U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

STATE-OF-THE-ART REACTOR CONSEQUENCE ANALYSES

Office of Nuclear Regulatory Research
Advisory Committee on Reactor Safeguards Briefing
November 16, 2007

Agenda

- Overview
- Process Review
- Preliminary Results of the Peach Bottom Atomic Power Station and Surry Power Station Assessments
  - Preliminary Findings
  - Sensitivity Analyses
  - Emergency Preparedness
  - Comparison with the 1982 Sandia Siting Study
- Commission Paper on Reporting Latent Cancer Fatalities
- Path Forward

SOARCA Objectives

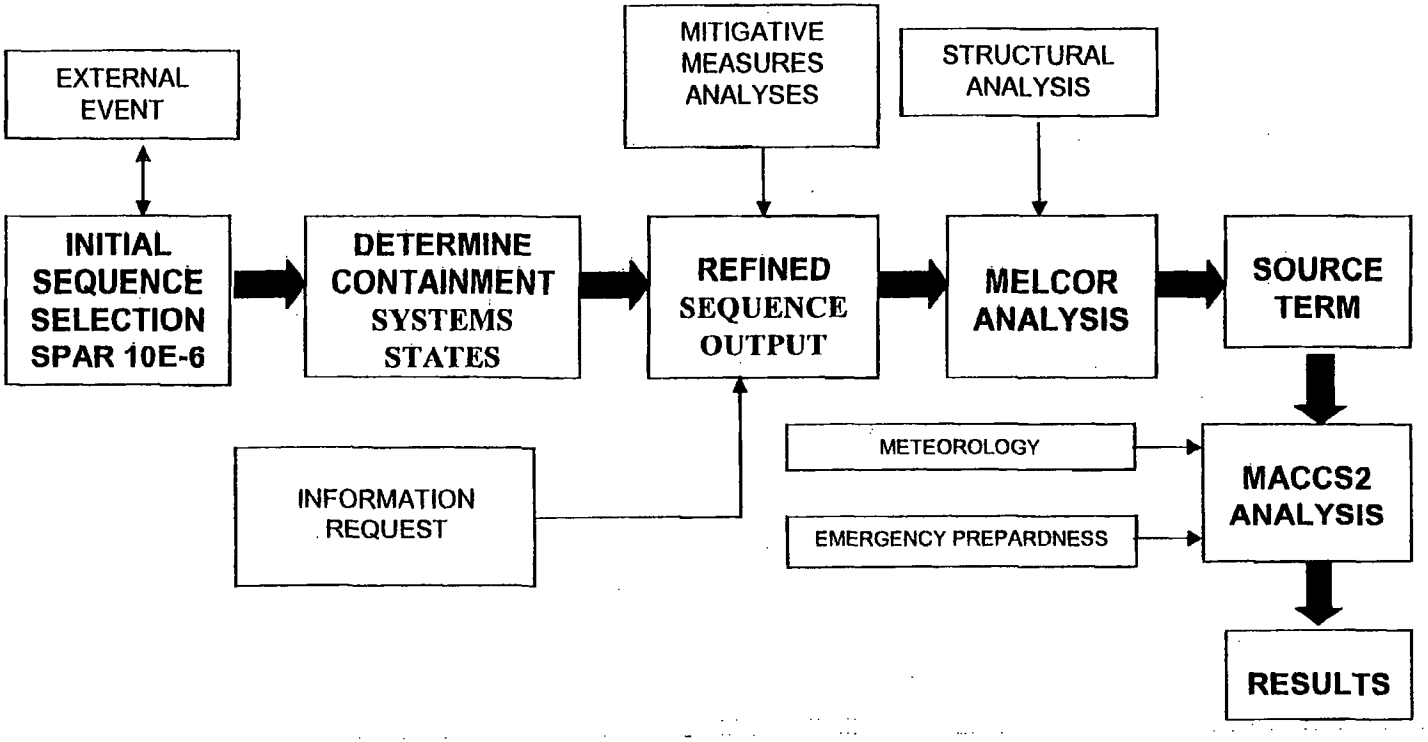
- Perform a state-of-the-art, realistic evaluation of severe accident progression, radiological releases and offsite consequences for dominant accident sequences
- Provide a more accurate assessment of potential offsite consequences to replace previous consequence analyses

Severe Accident Improvements

- 25 years of national and international research
- Regulatory improvements reduced the likelihood of severe accidents
- Improved modeling capability
- Improvements in plant design
- Other plant improvements

SOARCA OVERVIEW

SOARCA PROCESS



SOARCA Approach

- Full power operation
- Plant-specific sequences with a CDF$\geq 10^{-6}$ (CDF$\geq 10^{-7}$ for bypass events)
- External events included
- Consideration of all mitigative measures, including B.5.b
- Sensitivity analyses to assess the effectiveness of different safety measures
- State-of-the-art accident progression modeling based on 25 years of research to provide a best-estimate for accident progression, containment performance, time of release and fission product behavior
- More realistic offsite dispersion modeling
- Site-specific evaluation of public evacuation based on updated Emergency Plans
- Dose threshold for reporting latent cancer fatalities (5 rem in one year, 10 rem lifetime)

SOARCA Insights

- Sequences dominated by external events, primarily large seismic events (PWR also includes bypass events)
- Previously used sequences have a significantly lower probability of occurrence or are not consider to be feasible
  - Alpha mode failure
  - High pressure melt through
  - ATWS
- B.5.b measures are effective at preventing core damage and containment failure

SOARCA Preliminary Findings

- All events identified by the screening criteria (including bypass events) would be mitigated by B.5.b measures or, in some cases, by other plant systems
- Analyses were performed which confirmed effectiveness of mitigative measures
- Performed sensitivity analyses assuming no mitigative measures to further demonstrate the effectiveness of these mitigative measures and to provide results to compare with 1982 SNL Siting Study
- The analyses performed with and without mitigative measures resulted in significantly less severe consequences than the 1982 study

Sequence Screening Process

(Internal Events)

- Initial Screening - use enhanced SPAR models to screen out low CDFs initiating events with an overall CDF ≤1.0E-7 and sequences with a CDF <1.0E-8. This step eliminates <10% of the overall CDF (typically about 5%)
- Sequence Evaluation – identify and evaluate the dominant cutsets for the remaining sequences (~90% of initiator CDF). Determine system and equipment availability / unavailability and accident sequence timing
- Scenario Grouping - group sequences together that have similar times to core damage and equipment unavailability
- Sequences selected refined by external events and mitigative measures assessments

Sequence Screening Process

(External Events)

- Identify dominant externally initiated event sequences (e.g., fire, seismic, flooding, wind) based upon available probabilistic risk assessment documentation from NUREG-1150, IPEEE submittals, as well as any additional / available supporting documentation
- Seismic margin assessments were excluded from this effort because they do not provide the required risk information
- Identified potential mapping between dominant external events and internally initiated events identified by the SPAR analysis
- Where mapping between external and internal events are not possible or appropriate, a unique externally initiated event or sensitivity study was recommended
- The resulting limited set of scenarios obtained for each SOARCA plant was used for subsequent accident progression and consequence analysis

Containment Systems States

Identify the availability of engineered systems that can impact post-core damage containment accident progression, containment failure and radionuclide release

- Identify the anticipated availability of containment and containment support systems not considered in the Level 1 core damage analysis:
  - determine availability of front line system using cutset information
  - constructed a system dependency table showing the support systems required for performance of the target front line system
  - determine availability of front line system using engineering judgment
- Availability of systems such as low pressure injection that can impact containment accident progression (e.g. cooling debris in reactor cavity or cooling reactor vessel after core damage but prior to vessel failure) that were not evaluated in the Level 1 core damage analysis will be determined using engineering judgment

Mitigative Measures Analysis

- The mitigative measures analyses are qualitative, sequence-specific systems and operational analyses based on licensee identified mitigative measures from EOPs, SAMGs, and other severe accident guidelines that are applicable to, and determined to be available during a sequence groupings whose availability, capability and timing will be utilized as an input into the MELCOR analyses

Mitigative Measures Analysis Process

- For those dominating sequences / sequence groupings within the scope of SOARCA, applicable mitigative measures that are potentially available (not eliminated by initial conditions) are identify
- The staff performs systems and operations analyses based on the initial conditions and anticipated subsequent failures using applicable performance shaping factors to:
  - verify the availability of the primary system,
  - determine the availability of support systems and equipment
  - determine conservative time estimates for implementation
- The staff determines the anticipated availability, capability and the timing of implementation
- MELCOR will determine the effectiveness of those mitigative measures that are expected to be available at a given time

Emergency Preparedness

- Techniques used to model EP was previously presented to ACRS
- Effort was successful in developing cohort data
  - Population
  - Evacuation timing
  - Travel speed
  - Roadway network
- Data was used in MACCS2 to develop consequence estimates
- Staff is considering assessing earthquake impact on EP through sensitivity analyses

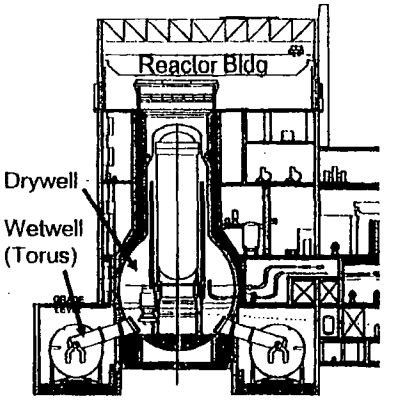
MACCS2 Assumptions

- Cancer detectability threshold for latent cancer fatalities
- No contaminated food or water consumed
- Latest federal guidelines used for dose conversion factors
- KI ingestion by half the 0 – 10 mile population, suboptimum timing
- Median values from US/CEC study of uncertainty for non-site specific parameter
- Site-specific population and meteorology
- Costs cost-of-living adjusted from NUREG-1150
- Projected dose during emergency period, 5 rem relocate in 1 day; 2 rem, 2 days
- Return criteria: 0.5 rem in 1 yr for Peach Bottom, 4 rem in 5 yr for Surry
- In general,1-hr plume segments are used

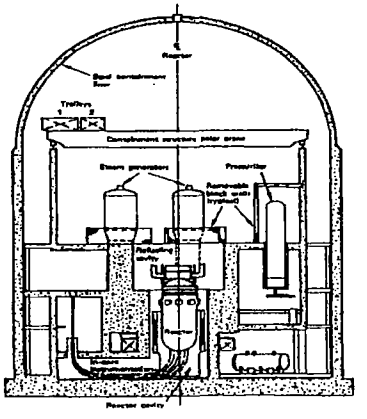
Structural Analyses Objective

Evaluating behavior of containment structures under severe accident conditions, and predicting the following performance criteria at the selected sites:

- Functional Failure Pressure - Leakage
- Structural Failure Pressure - Rupture
- Develop Leakage Rate and/or Leakage Area as a Function of Internal Pressure



Peach Bottom "Mark I – Steel Containment"



Surry "Reinforced Concrete Containment"

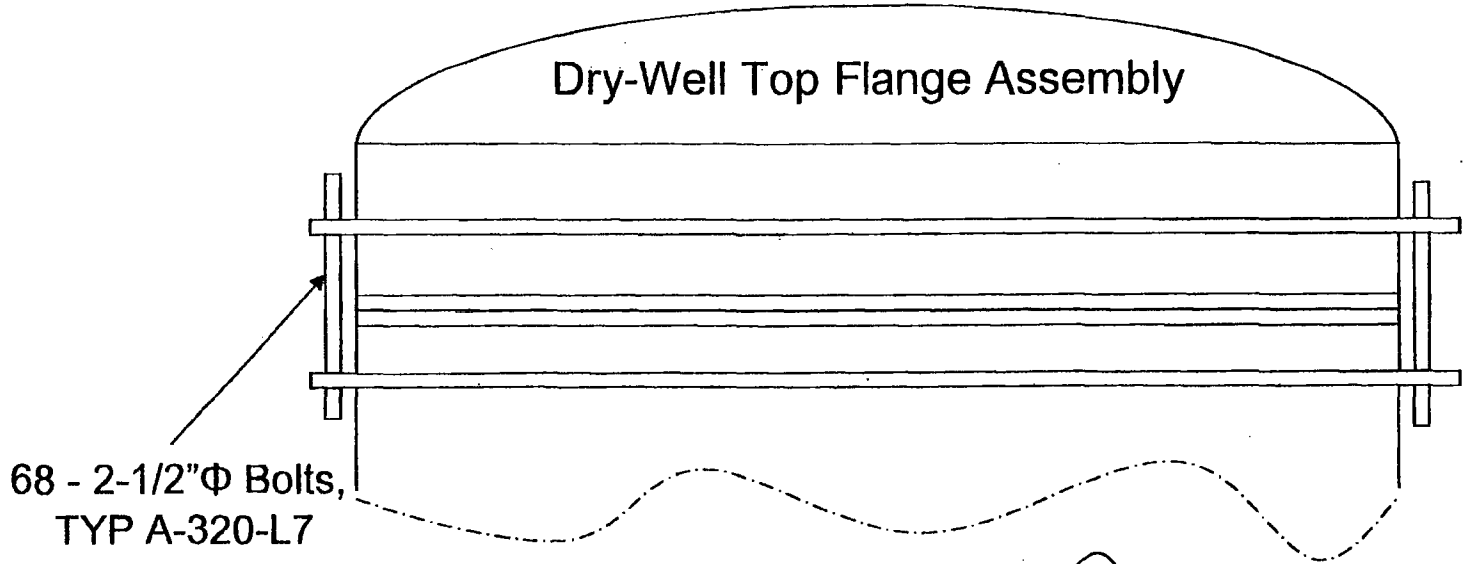
Peach Bottom Mark I – Steel Cont.

Approach:

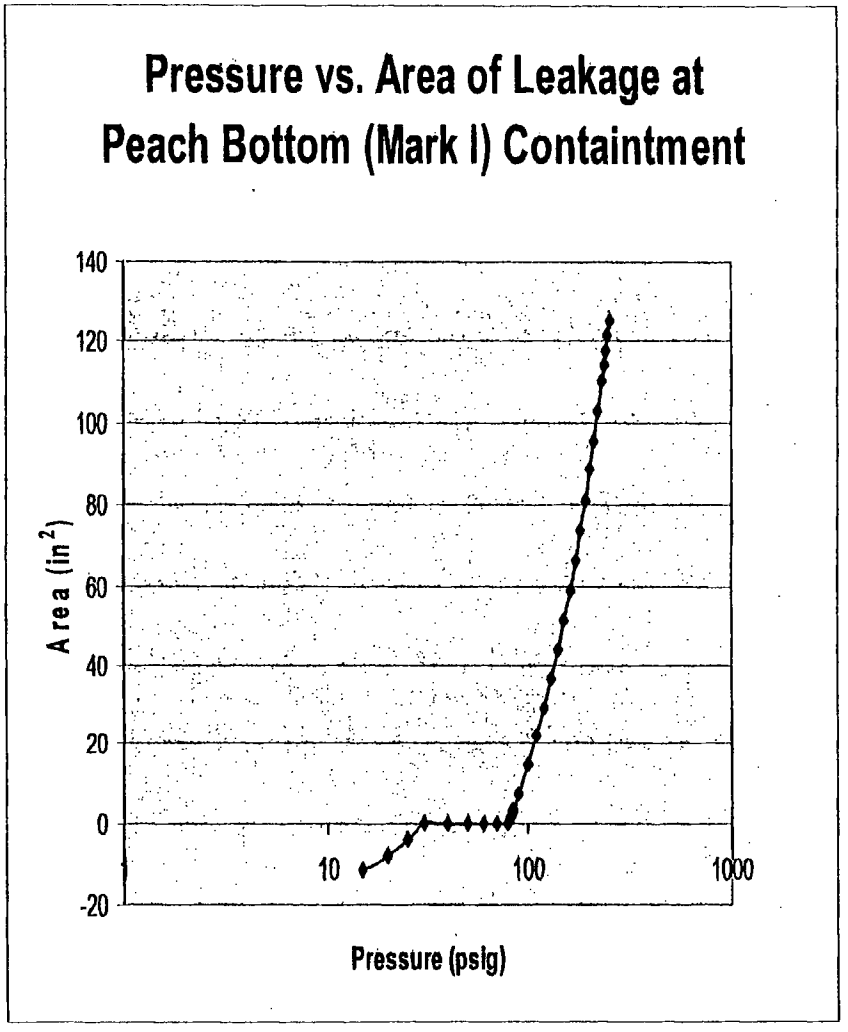
- Review/reevaluate major failure criteria based on 25 years of research and testing performed by SNL and other organizations

Result:

- The dominant cause for containment leakage is head flange bolt strain under gradually increasing internal pressure



Peach Bottom Results



P_T (psig)	Area of Leakage (in^2)	Bolt Elasticity
10	0.00	Elastic
15	0.00	Elastic
20	0.00	Elastic
25	0.00	Elastic
30	0.00	Elastic
40	0.00	Elastic, gasket
50	0.00	Elastic, gasket
60	0.00	Elastic, gasket
70	0.00	Elastic, gasket
80	0.00	Elastic, gasket
81	0.46	Elastic
82	1.20	Elastic
83	1.94	Elastic
84	2.68	Elastic
85	3.41	Elastic
90	7.10	Elastic
100	14.48	Elastic
120	29.24	Elastic

5% Relaxation of pre-load

P_d= 56 psig

Surry - Reinforced Concrete - Cont.

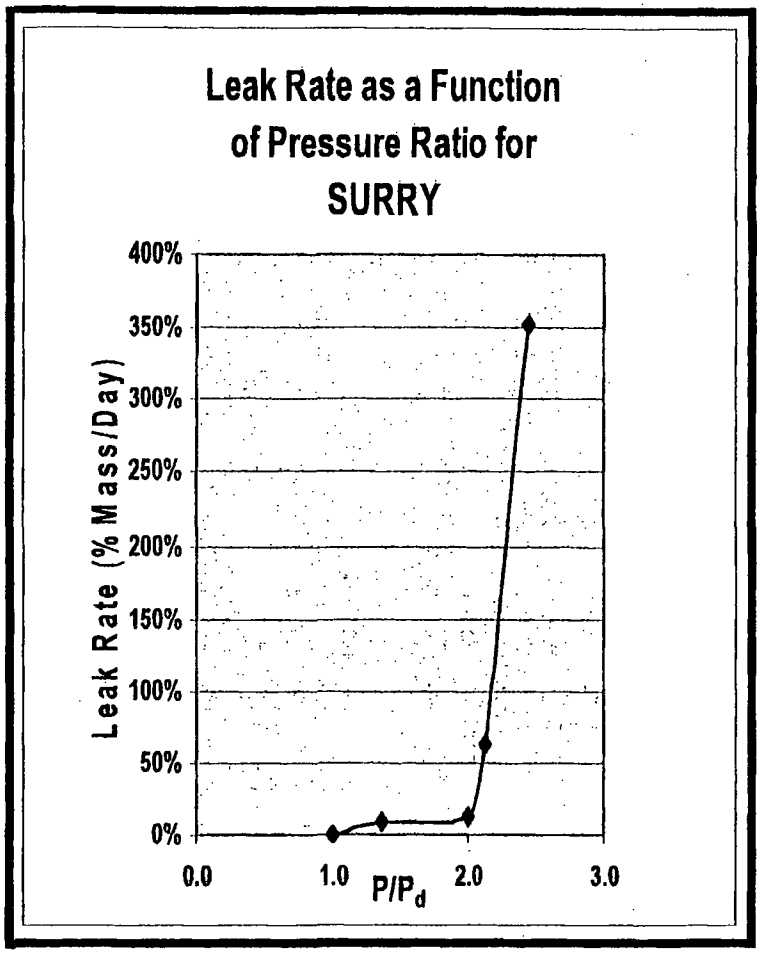
Approach:

- Research of 25 years of analyses and testing on reinforced concrete containments support the hypothesis of "leak-before-break" failure mode. Therefore, it is expected that the range of pressure needed for catastrophic burst can never be reached -- leakage should prevent catastrophic burst.
- General behavior of concrete containment under gradually increasing internal pressure:
  - **First,** cracking of containment concrete.
  - **Second,** yielding of liner then tearing, and path(s) for leakage is/are created.
  - **Third,** yielding of hoop-reinforcement, and enlarging.
  - **Finally,** reinforced concrete containment structures are predicted to have significant leakage once the global strain levels are reached on the order of 1% to 2%.

Evaluation of Reinforced Concrete Containment Structures

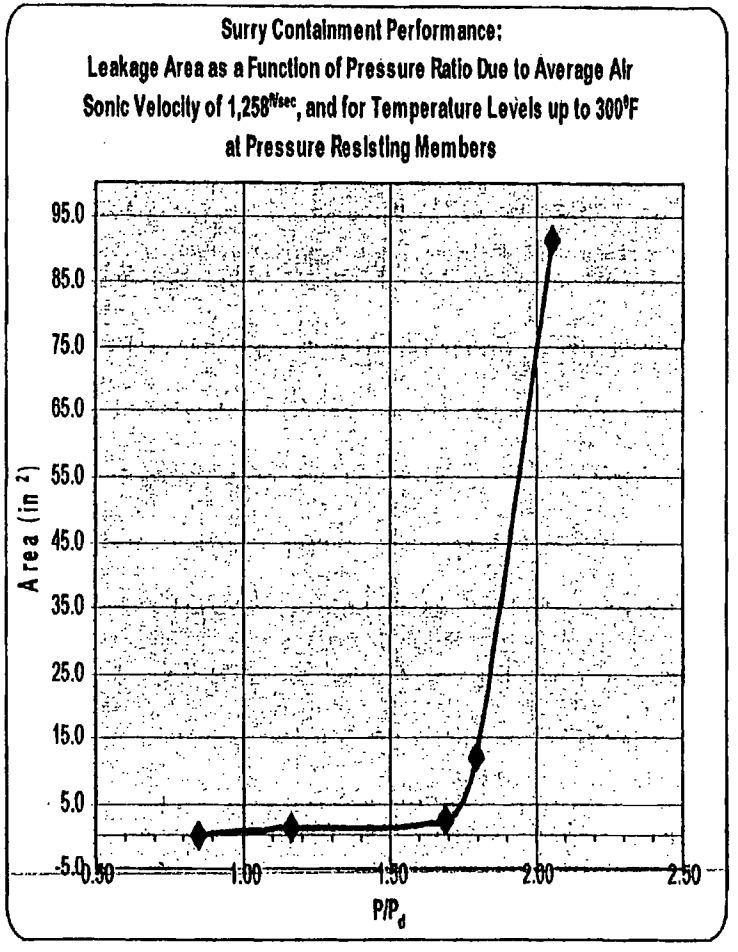
	[redacted]	Diablo Canyon	Salem	Seabrook	Surry
Containment Radius Inside R_c (ft)	[redacted]	70.00	70.00	70.00	63.00
Containment Volume V_c (ft^3)	[redacted]	2.63E+06	2.62E+06	2.70E+06	1.80E+06
Density ρ – N_2 or air (#/ft^3)	[redacted]	0.0752	0.0752	0.0752	0.0752
Atmospheric Pressure P_a (psia)	[redacted]	14.70	14.70	14.70	14.70
Liner Plate Thickness t_L (inch)	[redacted]	0.375	0.375	0.375	0.375
% of Liner Plate $\rho_L = t_L / t_c$	[redacted]	0.0089	0.0069	0.0069	0.0069
Containment Shell Wall Thick t_c (inch)	[redacted]	42.00	54.00	54.00	54.00
Hoop Rebar Area A_r (in^2/ft)	[redacted]	14.12	15.644	20.364	18.777
% of Hoop Rebar $\rho_H = A_r / t_c$	[redacted]	0.028	0.024	0.031	0.029
% of Total Steel $\rho_T = \rho_L + \rho_H$	[redacted]	0.037	0.031	0.038	0.036
Modulus of Elas. of Liner & Rebar (psi)	3.00E+07	3.00E+07	3.00E+07	3.00E+07	2.80E+07
Containment Design Pressure P_d (psig)	[redacted]	47.00	47.00	65.00	60.00
Liner Plate Yield Strength S_{y-L} (psi)	5.00E+04	5.00E+04	5.00E+04	5.00E+04	3.20E+04
Rebar Yield Strength S_{y-r} (psi)	7.00E+04	7.00E+04	7.00E+04	7.00E+04	5.00E+04
Rebar Strength @ 2%Strain$S_{2\%}$ (psi)	7.50E+04	7.50E+04	7.50E+04	7.50E+04	5.40E+04

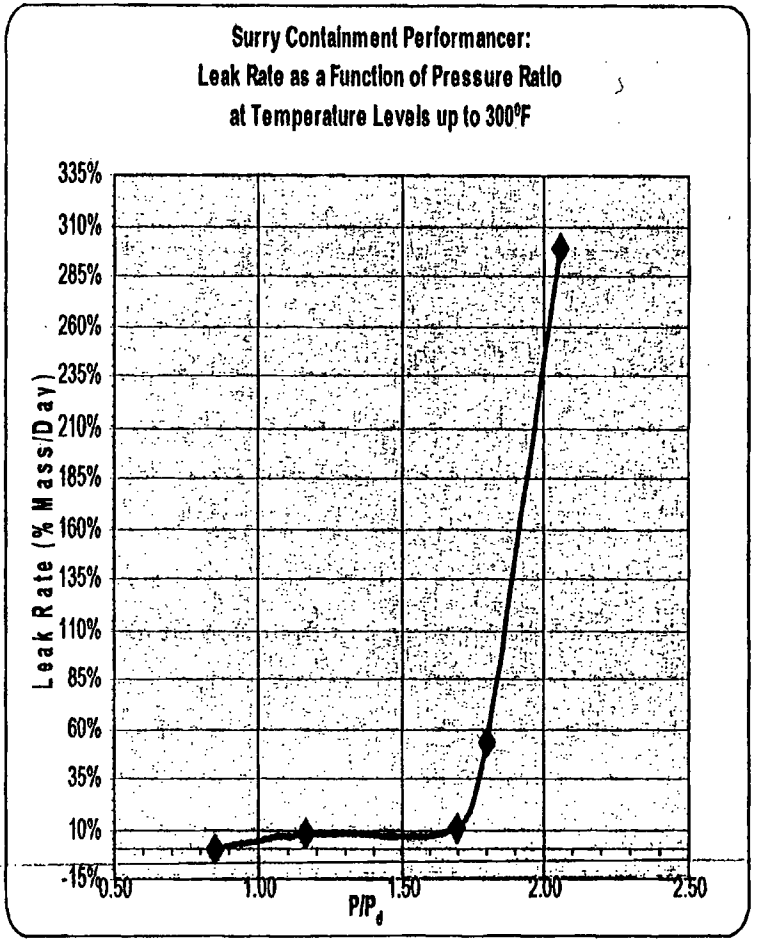
Surry - Reinforced Concrete - Cont.



