核電廠安全系統管路氣體聚集之議題討論

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暨核能安全研討會

98.12.16

Outline

- Overview of Gas Accumulation Management
- Activities and Experiences in USA
- AEC’s Concerns and Actions
- Plant Response and Implementation
- Concluding Remarks

Overview of Gas Accumulation Management

- In Jan. 2008, USNRC issued GL2008-01 “Managing Gas Accumulation in ECCS, Decay Heat Removal, and Containment Spray System” to request each licensee to evaluate licensing basis, system design, operation and test procedures for safety related systems to minimize and monitor gas intrusion in order to maintain system operability and compliance with 10CFR50, Appendices A and B.
- INPO also issued SER 2-05 Rev. 1 “Gas Intrusion in Safety System” in Jan. 2008.
- Nuclear Energy Institute (NEI) issued NEI 09-10 Rev. 0 Draft B “Guidelines for Effective Prevention and System Gas Management” in Sep. 2009.

Overview of Gas Accumulation Management (cont'd)

- Gas intrusion in system piping can be caused by several factors, including the following:

(1) Some design deficiencies may contribute to gas intrusion during accident conditions

(2) Ineffective fill and vent

(3) Leakage from Accumulators

(4) Leakage from RCS

(5) Leakage through valves (a series of NC valves)

(6) Temp. at or above sat. temp. at the lowest system pressure that will be experienced when system is used

(7) Vortexing in the suction sources or gas introduced from suction sources

Overview of Gas Accumulation Management (cont'd)

- NEI Workshops

  Nuclear Energy Institute (NEI) coordinating industry activities
  - owners groups, industry organizations, and licensees

  – ***Primary Systems Gas Accumulation Management Workshop, Jan. 17-18, 2008, Austin, TX.***
  – ***Systems Gas Accumulation Management Workshop, Feb. 11-12, 2009, Dana Point, CA.***
  – ***Gas Accumulation Workshop, Jan. 21-22, 2010, Savannah, Georgia.***

- NEI 09-10
  – Provide recommendations and guidance to licensees for the effective implementation of programs and processes to prevent and manage gas intrusion and accumulation in plant systems.
  – Provide the flowcharts for in-scope system and high point monitoring determination, and for monitoring and trending of gas accumulation.

Overview of Gas Accumulation Management (cont'd)

Gas events are counting to occur (Lyon 2008, USNRC)

- 12/3/2007 – Millstone 3 found both trains of safety injection pipe were less than 75% filled and declared them inoperable.

- 1/4/2008 – Wolf Creek train A safety injection piping vent time of > 100 seconds exceeded 2 seconds limit. 4 inch piping was found voided and train A was declared inoperable.

- 1/10/2008 – Wolf Creek found gas in common suction piping for both centrifugal charging pumps and both HPI pumps. The pumps were declared inoperable. The source of the gas was not understood at time of this report.

Overview of Gas Accumulation Management (cont'd)

- USNRC Mr. W. H. Ruland "Overview of Gas Accumulation Management for Safety Related Systems in the USA " at TECRO – AIT meeting, October 26 – 27, 2009.
  - Over 100 gas voids detected in safety systems in past few years in US plants (a recurring issue).
  - Extensive void transport testing and analyses are in progress to facilitate operability determinations
  - Licensees are Implementing improved procedures to manage gas accumulation and making plant modifications to prevent or find and fix voids
  - Applicable program improvements and surveillances will be incorporated into the plants' technical specifications
  - All licensees have responded to the GL (within 9 months)
  - All accessible piping systems have been walked down by licensees; inaccessible portions to be checked during the next applicable outage
  - Closure Plan
    - 12/31/2010 – Complete GL reviews and identify open items or issues to licensees
    - 03/31/2011 – Receive licensee responses to open items or issues
    - 06/30/2011 – All open items resolved and close GL 2008-01

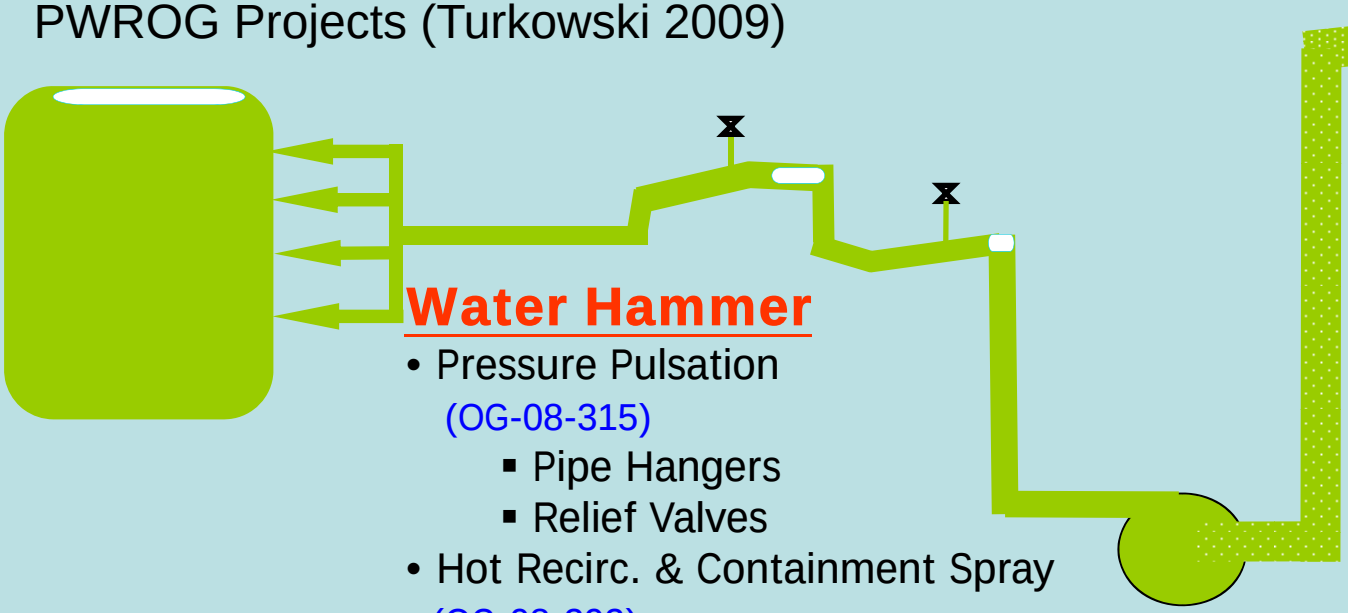
Activities and Experiences in USA

- Westinghouse proposes the resolution plan for GL 2008-01 (Ezekoye 2009)

