February 3, 2004

MEMORANDUM TO: Ashok Thadani, Director
Office of Nuclear Regulatory Research

FROM: Farouk Eltawila, Director ***/RA/*** by Farouk Eltawila
Division of Systems Analysis and Regulatory Effectiveness
Office of Nuclear Regulatory Research

SUBJECT: TASK ACTION PLAN FOR HIGH ENERGY PIPE BREAK EFFECTS INSIDE BWR MARK I AND II CONTAINMENTS

Attached for your information and approval is the task action plan (TAP) for the partial resolution of Generic Issues (GI) 156.6.1, "Pipe Break Effects on Systems and Components Inside Containment," and GI-80, "Pipe Break Effects on Control Rod Drive Hydraulic Lines in the Drywells of BWR Mark I and II Containments." The objective of the attached TAP is to determine through analysis if (1) a high energy pipe break inside a BWR Mark I containment has the potential to perforate the drywell shell and possibly disable accident mitigation systems, and (2) a high energy pipe break inside a BWR Mark I or Mark II containment can disable the control rod drive (CRD) scram system. The TAP is a follow-on to NUREG/CR-6395, "Enhanced Prioritization of Generic Safety Issue 156.6.1 Pipe Break Effects on Systems and Components Inside Containment," which was performed by the Idaho National Engineering and Environmental Laboratory (INEEL) and issued in November 1999, and the screening evaluation, "A Screening Evaluation of GSI-80 Pipe Break Effects on Control Rod Drive Hydraulic Lines in the Drywell of BWR Mark I and II Containments" attached to the February 14, 2003 memorandum from Thadani to Collins concerning GSI-80. Both generic issues will receive a technical assessment in accordance with Management Directive (MD) 6.4, "Generic Issues Program." The TAP need not be accomplished in sequential order, but should be accomplished in the order that appears to represent the most risk significant accident scenarios for GI-80 and 156.6.1. Individual TAP section reports will be issued when analysis information is obtained. All TAP sections are not required to be completed if a bounding analysis is found to be inconsequential. An integrated report will be issued in accordance with MD 6.4, combining the results of several section analyses, including draft recommendations for followup actions regarding either GI-156.6.1 or GI-80.

CONTACT: Ronald L. Lloyd, RES/DSARE/REAHFB
(301) 415-7479

Execution of the TAP will require coordination between DSARE and DET staff. Contractor support for specific event analysis, as needed, will be funded through RES/DSARE. Resource estimates for RES completion of the TAP include the following:

	FY2004
REAHFB	0.5 FTE
ERAB	0.6 FTE

Once the attached TAP is approved, specific milestones for completion can be established (based on work loads of DSARE and DET staff) and entered in the RES Operating Plan. As appropriate, this TAP may also be modified (e.g., scope and completion dates) to reflect ongoing analysis results. The projected completion period for the technical assessment portion of this TAP is 10 months.

Please contact me or Ronald Lloyd of my staff at 415-7479, if you have any questions or require additional information.

Attachment: As stated

cc w/att.:
C. Paperiello, DEDMRS

CONTACT: Ronald L. Lloyd, RES/DSARE/REAHFB
(301) 415-7479

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TASK ACTION PLAN
HIGH ENERGY PIPE BREAKS INSIDE BWR MARK I AND II CONTAINMENTS
(SUBSETS OF GENERIC ISSUES 80 and 156.6.1)

1. GENERIC ISSUES TO BE ASSESSED BY THIS TASK ACTION PLAN (TAP)

- Generic Issue-80, “Pipe Break Effects on Control Rod Drive Hydraulic Lines in the Drywells of BWR Mark I and II Containments.”

- Generic Issue (GI) 156.6.1, “Pipe Breaks Effects on Systems and Components”

2. OBJECTIVE

Perform a Stage 3 technical assessment of critical issues for GI-156.6.1 and GI-80 in accordance with Management Directive 6.4, “Generic Issues Program.” This TAP will perform an analysis of potential damage done to selected components inside the drywell of BWRs having Mark I and Mark II containments that could be caused by high energy lines breaks. Preliminary analysis of GI-156.6.1 and GI-80 indicate a high probability of either perforating the drywell shell or crimping of the insert and withdrawal control rod drive pipes. Each scenario would lead to core damage. When this TAP has been completed, draft recommendations will be proposed for each GI.

3. RESPONSIBLE PROJECT MANAGER

Ronald L. Lloyd is the Responsible Project Manager (RPM) and will be assigned portions of the TAP in addition to RES/DET staff.

4. GENERIC ISSUE CLASSIFICATION

Generic Issue 80 will be classified at the completion of the technical assessment.

Generic Issue 156.6.1 will be classified at the completion of the technical assessment.

5. GENERIC ISSUE STAGE

Generic Issue 80 and GI-156.6.1 are in Stage 3, “Technical Assessment” as defined in MD 6.4.