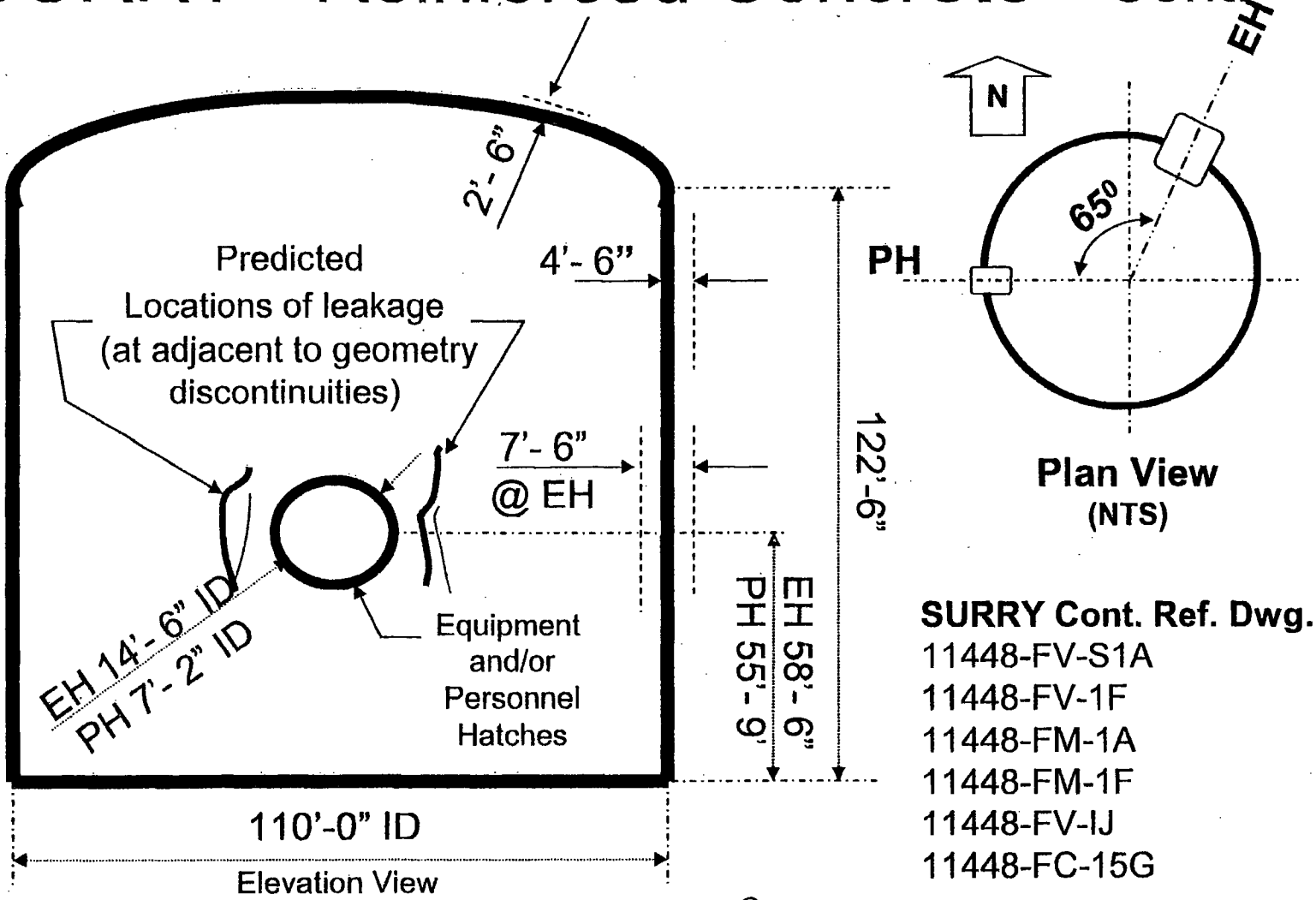
SURRY		
Pressure	P/P_d	LR (%Mass/Day)
$P = P_d = 60_{psig}$	1.00	0.14%
Liner @ S_{y-L}	1.37	10%
Rebar @ S_{y-r}	1.99	13%
2% Strain	2.13	62%
145 psig	2.42	352%

Surry Results





SURRY - Reinforced Concrete - Cont.



SURRY Cont. Ref. Dwg.:

11448-FV-S1A
11448-FV-1F
11448-FM-1A
11448-FM-1F
11448-FV-IJ
11448-FC-15G

Peach Bottom Accident Sequences

- PRA models indicate core damage probability dominated by seismic event, which is functionally a long-term SBO ($1x10^{-6}$ to $5x10^{-6}$ /yr)
  - Fire and flood events would be similar in terms of core damage progression
- Internal events have frequencies $<10^{-6}$/yr
  - Initially identified 1 sequence, Loss of Vital AC Bus E-12, as $>10^{-6}$/yr; subsequently determined to be $<10^{-6}$/yr
    - Notwithstanding, MELCOR analysis showed event to be mitigated without crediting B.5.b equipment
- Bypass events are of very low frequency: ~10^{-10}/yr

Peach Bottom LTSBO

Approach to MELCOR Analysis

- Perform MELCOR analysis crediting B.5.b equipment and procedures
  - Evaluate sufficiency of B.5.b measures to prevent environmental release
  - B.5.b measures were demonstrated to prevent core damage for LTSBO
- Perform MELCOR analysis without crediting B.5.b equipment and procedures
  - Understand value of mitigation strategies

Peach Bottom LTSBO

- Loss of offsite and onsite AC power
- RCIC starts automatically
- Operator, by procedure, depressurizes at 1 hr
- Batteries exhausted at 4 hours

- Mitigated
  - Portable power supply ensures long-term DC to hold SRV open and provide level indication (allows management of RCIC)

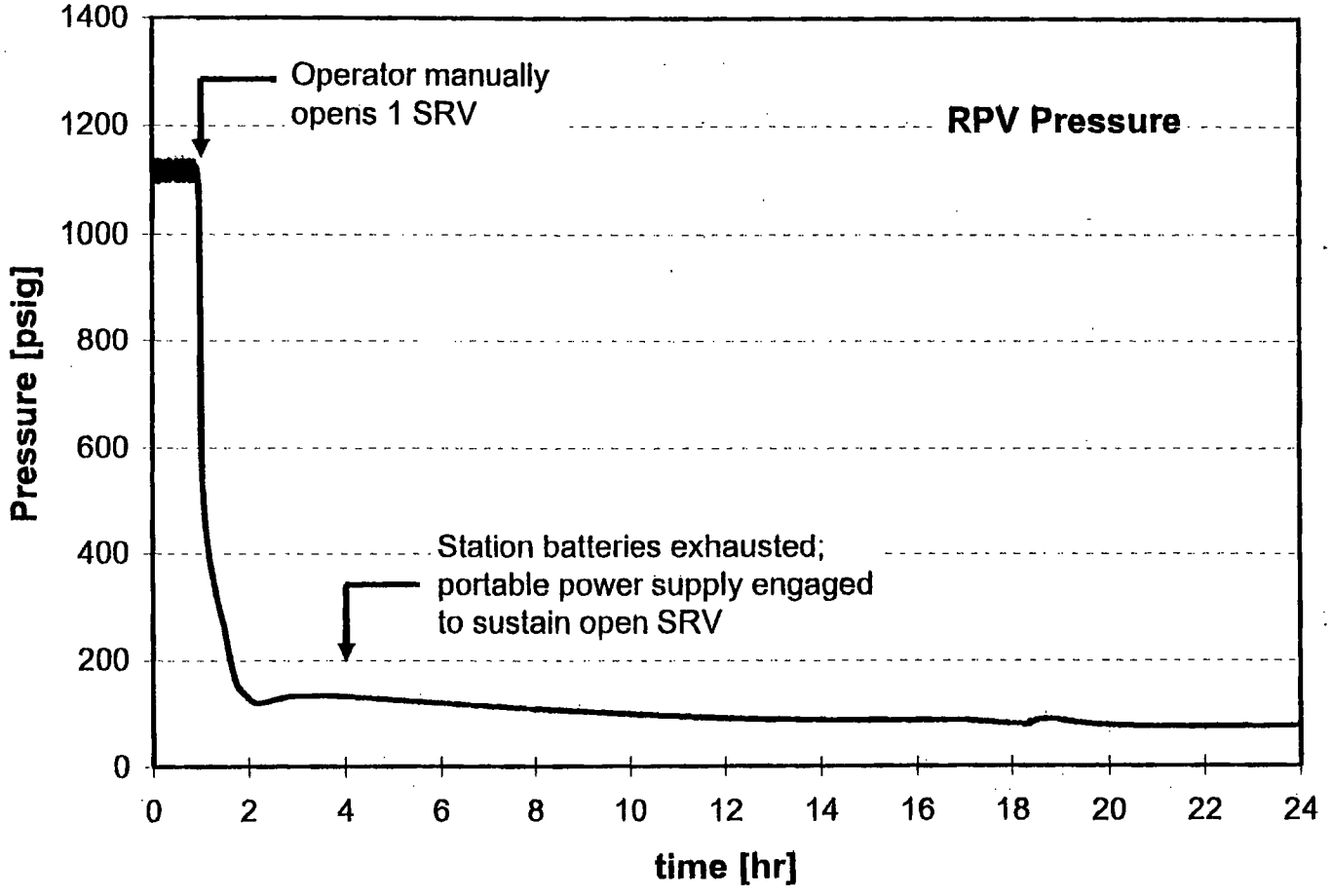
- Unmitigated
  - After 4 hrs:
    - Open SRV recloses
    - RCIC terminates
    - No subsequent actions taken

Peach Bottom LTSBO

- B.5.b mitigation
  - Portable power supply for SRV operation and reactor vessel level indication
    - Prevent excessive cycles on SRV
    - Provide level indication to manage injection
  - Manual control of RCIC without DC power
  - Portable diesel-driven pump (250 psi, 500 gpm) for makeup
  - Portable air supply to operate containment vent valves

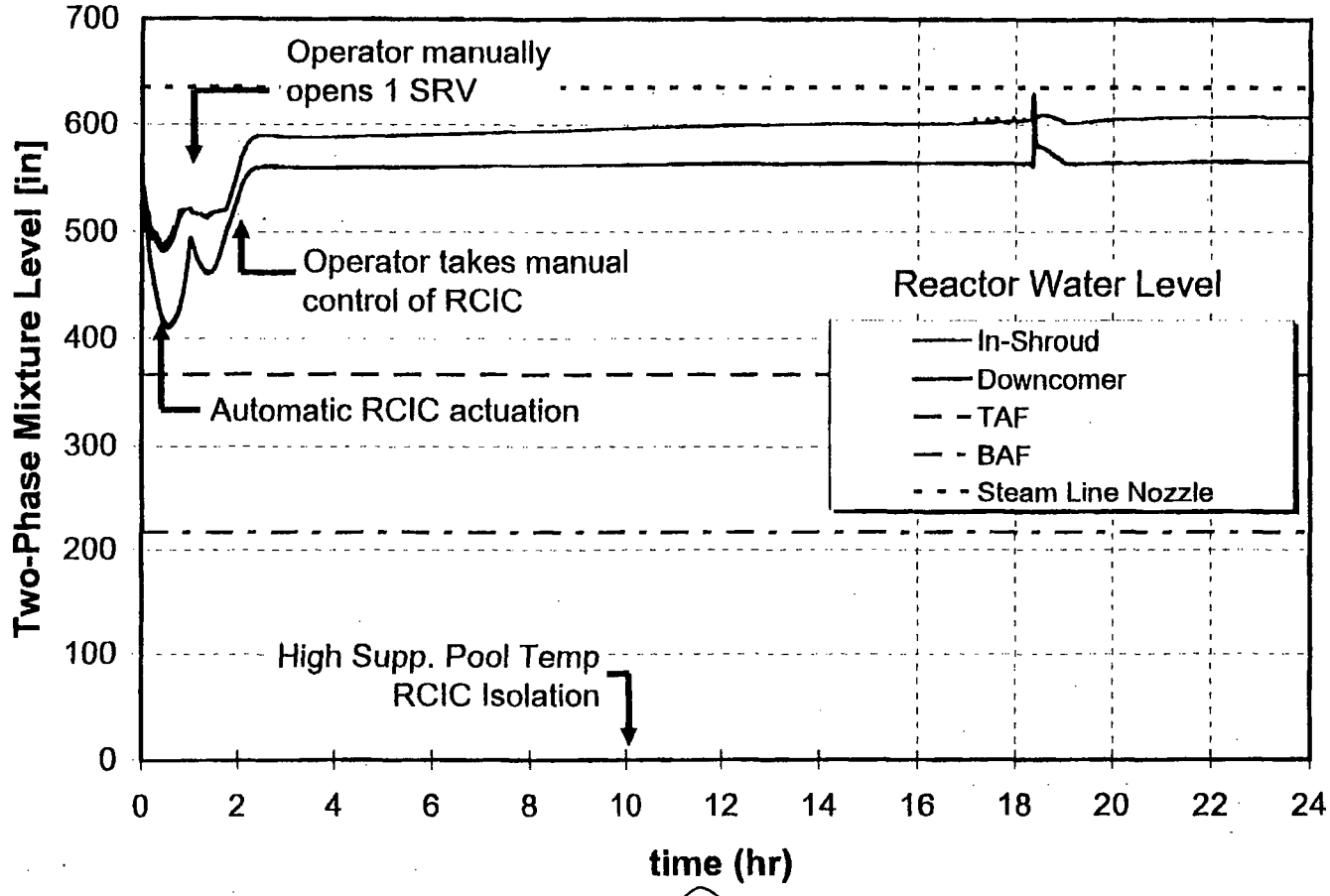
Peach Bottom LTSBO Pressure Response

Successful Mitigation with Portable Equipment



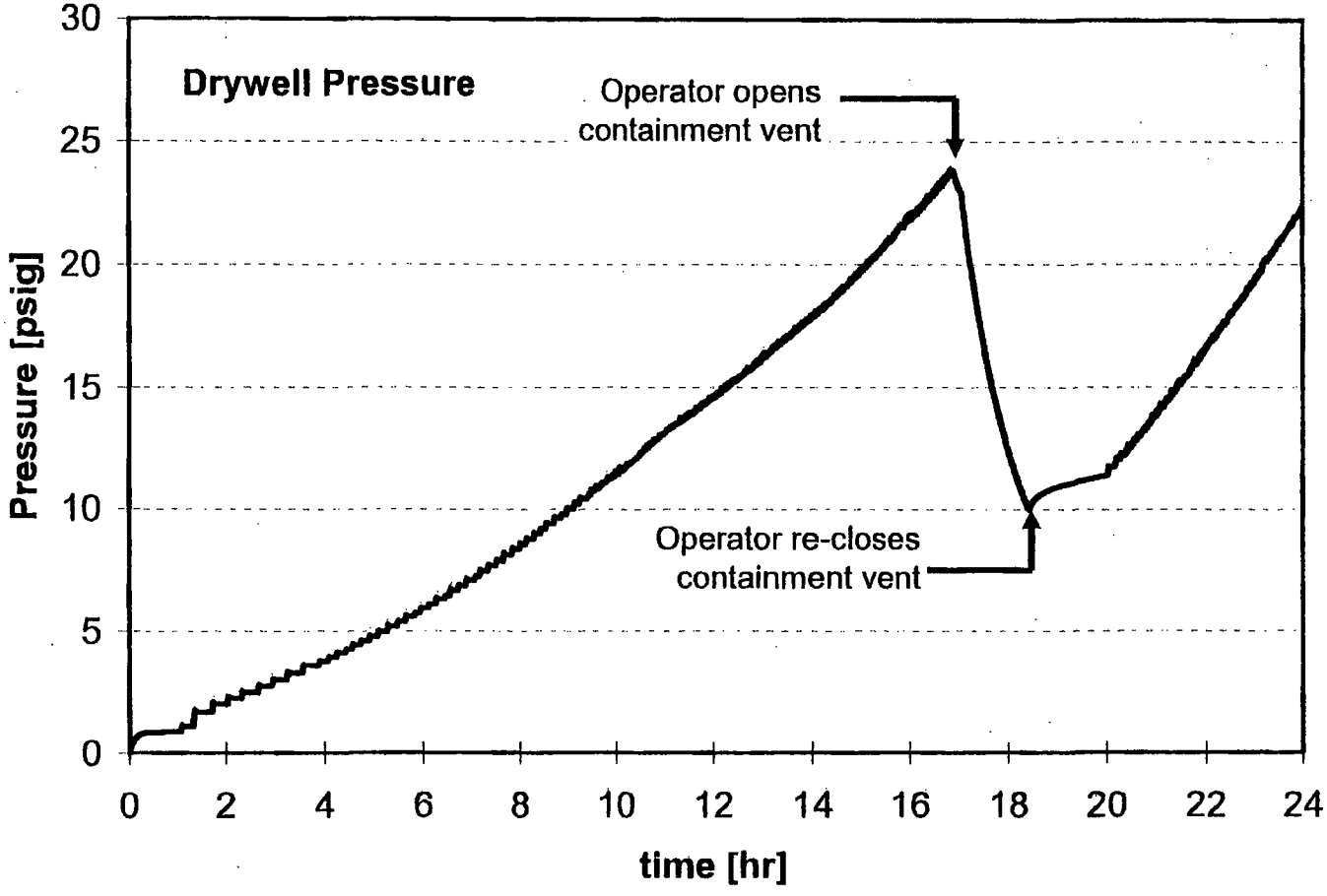
Peach Bottom LTSBO Level Response

Successful Mitigation with Portable Equipment



Peach Bottom LTSBO Pressure Response

Successful Mitigation with Portable Equipment



Peach Bottom LTSBO

Successful Mitigation with Portable Equipment

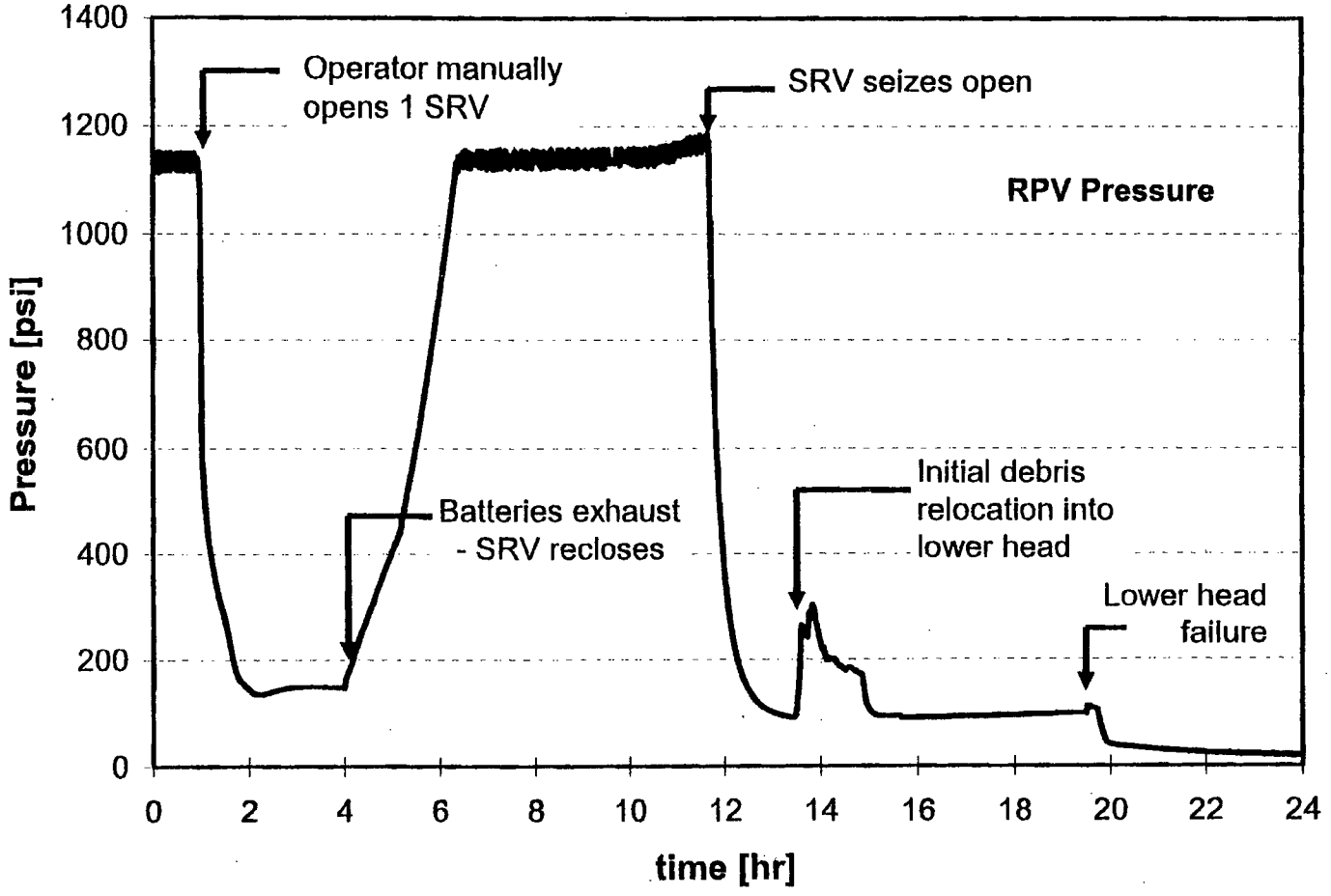
- B.5.b equipment is sufficient to prevent core damage
  - No source term
  - No offsite health consequences

Peach Bottom Mitigative Measures
Sensitivity Analysis

- Long-term SBO – without B.5.b mitigation
  - Loss of offsite and onsite AC power
  - RCIC starts automatically
  - Operator, by procedure, depressurizes at 1 hr
  - Batteries exhausted at 4 hrs
- Accident progression
  - RCIC lost at 5 hrs
  - Core uncovery in 9 hrs
  - Core damage in 10 hrs
  - RPV and containment failure in 20 hrs, start of radioactive release (liner melt-through)
  - Time from start of evacuation to radioactive release: ~17 hrs