	Short Term Activities	**LongTerm Activities**
Licensing Basis	● Review of TS, UFSAR, NRC Responses, Regulatory Commitments and License Conditions ● Identify Corrective Actions	● Update of TS
Design Basis	● Perform Accessible Walk Downs ● Identify Gas Intrusion Mechanisms ● Identify Gas Accumulation Locations ● Apply Gas Transport Acceptance Criteria ● Apply Suction/Discharge Pump Acceptance Criteria ● Identify Corrective Actions	● Perform Walkdowns During Outages ● Vent Valve Procurement & Installation ● Gas Accumulation Monitoring & Trending ● Gas Transport Testing & Modeling ● Pump Design & Operability Criteria Development
Testing	● Procedure Review ● Identify Corrective Actions	● Implement Standard Practices
Corrective Actions	● Summarize Corrective Actions for: Licensing, Design, Testing	● Implement Corrective Actions for: Licensing, Design, Testing ● Training

Activities and Experiences in USA (cont'd)

PWROG Projects (Turkowski 2009)



Water Hammer

- Pressure Pulsation
  (OG-08-315)
  - Pipe Hangers
  - Relief Valves
- Hot Recirc. & Containment Spray
  (OG-08-292)

Void Transport

(WCAP-16631 for 6" & 8")
On Going 4" & 12" @ Purdue

- Static Pressure
- Buoyancy
- Breaks down
- Transport Buffers
- Scaling of models

Non-Condensable Gas into the Reactor Vessel

(OG-08-293)

- ECCS Delay
- LOCA & Non-LOCA Qualitative Evaluation

Pump Interim Gas Ingestion Tolerance Criteria (V-EC-1866)

- Steady State & Transient Void Limits
- Types of Pumps
- Peak / Average Void Fraction
- Momentary TDH Degradation
- NPSHR vs. NPSHA

Activities and Experiences in USA (cont'd)

- **System Evaluation**

(A) Use Froude Number (F_r) to Identify Flow Conditions.

Conditions for pipe to run full of water (Henry 2008)

The Froude number, (F_r) is defined as, $F_r = U/\sqrt{gD}$

– A horizontal pipe will run full if the water velocity (one-dimensional) exceeds the drainage velocity.

– Experimental data (Wallis, Crowley and Hagi, 1977) shows that a pipe will run full when $F_r > 0.6$. For a conservative estimate, a value of unity is commonly used.

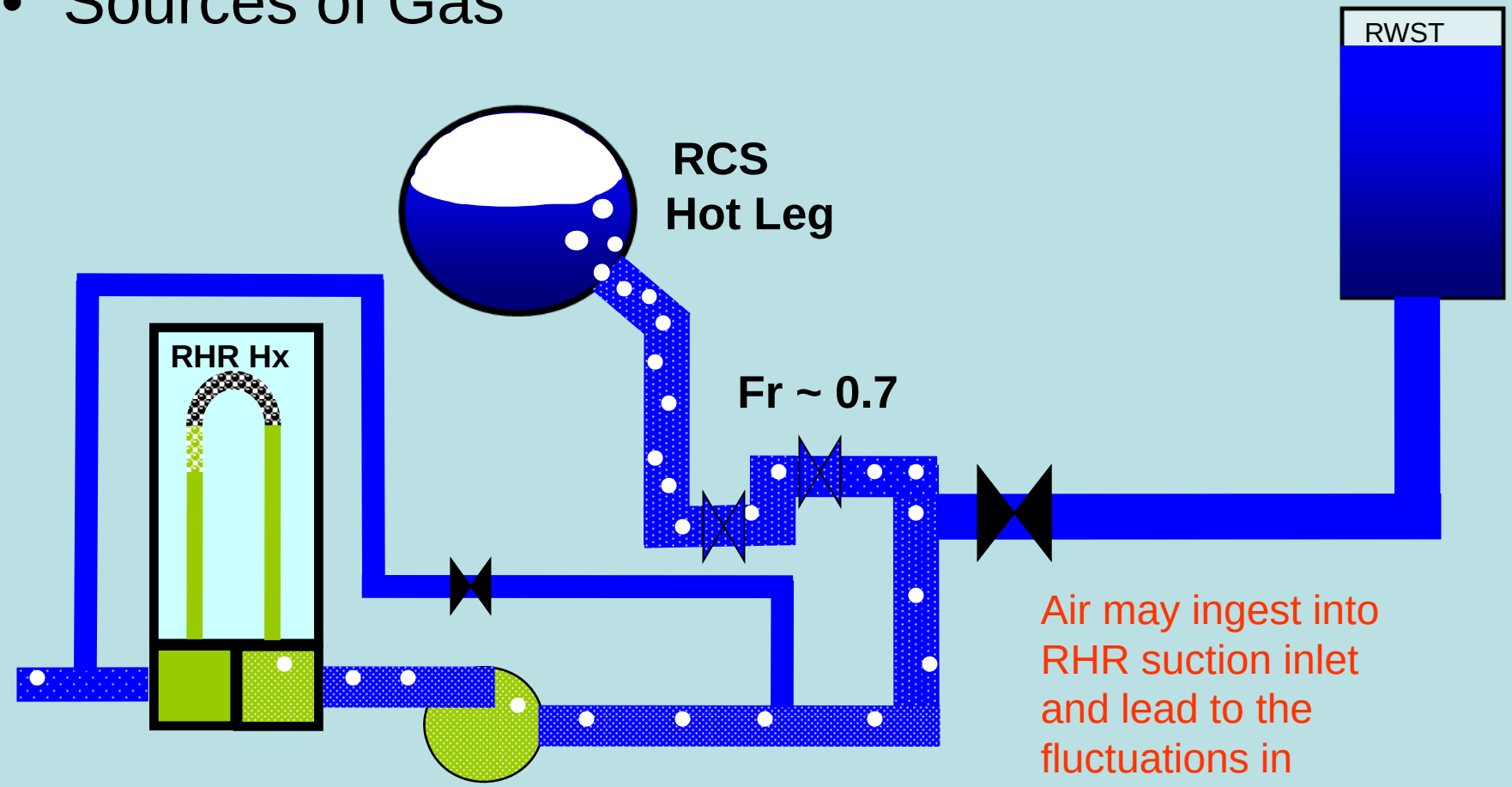
(B) General Rules

– 5% void limit– prevent pump cavitation / gas binding

– 20% void limit on the discharge piping – prevent water hammer

Activities and Experiences in USA (cont'd)