6. GENERIC ISSUE BACKGROUND INFORMATION

This TAP addresses potentially excessive conservatism in assigning probability values for high energy pipe break interactions inside the containments of typical BWRs having Mark I and Mark II containments, as they relate to Generic Issue (GI)-156.6.1, “Pipe Breaks Effects on Systems and Components,” and GI-80, “Pipe Break Effects on Control Rod Drive Hydraulic Lines in the Drywells of BWR Mark I and II Containments.” Preliminary analyses performed for both GI-156.6.1 and GI-80 concluded that work on a technical assessment (Stage 3 of Management

Directive 6.4, “Generic Issues Program”) should continue. Critical to the continuance of GI-156.6.1 and GI-80 is an analysis predicting the extent of potential damage to the drywell shell in Mark I containments, and to CRD piping bundles in both Mark I and Mark II containments following a high energy pipe break. Conservative analysis performed for GI-156.6.1 predicted that the drywell shell would likely be perforated upon pipe impact leading to the failure of all emergency core cooling systems (ECCS). Conservative analysis for GI-80 predicted that the CRD insert and withdrawal piping bundles could be impacted in such a manner as to completely close off the lines, resulting in a total loss of control rod movement capabilities. Table 1, “Applicable BWR plants,” lists the plants that are the subject of this TAP.

Table 1: Applicable BWR plants

BWR Mark I (SEP-III)	BWR Mark II
Nine Mile Point 1	Susquehanna 1 and 2
Monticello	Limerick 1 and 2
Dresden 3	LaSalle 1 and 2
Pilgrim	Nine Mile Point 2
Quad Cities 1 and 2	
Cooper	
Hatch 1	
Vermont Yankee	
Brown’s Ferry 1 and 2	
Peach Bottom 2 and 3	
Duane Arnold	
FitzPatrick	
Brunswick 2	

6.1 Problem Description for GI-156.6.1

GI-156.6.1: This generic issue assesses the need to review the 41 older nuclear power plant units (both PWRs and BWRs) referred to as the Systematic Evaluation Program Phase III (SEP-III) plants that were licensed while 10 CFR 50 Appendix A design criteria were evolving. Generic Issue 156.6.1 addresses whether the effects of pipe breaks inside containment have been adequately addressed in these plant designs. NUREG/CR-6395, “Enhanced Prioritization of Generic Safety Issue 156.6.1 Pipe Break Effects on Systems and Components Inside Containment,” (Ref. 1) which was performed by the Idaho National Engineering and Environmental Laboratory (INEEL) and issued in November 1999, resulted in GI-156.6.1 being given a high priority rating. The high priority rating was based on conservative outcomes of postulated inside containment high energy pipe break scenarios, which resulted in drywell shell perforation and loss of all ECCS. The INEEL report offered little quantitative or qualitative bases for the origin of the high failure probabilities. High energy pipe breaks at PWRs are not considered as part of this TAP because of low values of core damage frequencies or lack of site-specific information regarding system separation issues. Obtaining site-specific system separation information would be very time consuming and is outside the scope of this technical assessment. NUREG/CR-6395 indicated that one PWR event scenario (referred to as Event 9) had a mean core damage frequency (CDF) of 2.54E-05/RY, which involved a high energy pipe break of the main steam (MS), feedwater (FW), or primary coolant system inside containment. Event 9 postulated a high energy pipe break or jet impingement causing the failure of containment instrumentation and control systems, leading to the failure of accident mitigating systems. The INEEL report did not identify other PWR events that had a CDF greater than 1E-06/RY. Event 9 may be overly conservative because the actual physical separation conditions of instrumentation and control systems were unknown.

- In August 2000, the NRC requested the Boiling Water Reactor Owner's Group (BWROG) to review INEEL's enhanced prioritization (Ref. 1) and provide comments on five of the seven BWR cases. The BWROG formed a committee to coordinate a response for all affected plants, and, in November 2001, issued NEDC-33054, "Conservatism in NRC Prioritization of Pipe Break Effects on Systems and Components" (Ref. 2). The BWROG report was highly critical of the INEEL report, indicating that the prioritization should have been prioritized as "Low" or "Drop."

- The INEEL report assumed a containment impact probability of 0.25 for MS and FW piping and 0.5 for recirculation (RC) piping and residual heat removal (RHR) piping. The BWROG report indicated that the probability of a significant containment impact at a reasonably direct angle (high energy impact) should be considerably lower than the INEEL report because of the quantity of piping and structures in the drywell and different break locations.

- The INEEL report assumed a containment failure probability of 0.5 for RC piping, 0.25 for MS and FW piping, and 0.1 for RHR piping. In response, the BWROG report makes references to NRC safety evaluation reports indicating that there would be no containment rupture for an unrestrained pipe rupture (e.g., Nine Mile Point unit 1, Dresden unit 2), or that pipe ruptures in the cylindrical portion of the drywell do not result in impact energies sufficient to perforate the drywell shell (e.g., Pilgrim and Peach Bottom units 2 and 3). The BWROG report also claimed that for BWR Mark I containments, essentially the complete vertical section, is backed by reinforced concrete, and that greater than 80 percent of the spherical portion is backed by reinforced concrete or equivalently protected (e.g., pipe penetrations and jet deflectors).