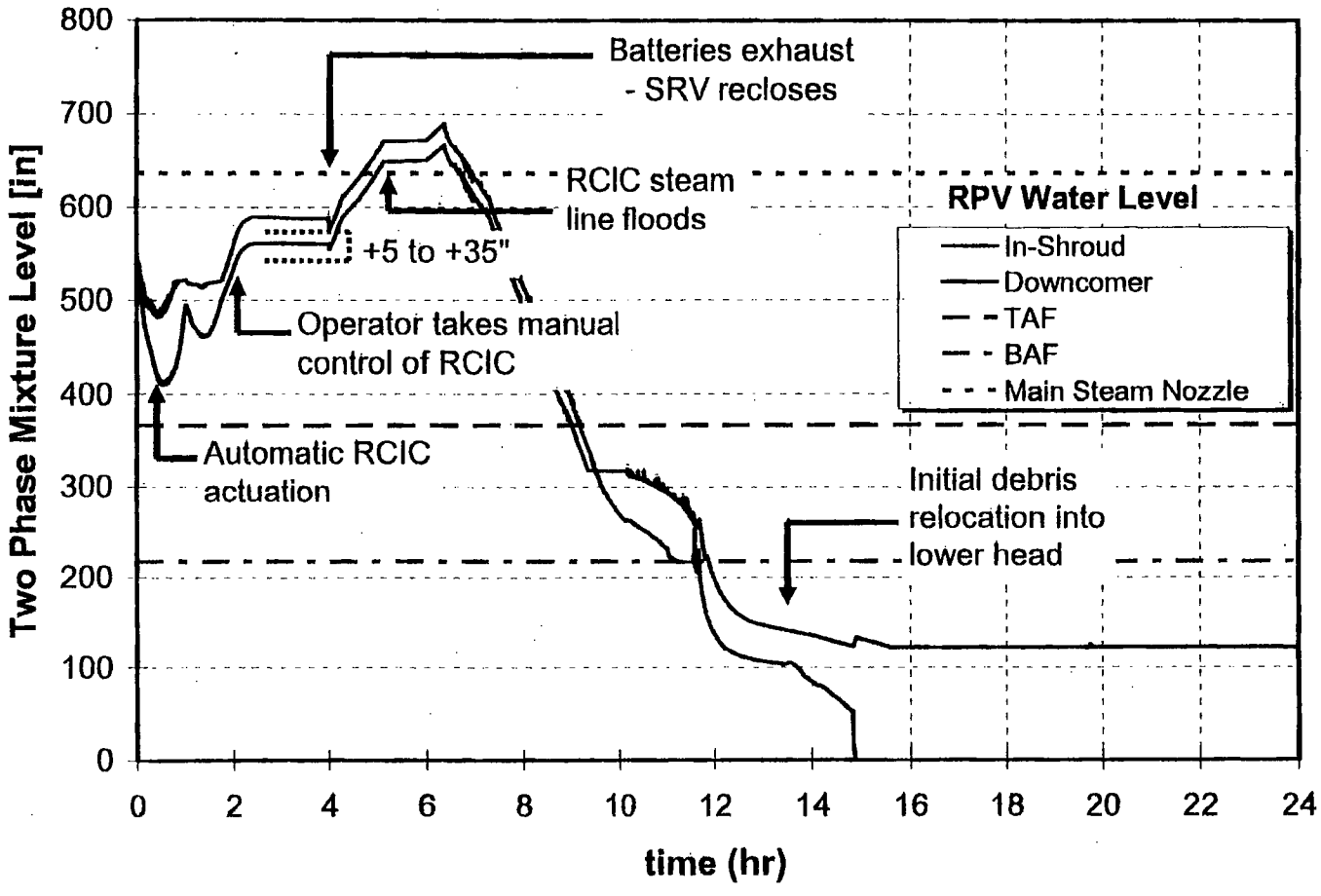
Peach Bottom LTSBO Pressure Response

No Mitigation with Portable Equipment

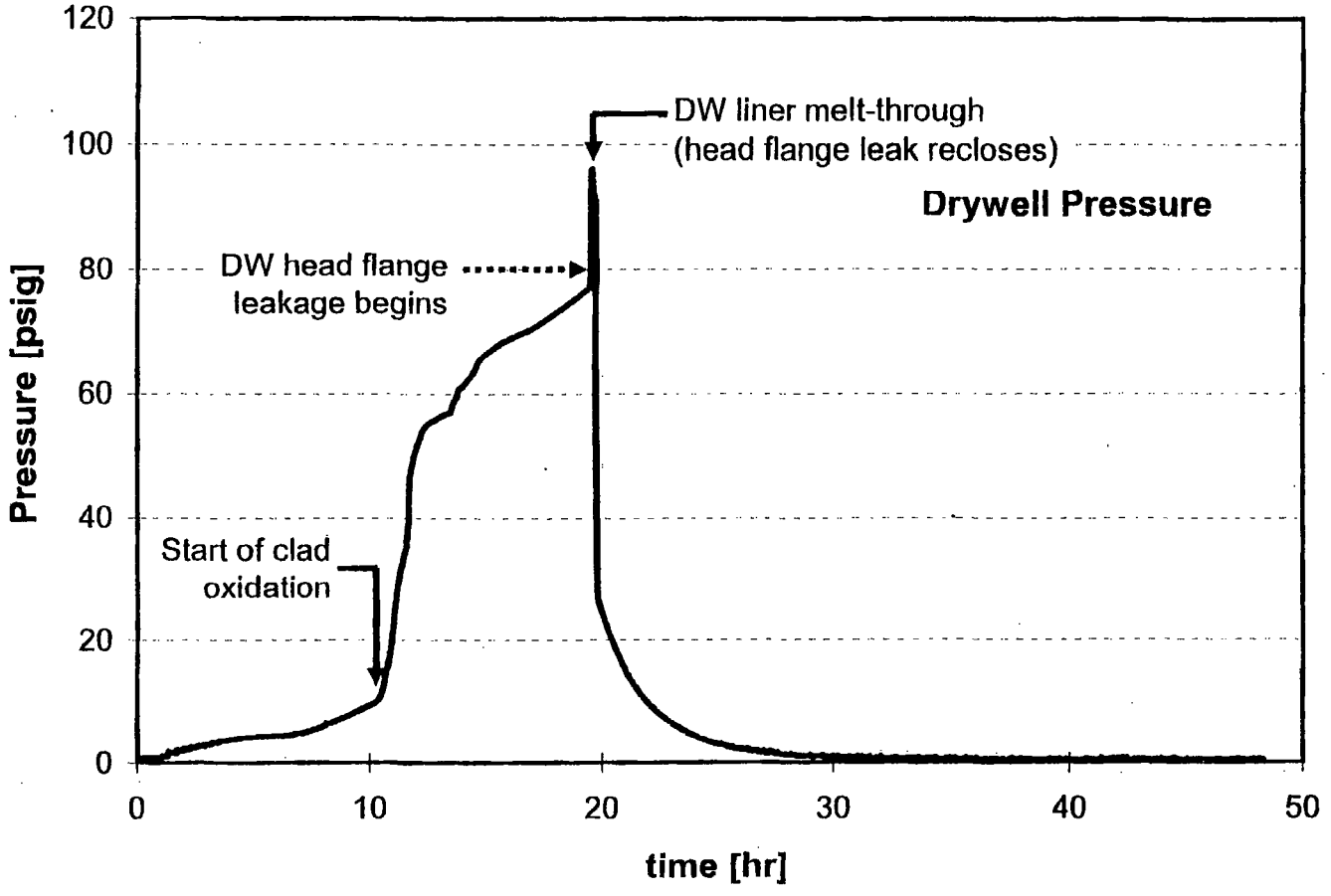


Peach Bottom LTSBO Level Response

No Mitigation with Portable Equipment

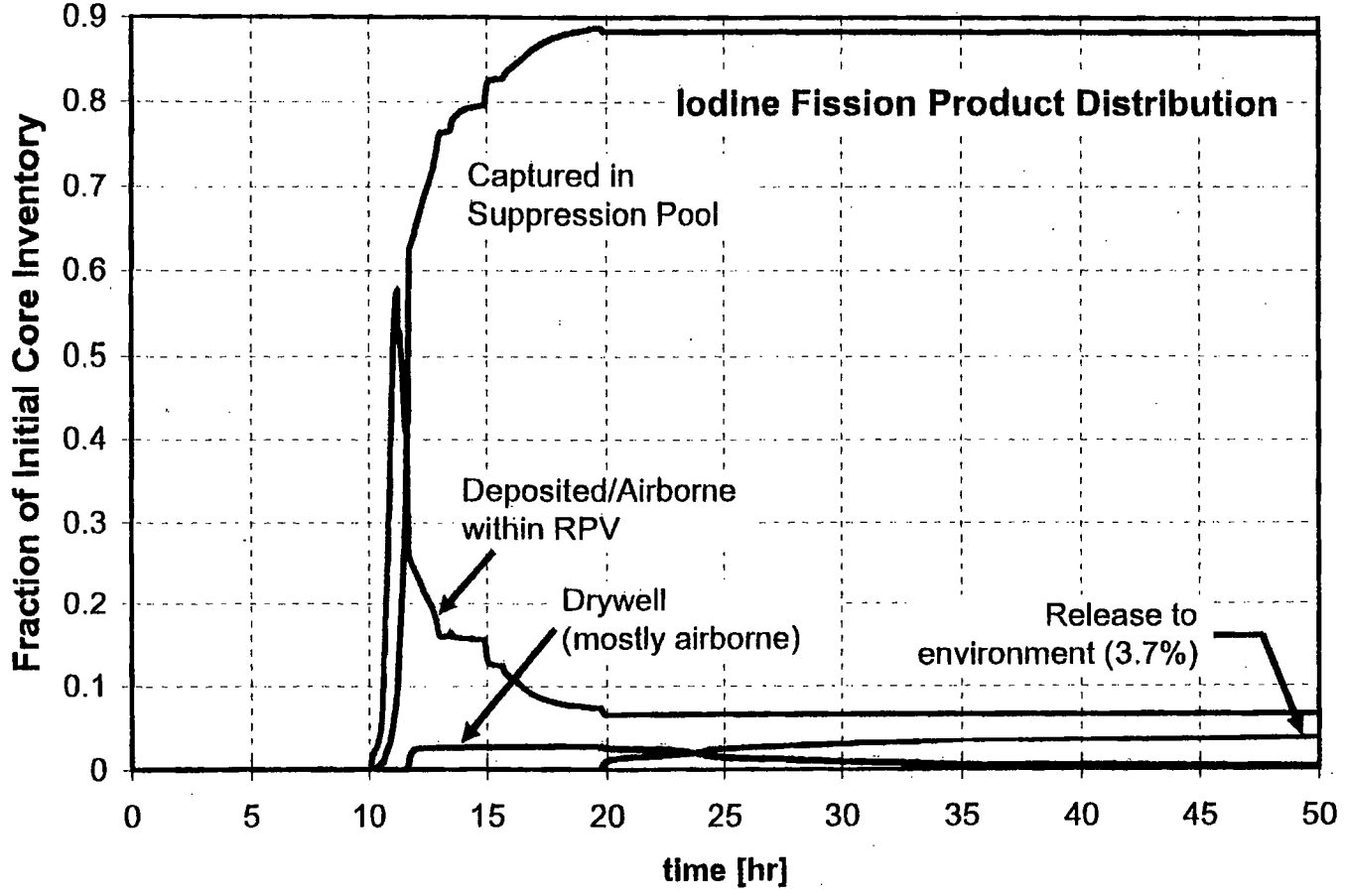


Peach Bottom LTSBO Containment Pressure Response
No Mitigation with Portable Equipment



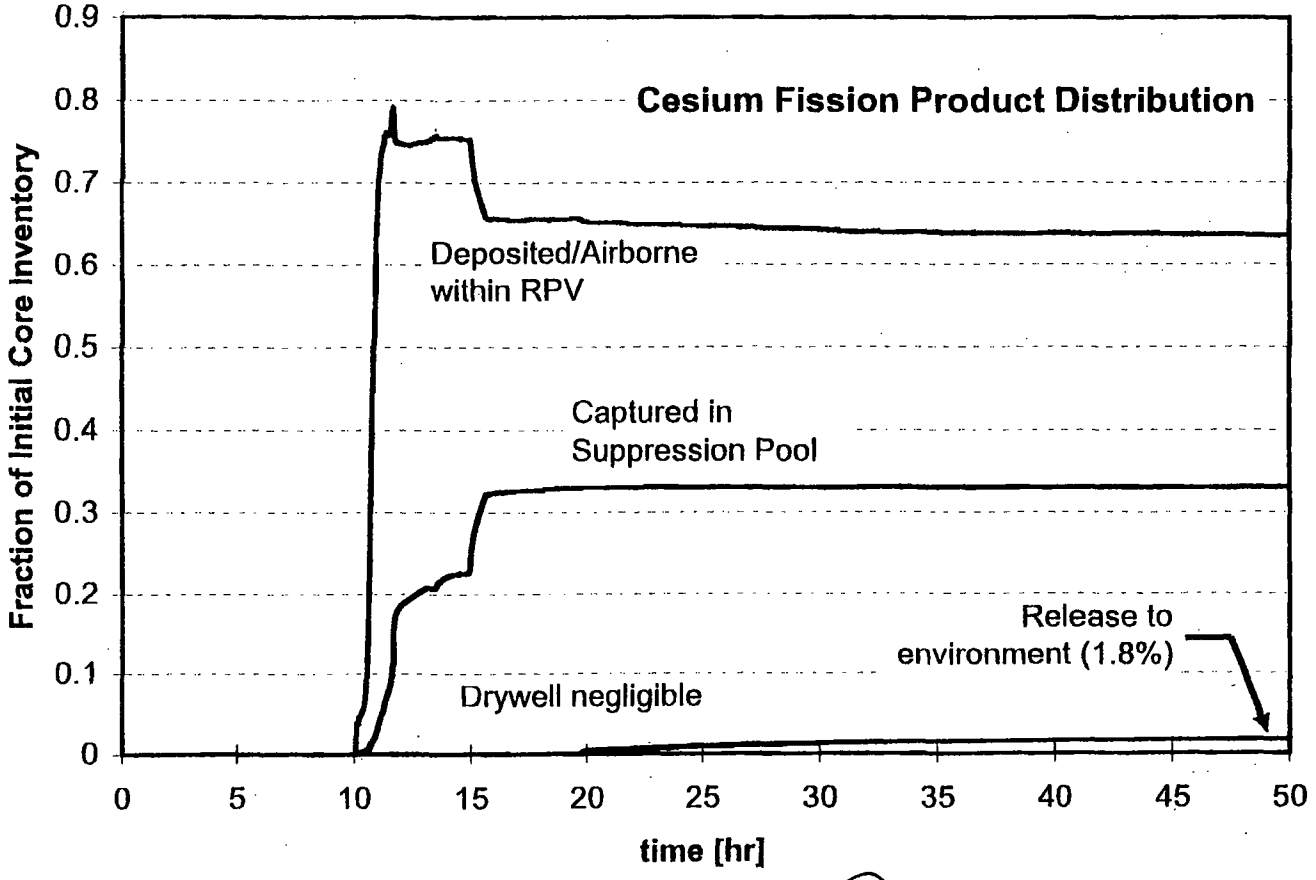
Peach Bottom LTSBO Iodine Release and Transport

No Mitigation with Portable Equipment



Peach Bottom LTSBO Cesium Release and Transport

No Mitigation with Portable Equipment



Peach Bottom LTSBO

No Mitigation with Portable Equipment

- Offsite radioactive release is small
  - 2 – 4 % release of volatiles, except noble gases
  - Release is much less severe than 1982 Siting Study (SST1)
- Accident progression timing and emergency evacuation significantly reduce potential consequences

Peach Bottom LTSBO

No Mitigation with Portable Equipment

- Comparison of consequences to 1982 Siting Study's SST1 release[1]

	Early Fatalities (mean)	Latent Cancer Fatalities[2] (mean)
LTSBO (without B.5.b)	0	25
1982 Siting Study	92	2700

1 **Comparison not based on same assumptions, e.g., different EP model used**
2 **SOARCA used dose threshold (5 rem/year, 10 rem lifetime), 1982 Siting Study used LNT**

Peach Bottom Loss of Vital AC Bus E-12

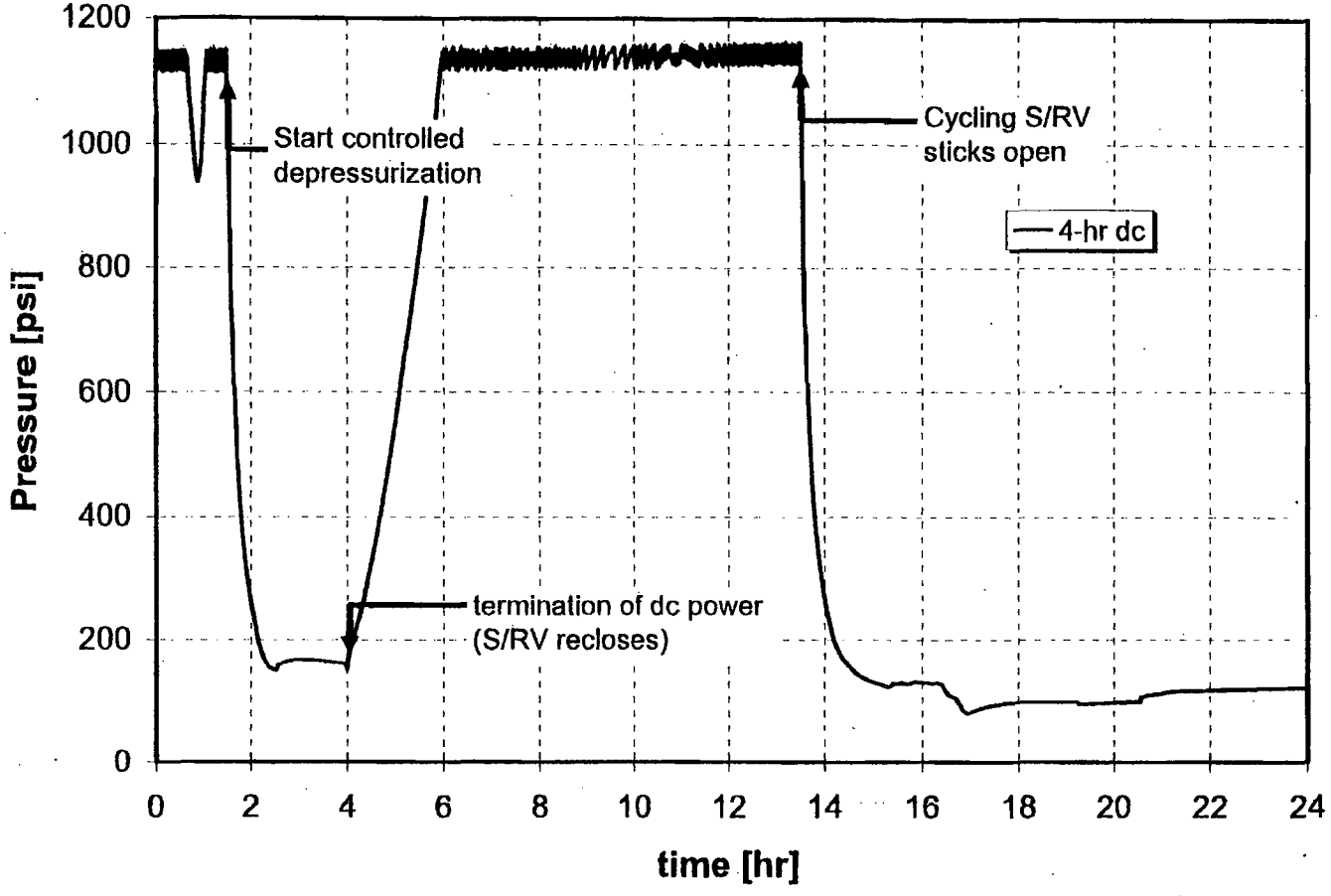
- Initially identified as having CDF>10^{-6}, subsequently determined to be <10^{-6}
- MELCOR analysis showed event to be mitigated without crediting B.5.b equipment

Peach Bottom Loss of Vital AC Bus E-12

- Initiator: Loss of Div IV dc power resulting in
  - SCRAM, MSIV closure, containment isolation
  - RCIC automatically starts, 1 CRDHS pump active
- Operator actions (base case):
  - Load shed to maximize duration of DC power
  - Maximize flow from single CRDHS pump (B.5.b-related)
  - Depressurize RCS at 1.5 hours
  - Secure CRDHS from 4 – 7 hrs to prevent RPV overfill
- Sufficient to prevent core damage

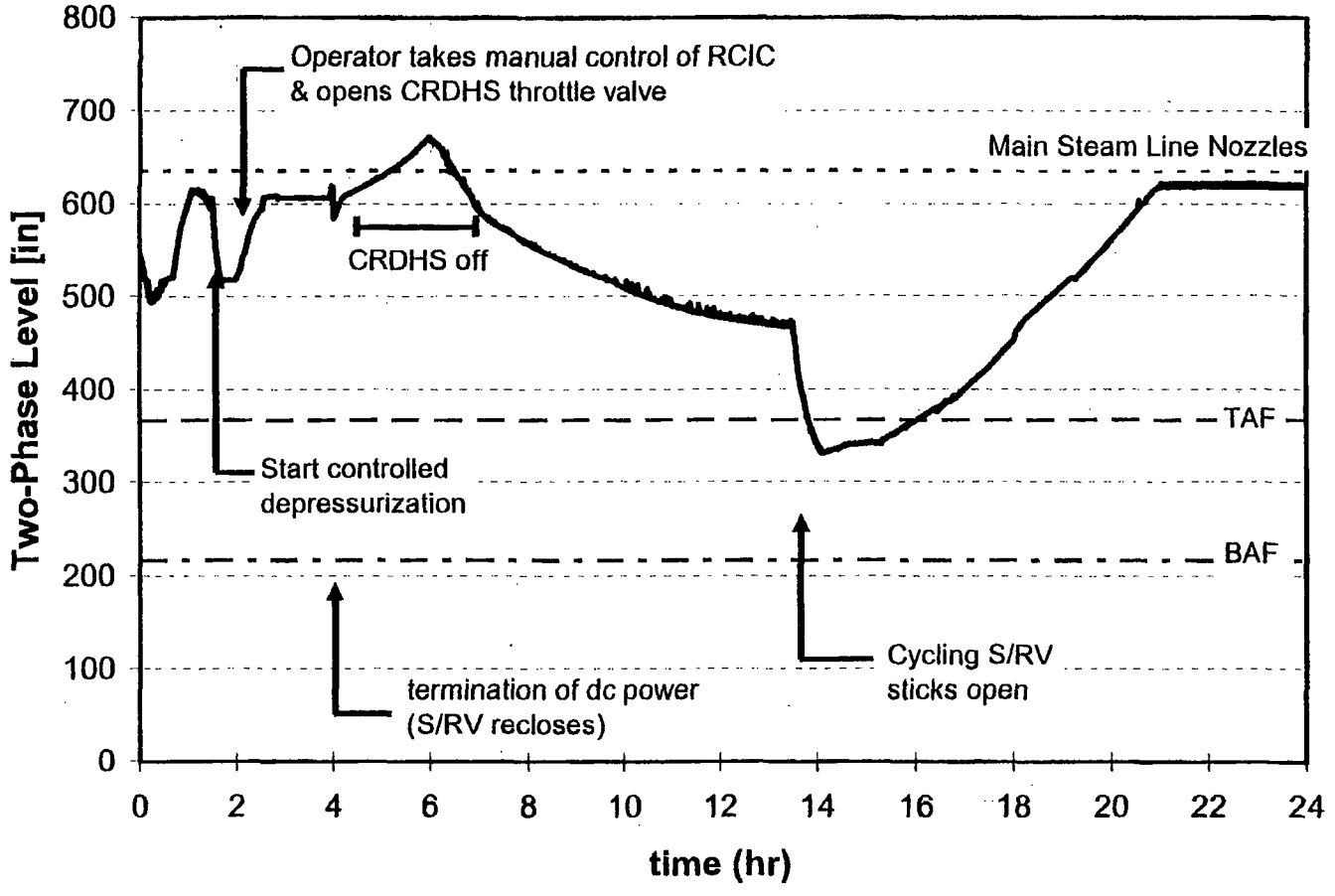
Peach Bottom Loss of Vital AC Bus E-12

Pressure Response



Peach Bottom Loss of Vital AC Bus E-12

Level Response



Peach Bottom Loss of Vital AC Bus E-12

Sensitivities

Sensitivity	RCIC duration	Maximize CRDHS flow[1] (B.5.b)	CRDHS off to prevent RPV overfill	Depressurize[2] (open SRV)	Repressurize (SRV closes)	Results
Baseline	4 hrs	1 hr	4.3 - 7 hrs	1.5 hrs	4 hrs	No CD
CRD Flow	"	Not done	"	"	"	No CD
CRD Flow	"	Not done	Not done	"	"	No CD
Battery life	2 - 6 hrs	Not done	Not done	"	2 - 6 hrs	≥3 hr life averts CD
Depressurize	2 - 6 hrs	Not done	Not done	Not done	N/A	CD, no VF

[1] Increases CRHDS flow from 110 to 140 gpm
[2] Increases CRDHS flow from 110 to 180 gpm

Injection required to replace water lost by boiling at 4 hours ~150 gpm

Peach Bottom Loss of Vital AC Bus E-12
Insights

- Sufficient injection without B.5.b equipment to prevent core damage
  - SPAR does not credit CRDHS for coolant makeup
- RPV depressurization and maximizing CRDHS flow are important operator actions to optimize recovery
- SLC (50 gpm) also available for high pressure injection
- Battery duration is important

Surry Accident Sequences

- Dominant PRA events
  - Long-term SBO ($1x10^{-5}$ to $2x10^{-5}$/yr)
  - Short-term SBO ($1x10^{-6}$ to $2x10^{-6}$/yr)
  - ISLOCA ($7x10^{-7}$/yr)
  - SGTR ($5x10^{-7}$/yr)
- SBO events are due to seismic, flooding and fire initiators, and are modeled as seismic event
  - Internal fire and internal flood events are less challenging, more mitigation available
- ISLOCA and SGTR are due to random equipment failures followed by operator errors