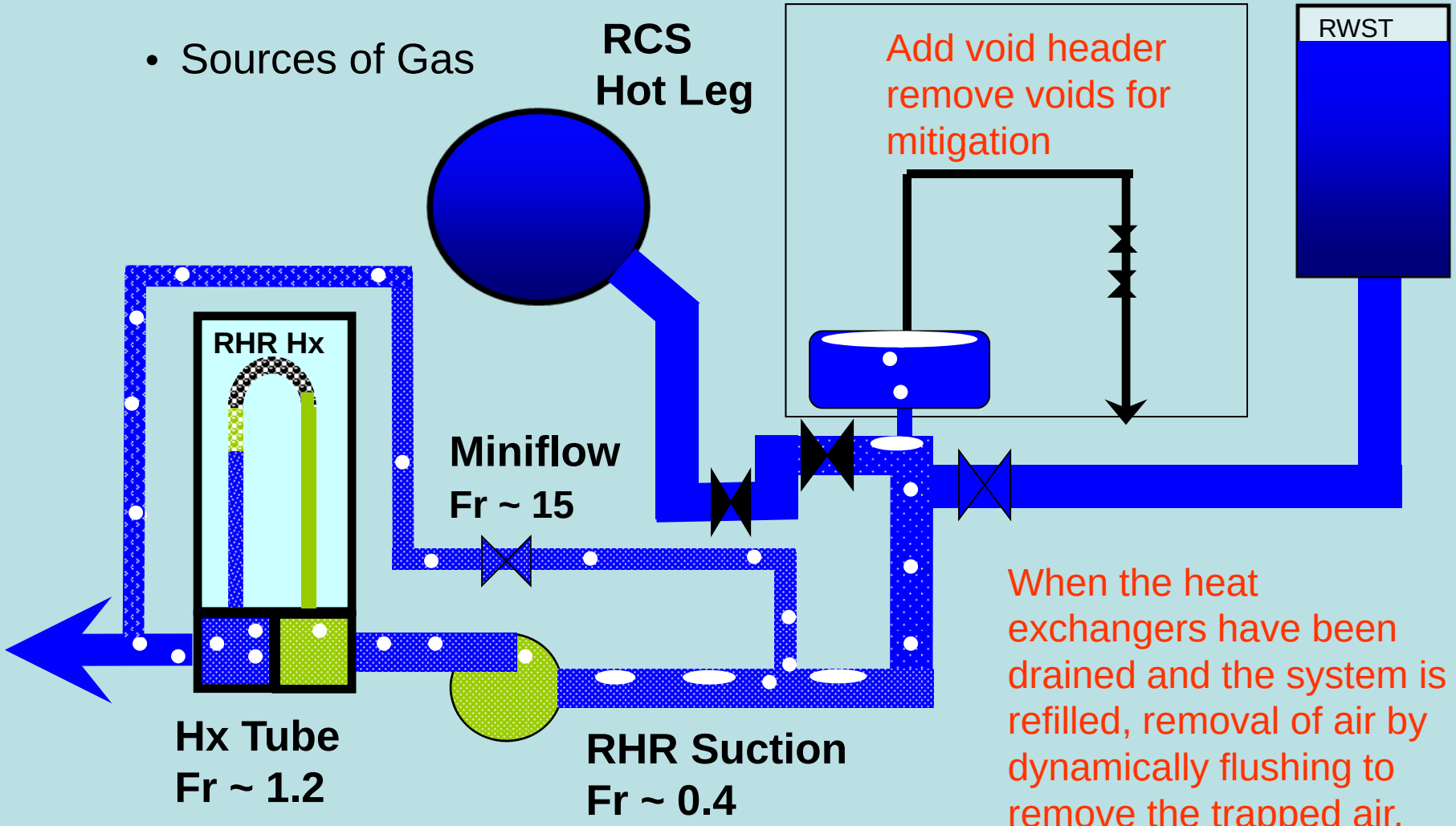
- Sources of Gas



RHR Pump Suction: Air Entrainment During RCS Mid-Loop Operation (Lin 2009, Diablo Canyon)

Activities and Experiences in USA (cont'd)

- Sources of Gas



When the heat exchangers have been drained and the system is refilled, removal of air by dynamically flushing to remove the trapped air.

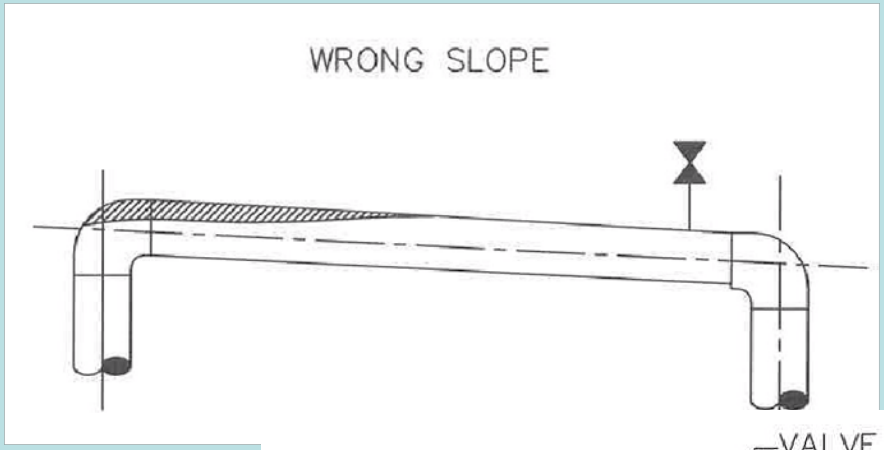
RHR Pump Suction: Air Transport / Recirculation During Quarterly Pump Test (Lin 2009, Diablo Canyon)

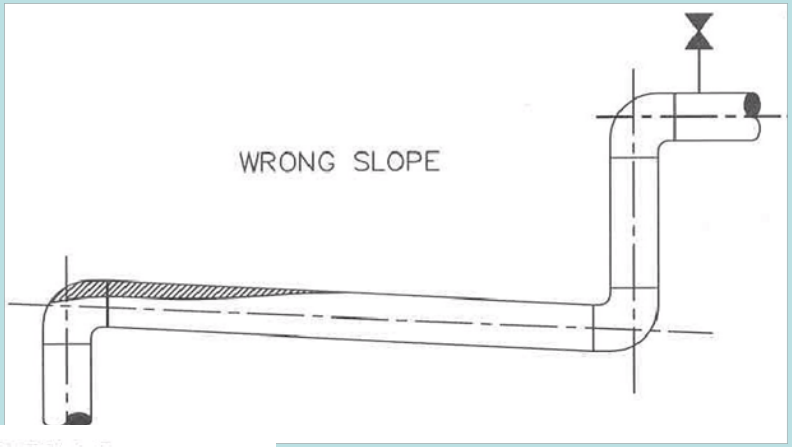
Activities and Experiences in USA (cont'd)

