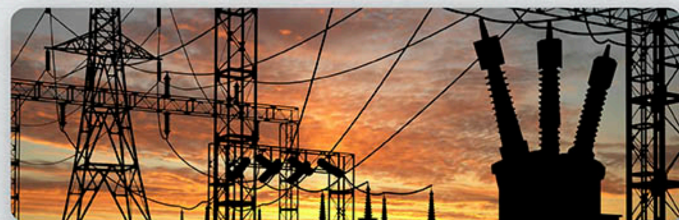

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Tabletop Exercises: Risk Informed Inservice Inspection

Results and Projected Risk Impacts for New Reactor Design

Sensitivity Study Results Using Alternate Risk Metrics

Risk-Informed Inservice Inspection
Results and Projected Risk Impacts for New Reactor Design

- Summary of the EPRI RI ISI Methodology Risk Measures
- Example RCS Diagram
- Example Consequence Evaluation/Rank
- Example DMs Evaluation/Rank
- Example Risk Ranking
- Example Delta Risk Calculation

Consequences Ranking
Current Numerical Criteria (1)

Consequence Category	Corresponding CCDP Range	Corresponding CLERP Range
High	CCDP > 1E-4	CCDP > 1E-5
Medium	1E-6 < CCDP ≤ 1E-4	1E-7 < CCDP ≤ 1E-5
Low	CCDP ≤ 1E-6	CCDP ≤ 1E-7

Consequences Ranking
Modified Numerical Criteria (2)

Consequence Category	Corresponding CCDP Range	Corresponding CLERP Range
High	CCDP > 1E-5	CCDP > 1E-6
Medium	1E-7 < CCDP ≤ 1E-5	1E-8 < CCDP ≤ 1E-6
Low	CCDP ≤ 1E-7	CCDP ≤ 1E-8

Degradation Mechanisms (DM) Ranking Current Criteria

Pipe Rupture Potential	Expected Leak Conditions	Degradation Mechanisms To Which The Segment is Susceptible
HIGH	Large	Flow Accelerated Corrosion (FAC)
MEDIUM	Small	Thermal Fatigue Stress Corrosion Cracking (IGSCC, TGSCC, PWSCC, ECSCC) Localized Corrosion (MIC, Crevice Corrosion and Pitting) Erosion-Cavitation
LOW	None	No Degradation Mechanisms Present

Risk Matrix

Risk Categories and Regions

RELATIVE POTENTIAL FOR RUPTURE	Consequence Category			
	None	Low	Medium	High
High	CAT7	CAT5	CAT3	CAT1
Medium	CAT7	CAT6	CAT5	CAT2
Small	CAT7	CAT7	CAT6	CAT4

- Inspection Region 1 (High Risk)
- Inspection Region 2 (Medium Risk)
- Inspection Region 3 (Low Risk)

Delta Risk
Current Acceptance Criteria

- **Plant Level:**
- < 1E-06 CDF
- < 1E-07 LERF

System Level:

< 1E-07 CDF

< 1E-08 LERF

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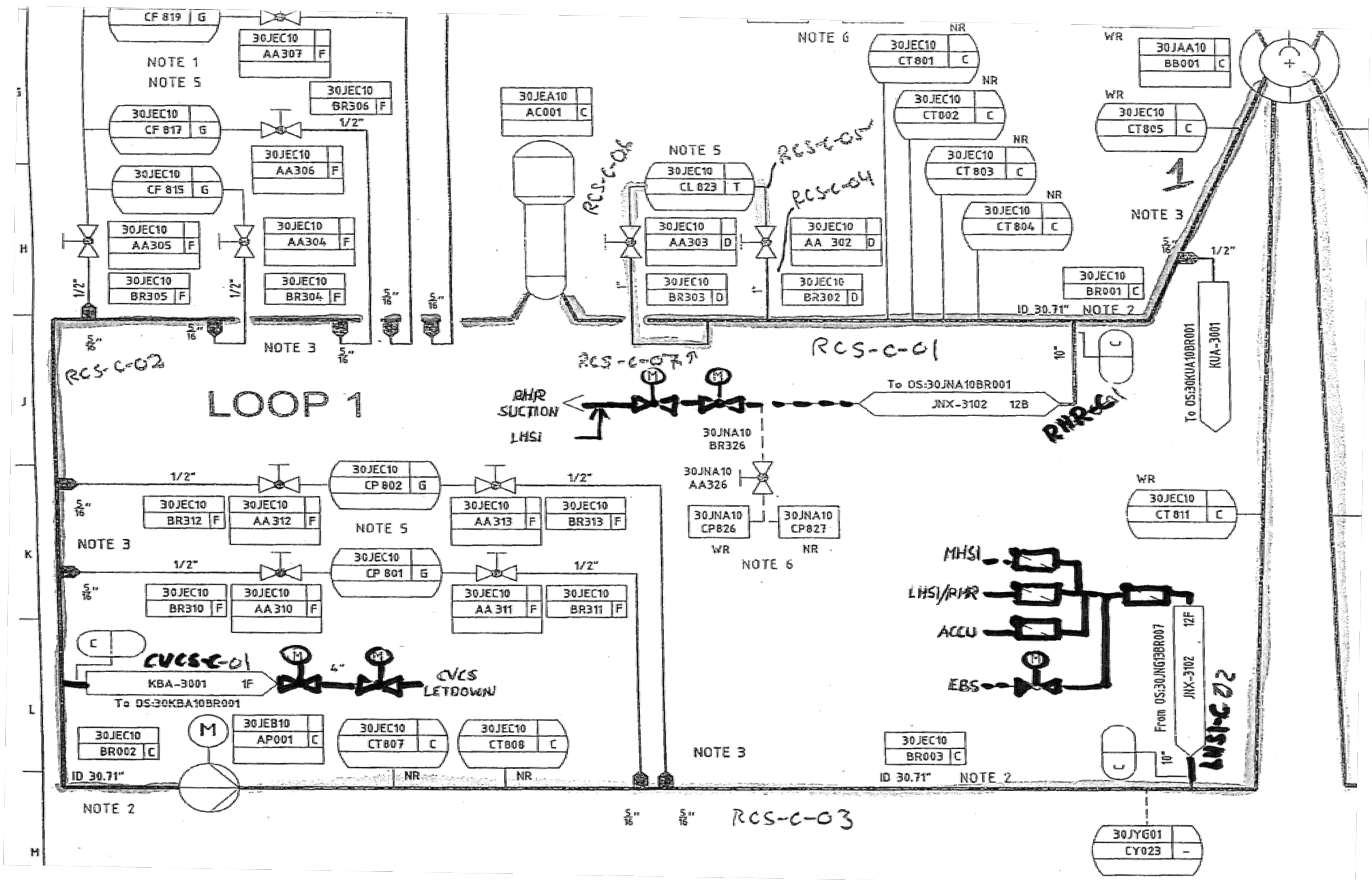
Example: Simplified Diagram One LOOP RCS – Class 1



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Example: LOCA Initiating Events Ranking Comparison (Active PWR)

Initiating Event	IE Freq. [1/yr]	CDF [1/yr]	CCDP	LERF [1/yr]	CLRP	RANK1	RANK2	Existing PWR
LLOCA Large LOCA (>6")	1.3E-06	2.6E-09	2.0E-03	3.6E-14	2.7E-08	**HIGH**	**HIGH**	**HIGH**
MLOCA Medium LOCA (3 to 6")	1.4E-05	9.3E-10	6.5E-05	1.6E-13	1.1E-08	**MEDIUM**	**HIGH**	**HIGH**
SLOCA Small LOCA (<3")	1.4E-03	5.1E-08	3.7E-05	6.4E-10	4.6E-07	**MEDIUM**	**HIGH**	**HIGH**

Example: PLOCA Initiating Events Ranking Comparison (Active PWR)

Conseq. Key	LOCA CCDP	LOCA CLRP	Valve Failure Rate (/demand)	Valve Failure Rate (/hour)	Yearly likelihood	Final CCDP	Final CLRP	RANK1	RANK2	Existing PWR
PSLOCA (>= 2V)	3.7E-05	4.6E-07		Negligible	Negligible	Negligible	Negligible	LOW	LOW	LOW
PLLOCA (CV)	2.0E-03	2.7E-08	-	5.0E-07	4.4E-03	8.6E-06	1.2E-10	MEDIUM	MEDIUM	High
PLLOCA (MOV)	2.0E-03	2.7E-08	-	4.5E-07	3.9E-03	7.8E-06	1.1E-10	MEDIUM	MEDIUM	High
PMLOCA (CV)	6.5E-05	1.1E-08	-	5.0E-07	4.4E-03	2.8E-07	4.7E-11	LOW	MEDIUM	Medium
PMLOCA (MOV)	6.5E-05	1.1E-08	-	4.5E-07	3.9E-03	2.6E-07	4.2E-11	LOW	MEDIUM	Medium
PSLOCA (CV)	3.7E-05	4.6E-07	-	5.0E-07	4.4E-03	1.6E-07	2.0E-09	LOW	MEDIUM	Medium
PSLOCA (MOV)	3.7E-05	4.6E-07	-	4.5E-07	3.9E-03	1.4E-07	1.8E-09	LOW	MEDIUM	Medium
IMLOCA (MOV)	6.5E-05	1.1E-08	3.5E-03	-	3.5E-03	2.3E-07	3.8E-11	LOW	MEDIUM	Medium
Isolable SLOCA (MOV)	3.7E-05	4.6E-07	3.5E-03	-	3.5E-03	1.3E-07	1.6E-09	LOW	MEDIUM	Medium
Isolable SLOCA (CV)	3.7E-05	4.6E-07	1.0E-03	-	1.0E-03	3.7E-08	4.6E-10	LOW	LOW	Medium