Surry LTSBO

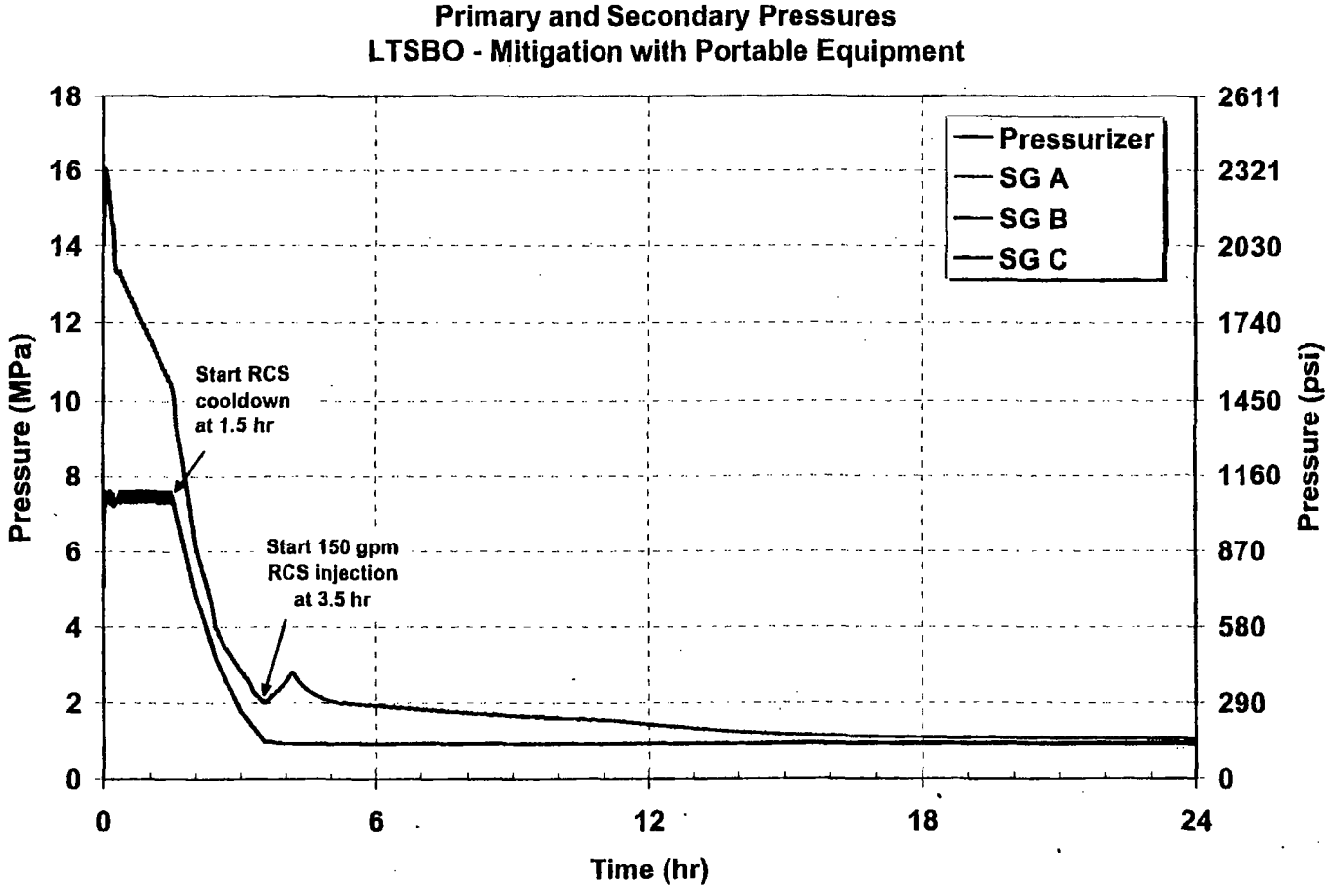
- Initial loss of AC power
- TD-AFW starts automatically to fill SGs
  - At 15 min, operator throttles flow to maintain normal level
- Open SG PORVs for 100 F/hr RCS cooldown
- Batteries exhaust at 8 hrs
- Mitigated
  - Portable equipment used to manage TD-AFW and make up for RCP seal leakage
- Unmitigated
  - After 5 hrs:
    - ECST empty
    - No subsequent actions taken

Surry LTSBO

- B.5.b mitigation
  - Portable air bottles to operate SG PORVs
    - Depressurize and cooldown RCS
  - Portable power supply to restore SG and RCS level indication
  - Manual operation of TD-AFW without dc power
  - Portable diesel-driven high-pressure pump for injecting into the RCS
    - Makeup for RCP seal leakage
  - Portable diesel-driven low-pressure pump for refilling Emergency CST

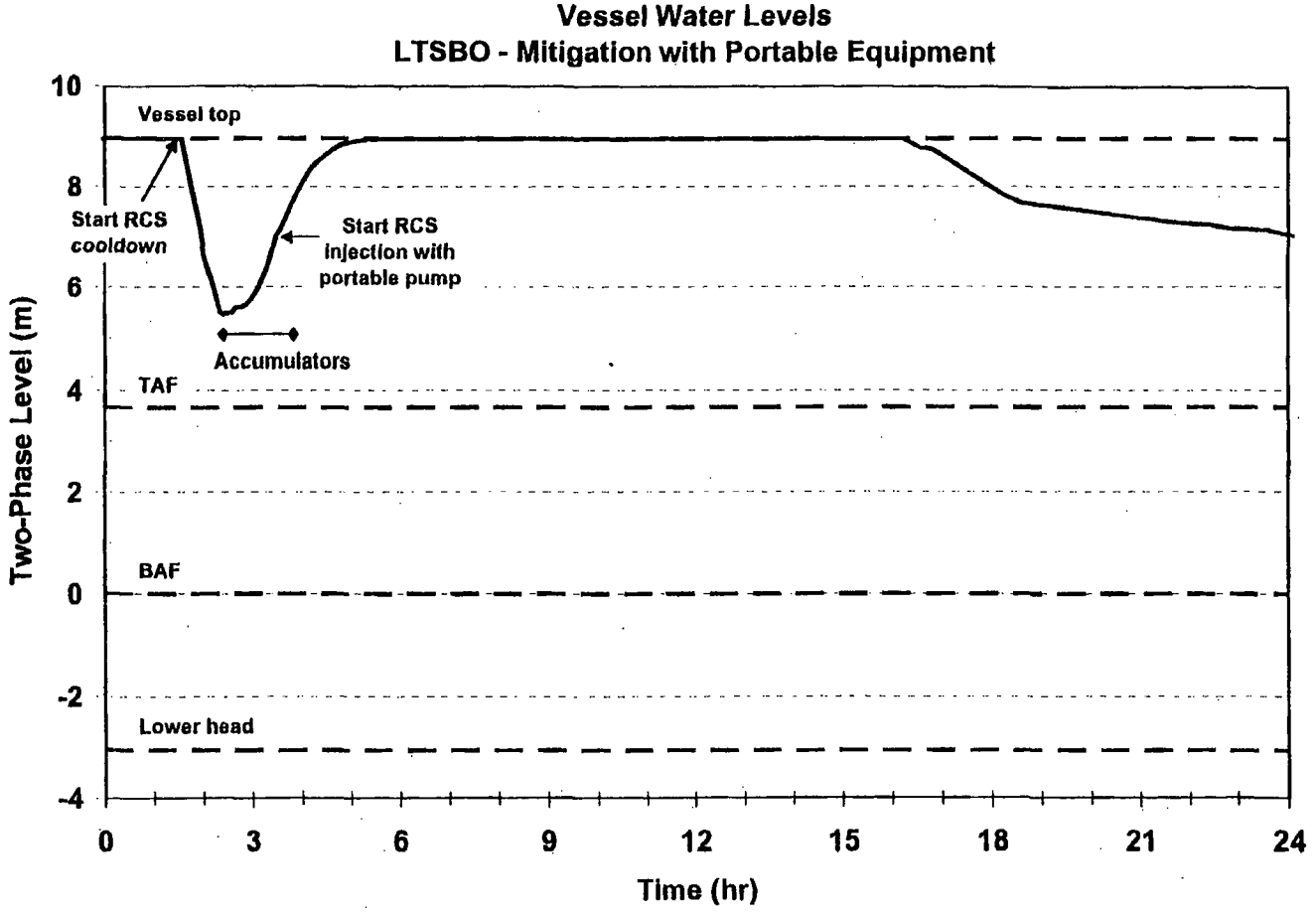
Surry LTSBO Pressure Response

Successful Mitigation with Portable Equipment



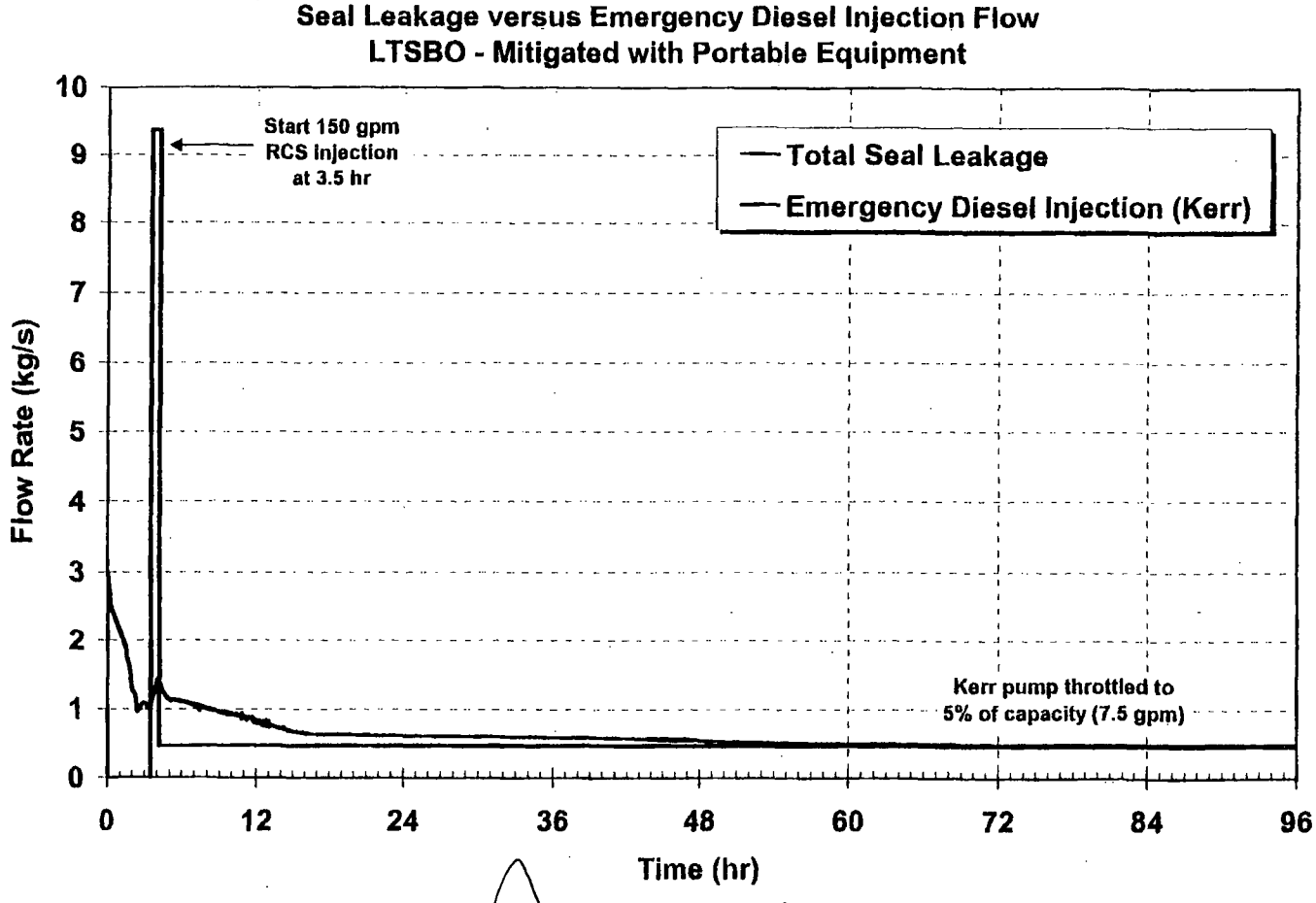
Surry LTSBO Level Response

Successful Mitigation with Portable Equipment



Surry LTSBO Seal Leakage vs Injection Response

Successful Mitigation with Portable Equipment



Surry LTSBO

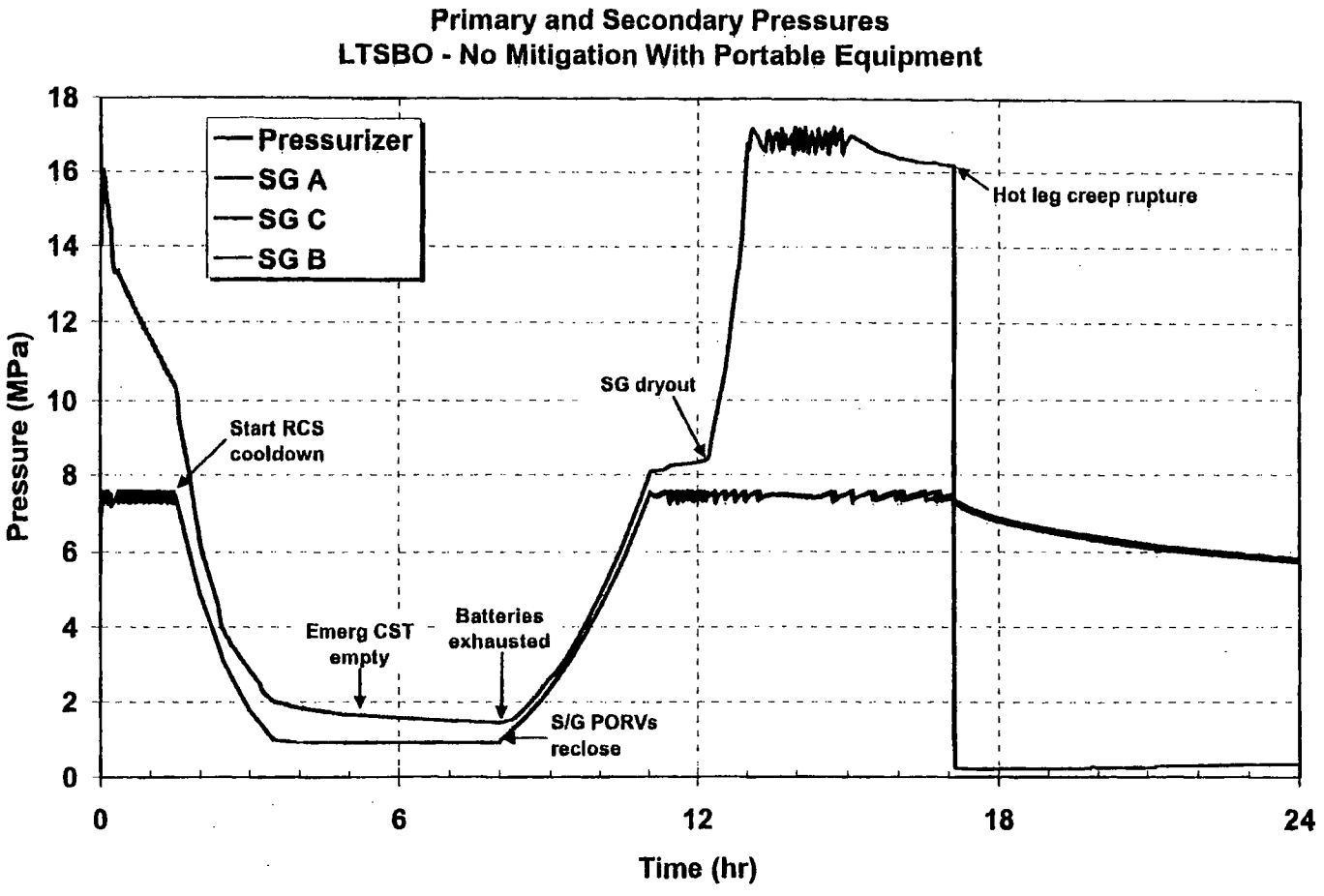
- B.5.b mitigation is sufficient to prevent core damage
  - No source term
  - No offsite health consequences

Surry Mitigative Measures Sensitivity Analysis

- Long-term SBO – without B.5.b mitigation
  - Loss of offsite and onsite AC power
  - TD-AFW starts automatically to fill SGs
    - At 15 min, operator throttles flow to maintain normal level
  - Open SG PORVs for 100 F/hr RCS cooldown
  - TD-AFW lost at 5 hours (Emergency CST empty)
  - Batteries exhaust at 8 hours
- Accident progression
  - Core damage at 16 hrs
  - Containment failure at 45 hrs (increased containment leakage)
  - Public evacuation begins at 2.5 hrs