- Gas Accumulation Locations

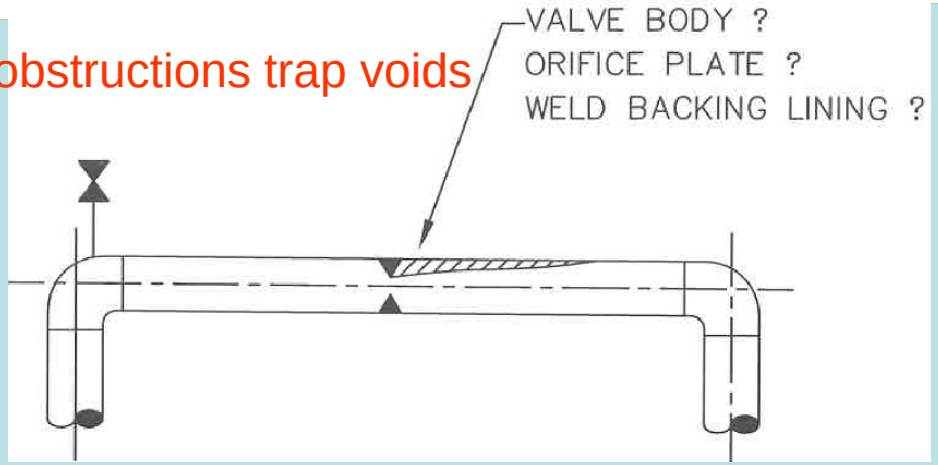
Voids From Piping Slope Issues (Garrett/Pendergrass 2008)

Not sloped to vent properly





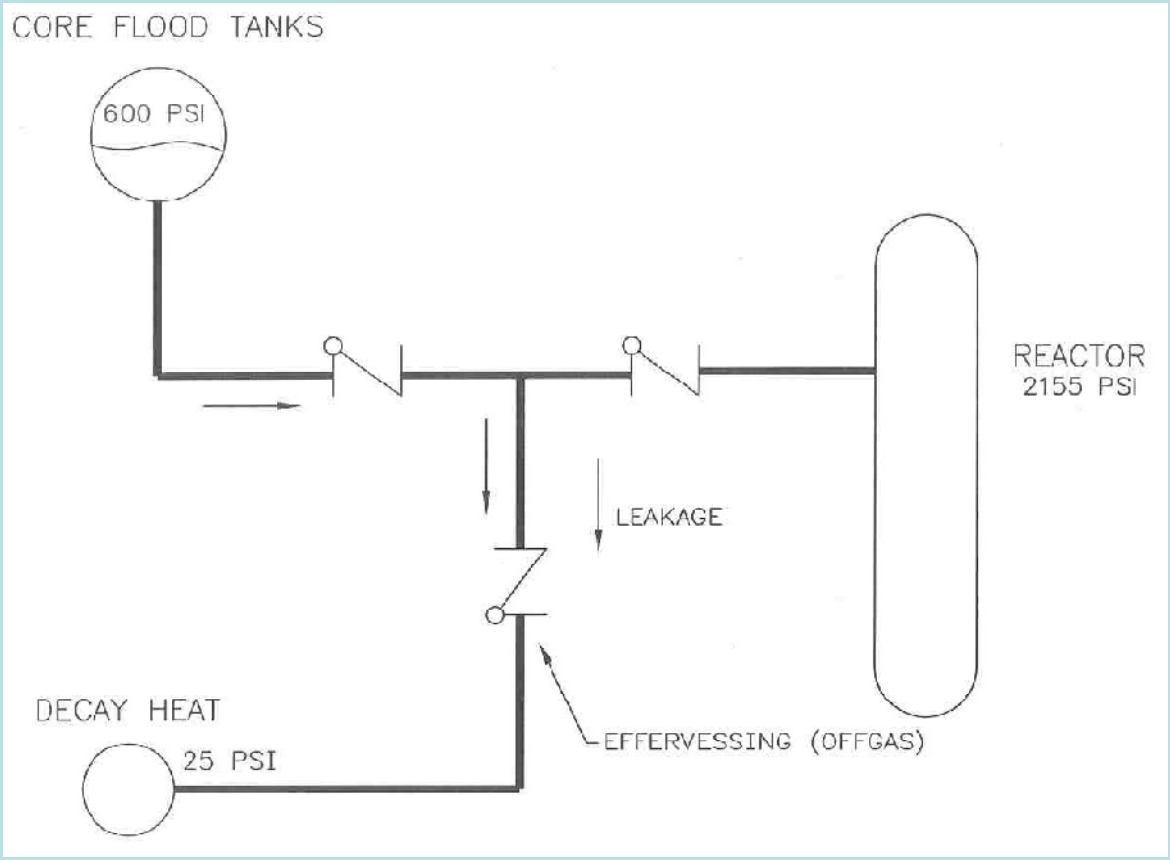
Piping obstructions trap voids



Periodic UT

Activities and Experiences in USA (cont'd)

Off Gassing-High Pressure to Low Pressure Interface (Garrett/Pendergrass)

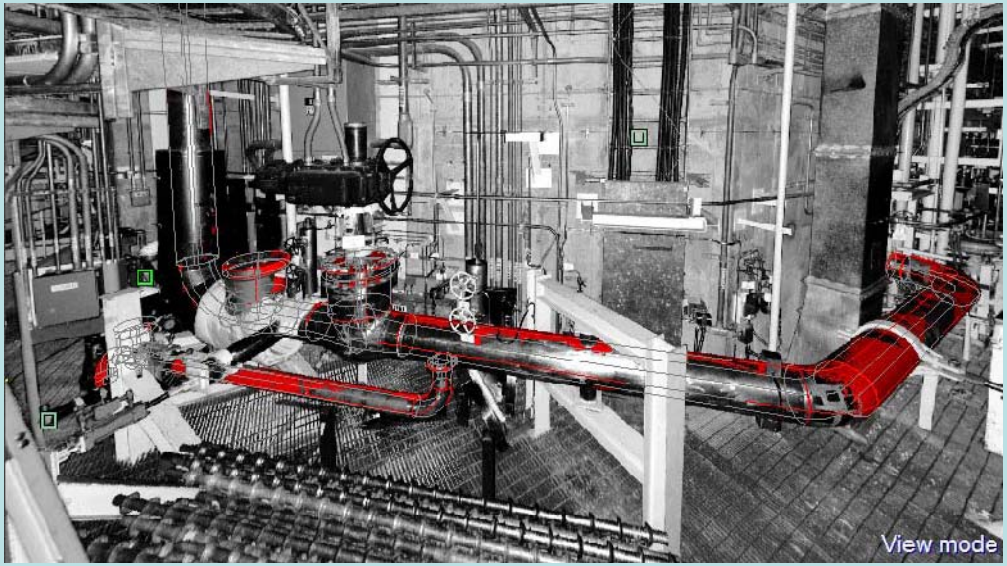


Activities and Experiences in USA (cont'd)

- Gas Accumulation Locations (Measurement)