- Information Systems Laboratories (ISL) produced a report (Ref. 3) that compared the event probabilities stated in the INEEL report, with those suggested in the BWROG report. In most instances, the ISL agreed with the statements made by the BWROG. All three reports (e.g., INEEL, BWROG, and ISL) tend to be subjective and lack a firm technical basis for statements that are made.

6.2 Problem Description for GI-80

GI-80: This generic issue assesses the need to further review concerns regarding the likelihood and effects of a LOCA which could cause interactions with the CRD hydraulic lines in such a way as to prevent rod insertion (e.g., crimping of all insert and withdraw CRD piping lines), creating the potential for recriticality when the core is reflooded. This scenario could lead to a situation where ECCS may not be sufficient to remove this extra energy, resulting in coolant boil-off, containment failure, and core melt. The most likely condition that would prevent control rod insertion would be the crimping of the insert/withdraw CRD piping bundles as the result of a high energy pipe break (recirculation system) inside containment. This scenario is discussed in the INEEL report (Ref. 1) and in greater detail in an NRC screening evaluation issued in February 2003 (Ref. 4).

- The INEEL report offered no quantitative bases for the origin of the high failure probabilities. Although the NRC screening evaluation (Ref. 4), "A Screening Evaluation of GSI-80 Pipe Break Effects on Control Rod Drive Hydraulic Lines in the Drywell of BWR Mark I and II Containments" attached to the February 14, 2003 memorandum from Thadani to Collins concerning GSI-80 provides qualitative information, it does not credit the existence of pipe whip restraints on high energy piping systems that are located near the CRD bundles. The NRC evaluation also does not comment on licensee pipe break analyses which show potential locations for pipe failures. The basis for the high priority rating of GI-80 is the calculated value of large early release frequencies (LERF), the bases for which are not well documented.

7. REGULATORY ASSESSMENT

Very conservative analyses of GI-80 and GI-156.6.1 indicted that a technical assessment should continue. Both GIs require the completion of a more rigorous evaluation.

8. PROPOSED ACTIONS

Continue with the technical assessment of both GIs. Propose recommendations based on this TAP and the analysis results. If it is found that risk thresholds per Appendix C of MD 6.4 are exceeded, it would be recommended to proceed with Stage 4 of the generic issue process. If risk thresholds are not met, recommendations for action may still be proposed, but the GI would be dropped.

9. SCHEDULED MILESTONES

Specific milestones will be established once human resources are better known, however, it is expected that the technical analysis portion of this TAP should be completed within 10 months of initiation. Contractor support (provided through RES/DSARE) for specific event analysis may be necessary and would impact the schedule. Specific tasks and lead responsibilities are shown in Section 9 of this TAP. Basic background design information is contained in Section 12.

9.1 High Energy Piping Interactions with BWR Mark I Drywell Shells (GI-156.6.1)

Perform calculations based on information provided in the above sections, and the variables discussed in this section to determine potential structural damage caused by a double ended pipe break inside containment. Provide the rationale for the range of variables that were chosen.

9.1.1 Establish Likely High Energy Systems That May Perforate the Drywell Shell (<u>DSARE</u>)

Based on information already provided by licensees in FSARs, or through document requests from licensees, it is expected that the RC, MS, and FW systems are the systems that would be capable of damaging or perforating the drywell shell, or flattening a CRD piping bundle.

Provide a discussion for other high energy lines (e.g., in addition to RC, MS, or FW) that may be inside the containment that may be capable of perforating the drywell shell.

Completion Date: February 2004

9.1.2 Establish Likely Pipe Sizes and Lengths for Each System That May Impact and Perforate the Drywell Shell Because of a Double Ended Break (Joint DSARE/DET)

This information is generally not contained in plant FSARs. Choose varying lengths of pipes based on drywell layout, placement of tees, elbows, and supports (if known).

Completion Date: February 2004

9.1.3 Establish Likely Pipe-to-Drywell Shell Impact Locations (Joint DSARE/DET)

This information is generally not contained in plant FSARs. Drywell shell impact locations should be chosen based on the postulated location of the double ended break. The impact locations will also be dependent on the length of the pipes, the distances from the break to the drywell shell, and structural or component interferences between the break and the drywell shell. Larger structural or component interferences between the break and the drywell shell will be determined from a review of detailed drawings from representative facilities.

Completion Date: February 2004

9.1.4 Establish Likely Pipe-to-Drywell Shell Impact Angles (Joint DSARE/DET)

The geometry of the double ended break will determine the angles at which the pipes will impact the drywell shell. Choose varying pipe impact angles (based on break locations inside containment) to determine the changes in the structural damage to the steel drywell shell and the concrete structure adjacent to the shell.

