Clinton Power Station Regulatory Conference

Reactor Core Isolation Cooling Water Storage Tank

December 19, 2006

AGENDA

- **Objectives** – *Patrick Simpson*
- **Finding** – *Michael McDowell*
- **High Pressure Core Spray (HPCS) System Overview** – *Tom Chalmers*
- **History of Vortexing Issue** – *Russell Peak*
- **Scale Model Testing and Results** – *Russell Peak*
- **Risk Assessment** – *Gregory Krueger*
- **Conclusions** – *Michael McDowell*

Objectives

Patrick Simpson

CPS Regulatory Assurance Manager

Objectives

- Provide insights gained from recent scale model testing
  - Transfer of suction from RCIC water storage tank to suppression pool would have occurred prior to significant air entrainment to HPCS pump
  - Demonstrates HPCS was capable of performing its safety function when aligned to RCIC water storage tank (i.e., Green)
- Demonstrate HPCS capable of performing its function for the majority of risk significant scenarios
  - Assumes HPCS pump functionality impacted by significant air entrainment
  - Supports conclusion that RCIC water storage tank vortexing finding is of low to moderate safety significance (i.e., White)
- Provide additional technical information requested by NRC's November 29, 2006 letter

Finding

Michael McDowell

CPS Plant Manager

Finding

Potentially Greater Than Green Finding

The licensee failed to adequately address vortexing in the RCIC water storage tank. As a result, the setpoint for the HPCS pump suction source to transfer from the RCIC water storage tank to the suppression pool may be too low and result in significant air entrainment such that the HPCS pump would not be capable of completing its safety function.

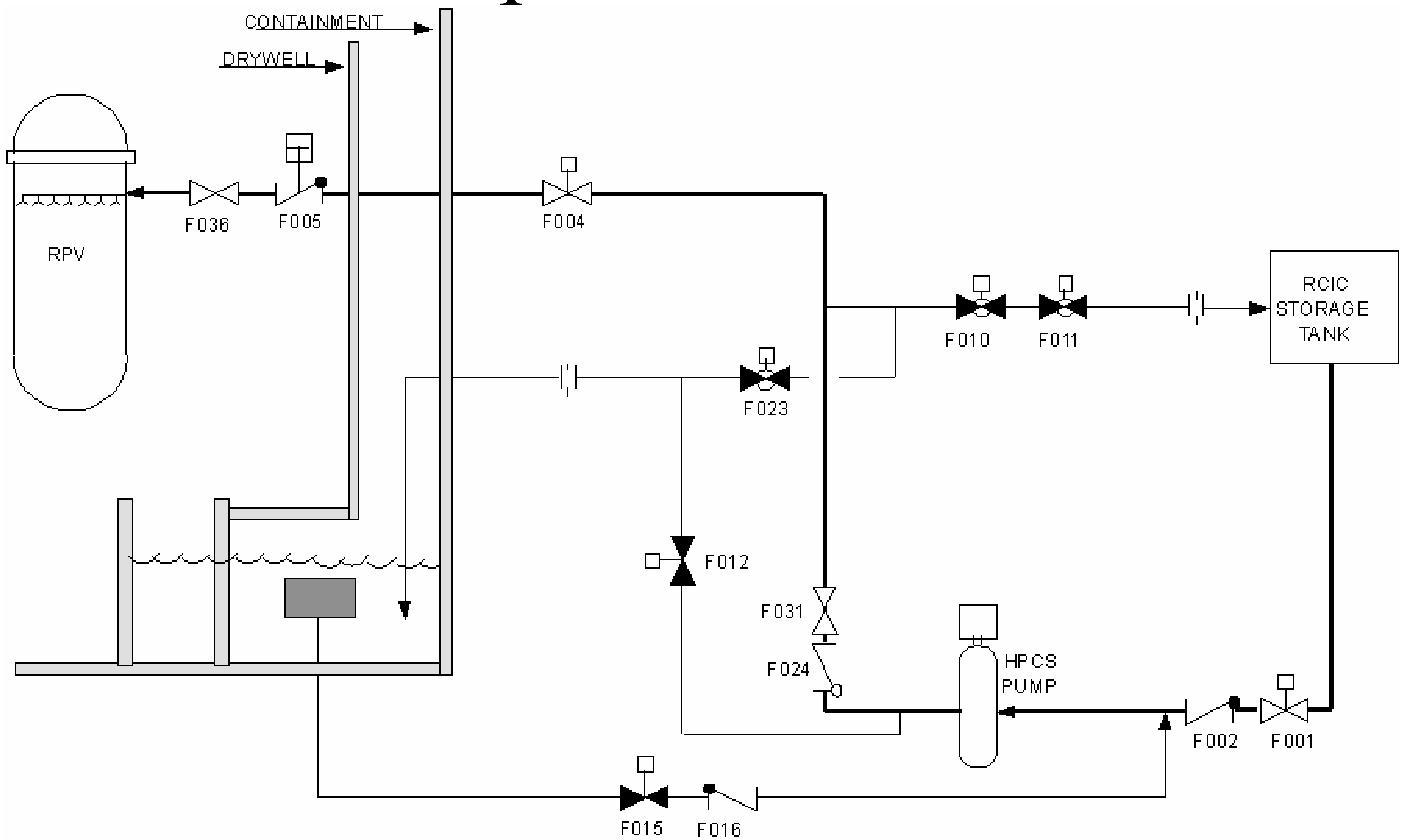
Actions Taken

- Aligned HPCS suction to suppression pool on December 1, 2005
  - Precautionary action due to uncertainties
- Modification implemented August 11, 2006, added a downward turned elbow on the HPCS suction piping inside RCIC water storage tank
  - Provides additional margin
- Completed scale model testing which supports conclusion that HPCS suction transfer occurs prior to significant air entrainment reaching HPCS pump