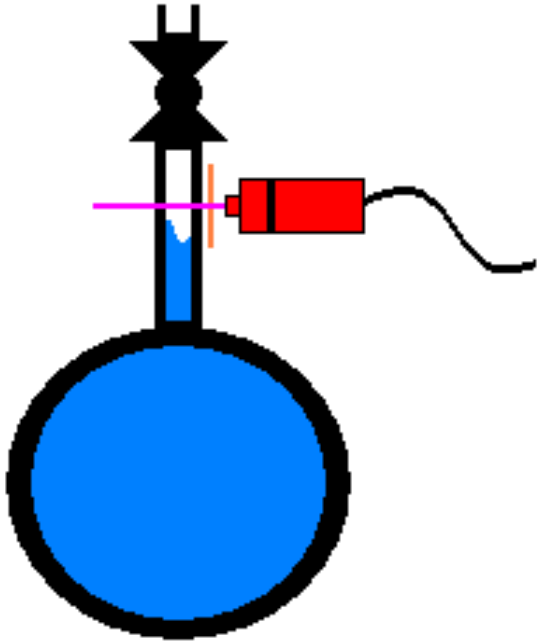
  (1) Laser scanning the pipe areas and 3D CAD pipe model verified

(Burger 2009)

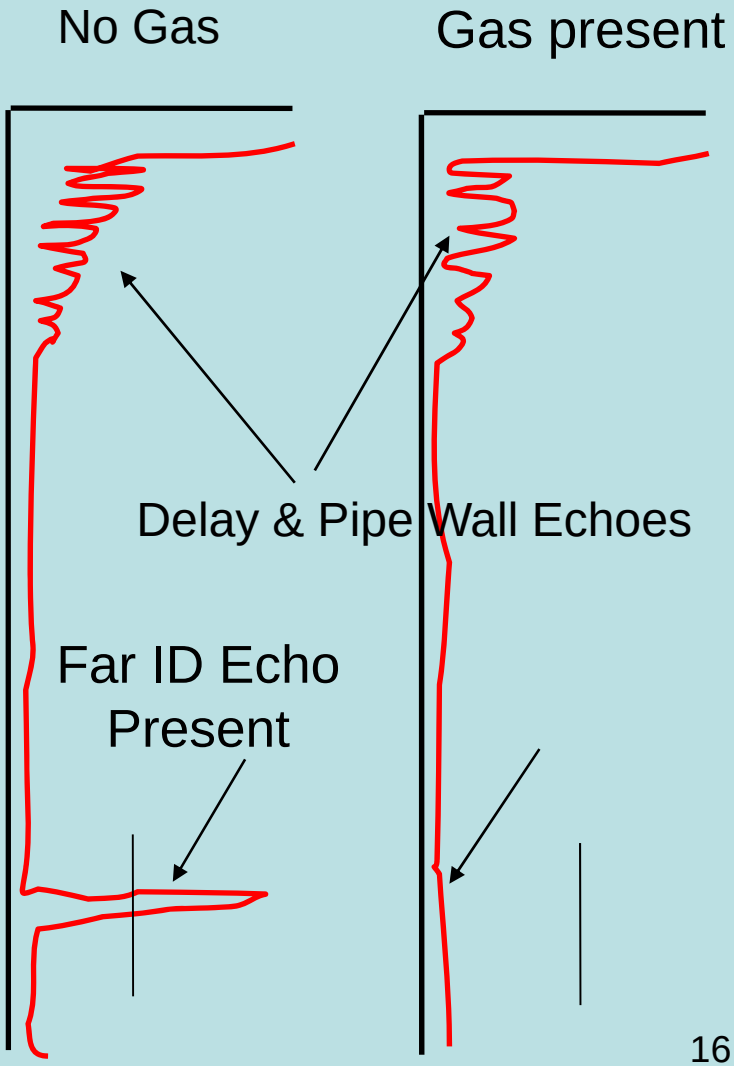


Activities and Experiences in USA (cont'd)