Completion Date: February 2004

9.1.5 Establish Likely Pipe-to-Drywell Shell Impact Velocities (Joint DET/DSARE)

This information is generally not contained in plant FSARs. From preliminary analysis, choose a varying range of likely pipe impact velocities including threshold velocities (based on analysis) that would be necessary for the pipe to perforate the drywell shell.

Completion Date: March 2004

9.2 High Energy Piping Interactions with CRD Piping Bundles in BWR Mark I Drywells (GI-80)

Perform calculations based on information provided in the above sections, and the variables discussed in this section to determine potential damage caused by a double ended pipe break and impact on a CRD piping bundle inside the drywell. Provide the rational for the range of variables that was chosen.

9.2.1 Establish Likely Pipe Sizes and Lengths for Each System That May Negatively Impact the CRD Piping Bundles (DSARE)

Completion Date: April 2004

9.2.2 Establish Likely Pipe-to-CRD Piping Bundle Impact Locations (Joint DSARE/DET)

Completion Date: April 2004

9.2.3 Establish Likely Pipe-to-CRD Piping Bundle Impact Angles (Joint DSARE/DET)

Completion Date: April 2004

9.2.4 Establish Likely Pipe-to-CRD Piping Bundle Impact Velocities (Joint DET/DSARE)

Choose a varying range of likely pipe impact velocities including threshold velocities (based on analysis) that would be necessary for the pipe to totally flatten one or more CRD piping bundles. It is recognized that CRD piping may also be severed or fail longitudinally during the pipe impact.

Completion Date: May 2004

9.3 High Energy Piping Interactions with CRD Piping Bundles in BWR Mark II Drywells (GI-80)

Perform calculations based on information provided in the above sections, and the variables discussed in this section to determine potential damage caused by a double ended pipe break and impact on a CRD piping bundle inside the drywell. Provide the rationale for the range of variables that was chosen.

9.3.1 Establish Likely Pipe Sizes and Lengths for Each System That May Impact the CRD Piping Bundle (DSARE)

Completion Date: May 2004

9.3.2 Establish Likely Pipe-to-CRD Piping Bundle Impact Locations and Impact Surface Areas (Deformed Contact Areas) (Joint DSARE/DET)

Completion Date: May 2004

9.3.3 Establish Likely Pipe-to-CRD Piping Bundle Impact Angles (Joint DSARE/DET)

Completion Date: May 2004

9.3.4 Establish Likely Pipe-to-CRD Piping Bundle Impact Velocities (Joint DET/DSARE)

Choose a varying range of likely pipe impact velocities including threshold velocities (based on analysis) that would be necessary for the pipe to totally flatten one or more CRD piping bundles. It is recognized that CRD piping may also be severed or fail longitudinally during the pipe impact.

Completion Date: May 2004

9.4 Analysis and Documentation of Calculation Results for GI-156.6.1

Provide an analysis of calculation results based on the accident scenario variables in Section 9.1, given the basic design information provided in Section 12.

9.4.1 Potential Damage to the Steel Spherical Section of the Drywell Shell (DET)

Following an analysis, provide a summary discussion including a table of results of the potential drywell shell damage in the spherical section caused by the accident scenario variables in Section 9.1.

Completion Date: April 2004

9.4.2 Potential Damage to the Steel Cylindrical Section of the Drywell Shell (DET)

Following an analysis, provide a summary discussion including a table of results of the potential drywell shell damage in the cylindrical section caused by the accident scenario variables in Section 9.1.

Completion Date: April 2004

9.4.3 Potential Damage to the Steel Top Head Section of the Drywell Shell (DET)

Following an analysis, provide a summary discussion including a table of results of the potential drywell shell damage in the top head section caused by the accident scenario variables in Section 9.1.

Completion Date: April 2004

9.4.4 Potential Damage to the Concrete Structure Outside the Steel Spherical Section of the Drywell Shell (DET)

Following an analysis, provide a summary discussion including a table of results of the potential concrete structure damage outside the spherical shell section (that portion having an air space between the shell and the concrete) caused by the accident scenario variables in Section 9.1.

Completion Date: May 2004

9.4.5 Potential Damage to the Concrete Structure Inside the Lower Part of the Spherical Section of the Drywell (Vessel Support and Floor Areas) (DET)

Following an analysis, provide a summary discussion including a table of results of the potential concrete structure damage inside the lower part of the spherical drywell area caused by the accident scenario variables in Section 9.1.

Completion Date: May 2004

9.4.6 Potential Damage to the Concrete Structure Outside the Steel Cylindrical Section of the Drywell Shell (DET)

Following an analysis, provide a summary discussion including a table of results of the potential concrete structure damage outside the cylindrical shell section caused by the accident scenario variables in Section 9.1.