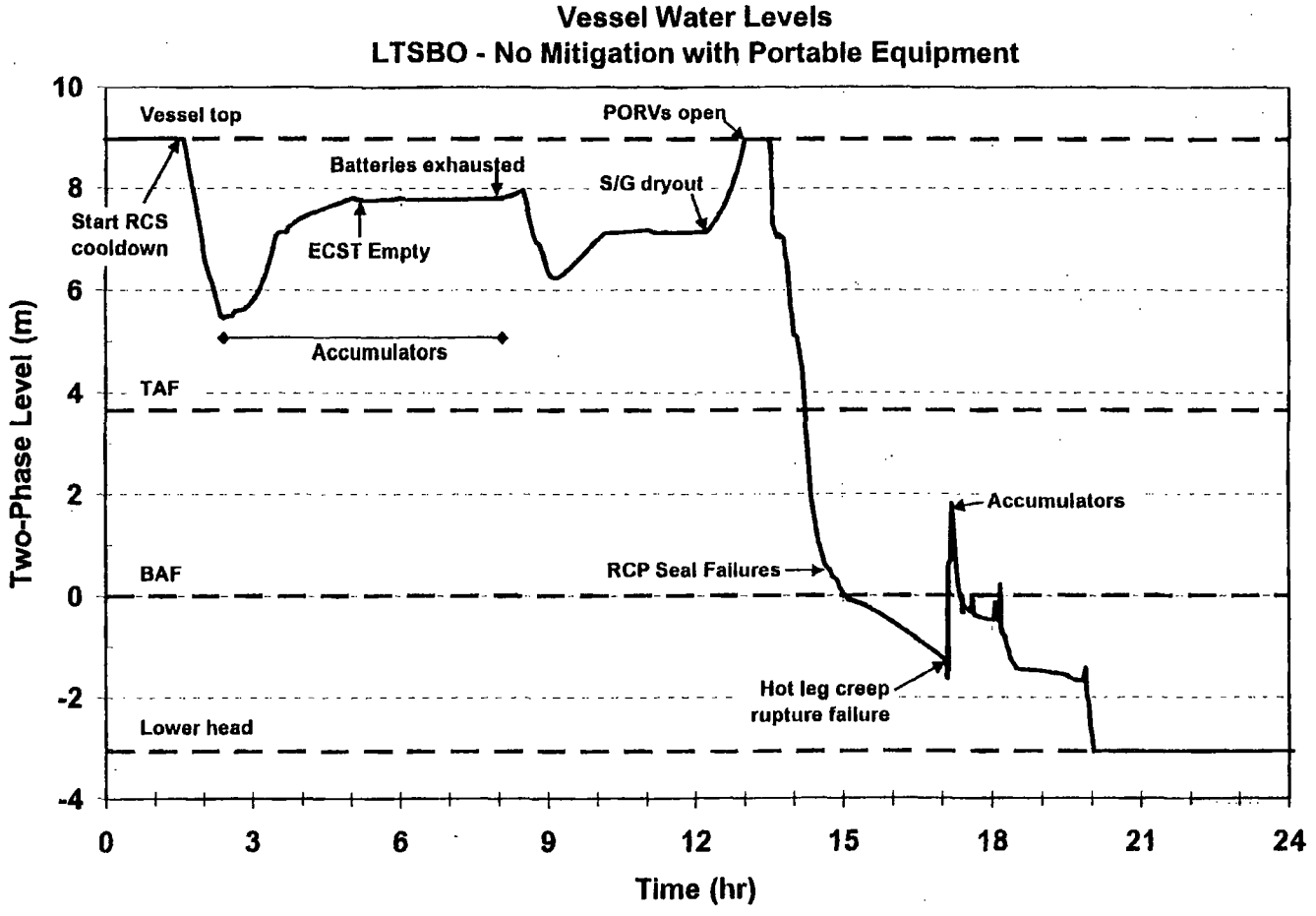
Surry LTSBO Pressure Response

No mitigation with Portable Equipment

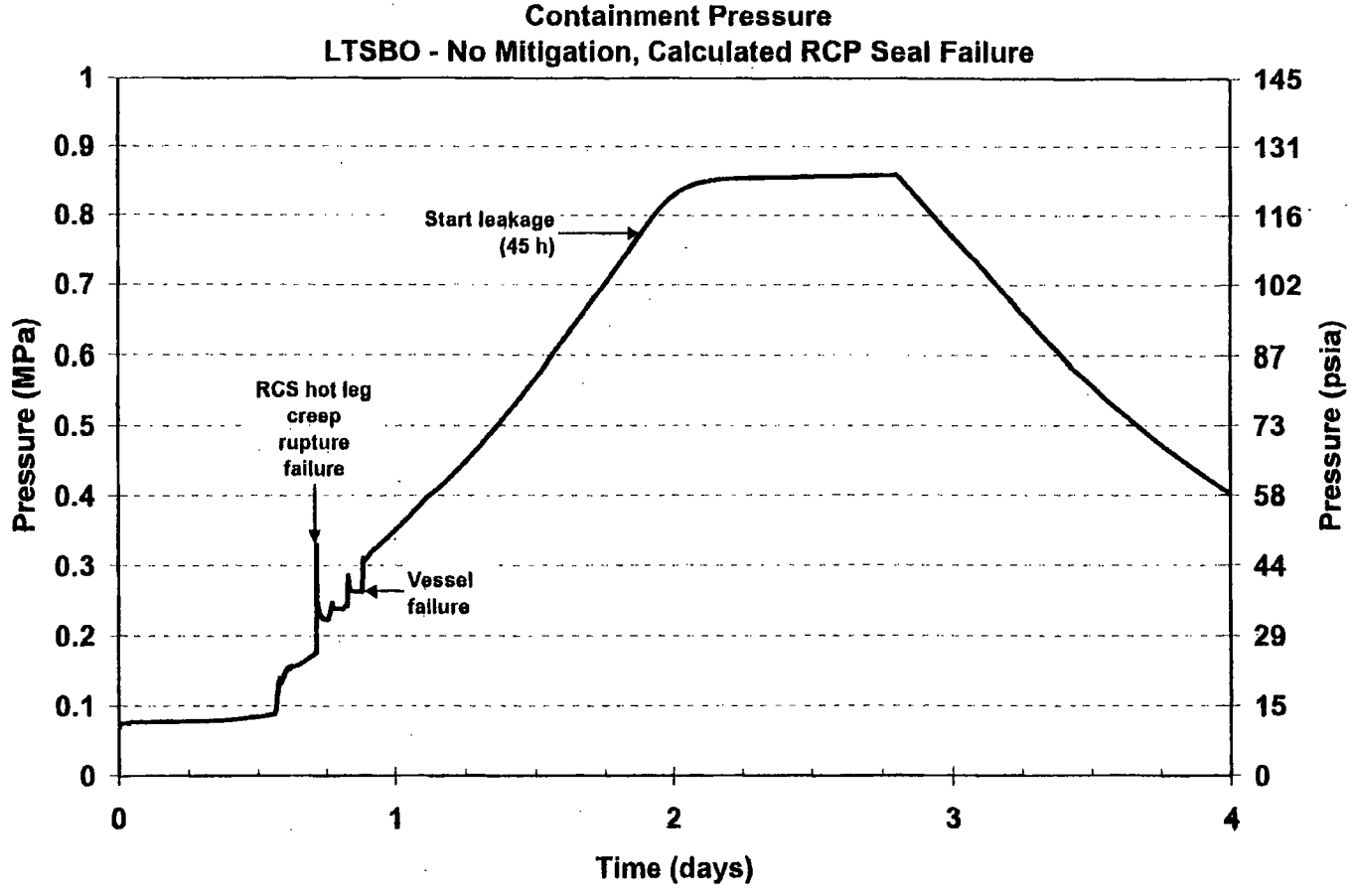


Surry LTSBO Level Response

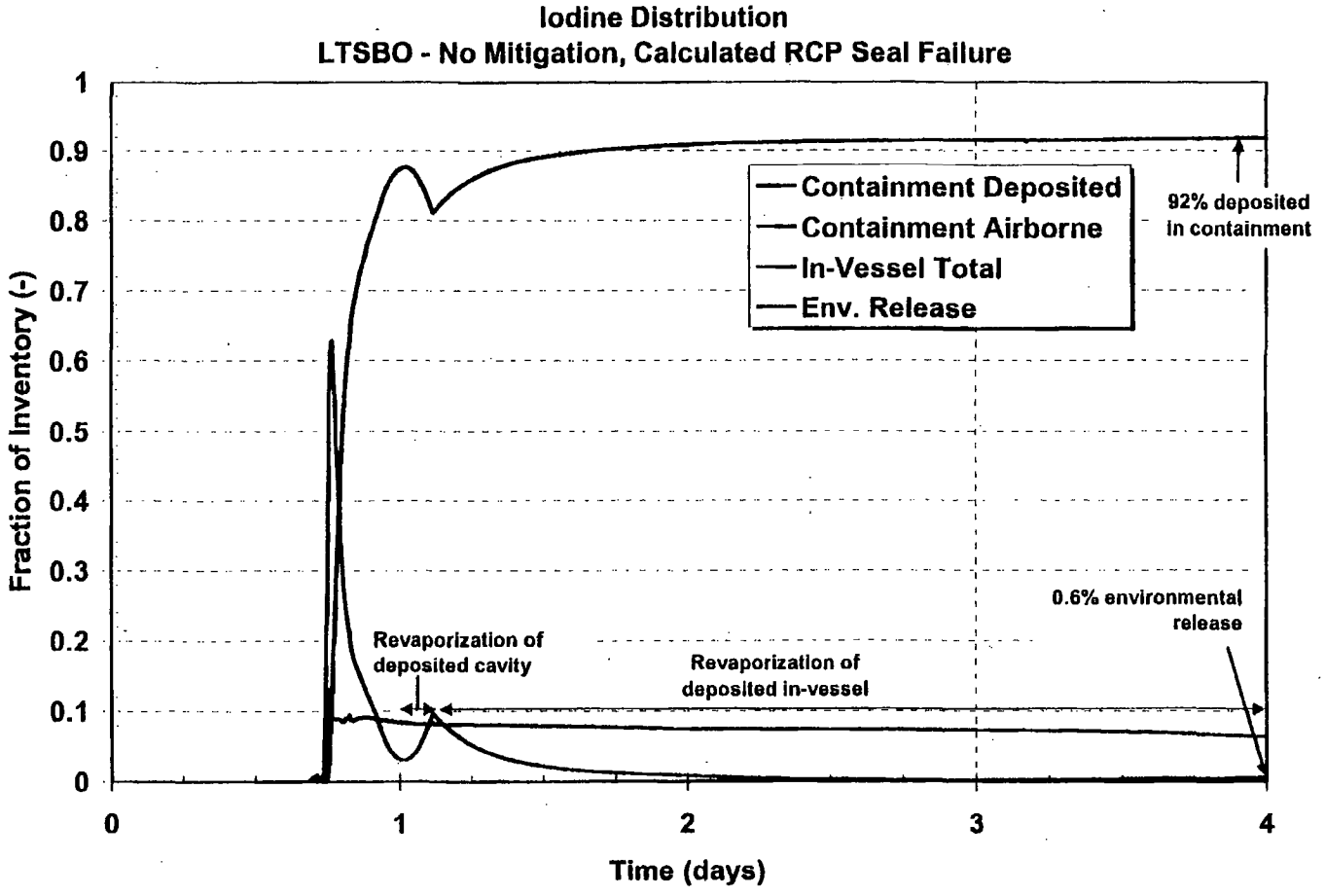
No mitigation with Portable Equipment



Surry LTSBO Containment Pressure Response
No mitigation with Portable Equipment

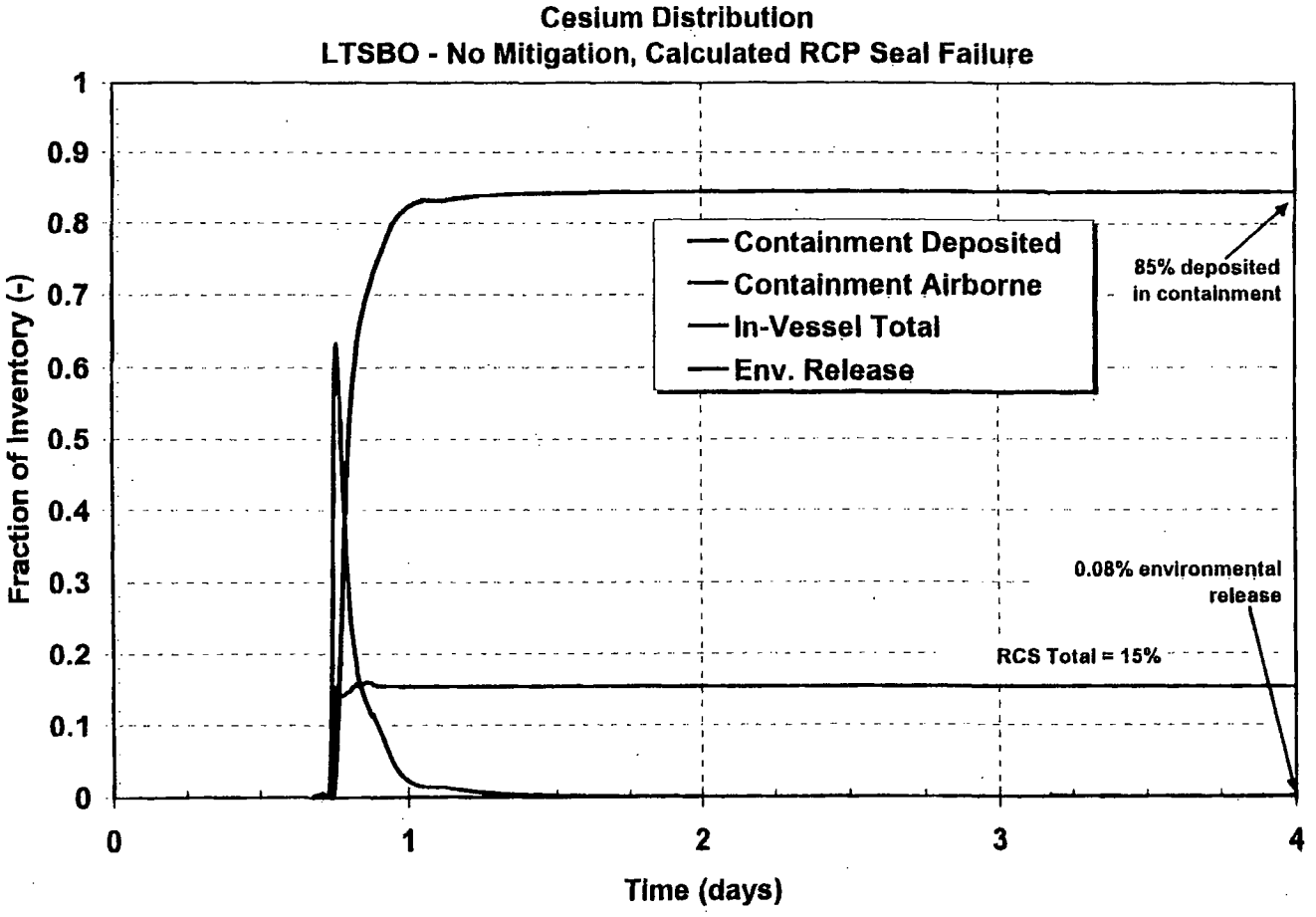


Surry LTSBO Iodine Release and Transport
No mitigation with Portable Equipment



Surry LTSBO Cesium Release and Transport

No mitigation with Portable Equipment



Surry STSBO

- Loss of offsite and onsite AC and DC power
- Mechanical failure of TD-AFW
- No instrumentation or injection

- Mitigated
  - At 8 hrs, portable pump connected to spray system

- Unmitigated
  - No action taken

Surry STSBO

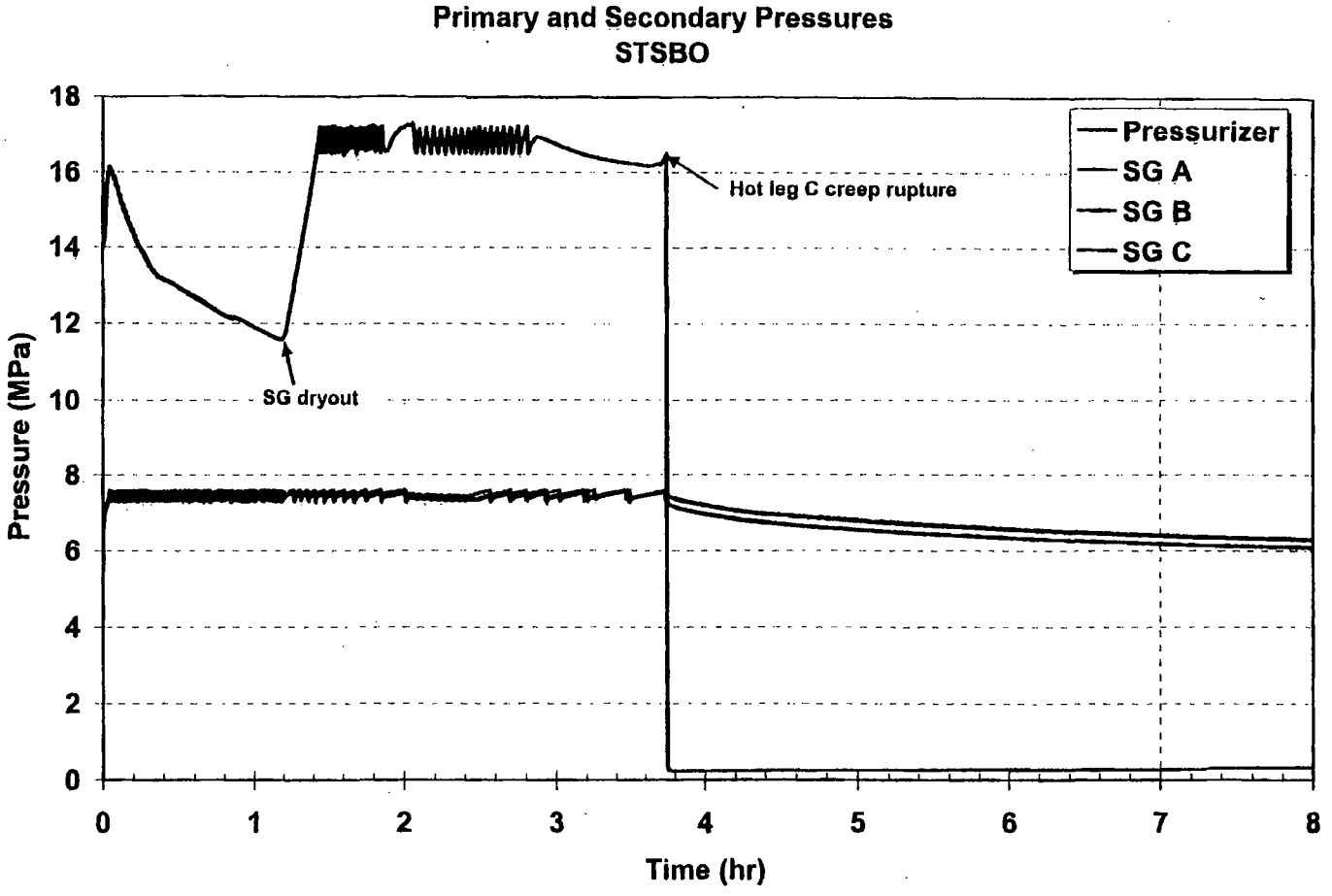
- B.5.b mitigation
  - SG and RCS injection with portable pump may not be practical due to accident progression timing and earthquake severity
    - Core damage at 3 hrs
    - Reactor vessel lower head failure at 7 hrs
  - Portable pump (2000 gpm) assumed to be connected to containment spray system at 8 hrs

Surry STSBO

- Emergency containment sprays
  - Portable pump assumed to run until containment filled to 1 m above the bottom of the vessel (1 million gallons)
  - Ex-vessel debris subsequently boils water in cavity
    - Late containment overpressure at 3 days
    - No airborne aerosol (only noble gas release to environment)
  - Better spray operation possible
    - Intermittent
    - More water

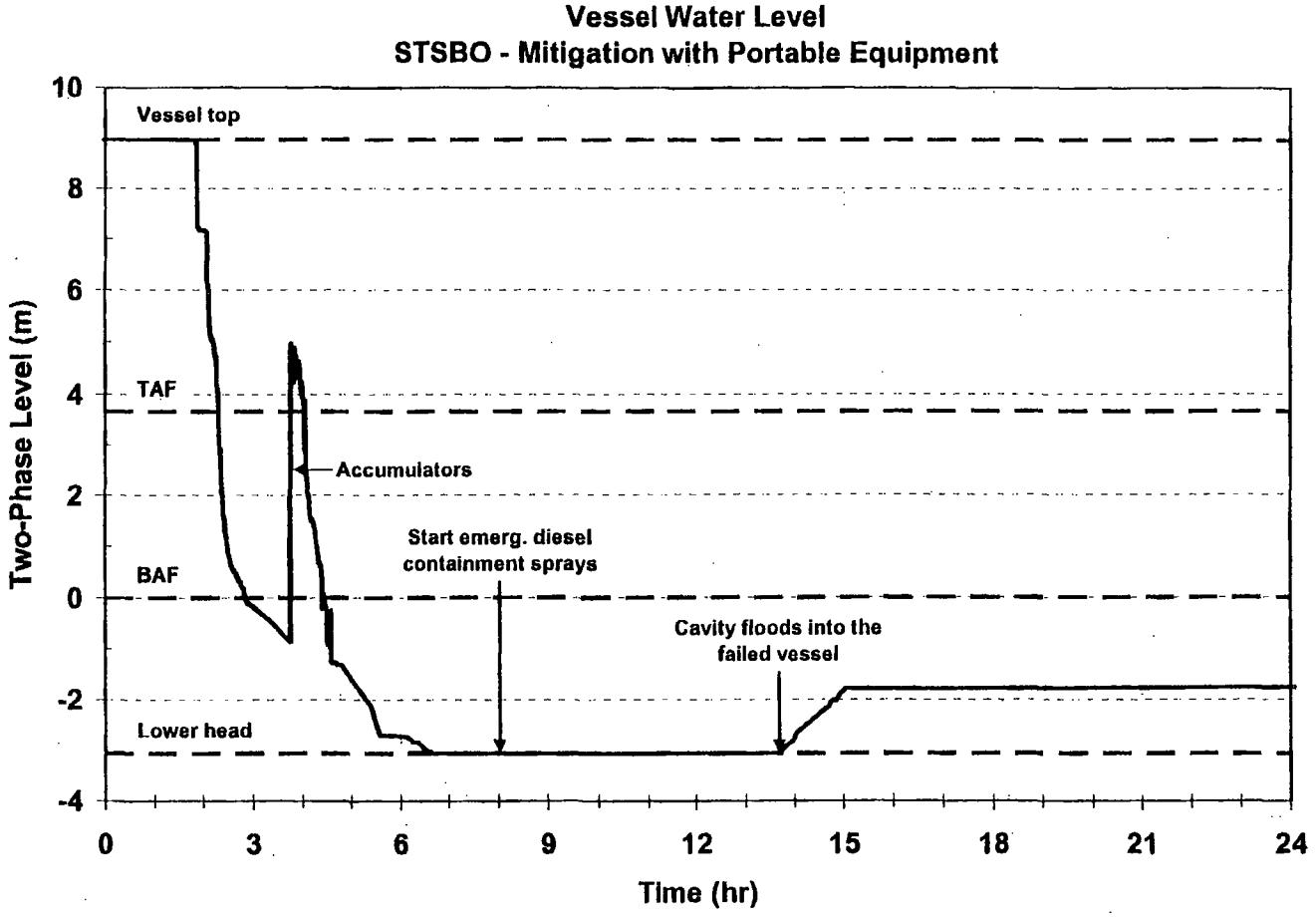
Surry STSBO Pressure Response

Mitigation with Portable Equipment



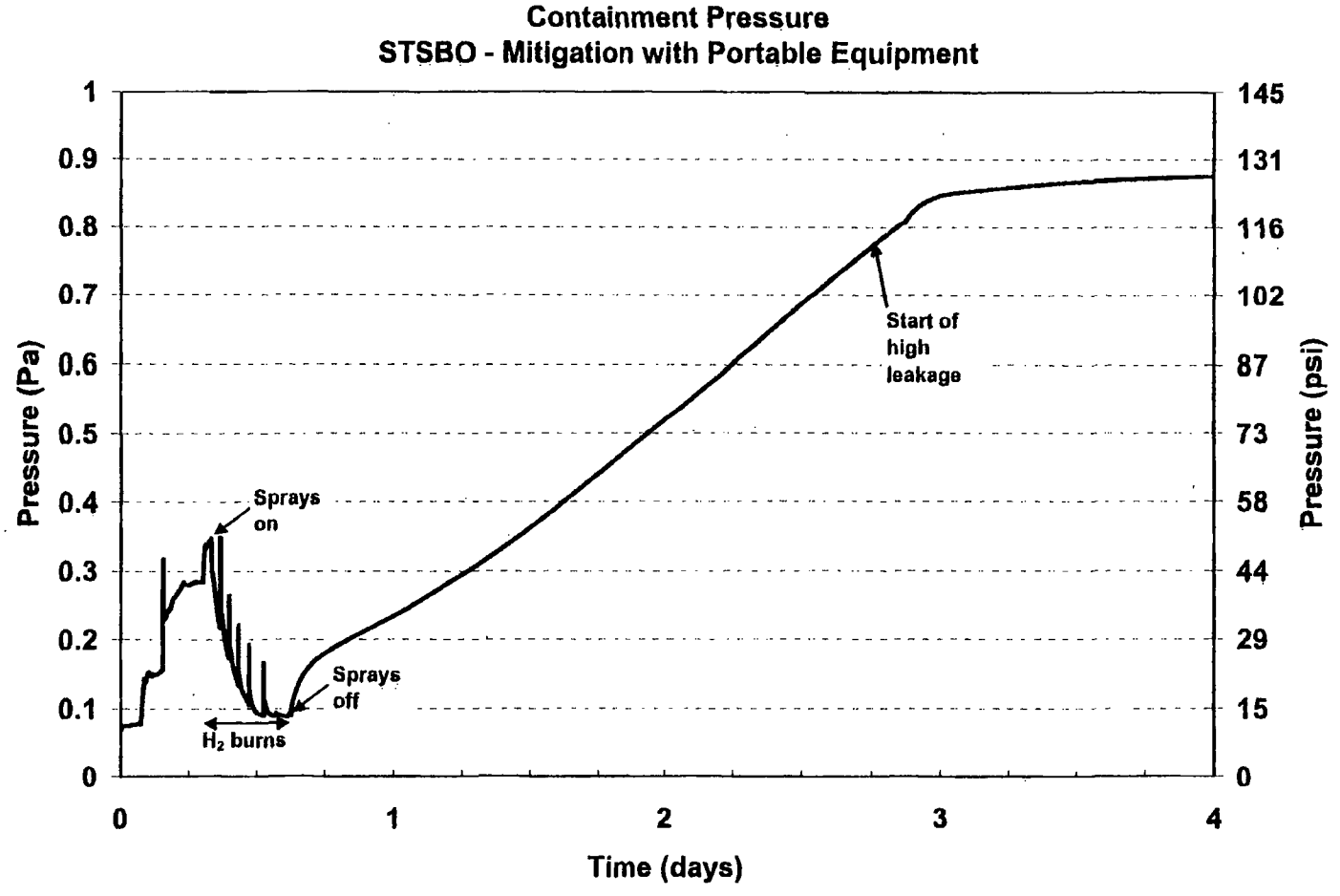
Surry STSBO Pressure Response

Mitigation with Portable Equipment



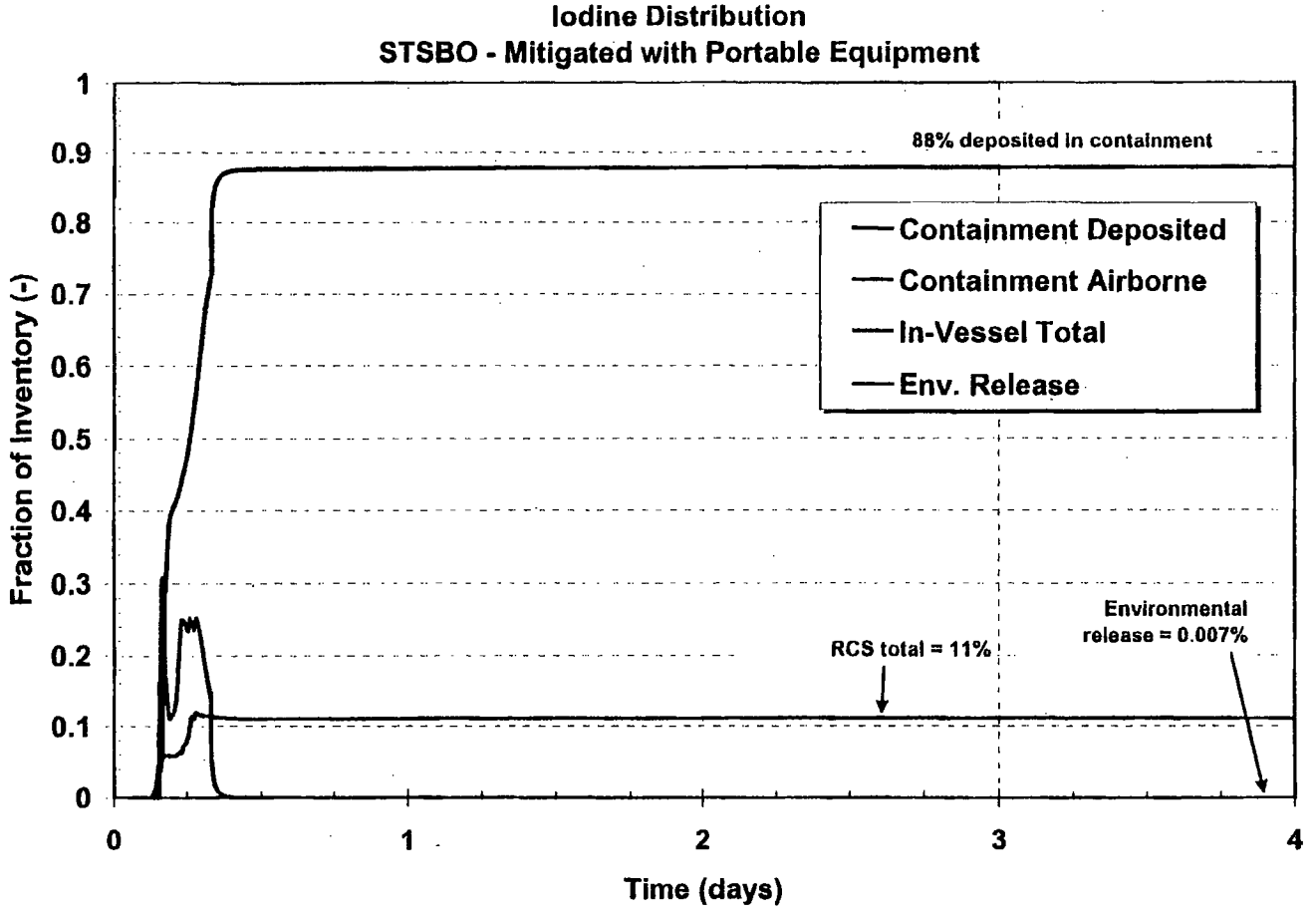
Surry STSBO Containment Pressure Response