(2) Use Ultrasonic Testing (UT) Sensor

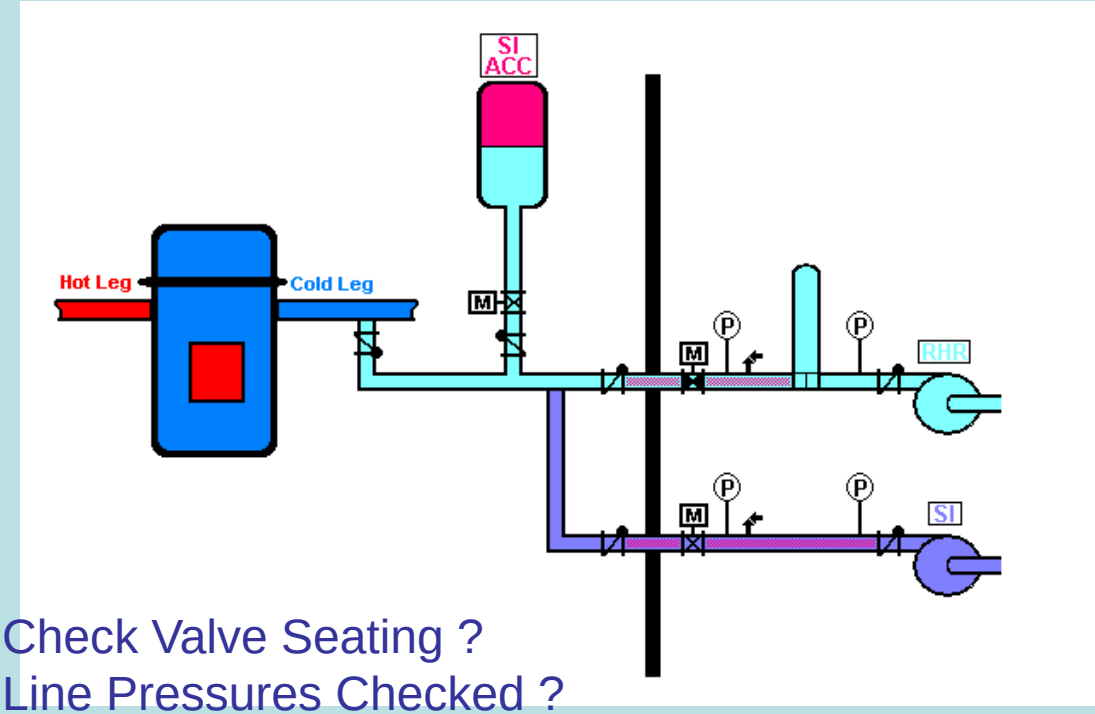


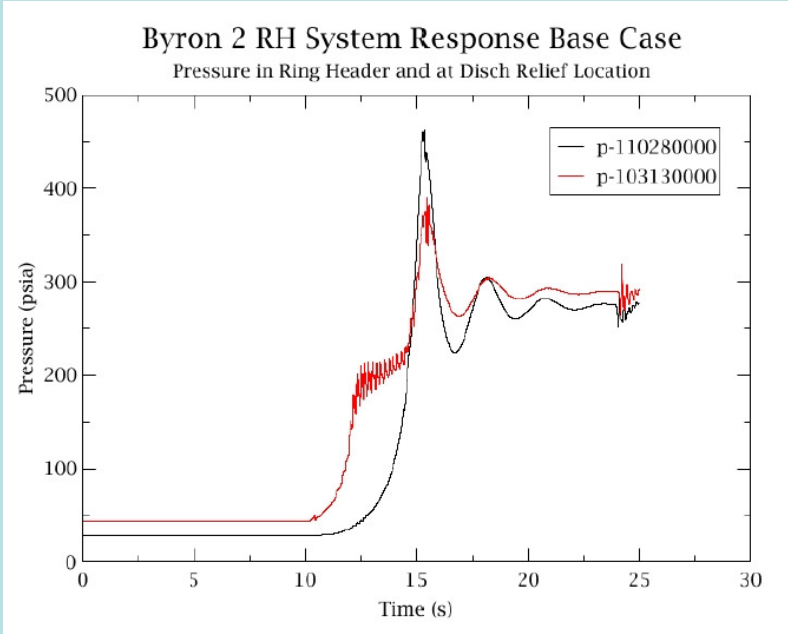
Semi-permanent mount
Non-invasive
High-rad, High-temp
(Brennan 2009)



Activities and Experiences in USA (cont'd)

Use UT for system periodic monitoring and apply for Braidwood and Byron plants (Brennan 2009)





Check Valve Seating ?

Line Pressures Checked ?

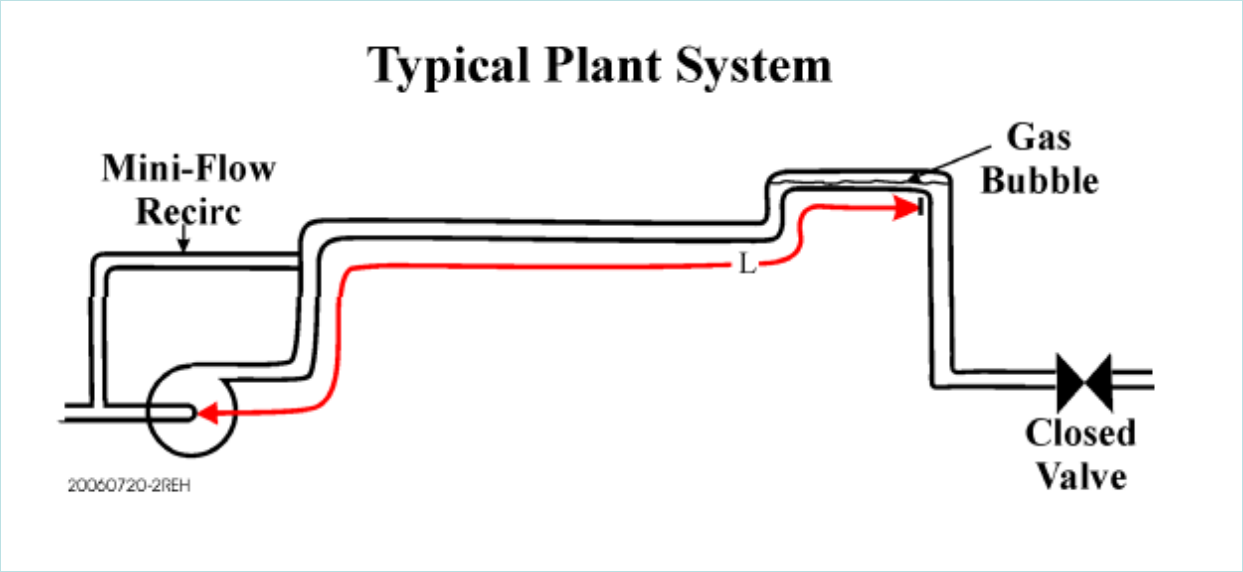
- SI Accumulator press 600 psig
- SI discharge press 1500 psig
- RHR discharge press 200 psig

Activities and Experiences in USA (cont'd)

- Determination of Gas Quantity
  - Use UT measurement combined with P, T measurements within the pipe
  - Measure the volume of gas released through vents
  - Observation of decreasing accumulator level

Activities and Experiences in USA (cont'd)

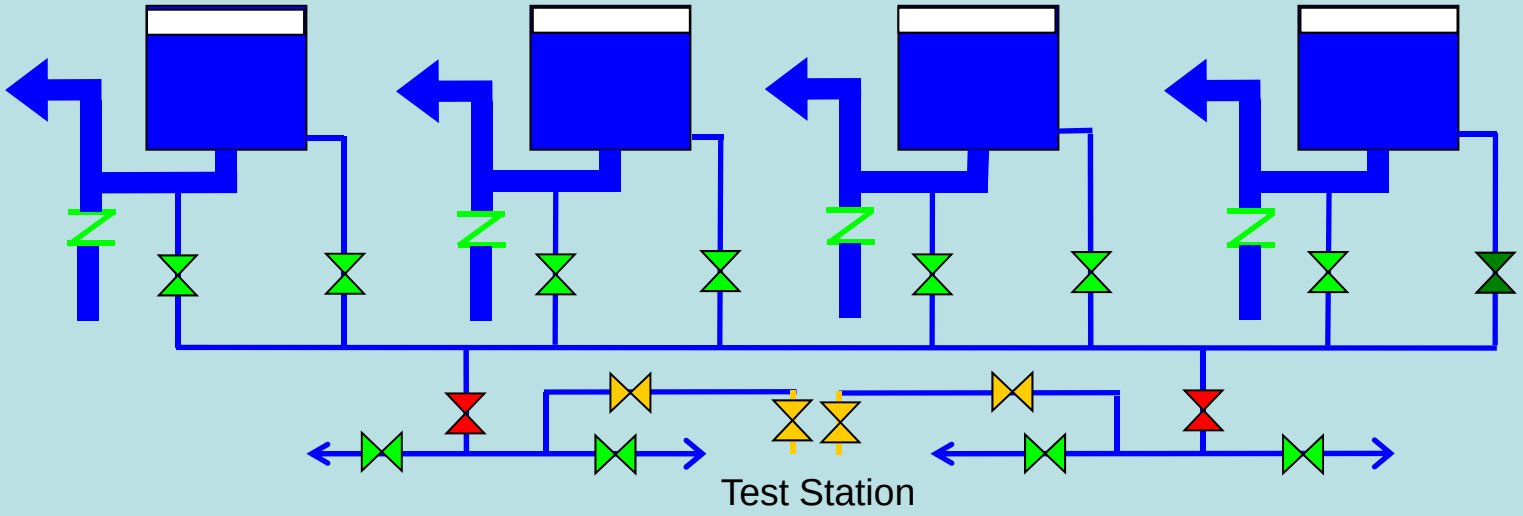
- Water Hammer and Acceptable Gas Quantity



• Fauske and Associates (FAI) developed a noncondensable gas-water waterhammer code, GW2, and verified by experimental data. Pressure and reaction force were measured during the experiments.
• FAI also used RELAP5 to perform the discharge side analyses.
• Numerical Application, Inc has verified GOTHIC capabilities for two-phase flow in vertical and horizontal pipes, dissolved gas release, and water hammer.