Completion Date: May 2004

9.4.7 Pipe-to-Drywell Shell Impact Energies and Momentums for Various High Energy Pipe Break Scenarios (DET)

Following an analysis, provide a summary discussion including a table of results regarding calculated impact energies and momentums for various accident scenarios in Section 9.4.1 through 9.4.6. Calculate the maximum energies and momentums that the various components would have to absorb to become disabled (drywell shell perforation, concrete spalled or cracked). Compare these maximum energies and momentums with calculated likely values based on the accident scenario variables in Section 9.1.

Completion Date: June 2004

9.5 Analysis and Documentation of Calculation Results for GI-80

Provide an analysis of calculation results based on the accident scenario variables in Sections 9.2 and 9.3, given the basic design information provided in Section 12.

9.5.1 Potential Pipe-to-CRD Piping Bundle Damage Inside a Mark I Drywell (DET)

- Following an analysis, provide a summary discussion including a table of results of the potential CRD piping bundle damage (i.e., an estimation of the number of totally flattened, partially flattened, split, or severed CRD pipes in each CRD bundle)

- Following an analysis, provide a summary discussion including a table of results regarding calculated impact energies and momentums for various accident scenario variables in Section 9.2. Calculate the maximum energies and momentums that the CRD piping bundle would have to absorb to become totally flattened. Compare these maximum energies and momentums with calculated likely values based on the accident scenario variables in Section 9.2.

Completion Date: June 2004

9.5.2 Potential Pipe-to-CRD Piping Bundle Damage Inside a Mark II Drywell (DET)

- Following an analysis, provide a summary discussion including a table of results of the potential CRD piping bundle damage (i.e., an estimation of the number of totally flattened, partially flattened, split, or severed CRD pipes in each CRD bundle)

- Following an analysis, provide a summary discussion including a table of results regarding calculated impact energies and momentums for various accident scenario variables in Section 9.3. Calculate the maximum energies and momentums that the CRD piping bundle would have to absorb to become totally flattened. Compare these maximum energies and momentums with calculated likely values based on the variables in Section 9.3.

Completion Date: July 2004

9.6 Recommendations for GI-156.6.1 (DSARE/DET)

Provide draft recommendations for further analysis, including the basis for any further analysis, as appropriate, for the summary results presented in Section 9.4. For example:

- If the drywell shell can be perforated (or that insufficient margin exists based on calculated probabilities and their uncertainties) by a pipe following a high energy pipe break, propose further actions, as appropriate.

- If the drywell shell penetrations can be pressurized by steam flowing into the air gap between the drywell shell and the concrete structure following a high energy pipe break, propose further actions, as appropriate.

- If the containment cannot be perforated by a pipe following a high energy pipe break, consider the need to take any corrective actions, as appropriate.

- If previously documented event scenarios have overly conservative probabilities, recommend new values, as appropriate.

Completion Date: August 2004

9.7 Recommendations for GI-80 (DSARE/DET)

Provide draft recommendations for further analysis, including the basis for any further analysis, as appropriate, for the summary results presented in Section 9.5. For example:

- If CRD piping bundles inside a BWR Mark I or II containment can be totally flattened, partially flattened, split, or severed by a pipe following a high energy pipe break (or that insufficient margin to failure exists), propose further actions, as appropriate.

- If previously documented event scenario probabilities in Ref. 1 are determined to be overly conservative, recommend new values, as appropriate.

Completion Date: October 2004

10. RESOURCE REQUIREMENTS

Execution of this TAP will require coordination between DSARE and DET staff. Contractor support is not expected to be required for this TAP.

Lead Organization:	Division of Systems Analysis and Regulatory Effectiveness (RES/DSARE)
Task Manager:	Ron Lloyd
Lead Manager:	Farouk Eltawila
NRC Principal Reviewers:	M. Mayfield, M. Evans, S. Ali, B. Tegeler, R. Lloyd
Applicability:	BWR Systematic Evaluation Program III Plants (licensing reviews completed before November 1975) having Mark I containments, and BWR plants having Mark II containments

Resource estimates for RES completion of the TAP include the following:

	FY2004
REAHFB	0.5 FTE
ERAB	0.6 FTE

Once the attached TAP is approved, specific milestones for completion can be established (based on work loads of DSARE and DET staff) and entered in the RES Operating Plan. As appropriate, this TAP may also be modified (e.g., scope and completion dates) to reflect ongoing analysis results. The projected completion period for the technical assessment portion of this TAP is 10 months.

11. OTHER CONTACTS

None.

12. BACKGROUND INFORMATION

As shown in Table 1, 16 BWR Mark I (SEP-III) units and seven BWR Mark II units are considered for this TAP. Several BWR Mark I (SEP-III) and BWR Mark II plant FSARs were reviewed to obtain drywell CRD piping bundle design information and the proximity of high energy lines.

12.1 BWR Mark I (SEP-III) Containments

Table 2, “BWR Mark I containment information (from FSARs),” is provided from a review of information contained in FSARs and available plant drawings, in addition to the following miscellaneous BWR Mark I design information:

- During operations, the internal pressure of the CRD insert and withdrawal piping is approximately 1000 psi. During a scram, the pressure is approximately 1500 psi.