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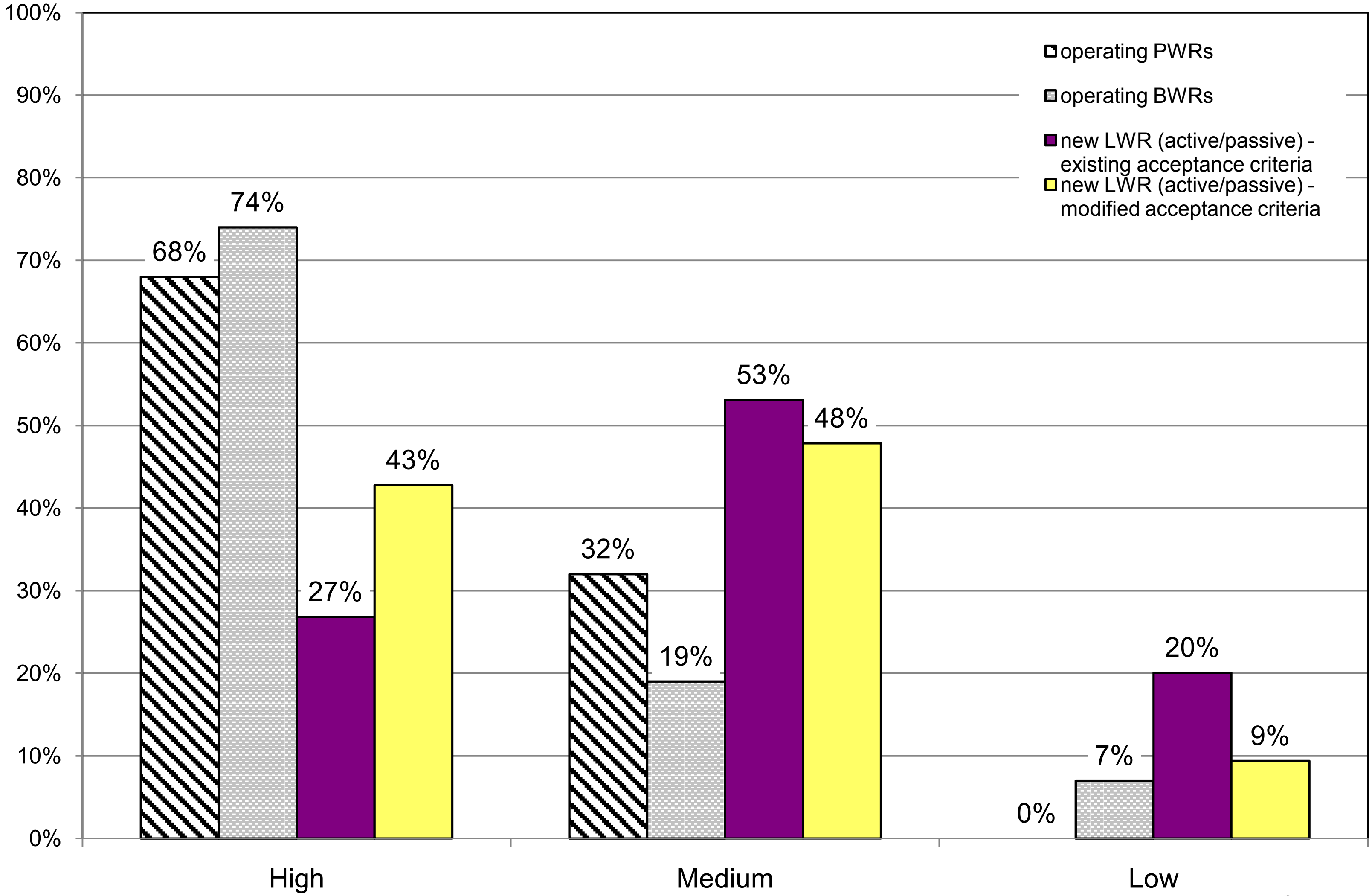
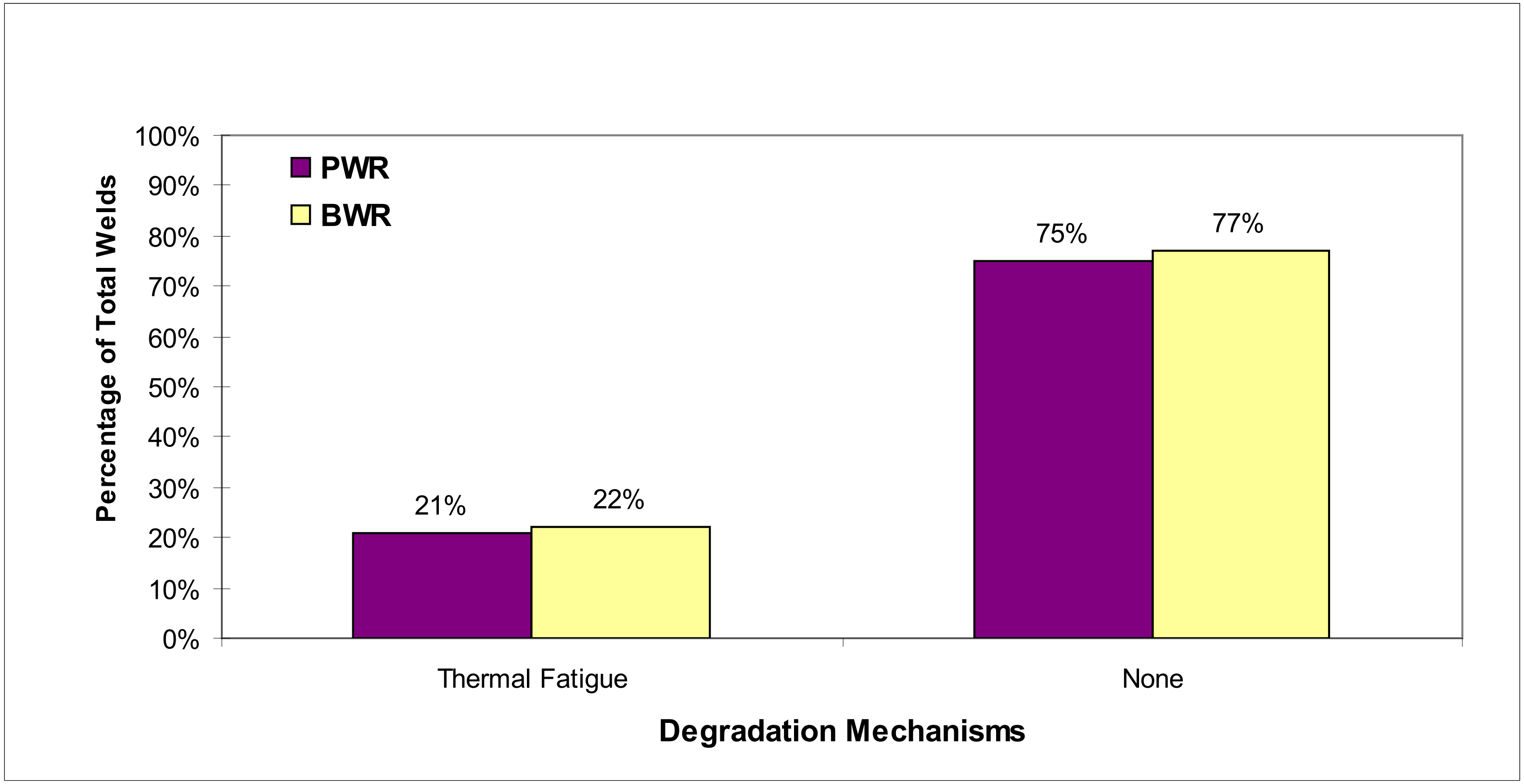
LOCA/PLOCA Initiating Events Ranking Comparison between Different Designs

