duane Pavel (NPPD)

Don Powel (Detroit Edison)

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ACRONYMS AND ABBREVIATIONS

ASME	American Society of Mechanical Engineers
BWR	Boiling Water Reactor
BWROG	Boiling Water Reactor Owners Group
CRD	Control Rod Drive
HPCI	High Pressure Coolant Injection
HWC	Hydrogen Water Chemistry
L/D	Length to diameter ratio
ppm	Parts per Million by weight
RCIC	Reactor Core Isolation Cooling
RHR	Residual Heat Removal
RPV	Reactor Pressure Vessel
RWCU	Reactor Water Cleanup

1. INTRODUCTION

In late 2001, incidents attributed to accumulation and detonation of radiolytic hydrogen caused piping ruptures to occur in two separate international BWRs. Given the similarities in failure modes and the close proximity in timing between the two events, GE Nuclear Energy convened a Task Force to review the events.

The Task Force concluded in Reference 1 that the probability of similar events in GE BWRs, while small, cannot be completely precluded. Given the small ignition energy and the lack of detonations within the GE BWR fleet, the configurations and conditions conducive to radiolytic gas accumulation are expected to be rare, and therefore the likelihood of future hydrogen detonation events within the GE BWR fleet is small. However, the possibility cannot be completely dismissed, particularly in the case of degraded component performance that may not be immediately recognizable. Very narrow combinations of geometry and plant materiel condition are likely required for radiolytic gas to accumulate, but should such gas accumulate, there is a potential for detonation, and a detonation from 1000 psi would almost certainly result in piping failure.

The GE Task Force recommended that BWR owners review their plant configurations to determine if piping configurations susceptible to potential gas accumulation exist, and to evaluate further actions on a case-by-case basis. As a result of this recommendation, the BWROG Hydrogen Accumulation Committee was formed and convened in August to consider methods to provide guidance to the BWR fleet for identifying and providing recommendations for equipment subject to hydrogen accumulation and potential rupture (Reference 2).

Following the BWROG committee meeting, it was requested that GE prepare this report, using the logic framework developed by the committee and the results of GE technical analyses, for the purpose of providing plant personnel with sufficient information to conduct the necessary reviews of plant piping configurations in order to assess the risk of hydrogen detonation. This is a non-proprietary version of the full report that contains detailed evaluation results and details of the methodology used in the evaluations.

Note that the evaluations in this report are valid for BWRs operating with either normal water chemistry or hydrogen water chemistry (HWC) conditions. As detailed in

Reference 1, HWC operation actually reduces the rate of radiolytic gas buildup as well as the probability and severity of detonation by altering the gas mixture away from stoichiometric conditions to hydrogen rich conditions.

2. SUMMARY

With knowledge of buildup rates and component survivability, the need for mitigating actions can be assessed and appropriate schedules established for corrective actions. The proprietary version of this report provides information necessary to evaluate the rate of hydrogen buildup to detonable concentrations and to determine whether piping and components are adequately designed to withstand a detonation within the system. With knowledge of buildup rates and component survivability, the need for mitigating actions can be assessed and appropriate schedules established for corrective actions.

3. DISCUSSION

3.1 Piping Screening Criteria

In References 1 and 3, GE provided recommended screening criteria for evaluating plant risk factors associated with hydrogen accumulation. From this guidance, the BWROG committee developed a logic diagram to assist in evaluating various piping configurations, along with classification and corrective action categories or bins to define further necessary action. The bin classifications are based on the relative vulnerability of the equipment or piping as determined by a) the assessed buildup rate of hydrogen, b) the safety classification of the system, c) whether the piping is process or instrument, and d) component and piping geometry based on the evaluation in Section 3.3.

3.2 Buildup Rate of Hydrogen in Piping Systems

When sufficient radiolytic gas is generated in the BWR core and accumulates in a stagnant piping section, the gas concentration may reach the detonability limit. In order to avoid the potential hazards associated with the hydrogen and oxygen gases, it is recommended to vent potential candidate piping sections periodically. In particular, it is highly desirable to vent on a quarterly schedule, because most instrument calibrations are

performed quarterly. This section evaluates the required thermal insulation for three, six, and ten-inch pipes to maintain the radiolytic gas concentration below the detonability limit based on a quarterly venting schedule.