- The concrete structure wall backing the drywell shell has a compressive strength of 4000 psi.

- Nine Mile Point 1 (NMP 1): Reactor recirculation suction lines are 28 inches in diameter, discharge lines are 26 inches in diameter, (material is 300 series stainless steel). A NMP 1 calculation predicted an impact velocity of RC pipe hitting the drywell shell following a high energy pipe break of 115 feet/second.

- NMP 1: Main steam piping is 24 inches in diameter, (material is ASTM A106, Grade B). A NMP 1 calculation predicted an impact velocity of the MS pipe hitting the drywell shell following a high energy pipe break of 100 feet/second. The calculation also assumed a pipe weight of 5050 pounds.

- NMP 1: Feedwater piping is 18 inches in diameter (entrance to drywell) and 10 inches in diameter (running horizontally and then vertically), (material is ASTM A106, Grade B). A NMP 1 calculation predicted an impact velocity of the FW pipe hitting the drywell shell following a high energy pipe break of 89 feet/second.

- NMP 1: The drywell shell material is ASTM A201 and A212 Grade B steel (moderate tensile strength carbon silicon steel) made to A300 requirements.

- NMP 1: The air gap between the drywell shell and the exterior concrete structure is ventilated at several locations. At the top of the air gap are two 12 inch diameter emergency condenser pipes just below the head cover. These pipes vent the air space to the outside of the biological shield concrete that surrounds the drywell shell. The annulus area between many of the drywell penetrations and their sleeves provide ventilation to the air space exterior to the air gap. The air gap is vented around the ten vent pipes (6 feet, 9 inches in diameter). This vent area would relieve pressure from the air gap to the room that contains the torus. In addition, the air gap has ten 4 inch diameter drain pipes at the top of the sand cushion to relieve any water or pressure build up.

- NMP 1: Water/steam jet impact forces (assumed some reduction based on the distance and the dispersion angle); licensees used an area equal to the largest pipe cross section area.

- Pilgrim: Mark I drywell shell thicknesses and layout are shown on Boston Edison drawings C1A1-8, M23, and M291.

- The general layout of major piping inside a Mark I drywell is shown in Figure 3-2 of NUREG/CR-6395 (Ref. 1).

- Quad Cities (QC): The drywell shell material is A-212 Grade B, which is moderate tensile strength carbon steel.

- QC: Small missiles propelled by liquid breaks were assumed to travel at a maximum velocity of 200 feet/second.

- Pilgrim: The drywell shell material is ASTM A516 Grade 70 fabricated to ASTM A300. The yield strength of the shell at 300 degrees Fahrenheit is approximately 33.7 ksi.

- Pilgrim: Chicago Bridge and Iron conducted a series of tests on a steel plate formed to simulate a portion of the drywell vessel to show that the plate could deflect up to 3 inches locally without failure. The tests were satisfactory and also provided data on the loading required to produce a given deflection, and the strain at various points of the shell. In performing these tests, permanent deformation was not considered as failure.

- Pilgrim: The maximum drywell design condition temperature is 281 degrees Fahrenheit.

- Pilgrim: The maximum jet force on the spherical part of the drywell is 665 kip/3.69 square feet. The maximum jet force on the cylindrical part of the drywell is 316 kip/1.76 square feet. The maximum force on top head part of the drywell is 32.6 kip/0.18 square feet.

Table 2: BWR Mark I containment information (from FSARs)

Plant	Spherical shell	Spherical shell to cylindrical neck	Cylindrical neck	Top head	Drywell to shield wall gap	Energy absorbing material on drywell interior	Bioshield wall	Shield wall	#CRDMs (one insert and one withdrawal line each)	Separation between CRD bundle pedestal penetrations
Cooper (GE 4)	Not specified	Not specified	Not specified	Not specified	~2"	In selected areas	Not specified	5/16" steel inner liner, 1/4" outer liner	137	See Hatch 1
Hatch 1 (GE 4)	1-1/8" (upper) 1-1/2" (lower)	Not specified	1-1/4" (upper) 13/16" (lower)	Not specified	Not specified	In selected areas	4-7 feet thick	Not specified	137	~75 inches
NMP 1 (GE 2)	0.7" (upper) to 1.1" (lower)	2-5/8"	Varies 0.7" to 1.1"	Not specified	~2-1/2"	Not specified	Not specified	5/8" steel liners on both sides	129	Three bundles; Either side of RC pump discharge ~ 60 inches; Either side of RC pump suction ~ 71 inches
Oyster Creek (GE 2)	0.722" (upper) 0.770" (center) 1.154" (lower)	2-9/16"	0.640"	1-3/16"	~3"	Not specified	4 feet minimum	Not specified	137	See NMP1
Pilgrim (GE 3)	13/16" (upper) to 1-1/16" (lower)	2-5/8"	1-1/4" (upper) 0.67" (lower)	1-7/16"	~2"	In selected areas (not in the cylindrical portion)	4-6 feet thick	Not specified	145	~70 inches
QC (GE 3)	11/16" (upper) to 1-1/8" (lower)	2-3/4"	1-1/2" (upper) 3/4" (lower)	1-1/4" to 1-7/16"	~2-3/4"	In selected areas	4-6 feet thick	Not specified	177	See Pilgrim
VY (GE 4)	11/16" (upper) to 1-1/8" (lower)	2-1/2"	1-1/2" (upper) 0.635" (lower)	1-5/16"	~2"	In selected areas	Not specified	Not specified	178	See Hatch 1