Activities and Experiences in USA (cont'd)

- Discharge Piping - Enhance Isolation From Accumulators & Replace Check Valves (Lin 2009) for Diablo Canyon
  - A. Replace **19 AOVs** with Anchor Darling Manual Valves And **4 RHR Check Valves**
  - B. Install Additional 5 Manual Isolation Valves in Test lines
  - C. Another 30 Manual Isolation Valves for Test Optimization Mods (At least 3 isolation valves in series)



Activities and Experiences in USA (cont'd)

- Pump Operation and Acceptable Gas Quantity
  - Criteria for accessing gas transport to pump suction and pump response to gas intrusion
    - By NRC
    - By NEI and licensees
    - By PWROG
  - Generic applicability of:
    - Gas transport testing
    - Pump gas intrusion testing

Activities and Experiences in USA (cont'd)

Gas/Void Ingestion Criteria for Pump Suction Side (Lin/Brennan 2009)

	$\%\frac{Q}{Q_{BEP}}$	BWR Typical Pumps	PWR Typical Pumps		
			Single Stage (WDF)	Multi-Stage Stiff Shaft (CA)	Multi-Stage Flexible Shaft (RLIJ, JHF)
Steady State Operation > 20 seconds	40%-120%	2%	2%	2%	2%
Steady State Operation > 20 seconds (see Note)	< 40% or > 120%	1%	1%	1%	1%
Transient Operation ≤ 5 seconds	70%-120%	10%			10%
Transient Operation ≤ 5 seconds (see Note)	< 70% or > 120%	5%			5%
Transient Operation ≤ 20 seconds	70%-120%		5%	20%	
Transient Operation ≤ 20 seconds (see Note)	< 70% or > 120%		5%	5%	

Note: Further review by the respective Owner's Groups may determine that criteria for pump operation below 70% BEP may not be required, as the conditions are bounded by the set of criteria for the 70%-120% BEP range.

Activities and Experiences in USA (cont'd)

- Gas Transport Testing & Modeling

– FAI performed RELAP 5 analysis and ¼ scale model test of suction side gas transport (Ramsden 2009) (McKercher 2009 for Millstone 3)
  - RELAP5 can appropriately model gas transport and captures the physics in a conservative fashion

– Westinghouse (Swantner 2009)
  - Phase I (2005) - Examined gas transport in 6" and 8" piping (WCAP-16631)
  - Phase II (2008-2010)
    – Examine gas transport in 4" and 12" piping
    – Determine temperature effects using 4" piping
    – Develop scaling methodology to cover 4" to 30" pipe

– MPR used SYSFLO for void transport analysis and benchmark with scaled test data for 8 stations.

AEC's Concerns and Actions

- AEC issued the requests to Chinshan, Kuosheng, and Maanshan NPPs to evaluate the following items and report.

  (1) gas sources

  (2) gas accumulation positions

  (3) gas accumulation amount

  (4) water hammer and the accept criteria for gas accumulation

  (5) pump operation and the accept criteria for gas accumulation

  (6)gas control.

AEC's Concerns and Actions (cont'd)

- AEC provided a template for licensees to follow in evaluation on 5/4/2009.

(1) Licensing Basis Evaluation

FSAR, TS and Base, Technical Requirements Manual (TRM) and Base

(2) Design Evaluation

Design Basis, Calculations, and Engineering Evaluation and Vendors Technical Documents

(3) Testing Evaluation

- Review venting and drain procedures, safety operation procedures, monitoring Procedures and test procedures

- Record time and following actions in monitoring gas venting

(4) Corrective Actions

- Tabulate the corrective actions.
- Perform the actions to update the documents, design changes
- Commitment for corrective actions – training, gas accumulation management program and plan, plant experiences and industry practice