IE ID	RANK Active and Passive BWRs	RANK Active and Passive PWRs
LLOCA	MEDIUM	HIGH
MLOCA	MEDIUM	MEDIUM
SLOCA	LOW	MEDIUM
PLOCA	LOW	LOW
ILOCA	LOW	LOW
ILOCA - OC	MEDIUM	N/A

Class 1 Welds
Consequence Ranking Comparison



Class 1, B-J Welds: Operating PWR vs. BWR Degradation Mechanisms



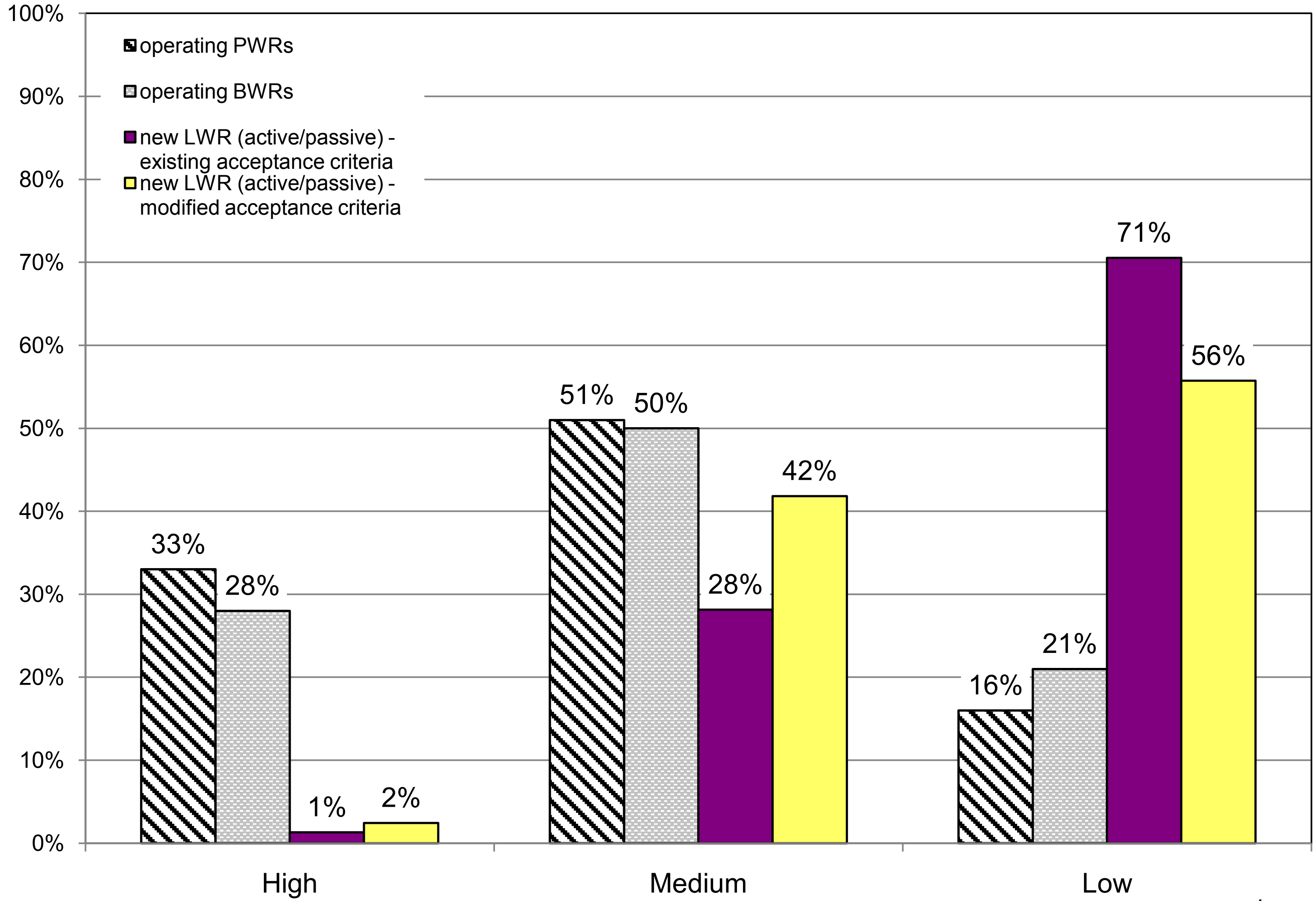
Class 1 Welds
Postulated Degradation Mechanisms - New Build

- **Thermal Fatigue**:
  - Pressurizer Surge Line
  - Pressurizer Spray

- **IGSCC**:
  - Injection Lines (stagnant flow)

- Smaller percentage of welds: ~**4%,** compare with the current plants (~20%): resistant materials, water chemistry, fabrication practices, etc.

Class 1 Welds
Risk Ranking Comparison



Loss of Mitigating Ability Impact Group (Applicable to Class 2)

Example of Guidelines for Assigning Consequence Categories to Pipe Failures Resulting in System/Train Loss

Affected Systems		Number of Unaffected Backup Trains							
Frequency of Challenge	**Exposure Time to Challenge**	**0.0**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**>=3.5**
Anticipated (DB Cat II)	All Year	H	H	H	H	M*	M	L*	L
	Between tests (1-3 months)	H	H	H	M*	M	L*	L	L
	Long AOT (<=1 week)	H	H	M*	M	L*	L	L	L
	Short AOT (<=1 day)	H	M*	M	L*	L	L	L	L
Infrequent (DB Cat. III)	All Year	H	H	H	M*	M	L*	L	L
	Between tests (1-3 months)	H	H	M*	M	L*	L	L	L
	Long AOT (<=1 week)	H	M*	M	L*	L	L	L	L
	Short AOT (<=1 day)	H	M	L*	L	L	L	L	L
Unexpected (DB Cat. IV)	All Year	H	H	M*	M	L*	L	L	L
	Between tests (1-3 months)	H	M*	M	L*	L	L	L	L
	Long AOT (<=1 week)	H	M	L*	L	L	L	L	L
	Short AOT (<=1 day)	H	L*	L	L	L	L	L	L

(Legend: black = High Consequence Category; grey = Medium Consequence Category; white = Low Consequence Category)

Containment Performance: If there is no containment barrier and the consequence category is marked by an *, the consequence category should be increased ("Medium" to "High" and "Low" to "Medium").