12.2 BWR Mark II Containments

Table 3, “BWR Mark II CRD piping bundle information (from FSARs),” and the following miscellaneous BWR Mark II design information are provided from a review of information contained in FSARs and available plant documents:

- During operations, internal pressure of the CRD insert and withdrawal piping is approximately 1000 psi. During a scram, the pressure is approximately 1500 psi.
- Susquehanna: FSAR Figure 3.8-3, “Reactor/Primary containment/reactor building composite overview,” shows the major interior components in the drywell. The recirculation system suction lines are shown.
- Susquehanna: FSAR Figure 3.8-5, “Reactor/Primary containment/reactor building composite overview,” shows the major interior components in the drywell. The recirculation system discharge lines are shown.
- Susquehanna: FSAR Figure 3.8-19-1, “ Reactor Building Units 1&2 liner plate drywell penetration details,” shows the four CRD piping bundles (112 individual penetrations are in each bundle). Two bundles are located at 90 degrees, two bundles are located at 270 degrees. Each of the bundles is separated by approximately 13 feet.
- Susquehanna: FSAR Figures 5.1-41, 4-1, and 4-3, show the reactor coolant system elevation and plan views.
- NMP 2: FSAR Figure 1.2-7 (sheet 2 of 2), “General Arrangement reactor building plan Elev. 240'-0",“ shows the plan view of suction and discharge piping for the recirculation pumps.
- NMP 2: FSAR Figure 1.2-8 (sheet 1 of 2), “General arrangement reactor building plan Elev. 261'-0" and miscellaneous,” shows the plan view of suction and discharge piping for the recirculation pumps, general placement of the four CRD (also abbreviated as RDS) piping bundle penetrations, and the placement of the CRD hydraulic units. Two of the four CRD piping bundle penetrations exit the reactor vessel pedestal area at the north (90 degrees), and the remaining two exit the reactor vessel pedestal area at the south (270 degrees).
- NMP 2: FSAR Figure 1.2-11 sheet 1 of 4), “General arrangement reactor building sections,” shows the general placement of the CRD piping bundle as it penetrates the reactor vessel pedestal, the containment, and on to the CRD hydraulic units.
- NMP 2: FSAR Figure 3.6A-53, “High energy piping composite plan Elev. 240'-0",” shows the suction and discharge lines of the recirculation pumps and other major components on the 240 feet level. This is the elevation level at which the CRD piping bundles exit the reactor vessel pedestal, but they are not shown on the drawing.
- NMP 2: FSAR Figure 3.6A-54, “High energy piping composite plan Elev. 261'-0",” shows the suction and discharge lines of the recirculation pumps and other major components on the 261 feet level.

- NMP 2: FSAR Figure 3.6A-58, “High energy piping composite section1-1,” shows an elevation view of the high energy piping inside the drywell such as the discharge and suction recirculation piping.

- NMP 2: FSAR Figure 3.6A-59, “High energy piping composite section 2-2,” shows an elevation view of the high energy piping inside the drywell such as the discharge and suction recirculation piping.

- NMP 2: The general plan layout of the CRD (RDS) piping as it goes through the reactor pedestal is shown on FSAR Figure 1.2-8, “General arrangement reactor building plan elev. 261'-0" and miscellaneous.”

- Limerick: The 12 inch RHR shutdown cooling return lines (loops A and B) that connect to the RC suction or discharge piping is considered as moderate energy upstream of the check valve. The RHR connection line also has a pipe whip restraint just upstream of the check valve.

- Limerick: The 20 inch RHR shutdown cooling suction line (loop B) that connects to the RC suction piping is considered a “moderate energy” system upstream of the second isolation valve. The RHR connection line also has two pipe whip restraints adjacent to the energy boundary change.

- Limerick: FSAR Figure 3.8-38, “Reactor vessel and reactor shield wall base connections,” shows the CRD piping bundle pedestal penetrations (Penetrations X-31 A, B, C, and D).

- Limerick: FSAR Figure 3.8-39, “Reactor pedestal reinforcement above diaphragm slab” shows the CRD piping bundle pedestal penetrations (Penetrations X-31 A, B, C, and D).