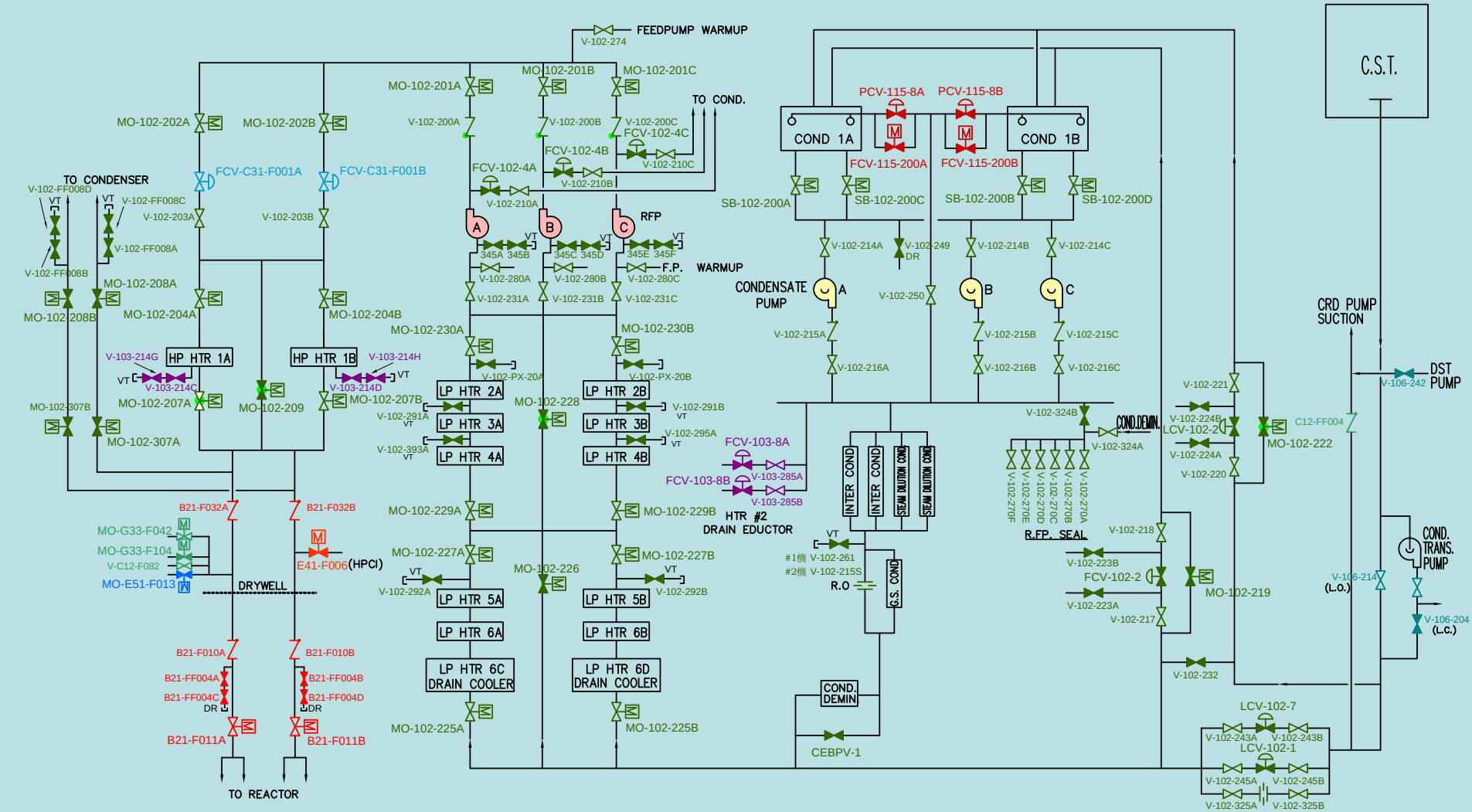
Plant Response and Implementation

- Taipower responded to AEC on 2/2/2009.
  - Chinshan NPP Activities
  - Kuosheng NPP Activities
  - Maanshan NPP Activities
- After review Taipower's responses, AEC requested Taipower provides additional information in the end of 2009 on the licensing basis, design, testing, and corrective actions according to the template provided on 5/4/2009.

Chinshan NPP Activities

Item	Contributing	HPCI	RHR	CS	RCIC
gas sources	Leak from RCS To ECCS	If MOV-F006 & CV-F005 Leak	If AOV-F050 & MOV-F015 Leak	If AOV-F006 & MOV-F005 Leak	If MOV-F013 & F014 leak
	Outgassing of dissolved gas because of pressure reduction	1. Existing with design. 2. Full the pipes to minimize outgassing	Same as HPCI	Same as HPCI	Same as HPCI
	Incorrect operation or maintenance	Incorrect venting, filling, etc. will cause air accumulation	Same as HPCI	Same as HPCI	Same as HPCI
	T≧Tsat	Heated to Tsat is possible, if leaks through boundary valves.	System temperature low. Impossible to be heated to Tsat	Same as RHR	Same as HPCI
	Vortex or gas in suction	1.If suppression pool level low. 2. Vortex is prevented by the venting pipes in suppression pool.	1. Suction elevation is lower than intake source (suppression pool), air intrusion from suction is impossible. 2.Vortex is prevented by the venting pipes in suppression pool	Same as RHR	Same as HPCI

冷凝水暨飼水系統流程簡圖



Chinshan NPP Activities (cont'd)

Item	Contributors	HPCI	RHR	CS	RCIC
gas accumulation locations	High points in pipe runs	possible	same as HPCI	same as HPCI	same as HPCI
	Under closed valves	possible	same as HPCI	same as HPCI	same as HPCI
	RHR HX U-tubes	NA	possible, due to incomplete venting	NA	NA
	Horizontal pipe diameter transitions	low possibility	low possibility	low possibility	low possibility
	In branch stagnant pipe from tees	low possibility	low possibility	low possibility	low possibility
	In valve bonnets	possible, due to incomplete venting	same as HPCI	same as HPCI	same as HPCI
	In pump casings	possible, due to incomplete venting	same as HPCI	same as HPCI	same as HPCI
gas accumulation amount	In piping when the temp is at or above the sat. temp.	1. Daily monitor & record system temperature and pressure per procedure 602.6.7. Evaluate if FW leak into HPCI system. 2.Charging pump keeps the system full.	1. Charging pump keeps the system full. 2.Records the venting time to evaluate the amount of gas accumulated.	same as RHR	Daily monitor & record system temperature and pressure per procedure 602.6.7.

Chinshan NPP Activities (cont'd)

Item	Contributors	HPCI	RHR	CS	RCIC
water hammer & acceptable gas quantity		Gas accumulation quantity is difficult to estimate/measure	Same as HPCI	Same as HPCI	Same as HPCI
pump operation & acceptable gas quantity		Gas accumulation quantity is difficult to estimate/measure	Same as HPCI	Same as HPCI	Same as HPCI
gas control	Procedures, valve labeling etc.	Shall follow procedure, inconsistent between drawing and field must be corrected.	Same as HPCI	Same as HPCI	Same as HPCI
	Vent periodically	Monitoring system P and T daily	Perform periodically and records venting time	Same as RHR	Check discharge line daily
	Surveillance Test	Monitoring P and T daily and test periodically	Confirm leg pump is running before test.	Same as RHR	Same as HPCI
	Confirm pump discharge pressure	Monitor pump discharge line daily	Leg pump runs continuously	Same as RHR	Same as HPCI
	Confirm suction water level	Suction from CST, water level much higher than pump.	Suction from TORUS, NPSH already considered	Same as RHR	Same as HPCI
	Vent valve numbers and location	Identical between drawing and field	Vent will be added on relative high points	Same as HPCI	Same as RHR
	Prevent leakage from high pressure/high temp. systems	Monitoring system P and T daily to evaluate if leakage from other system	Same as HPCI	Same as HPCI	Same as HPCI

Chinshan NPP Activities (cont'd)

Base on the above evaluation, corrective action as:

- Correction completed

  (1) Operator training

  (2) Publish related Chinese technical Information.

  (3) Revise CS/RHR pump test procedure (606.11 /606.2.1)

  (4) Confirmation of vent/drain valves between drawing and field.

  (5) Recheck the appositeness of related procedures

- Correction to be implemented

  (1) 9 vent valves will be added for each unit.

  - 3 on pump suction(6"-RCIC-30, 24"-RHR-1A, 24"-RHR-1B)

  - 6 on pump discharge(4"-RCIC-6, 2"-RCIC-15, 16"-RHR-16A, 16"-RHR-16B, 16"-RHR-26A, 16"-RHR-26B)

  - Units 1/2 will be completed on March 2010/ March 2011, respectively

Concluding Remarks

(1) AEC requested Chinshan, Kuosheng, and Maanshan NPS to submit the report to demonstrate the related systems are in compliance with GL 2008-01 requirements.

Taipower has responded to AEC's requests, however the response can not fulfill GL 2008-01 requirements. All three plants lack to provide detail information for the following items:

- Assessment of design adequacy to prevent gas accumulation
- Justification the validity of licensing basis documents (e.g. FSAR, TS)
- Methods to quantify the volume of accumulated gas.
- Acceptable criteria of gas accumulation for water hammer and pump operation.
- Discussion about the completeness of surveillance test, e.g. just a portion of system is tested?

Thus, additional information are requested.

Concluding Remarks (cont'd)

(2) In general, licensees can provide the following information:

- a program plan
- the possible locations of gas accumulation.
  Chinshan has identified the installed locations for the additional vent valves.
- Identification of valves through which the high pressure and high temperature fluid may leak into.
- Procedures (venting, draining, testing ..) needed to be revised.

Thank You for Your Attention