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Using Risk Importance to Evaluate an Impact on Mitigating Ability

CCDP values are determined based on the following equation:

CCDP (given loss of a system) = [CDF(given loss of a system – CDF(Base)] * [Exposure Time]
= [RAW-1] * CDF (Base) * [Exposure Time]

where

- [CDF (given loss of a system) – CDF (Base)] = Risk Increase
- RAW is Risk Achievement Worth:
  RAW (system) = CDF (given loss of system)/CDF(Base)
- Exposure time is defined in the previous subsection, and it is equal to 1 year for non-tested lines, and to 3 months for tested lines

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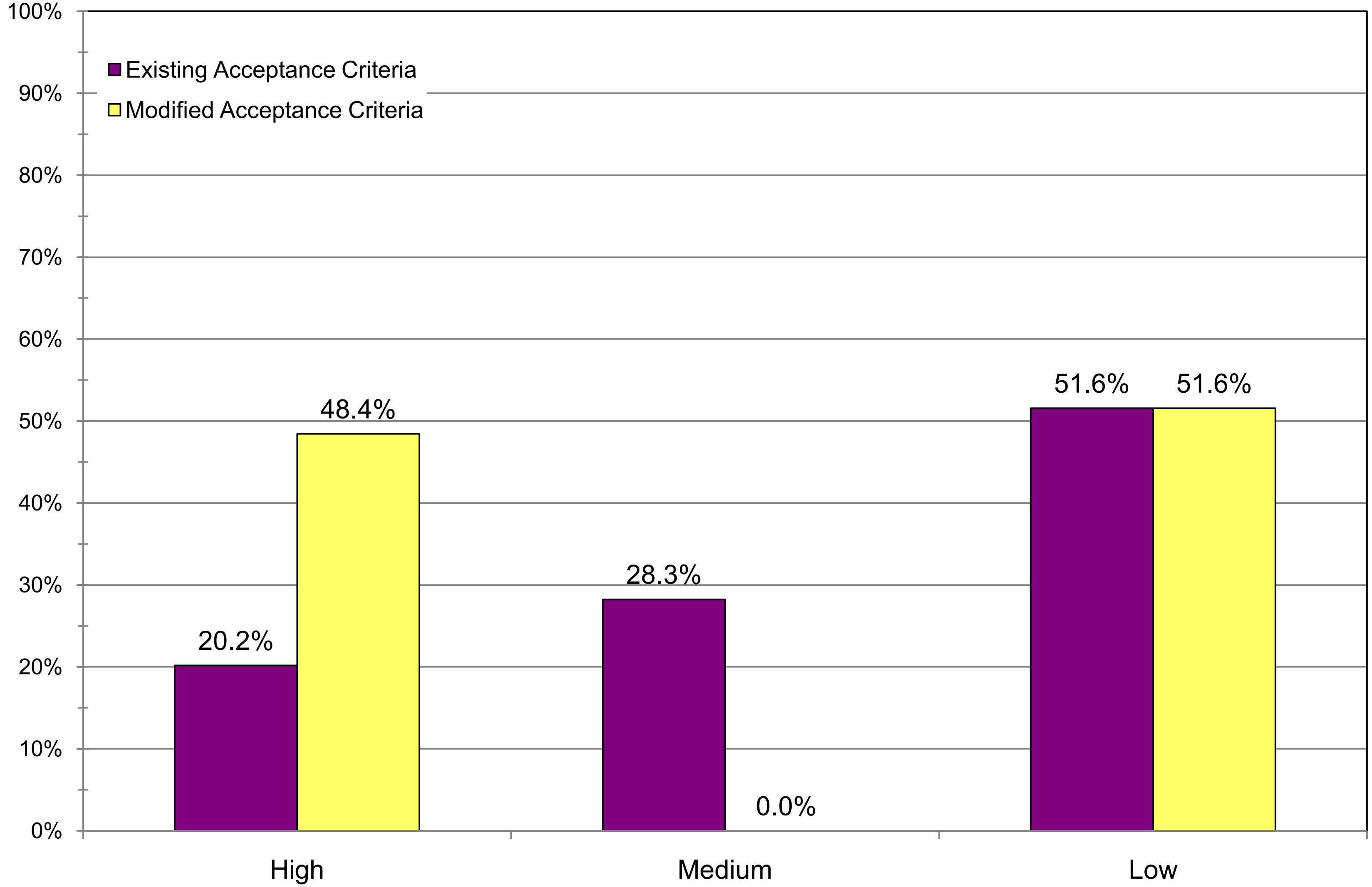
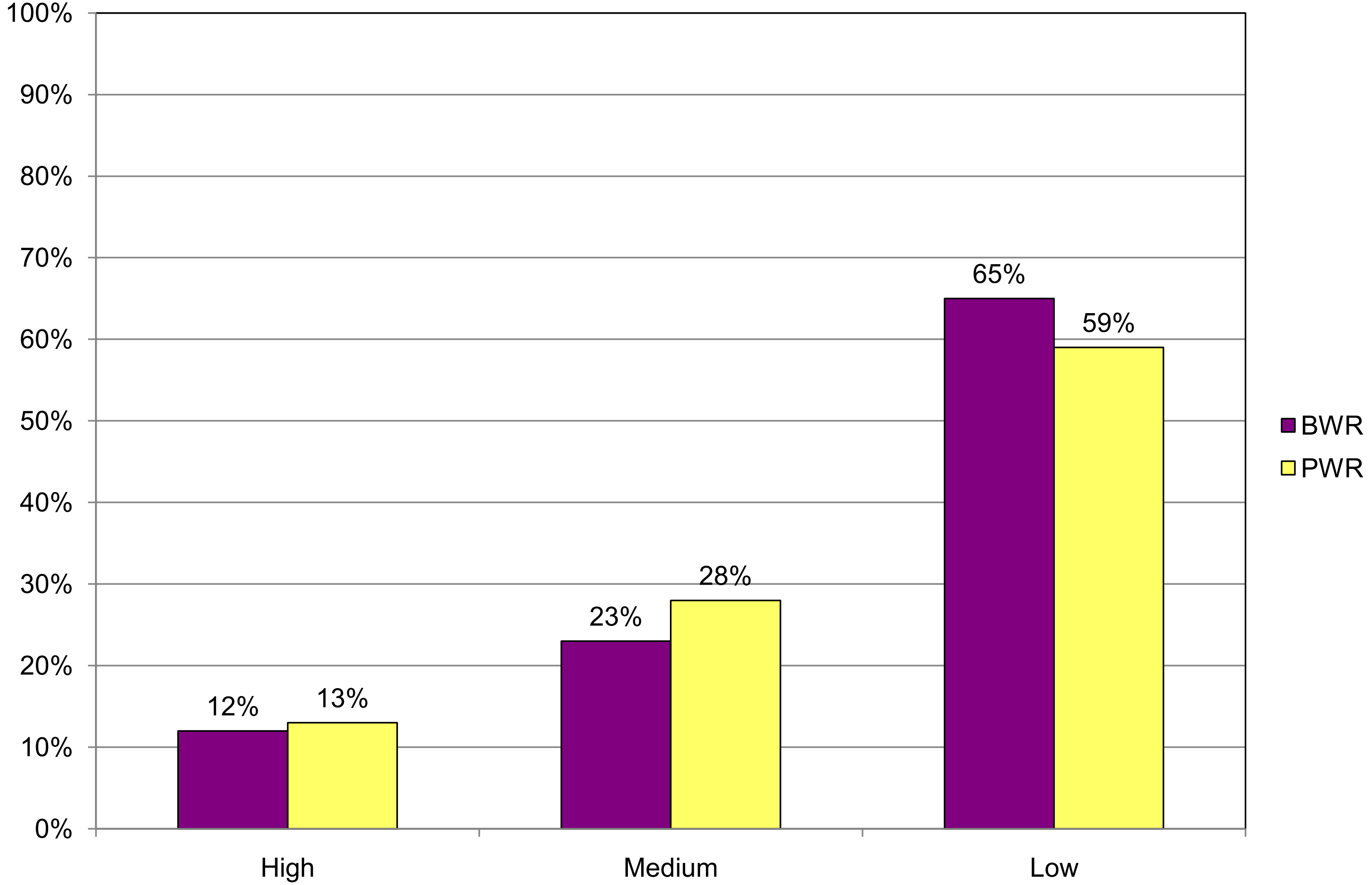
Class 2 Welds: Consequence Ranking Comparison (MHSI – Active PWR)