Mitigation with Portable Equipment



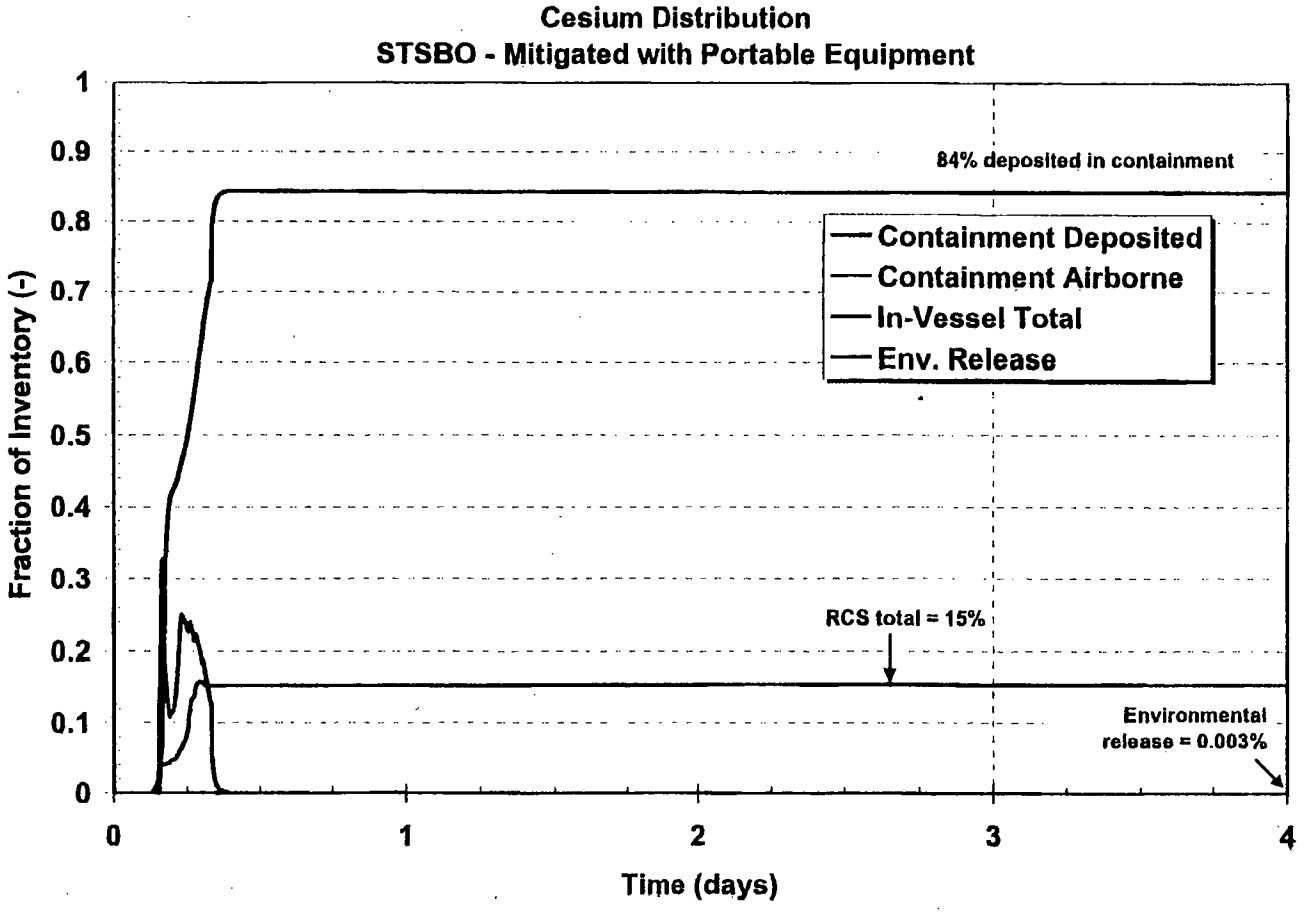
Surry STSBO Iodine Release and Transport

Mitigation with Portable Equipment



Surry STSBO Cesium Release and Transport

Mitigation with Portable Equipment



Surry STSBO

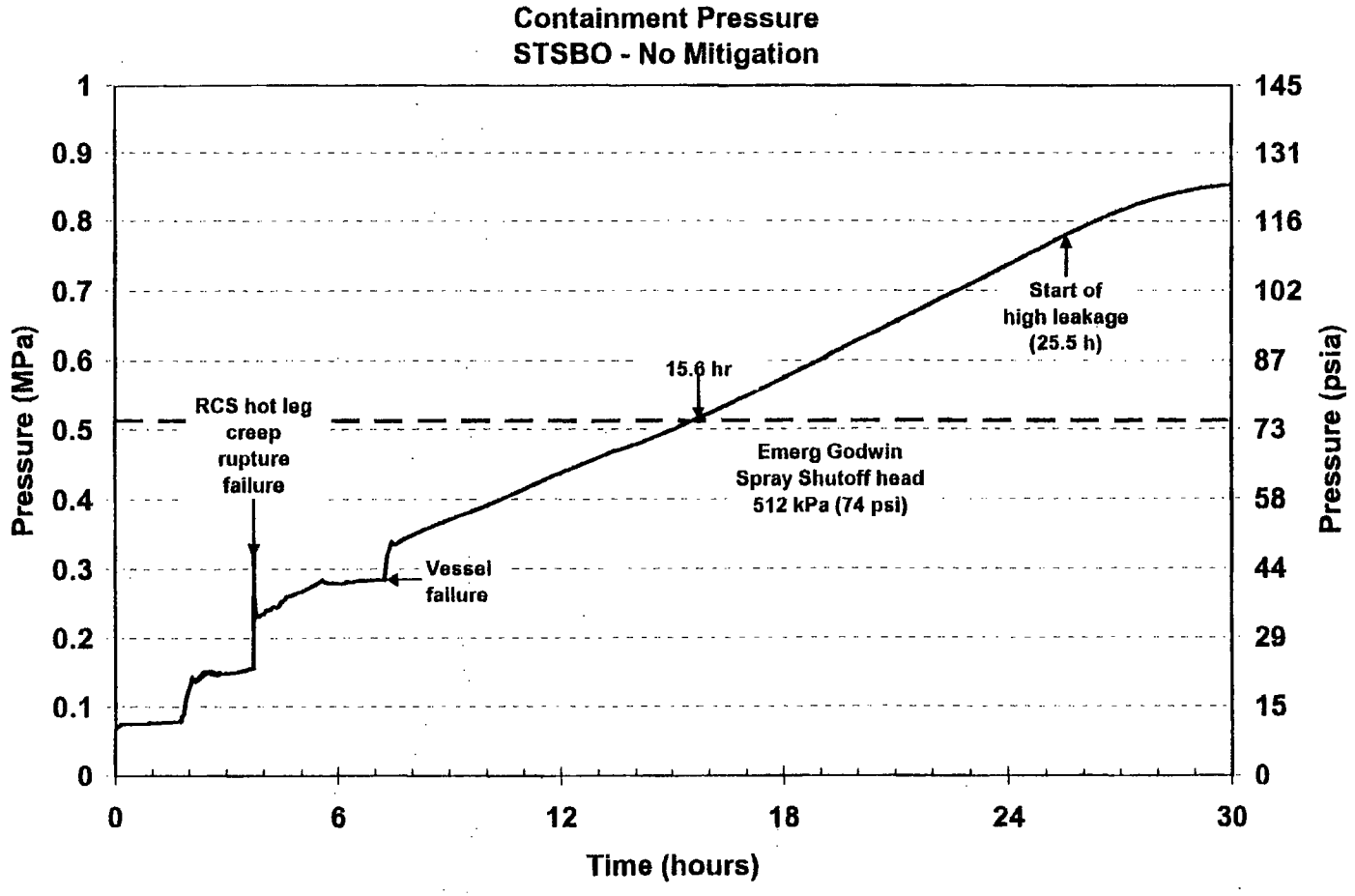
- B.5.b mitigation is sufficient to prevent offsite release (except noble gases)
  - No early fatalities
  - No latent cancer fatalities

Surry Mitigative Measures Sensitivity Analysis

- Short-term SBO – without B.5.b mitigation
  - Loss of offsite and onsite AC and DC power
  - Mechanical failure of TD-AFW
  - No indication or injection
- Accident progression
  - Core damage at 3 hrs
  - Containment failure at 25 hrs
  - Public evacuation begins at 2.5 hrs

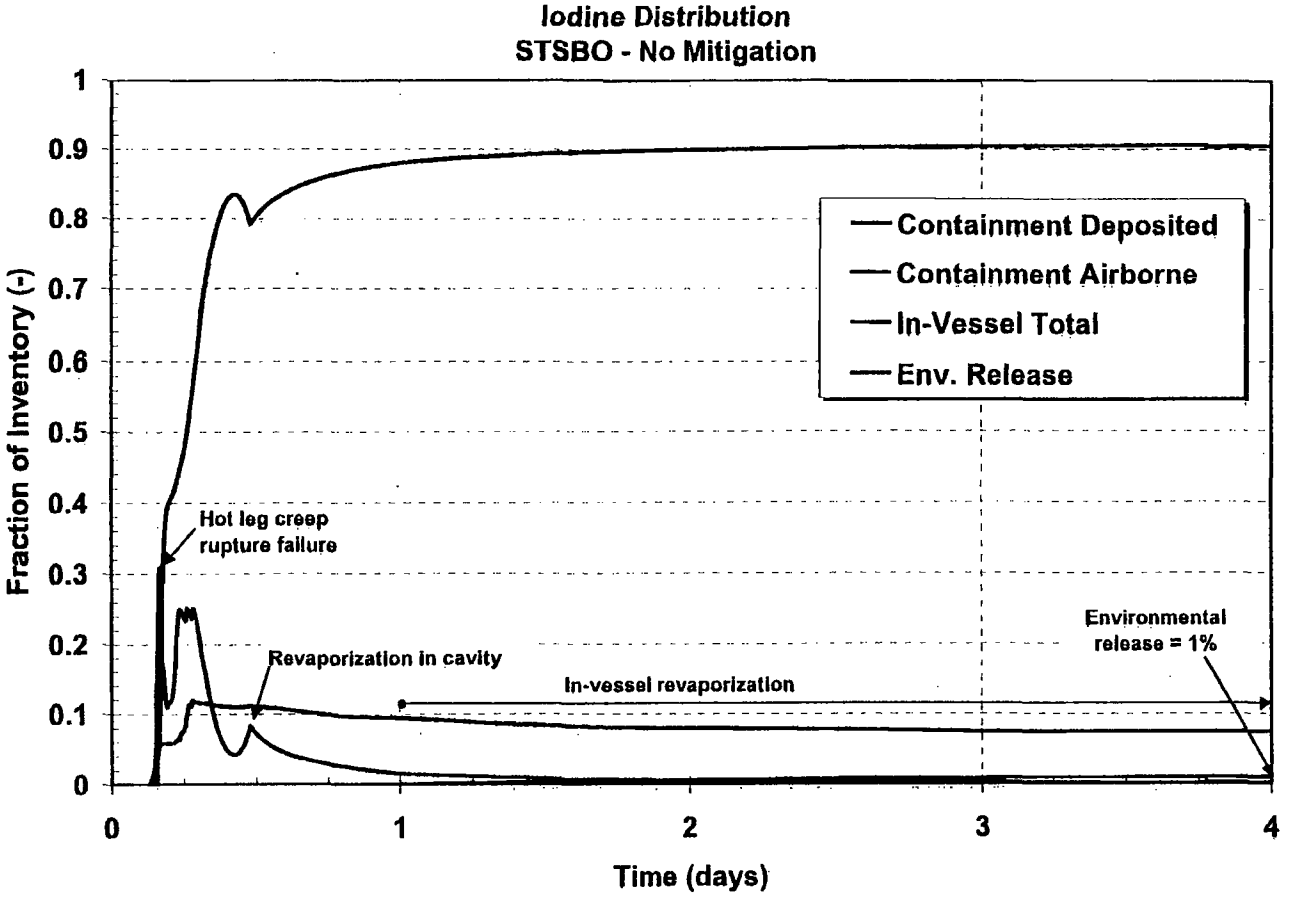
Surry STSBO Containment Pressure Response

No Mitigation with Portable Equipment



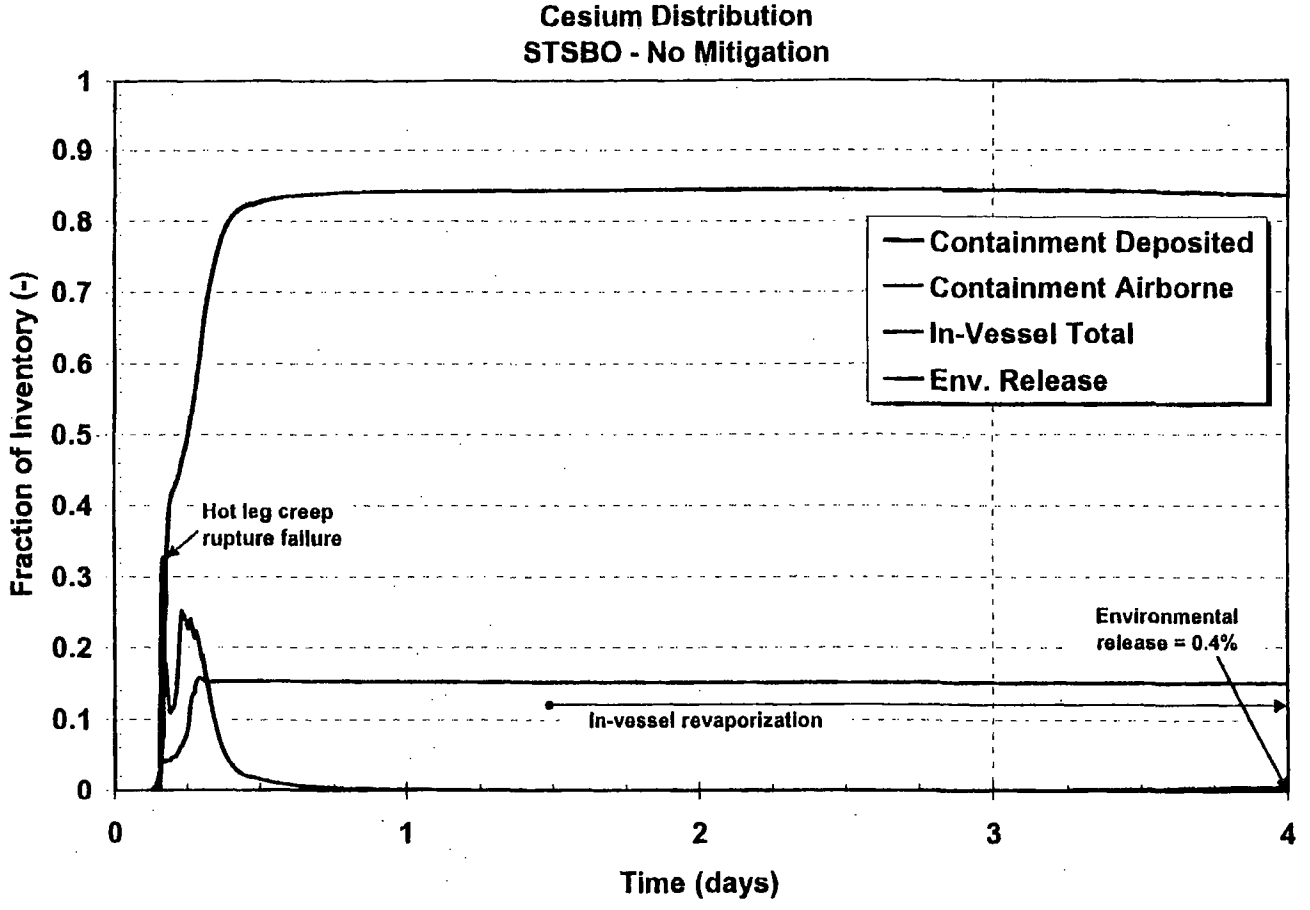
Surry STSBO Iodine Release and Transport

No Mitigation with Portable Equipment



Surry STSBO Cesium Release and Transport

Mitigation with Portable Equipment



Surry LTSBO and STSBO

No Mitigation with Portable Equipment

- SBO sequences without B.5.b measures have relatively small releases, 1% or less of volatile radionuclides
- Comparison of consequences[1]

	Early Fatalities (mean)	Latent Cancer Fatalities[2] (mean)
LTSBO (without B.5.b)	0	0
STSBO (without B.5.b)	0	0
1982 Siting Study	45	1300

1 Comparison not based on same assumptions, e.g., different EP model used

2 SOARCA used dose threshold (5 rem/year, 10 rem lifetime), 1982 Siting Study used LNT

Surry SGTR

- Break of single tube
- Plant response
  - HPI, AFW initiate
  - Turbine stop valves close
  - Steam dump valves throttle and close
  - Faulted SG floods at 40 min
- Operator response
  - AFW delivery to faulted SG secured by operator on high level at 10 min

Surry SGTR

- SPAR: Operator errors result in core damage
  - Fail to depressurize and cool down the RCS
  - Fail to refill RWST or cross-connect to unaffected unit's RWST
  - Fail to isolate faulted SG
- SOARCA mitigation measure review
  - Concluded that, within a couple of hours, the operators with assistance from TSC and EOF would correct errors

Surry SGTR

Mitigation Starts at 2.5 Hrs

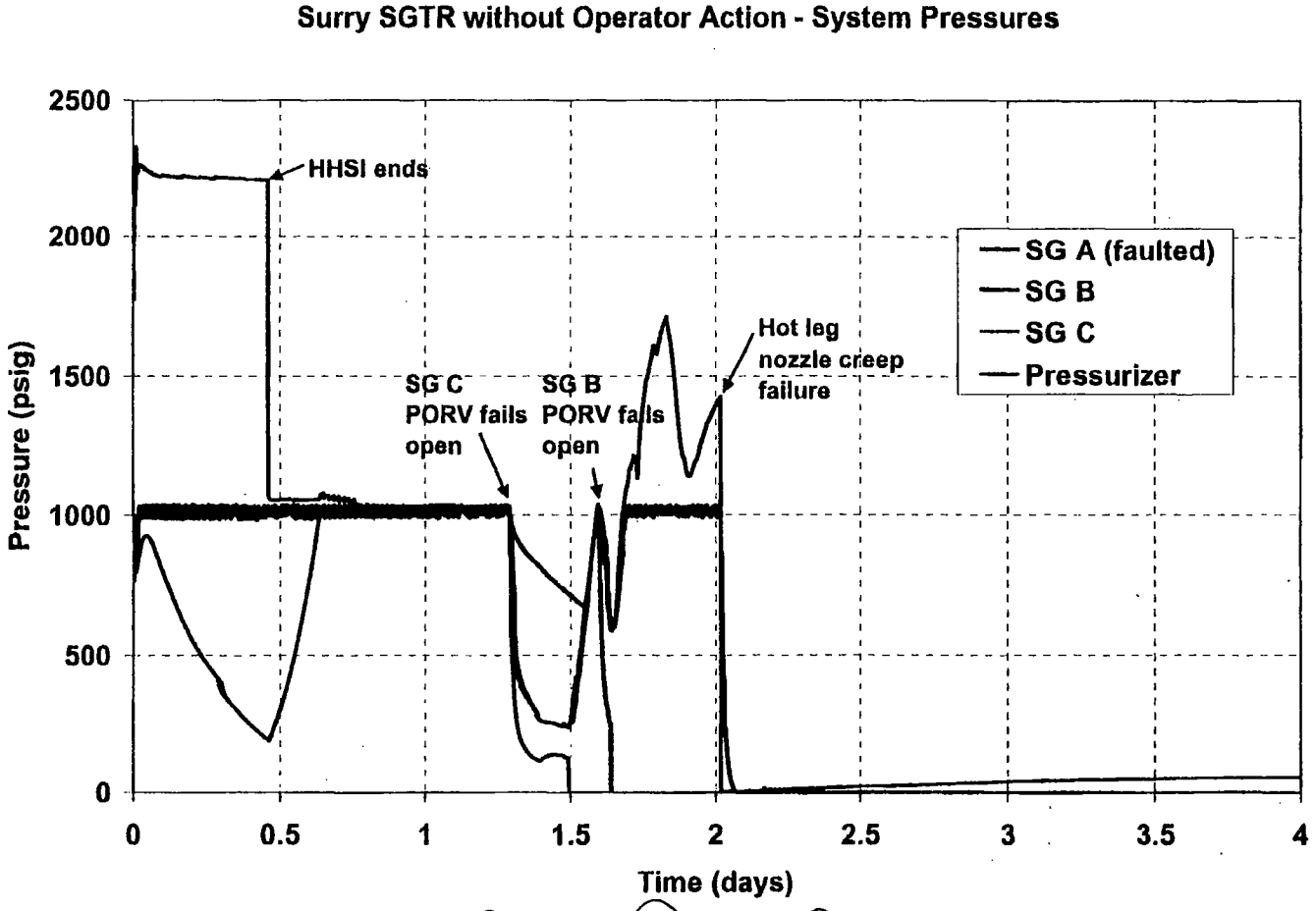
- Assumed operator begins mitigation at 2.5 hrs
  - Operator recognizes SGTR occurred
    - SG floods at 40 min even though AFW is secured to that SG
  - Operator actions
    - Isolate faulted SG (close MSIV)
    - Secure HHSI
    - Initiate controlled cool-down (100 deg F/hr) utilizing intact SGs and steam dump valves
    - Enter RHR at 4 hrs
- MELCOR analysis showed no core damage

Surry SGTR
No Mitigation

- Accident progression
  - RWST empty at 11 hrs
  - ECST empty at 1.5 days
  - Core damage at 2 days

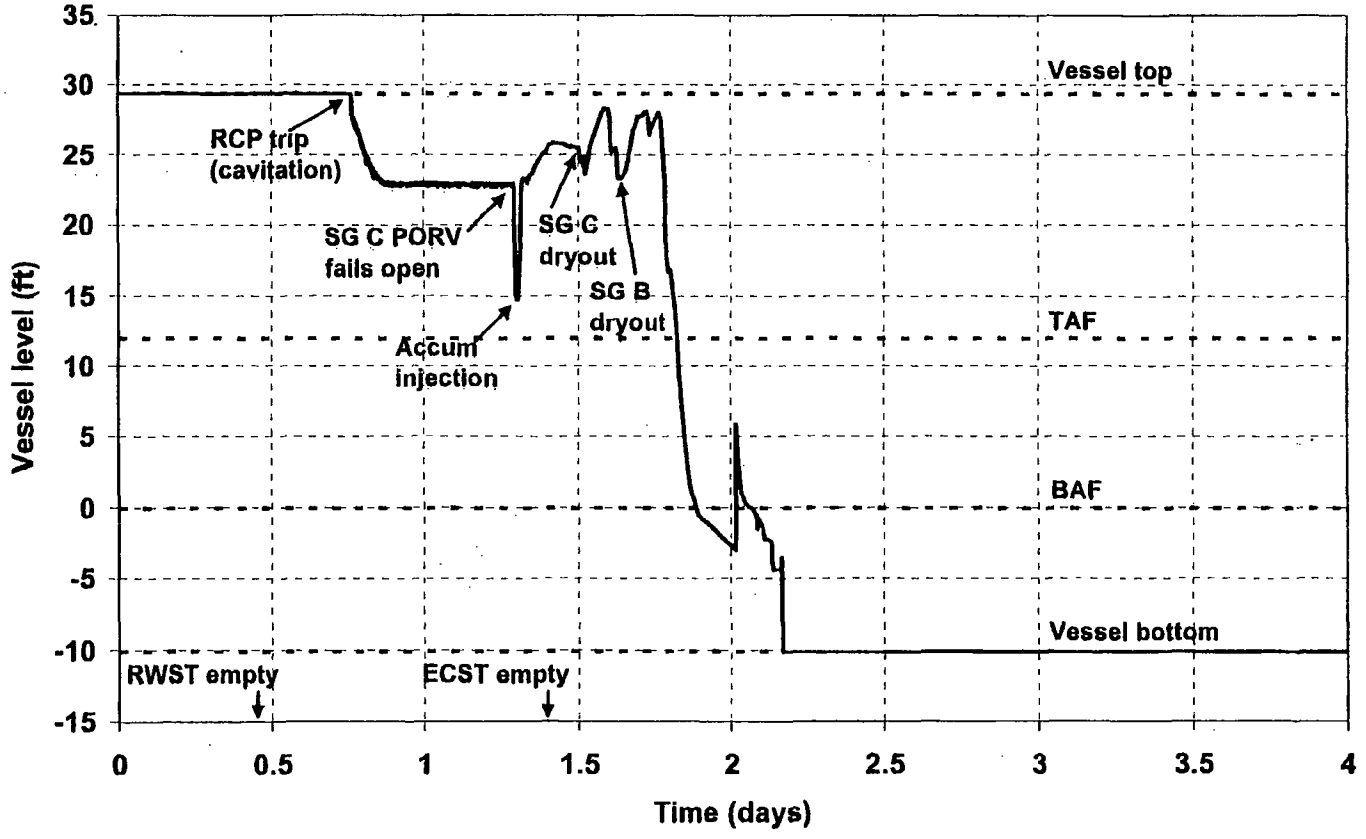
Surry SGTR Pressure Response

No Mitigation



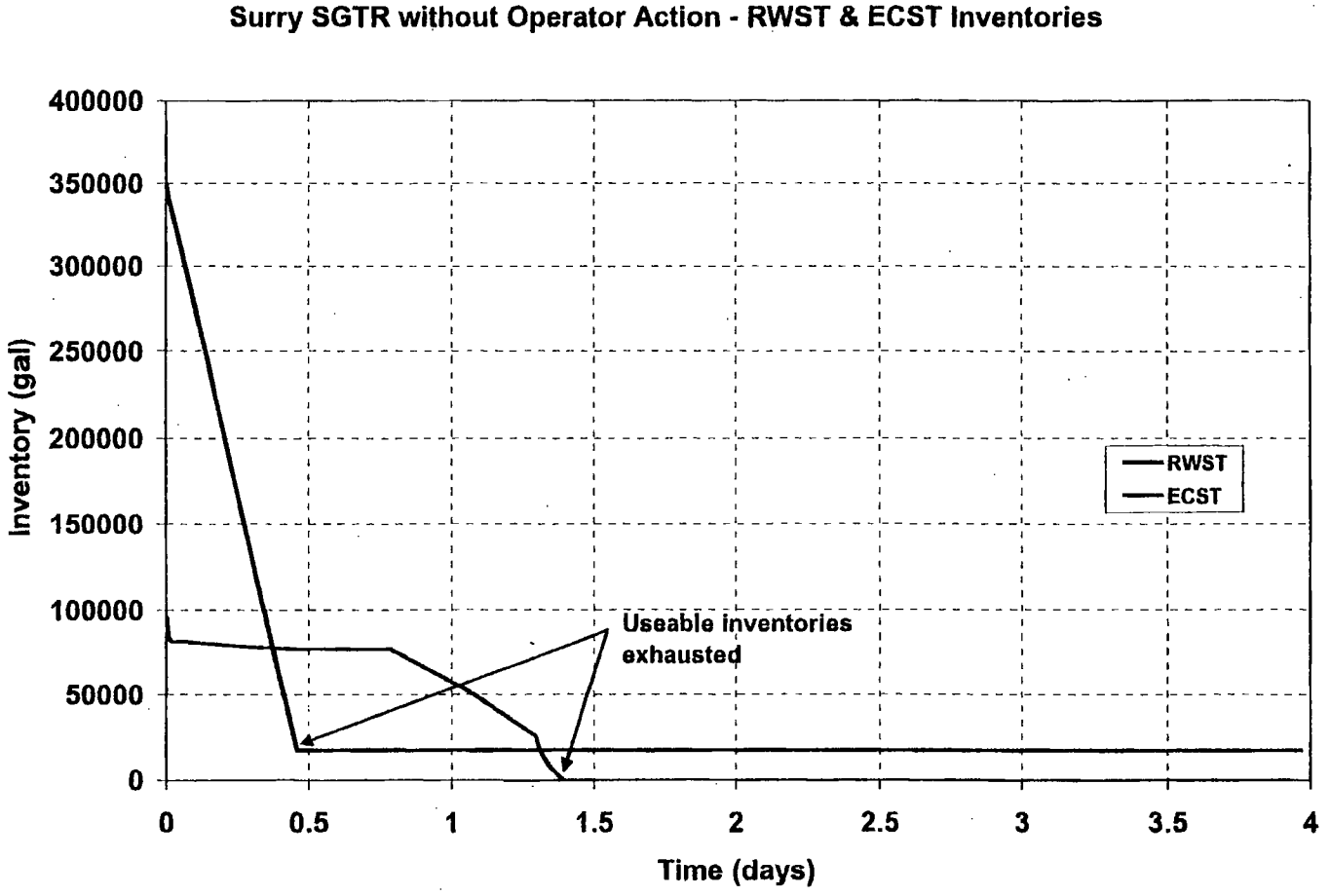
Surry SGTR Vessel Level Response

No Mitigation



Surry SGTR RWST Inventory Response

No Mitigation



Surry SGTR
No Mitigation

- Sensitivity: SG PORV on faulted SG sticks open due to overfill and water passing through valve
  - Accident progression
    - RWST empty at 9 hours
    - Core damage at 1 day