The calculation was performed over a period of 700 days, using a time interval for integration of one day. The steam properties used are from the ASME steam tables. A special iteration was performed for each time step to calculate the heat transfer coefficients and the steam properties as functions of appropriate temperatures. The analysis was performed for three, six, and ten-inch pipes with varying degrees of thermal insulation, and provides the thermal insulation required to maintain non-condensable gas accumulation below the detonability limit for a 115-day period.

As a result of the evaluation, several general observations can be made:

1. When non-condensable gases accumulate, the pipe temperature decreases to the saturation temperature of the steam partial pressure. Steam partial pressure and the pipe temperature decrease with time.

2. More thermal insulation on a pipe section slows the accumulation rate of non-condensable gases.

3. A larger pipe takes a longer time to accumulate non-condensable gas.

3.3 Pressure Integrity of Susceptible Piping and Components

Using the methodology established in NEDE-11146, "Pressure Integrity Design Basis for New Off-Gas Systems" (Reference 4), calculations were performed to evaluate the ability of BWR piping and reactor water level condensing pots to survive the peak internal pressures developed during a hydrogen detonation. Dynamic material properties used in the evaluation were taken from the GE task force report (Reference 1). Because the dynamic yield properties for stainless steel are not well known, the values from Reference 1 are based on the known values for the ultimate dynamic stress for stainless steel, adjusted for the known relationship between the dynamic yield and dynamic ultimate stress values for carbon steel. Also, because of the limited available data on dynamic material properties, the stainless steel and carbon steel material properties in Reference 1 are assumed to be valid for all types of stainless and carbon steels materials in general use in power plants. A value of 1.0 for both the safety factor and the dynamic

load factor was used in the analysis, as is appropriate for piping lengths of less than 30 feet. For piping lengths over 30 feet, these results may be less conservative than for shorter pipe runs.

Two sets of peak detonation pressure conditions were evaluated based on Reference 4 methodology: 1) for component or piping geometries with a length to diameter ratio less than 7 ($L/D \leq 7$), a peak pressure of 17 times initial, and 2) for $L/D > 7$, a peak pressure of 68 times initial. Under certain conditions involving a reflected pressure wave near the end of a straight section of long piping, pressure ratios up to 170 times initial are possible. However, under these conditions, the impulse imparted to the piping is not appreciably different from the impulse that occurs when peak pressures are 68 times initial. Thus, while the potential exists for peak pressures higher than 68 times initial under certain conditions relating to piping geometry, ignition source location, and distance from the ignition source, these higher pressures need not be considered when evaluating potential damage to piping (References 5-8).

Results are based on the ultimate strength and the yield strength properties. Wall thickness based on the ultimate strength properties are utilized when fewer than ten events in a system are expected during the plant life (Reference 4), as would generally be the case for the type of events addressed in this report. Thickness based on yield strength should only be utilized when ten or more events are expected during the plant life, such as in original offgas system designs where detonable hydrogen mixtures were continuously present. Results are obtained for temperatures of 150°F, 300°F, and 500°F to cover the range from 1) conditions expected for piping in equilibrium with drywell conditions to 2) the maximum temperature that will support detonable mixtures of hydrogen, oxygen and water vapor.

General observations from the evaluation are summarized below:

1. Condensing pots with piping configurations that result in operating temperatures below 467°F require further analysis.
2. In general, carbon steel piping and higher operating temperatures and pressures are more susceptible than stainless steel piping or lower operating temperatures or pressures
3. Larger diameter piping will generally fail from detonation when operating near reactor temperature and pressure.

4. CONCLUSIONS

Evaluations of hydrogen buildup rates and survivability of components and piping were performed to enable BWR plant personnel to evaluate the potential for radiolytic gas buildup and the associated risk of such buildup. These evaluations led to the following conclusions. Specific results are included in the proprietary version of this report.

- When non-condensable or radiolytic gases accumulate, the pipe temperature decreases to the saturation temperature of the steam partial pressure. Steam partial pressure and the pipe temperature decrease as time passes.
- Larger diameter pipes take longer for radiolytic gases to accumulate that do smaller pipes.
- Condensing pots with piping configurations that result in operating temperatures below 467°F require further analysis.
- In general, carbon steel piping and higher operating temperatures and pressures are more susceptible than stainless steel piping or lower operating temperatures or pressures.
- Larger diameter piping will generally fail from detonation when operating near reactor temperature and pressure.

5. REFERENCES

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