Classes 1 & 2
Operating BWR & PWR Risk Ranking



Example: Delta Risk Estimates for an Operating PWR

System	CDF Impact		LERF Impact	
	w/POD	wo/POD	w/POD	wo/POD
CS	-2.66E-09	8.56E-10	-7.70E-10	2.44E-10
EF	-4.37E-10	1.90E-11	-1.27E-10	5.50E-12
FW	-1.18E-09	-4.18E-10	-3.41E-10	-1.21E-10
MS	-1.90E-11	-1.90E-11	-5.50E-12	-5.50E-12
RC	-1.01E-09	7.05E-09	-2.92E-10	2.04E-09
RHR	-1.03E-09	-1.05E-10	-2.93E-10	-2.85E-11
SI	-1.93E-09	2.07E-09	-5.60E-10	5.89E-10
SP	-1.90E-11	-1.90E-11	-5.50E-12	-5.50E-12
SW	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	**-8.27E-09**	**9.44E-09**	**-2.39E-09**	**2.72E-09**

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Delta Risk Estimates – Current Acceptance Criteria

Risk	DM	# of Section XI Inspections	# of RI ISI Inspections	Delta in Number of Inspections	CCDP	PBF Frequency per Weld [1/yr]	Delta Risk [1/yr]
High	TF	2	2	0	2.E-03	2.E-07	0.E+00
Medium	IGSCC/TF	4	2	2	1.E-04	2.E-07	4.E-11
Medium	None	34	14	20	1.E-04	1.E-08	2.E-11
Low	None	94	0	94	1.E-06	1.E-08	9.E-13
ACTIVE, Current AC - Average Case	Totals:	134	18	116			6.1E-11
		25.1%	3.4%				