Surry SGTR – Insights

- MELCOR analysis indicates that operators and others (TSC, EOF) have time to correct errors
  - Event can be mitigated with installed (non-B.5.b) equipment
  - Other mitigation options exist
    - Refill RWST or cross-connect to unaffected unit's RWST
    - Use B.5.b pumps to feed RCS and steam generators
- Unmitigated cases have 1 to 2 day delay until core damage
  - Suggests unmitigated case is unrealistic

Surry ISLOCA

- Failure of LPI check valves' disks resulting in LPI pipe break in Safeguards Bldg
- Plant response
  - HPI, LPI, AFW initiate
  - 2/3 of HPI goes into cold legs, 1/3 goes out break
  - LPI pumps stop due to Safeguards Bldg flooding
    - Subsequently, RWST gravity drains through break
- Operator response
  - Per procedures, secure 1 HPI pump at 15 min
  - Shift HPI to hot legs at 45 min
  - Open SG PORVs for 100 F/hr RCS cooldown

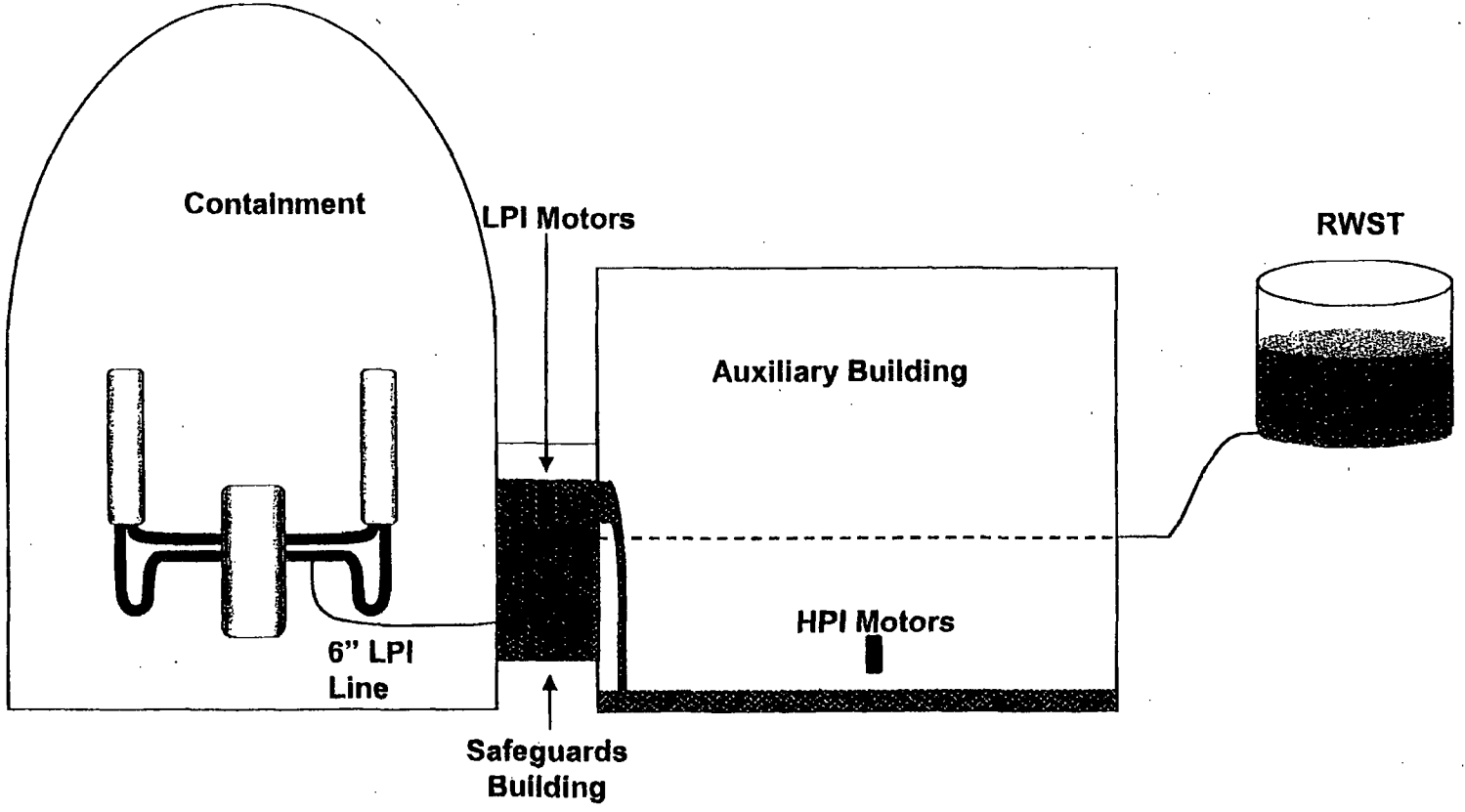
Surry ISLOCA

- SPAR: Operator error results in core damage
  - Fail to refill RWST or cross-connect to unaffected unit's RWST
- SOARCA migitation measure review
  - Concluded that, within a couple of hours, the operators with assistance from TSC and EOF would recognize the need to cross-connect to unaffected unit's RWST

Surry ISLOCA
Mitigation with Unaffected Unit's RWST

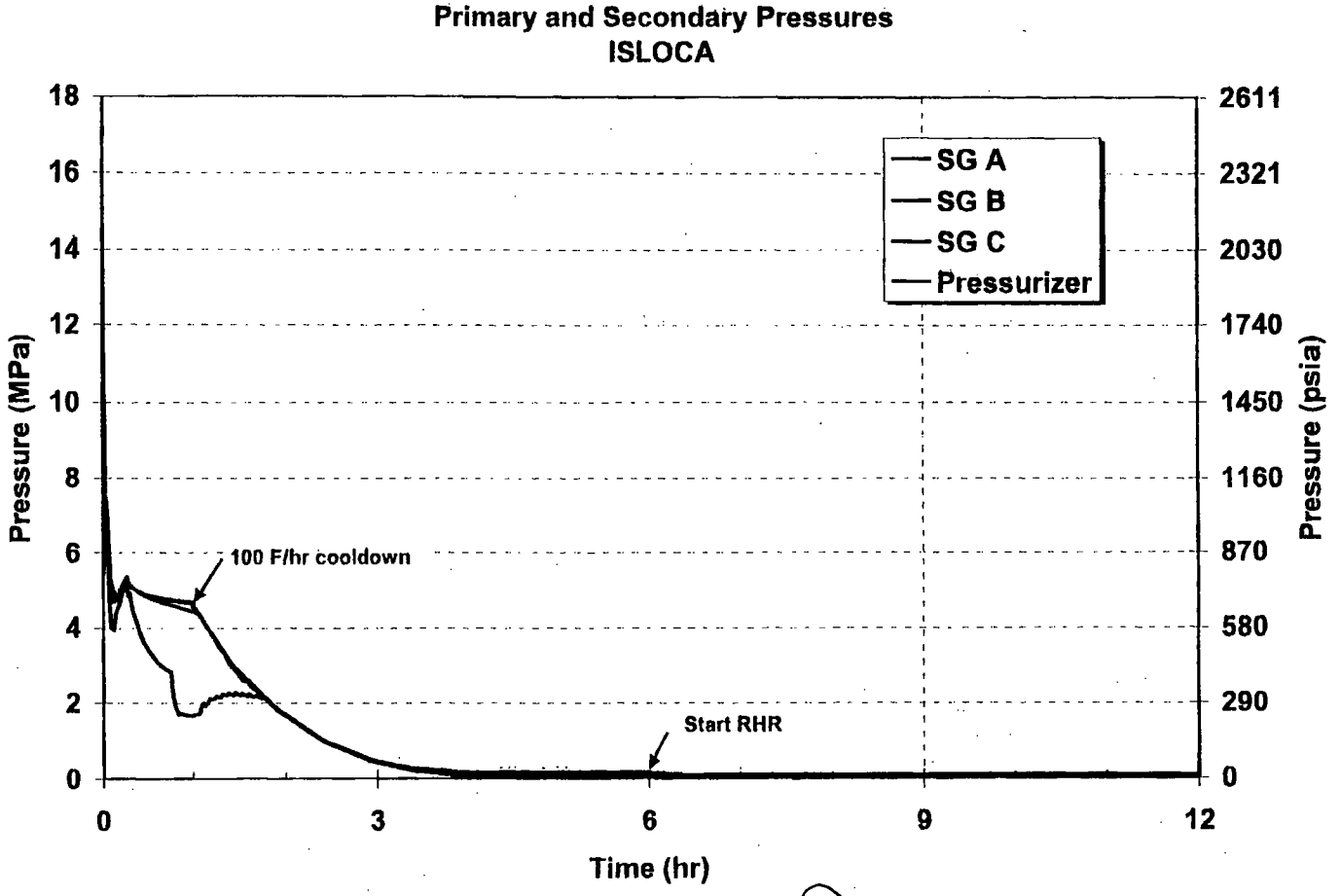
- Operator begins mitigation at 1.75 hours
  - Operator recognizes ISLOCA occurred
    - Flooding in Safeguards Building and Auxiliary Building
    - Initiation of safety injection
  - Cross-connect to unaffected unit's RWST at 1.75 hrs
  - Start RHR cooling at 6 hrs
- MELCOR analysis showed no core damage