Table 3: BWR Mark II CRD piping bundle information (from FSARs)

Plant	Minimum CRD bundle separation at reactor pedestal exit	Pipe break postulation	Minimum CRD bundle separation at the drywell	# CRDMs (one insert line and one withdrawal line each)
LaSalle (GE 5)	See NMP2	Pipe breaks are not postulated near the CRD bundles at the reactor pedestal. The nearest break is at the lower end of the 12" recirculation risers next to the header ring.	See NMP2	185
Limerick 1and 2 (GE 4)	CRD bundle penetration separation distance is ~79 inches	Pipe breaks are not postulated near the CRD bundles at the reactor pedestal. The nearest break is at the lower end of the 12" recirculation risers next to the header ring.	~13 feet	185
NMP 2 (GE 5)	CRD bundle penetration separation distance is ~48 inches.	Similar analysis to Susquehanna except that some of the restraints installed in the Susquehanna plant have been disabled. No mention is made to indicate that NMP 2 has disabled any of its restraints.	~67 inches	185
Susquehanna 1 and 2 (GE 4)	CRD bundle penetration separation distance is ~79 inches.	Provides an extensive listing of potential pipe break locations for multiple systems in Section 3.6 of the FSAR. It appears that the RC discharge line has had its restraints disabled, and no breaks are postulated except for the lower end of the 12" RC risers. The CRD bundles are on either side of the vertical RC discharge line.	~13 feet	(185)

12.3 Failure Probabilities for piping and components for GI-156.6.1

The INEEL report lists several accident scenarios that involve high energy pipe breaks and perforation of the drywell shell resulting in eventual core damage. Each of the fractions, frequencies, and probabilities should be reviewed based upon this TAP analysis, to determine if excessive conservatism exists, and to suggest alternate values, if appropriate.

<u>INEEL report (BWR Event 1)</u>

- Assumed the fraction of primary piping inside containment that is MS or FW to be 0.40.

- Assumed the fraction of primary piping inside containment that is MS or FW that can impact the drywell shell by pipe whip to be 0.25.

- Assumed the fraction of MS or FW piping that can rupture the drywell shell by pipe whip to be 0.25.

- Assumed the probability of overpressure in the air gap failing piping penetrating the drywell to be 0.80.

<u>INEEL report (BWR Event 9)</u>

- Assumed the fraction of primary piping inside containment that is RC to be 0.20.

- Assumed the fraction of primary piping inside containment that is RC that can impact the drywell shell by pipe whip to be 0.50.

- Assumed the probability of RC pipe whip rupturing the drywell shell (for plants with no pipe whip restraints) to be 0.50.

- Assumed the probability of overpressure in the air gap failing piping penetrating the drywell or by steam in the auxiliary areas caused EQ failures to be 0.80.

<u>INEEL report (BWR Event 12)</u>

- Assumed the fraction of primary piping inside containment that is RHR to be 0.10.

- Assumed the fraction of primary piping inside containment that is RHR that can impact the drywell shell by pipe whip to be 0.50.

- Assumed the probability of RHR pipe whip rupturing the drywell shell to be 0.10.

- Assumed the probability of overpressure in the air gap failing piping penetrating the drywell or by steam in the auxiliary areas caused EQ failures to be 0.80.

12.4 Failure Probabilities for piping and components for GI-80

The INEEL report lists accident scenarios that involve high energy pipe breaks and crimping of the CRD insert and withdrawal piping resulting in no control rod movement and eventual core damage. Each of the fractions, frequencies, and probabilities should be reviewed based upon this TAP analysis, to determine if excessive conservatism exists, and to suggest alternate values, if appropriate.

<u>INEEL report (BWR Event 5)</u>

- Assumed the fraction of primary piping inside containment that is RC to be 0.20.

- Assumed the fraction of recirculation piping that can impact CRD lines by pipe whip or jet impingement to be 0.25.

- Assumed the probability of pipe whip or jet impingement failing CRD lines to be 1.00.

INEEL report (BWR Event 10)

- Assumed the fraction of primary piping inside containment that is RHR to be 0.10.
- Assumed the fraction of RHR piping that can impact CRD lines by pipe whip or jet impingement to be 0.25.
- Assumed the probability of RHR pipe whip or jet impingement failing CRD lines to be 1.00.

12.5 Report References

1. NUREG/CR-6395, “Enhanced Prioritization of Generic Safety Issue 156.6.1 Pipe Break Effects on Systems and Components Inside Containment,” November 1999.

2. BWROG report, NEDC-33054, “Conservatism in NRC Prioritization of Pipe Break Effects on Systems and Components,” November 2001

3. Information Systems Laboratories report, “Review of Event Probabilities and Frequencies Used in NUREG/CR-6395 Enhanced Prioritization of Generic Safety Issue 156.6.1, Pipe Break Effects on Systems and Components Inside Containment,” December 2002

4. Attachment to NRC memorandum Thadani to Collins, “Generic Safety Issue 80, Pipe Break Effects on Control Rod Drive Hydraulic Lines in the Drywells of BWR Mark I and II Containments,” February 2003