Risk	DM	# of Section XI Inspections	# of RI ISI Inspections	Delta in Number of Inspections	CCDP	PBF Frequency per Weld [1/yr]	Delta Risk [1/yr]
High	TF	4	4	0	2.E-03	2.E-07	0.E+00
Medium	IGSCC/TF	7	3	4	1.E-04	2.E-07	8.E-11
Medium	None	68	28	40	1.E-04	1.E-08	4.E-11
Low	None	188	0	188	1.E-06	1.E-08	2.E-12
PASSIVE, Current AC - Average Case	Totals:	267	35	232			1.2E-10
		25.0%	3.3%				

Delta Risk Estimates – Modified Acceptance Criteria

Risk	DM	# of Section XI Inspections	# of RI ISI Inspections	Delta in Number of Inspections	CCDP	PBF Frequency per Weld [1/yr]	Delta Risk [1/yr]
High	TF	4	4	0	2.E-03	2.E-07	0.E+00
Medium	IGSCC	2	1	1	1.E-04	2.E-07	2.E-11
Medium	None	55	22	33	1.E-04	1.E-08	3.E-11
Low	None	74	0	74	1.E-06	1.E-08	7.E-13
ACTIVE, Modifed AC - Average Case	Totals:	135	27	108			5.4E-11
		25.3%	5.1%				

Risk	DM	# of Section XI Inspections	# of RI ISI Inspections	Delta in Number of Inspections	CCDP	PBF Frequency per Weld [1/yr]	Delta Risk [1/yr]
High	TF	7	7	0	2.E-03	2.E-07	0.E+00
Medium	IGSCC	4	2	2	1.E-04	2.E-07	4.E-11
Medium	None	68	44	24	1.E-04	1.E-08	2.E-11
Low	None	188	0	188	1.E-06	1.E-08	2.E-12
PASSIVE, Modifed AC - Average Case	Totals:	267	53	214			6.6E-11
		25.0%	5.0%				

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Delta Risk Estimates – Current Acceptance Criteria – Best Selection

Risk	DM	# of Section XI Inspections	# of RI ISI Inspections	Delta in Number of Inspections	CCDP	PBF Frequency per Weld [1/yr]	Delta Risk [1/yr]
High	TF	2	2	0	2E-03	2E-07	0E+00
Medium	IGSCC/TF	4	10	-6	1E-04	2E-07	-1E-10
Medium	None	34	5	29	1E-04	1E-08	3E-11
Low	None	94	0	94	1E-06	1E-08	9E-13
ACTIVE, Current AC - Best Case	Totals:	134	17	117			-9.0E-11
		25.1%	3.2%				

Risk	DM	# of Section XI Inspections	# of RI ISI Inspections	Delta in Number of Inspections	CCDP	PBF Frequency per Weld [1/yr]	Delta Risk [1/yr]
High	TF	4	4	0	2E-03	2E-07	0E+00
Medium	IGSCC/TF	7	13	-6	1E-04	2E-07	-1E-10
Medium	None	68	7	61	1E-04	1E-08	6E-11
Low	None	188	0	188	1E-06	1E-08	2E-12
PASSIVE, Current AC - Best Case	Totals:	267	24	243			-5.7E-11
		25.0%	2.3%				

Impact on New Build Enhanced Safety Features

No	EPR Design Feature Description	RI-ISI
1	**High level of redundancy and independence for safety systems** The U.S. EPR design incorporates four trains of most safety systems, and provides for significant separation: Four trains of the safety injection systems (LHSI, MHSI, and accumulators). Four trains of emergency feedwater (EFW), supplying four steam generators. Each train has an EFW water storage tank for its suction source. Four safety trains of support systems (cooling trains, building HVAC, and electric power).	Neutral
2	**Physical separation of safety systems** In addition to being highly redundant, the four trains of safety systems are physically separated by being located in different safeguard buildings. This significantly reduces the potential for core-damage accidents due to internal flooding, internal fires, or external events for which spatial considerations are important.	N/A
3	**In-containment refueling water storage tank (IRWST)** The design of the IRWST eliminates some failure modes that have been important for current-generation plants: Use of the IRWST eliminates the need to change system alignment by switching suction sources for safety injection following a LOCA. The failure to accomplish this switchover has been an important contributor to failure of long term safety injection for many current-generation PWRs. Eliminating the need for switchover also obviates the need to isolate the suction path used during the injection phase. For some current-generation PWRs, failure to isolate this path has been assessed to result in inadequate NPSH for the safety injection paths, and may create a release path after the recirculation path is opened. The reactor containment building affords the IRWST better protection against some types of external events than is the case for equivalent tanks at current-generation plants.	Neutral/ Positive

Summary

- RI ISI Applications **do not**
  - Impact Enhanced Safety Features of the New Builds
  - Impact Defense and Depth or Safety Margins
- RI ISI Applications **do**:
  - Improve on current (Section XI) ISI programs by inspecting for specific DMs
  - Reduce Workers Exposure
- Are Evaluated as **Risk - Neutral**

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