Surry ISLOCA Geometry Schematic



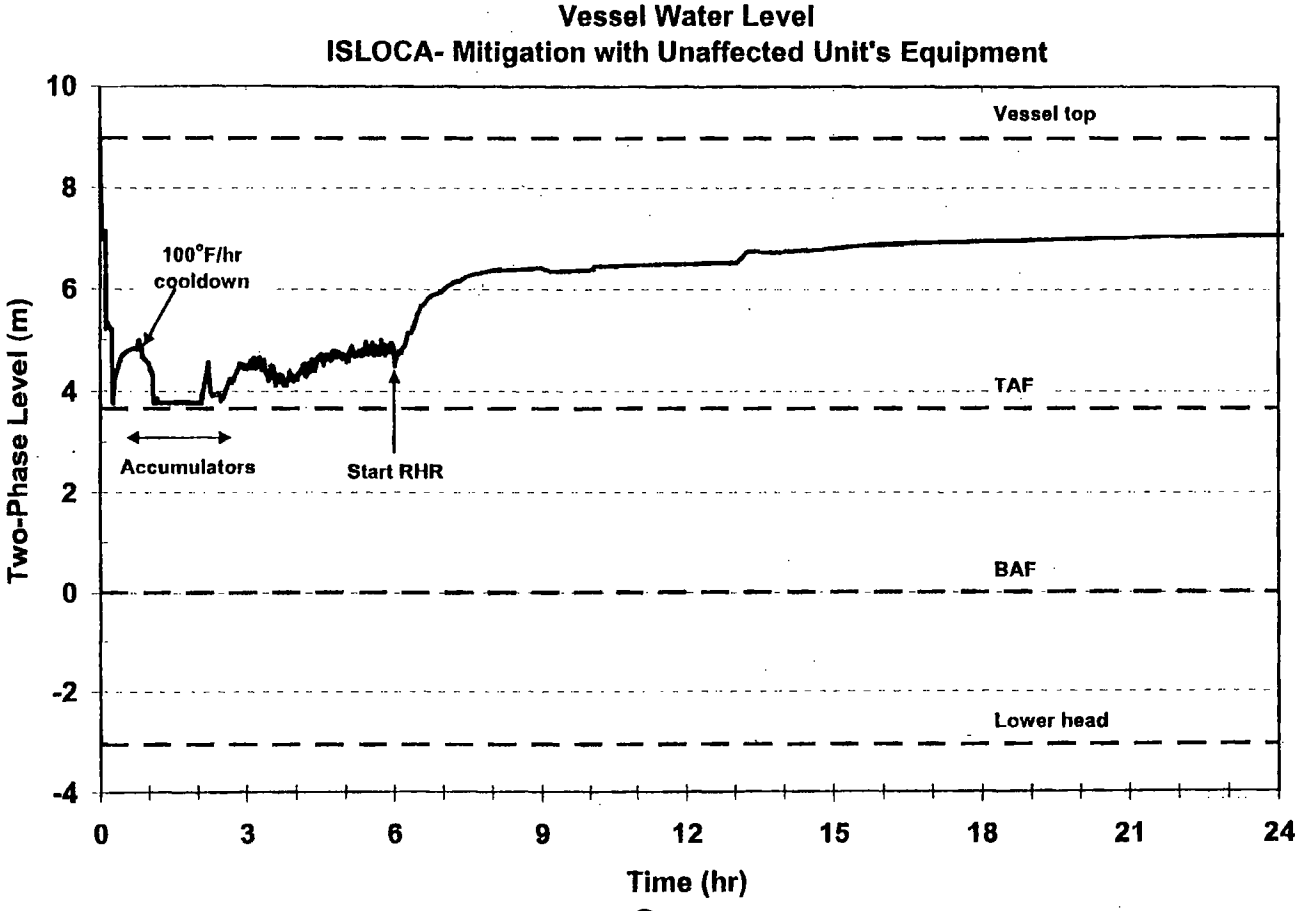
Surry ISLOCA Pressure Response

Mitigation with Unaffected Unit's RWST



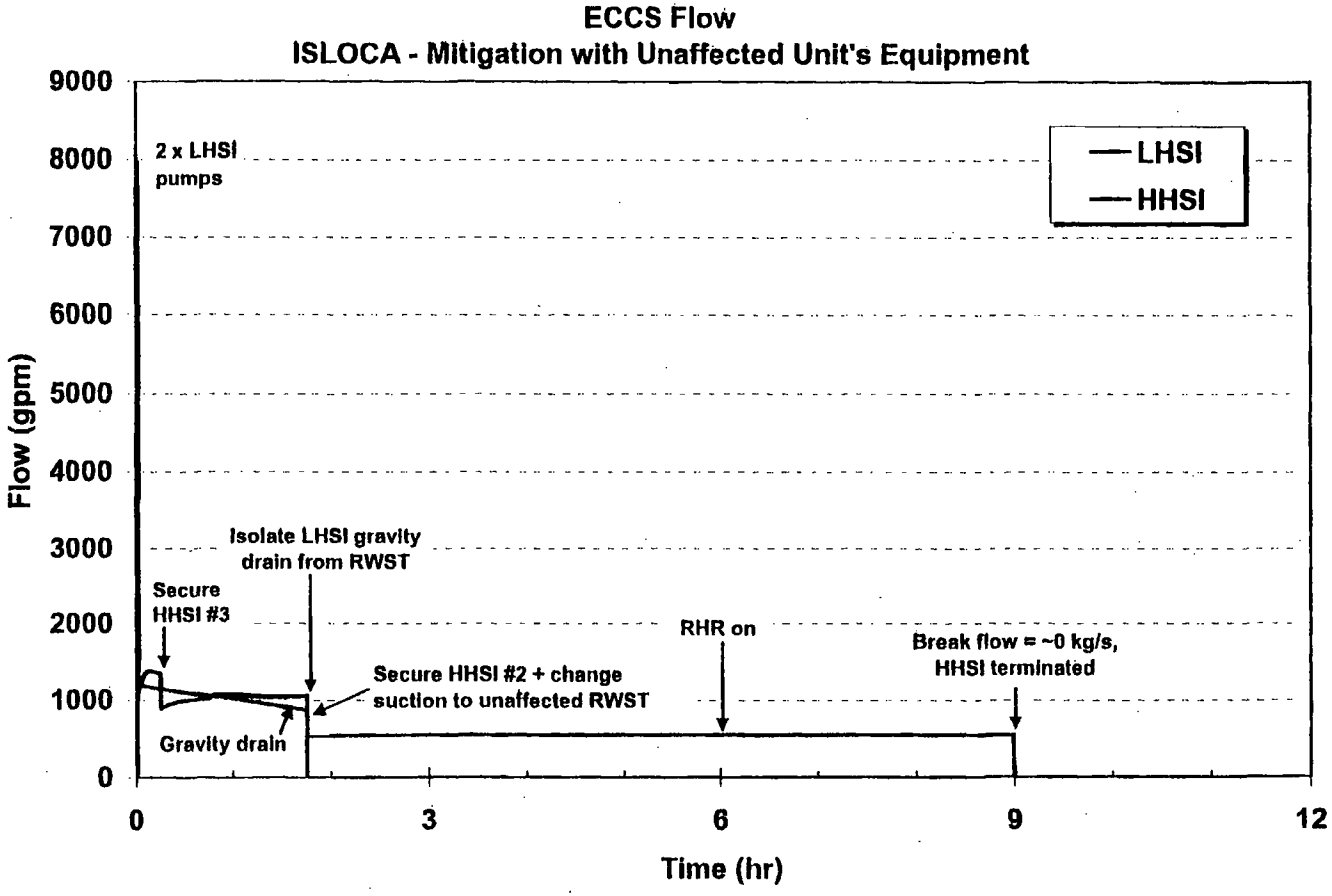
Surry ISLOCA Level Response

Mitigation with Unaffected Unit's RWST



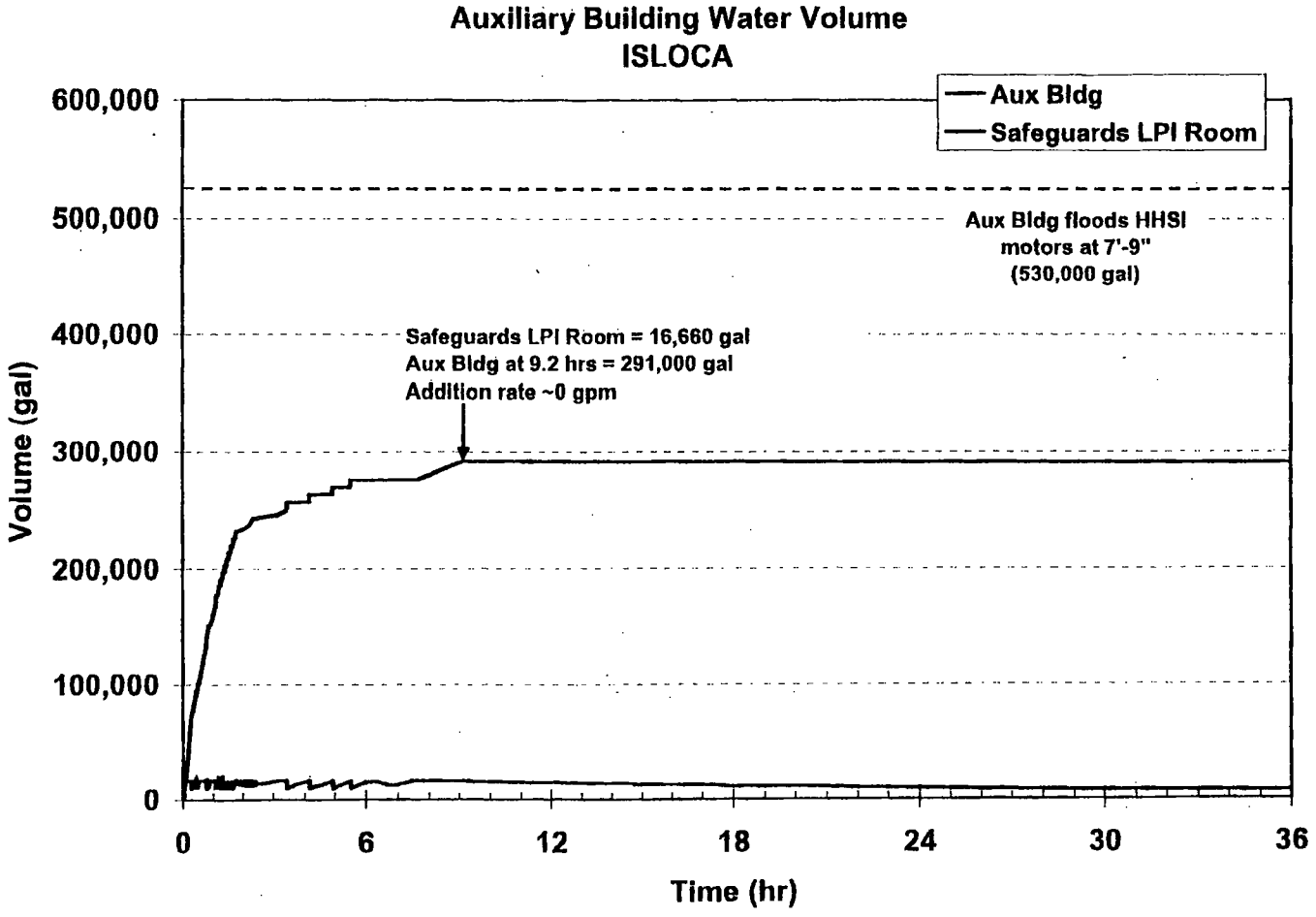
Surry ISLOCA ECCS Flow Response

Mitigation with Unaffected Unit's RWST



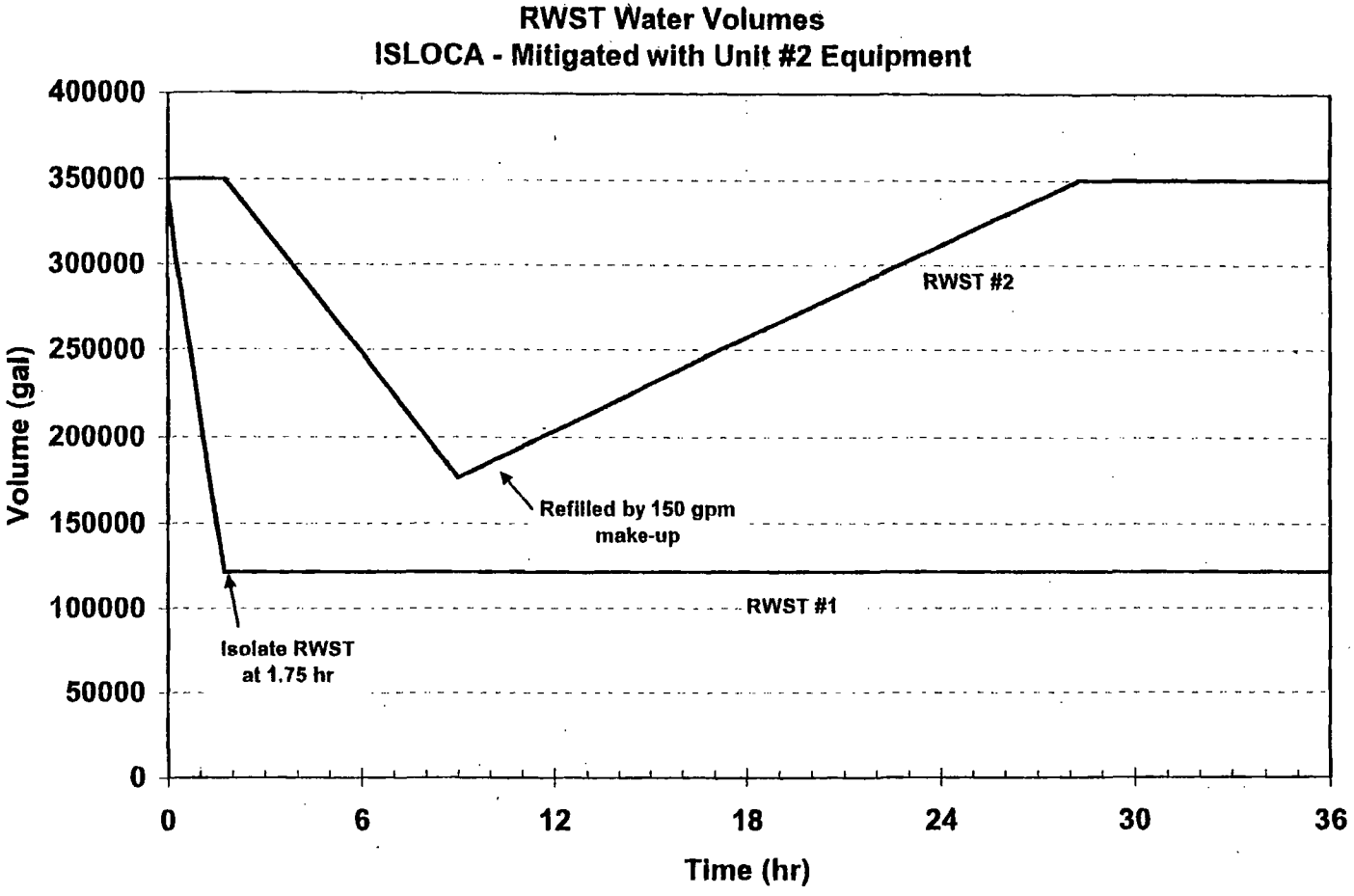
Surry ISLOCA Level Response

Mitigation with Unaffected Unit's RWST



Surry ISLOCA RWST Level Response

Mitigation with Unaffected Unit's RWST



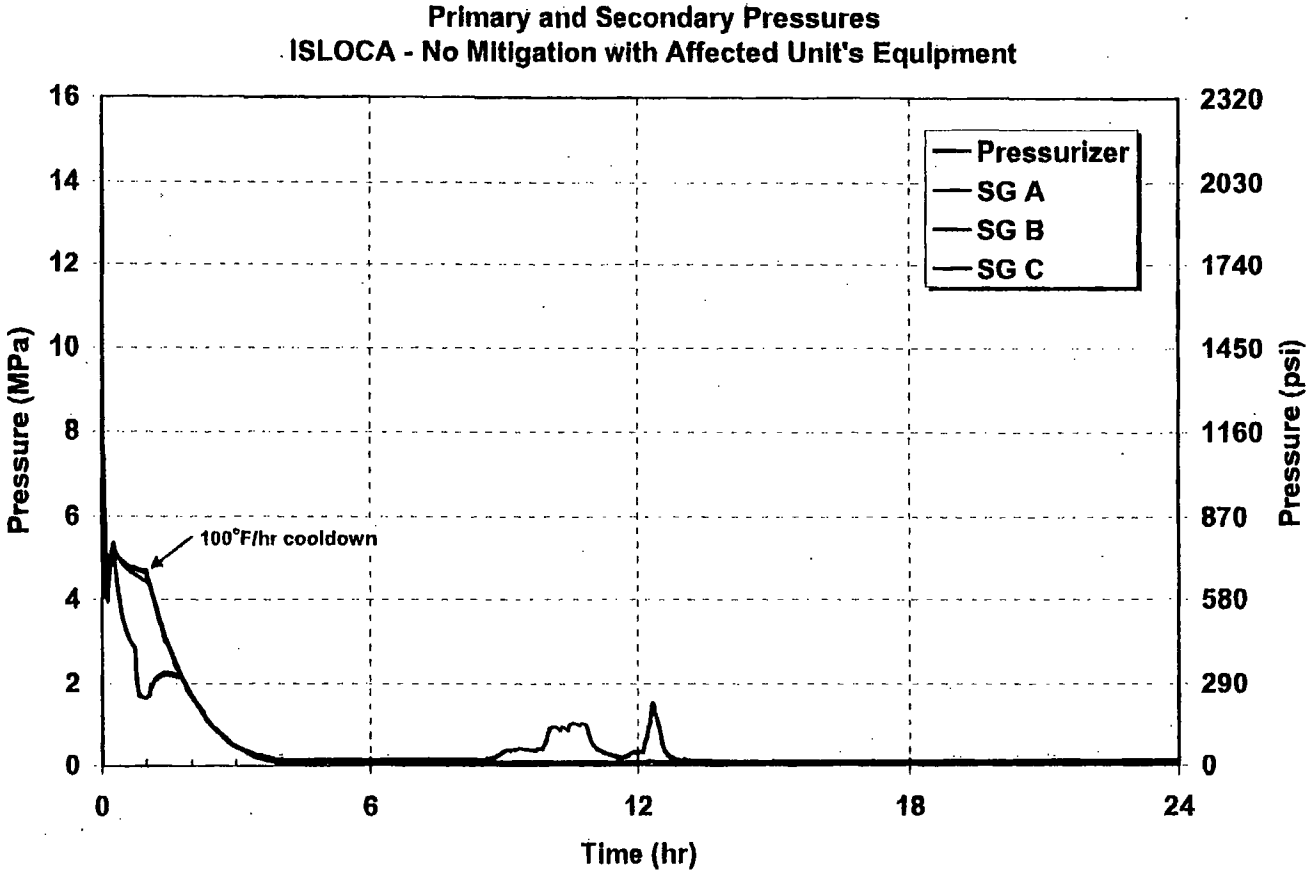
Surry ISLOCA

No Mitigation with Unaffected Unit's RWST

- Accident progression
  - RWST empty at 3 hrs
    - Assumes double-ended break of LHI pipe, resulting in gravity draining the RWST through the break in 3 hours
  - Release starts at 10 hrs
    - Release is scrubbed by water over break

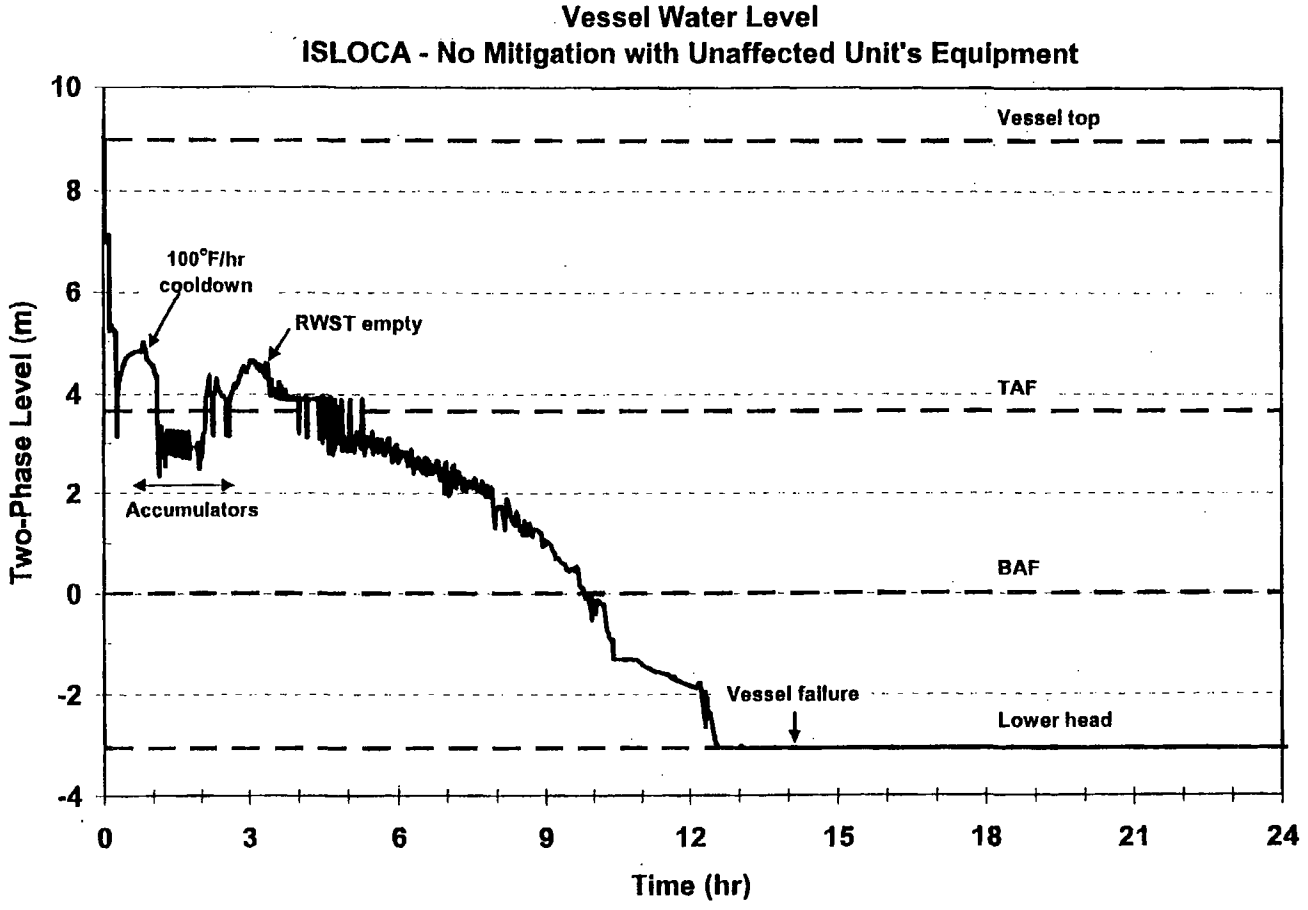
Surry ISLOCA Pressure Response

No Mitigation with Unaffected Unit's RWST



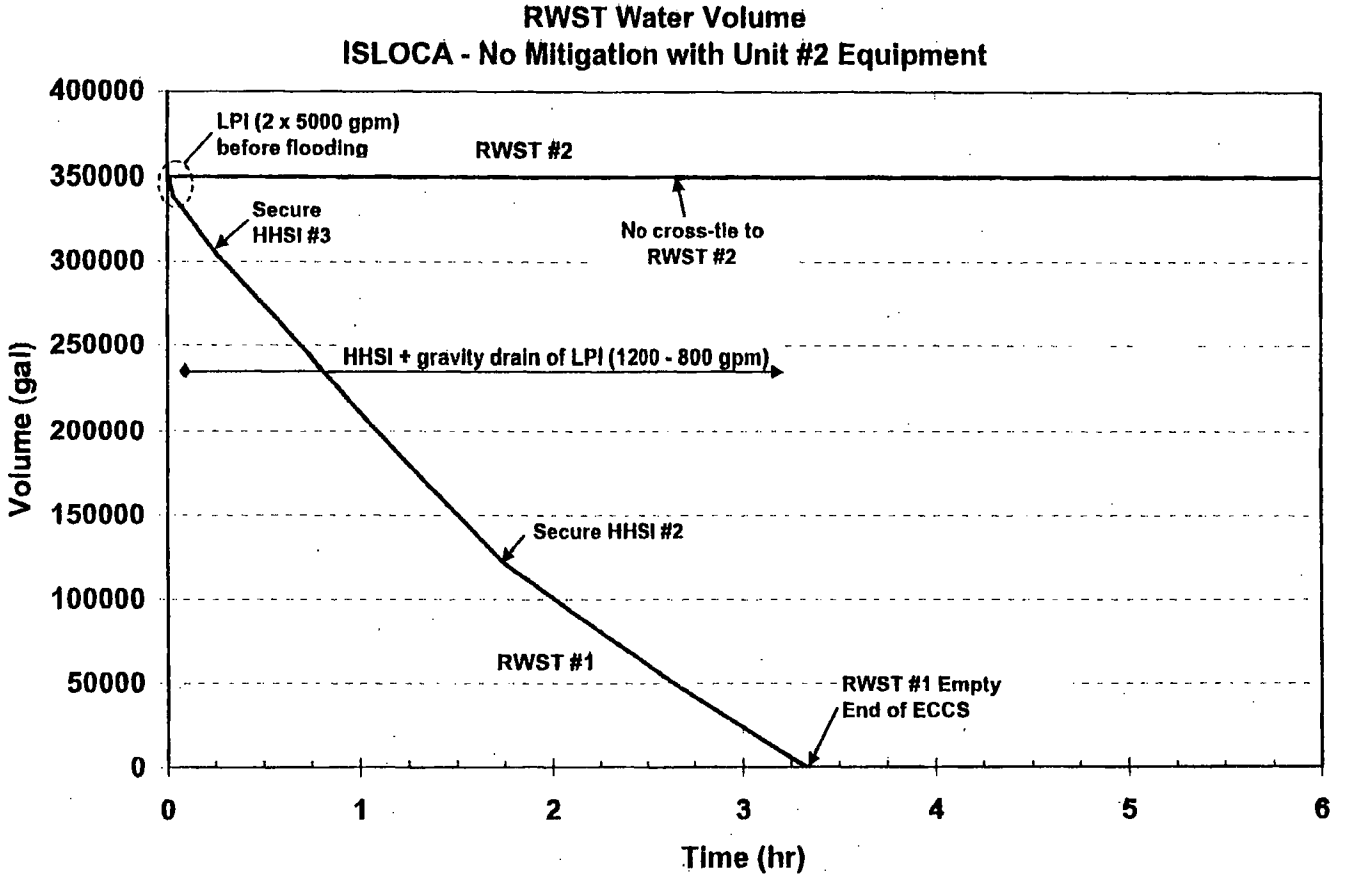
Surry ISLOCA Level Response

No Mitigation with Unaffected Unit's RWST



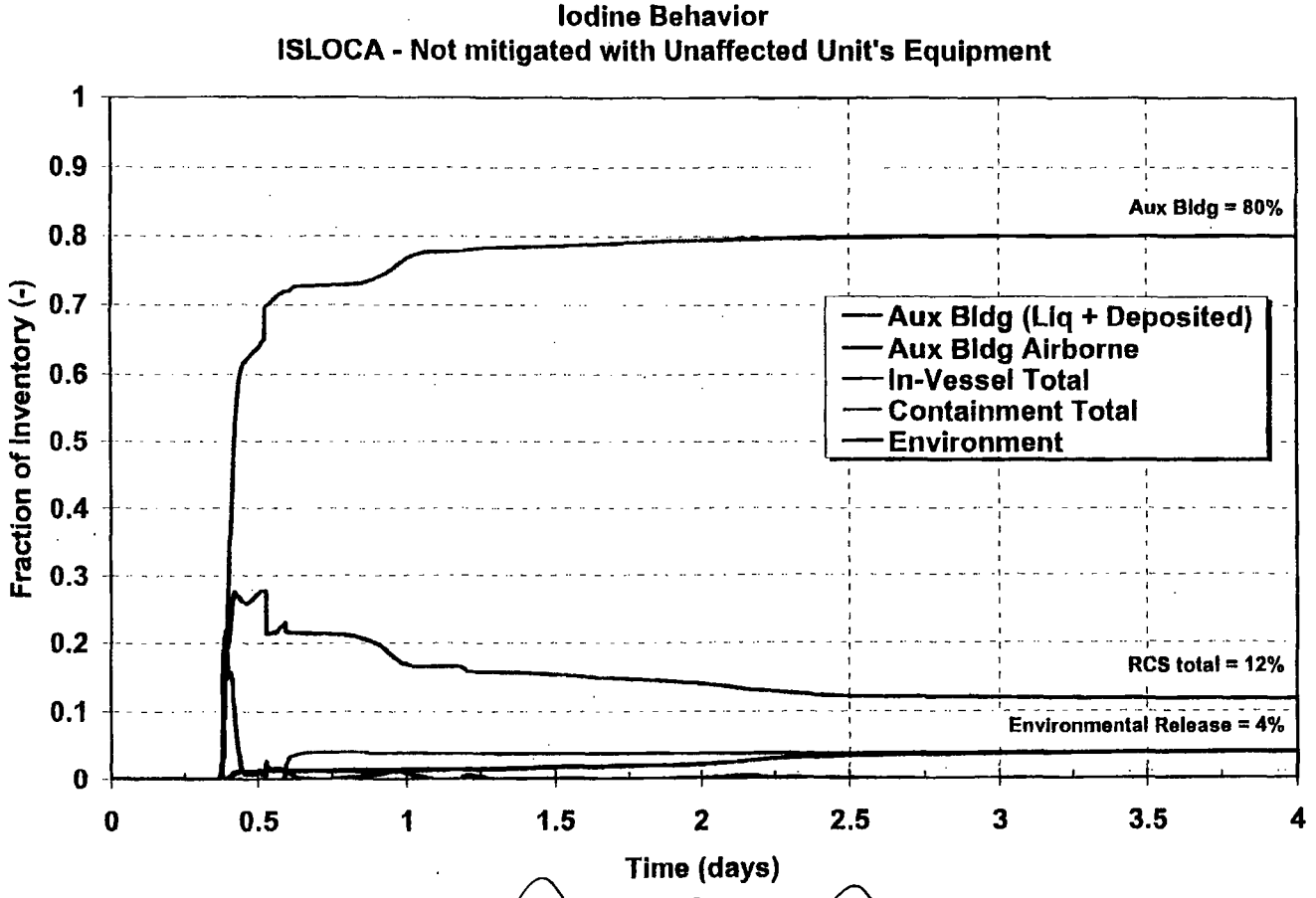
Surry ISLOCA RWST Level Response

No Mitigation with Unaffected Unit's RWST



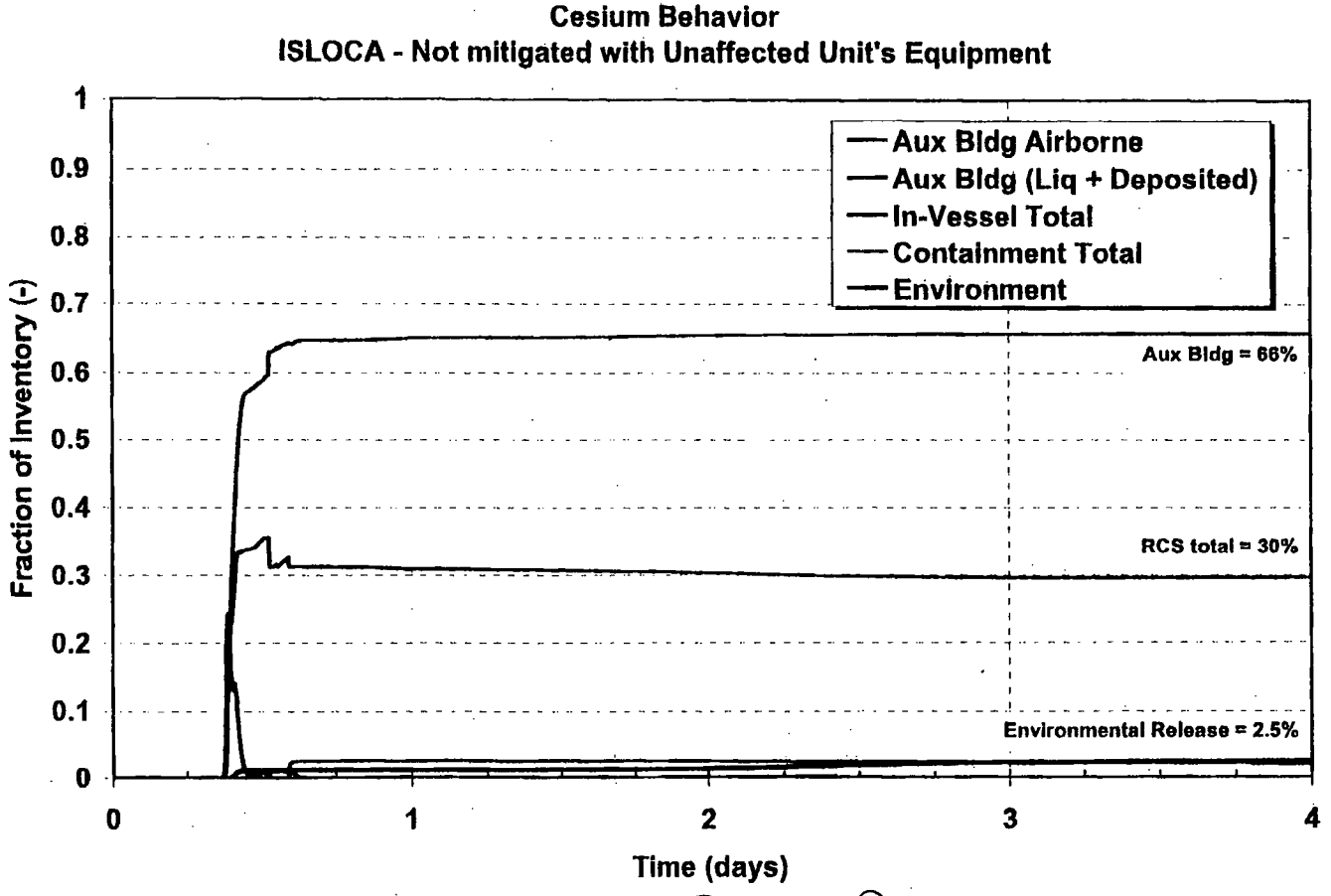
Surry ISLOCA Iodine Release and Transport

No Mitigation with Unaffected Unit's RWST



Surry ISLOCA Cesium Release and Transport

No Mitigation with Unaffected Unit's RWST



Surry ISLOCA

- Insights
  - MELCOR analysis indicates that operators and others (TSC, EOF) have time to correct errors
    - Event can be mitigated with installed (non-B.5.b) equipment
    - Other mitigation options exist
      - Use B.5.b pumps to feed RCS and steam generators
  - Unmitigated case has scrubbed release
    - Suggests small offsite health consequences
    - Offsite consequence analysis ongoing

Summary

- Peach Bottom LTSBO
  - Turbine-driven system (RCIC) and B.5.b prevent core damage
  - Without B.5.b
    - No early fatalities
    - 25 latent cancer fatalities
- Surry LTSBO
  - Turbine-driven system (AFW) and B.5.b prevent core damage
  - Without B.5.b
    - No early fatalities
    - No latent cancer fatalities
- Surry STSBO
  - B.5.b emergency containment spray prevents environmental release (except noble gases)
  - Without B.5.b
    - No early fatalities
    - No latent cancer fatalities

Summary

- Peach Bottom and Surry SBO scenarios
  - B.5.b provides an additional layer of injection capability
  - Sufficient time to implement B.5.b equipment
  - Accident progression timing (long time to core damage and containment failure) and mitigative measures significantly reduce the potential for core damage and/or containment failure

Summary

- Surry SGTR
  - Installed systems (HPI, AFW, RWST) sufficient to prevent core damage
  - Assuming no mitigation results in 1 – 2 day delay until core damage
    - Unrealistic to assume operators delay this long
- Surry ISLOCA
  - Installed systems (HPI, unaffected unit's RWST) sufficient to prevent core damage
    - MELCOR analysis shows 3 hours until RWST depleted
      - More time available if LHI pipe break is smaller than double-ended
  - Assuming no mitigation with unaffected unit's RWST
    - Release scrubbed by water over break
- Surry bypass scenarios
  - Accident progression timing (long time to core damage) and mitigative measures significantly reduce the potential for core damage and/or containment failure
  - Additional injection capability provided by B.5.b equipment not necessary

Reporting Latent Cancer Fatalities

- Commission Paper – Notation Vote
- Options
  - Range of thresholds (0 – 5 rem)
  - Linear no threshold (LNT)
  - Estimate point value from Health Physics Society
    - 5 rem in one year, 10 rem in a life time
- Staff Analysis
  - Estimate point value from Health Physics Society
    - 5 rem in one year, 10 rem in a life time
- In staff review

Status of Pilot Plants

- Peach Bottom, Surry and Sequoyah volunteered
- Recommend completing Peach Bottom and Surry, publishing the results, then solicit additional volunteers
  - Dialogue with stakeholders and potential volunteers
  - Solicit additional volunteers

SOARCA SCHEDULE

- SOARCA Initial Results — September 2007
- Additional SOARCA Analyses — December 2008
  - 1 additional plant
  - Finalize initial results
  - Source term uncertainty analysis
  - Additional sensitivity analyses
  - Peer review
- SOARCA Analyses (up to 5 additional plants) — TBD