HPCS System Overview

Tom Chalmers
CPS Shift Operations Superintendent

HPCS Simplified Schematic



HPCS INJECTION FLOW PATH

HPCS Operational Characteristics

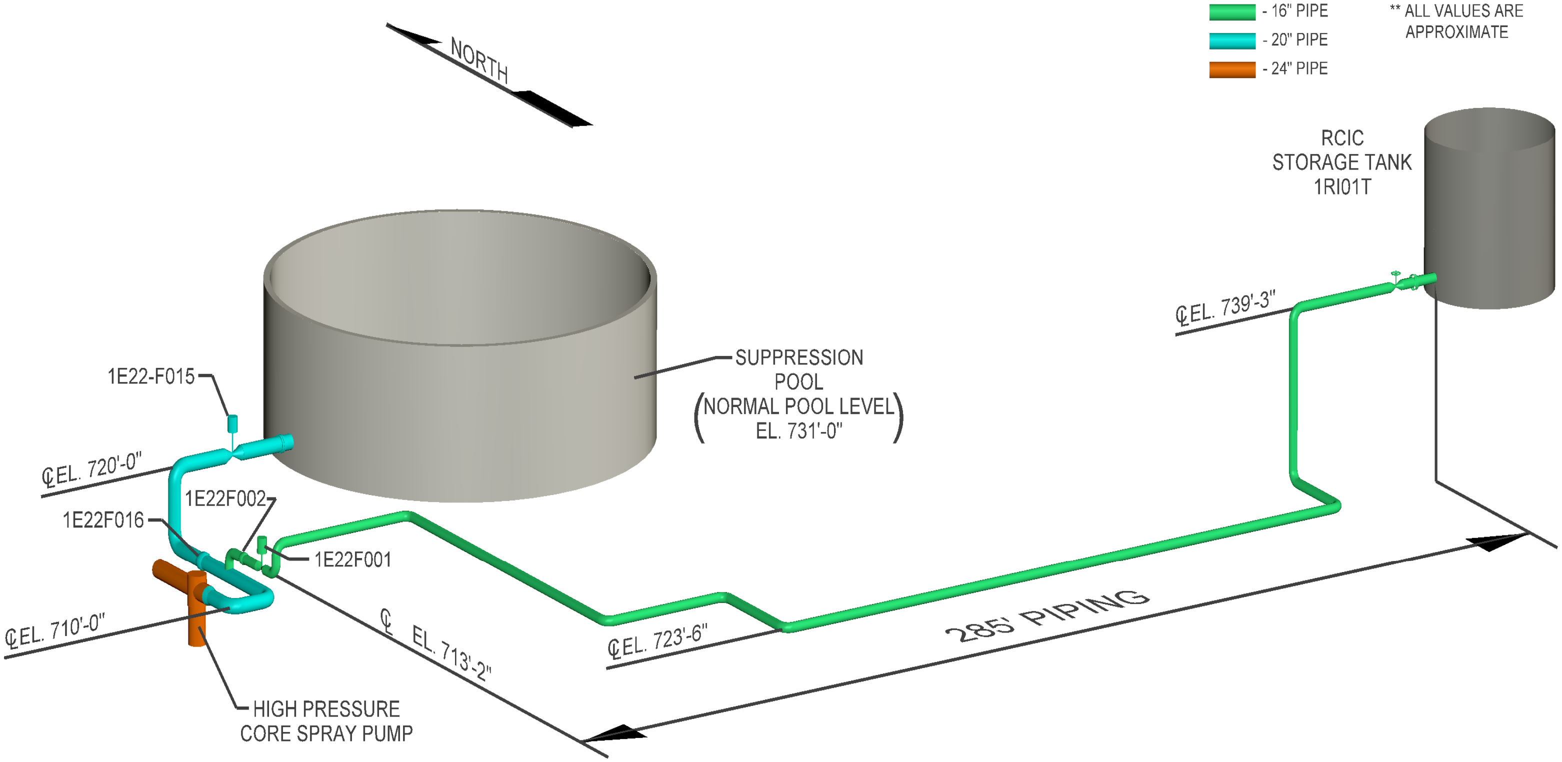
- Operation Modes
  - Suction pathways
  - Reactor pressure vessel injection
  - Minimum flow
- Automatic Actions/Interlocks
  - Suction valves (1E22-F001 and 1E22-F015)
    - Suction automatically transfers from RCIC water storage tank on either low RCIC storage tank water level or high suppression pool water level
    - RCIC storage tank suction valve will not close until suppression pool suction valve full open
  - Injection valve (1E22-F004)
    - Opens on low low reactor water level (L2)
    - Closes on high reactor water level (L8)
  - Minimum flow valve (1E22-F012)
    - Opens on flow < 625 gpm and discharge pressure >145 psig

HPCS SUCTION PIPING

PIPE DIAMETER	LENGTH	LOCATION
20"	72'	FROM SUPPRESSION POOL TO REDUCER/EXPANDER
20"	26'	FROM TEE TO REDUCER/EXPANDER
16"	300'	FROM TANK TO TEE
24"	5'	REDUCER/EXPANDER TO HPCS PUMP
20"	6'	FROM SUPPRESSION POOL (CONTAINMENT WALL) TO 1E22F015 VALVE
16"	285'	FROM RCIC TANK TO 1E22F001 VALVE
VARIES	331'	FROM TANK TO PUMP
VARIES	77'	FROM SUPPRESSION POOL TO HPCS PUMP

- 16" PIPE
- 20" PIPE
- 24" PIPE

** ALL VALUES ARE APPROXIMATE



HPCS Layout

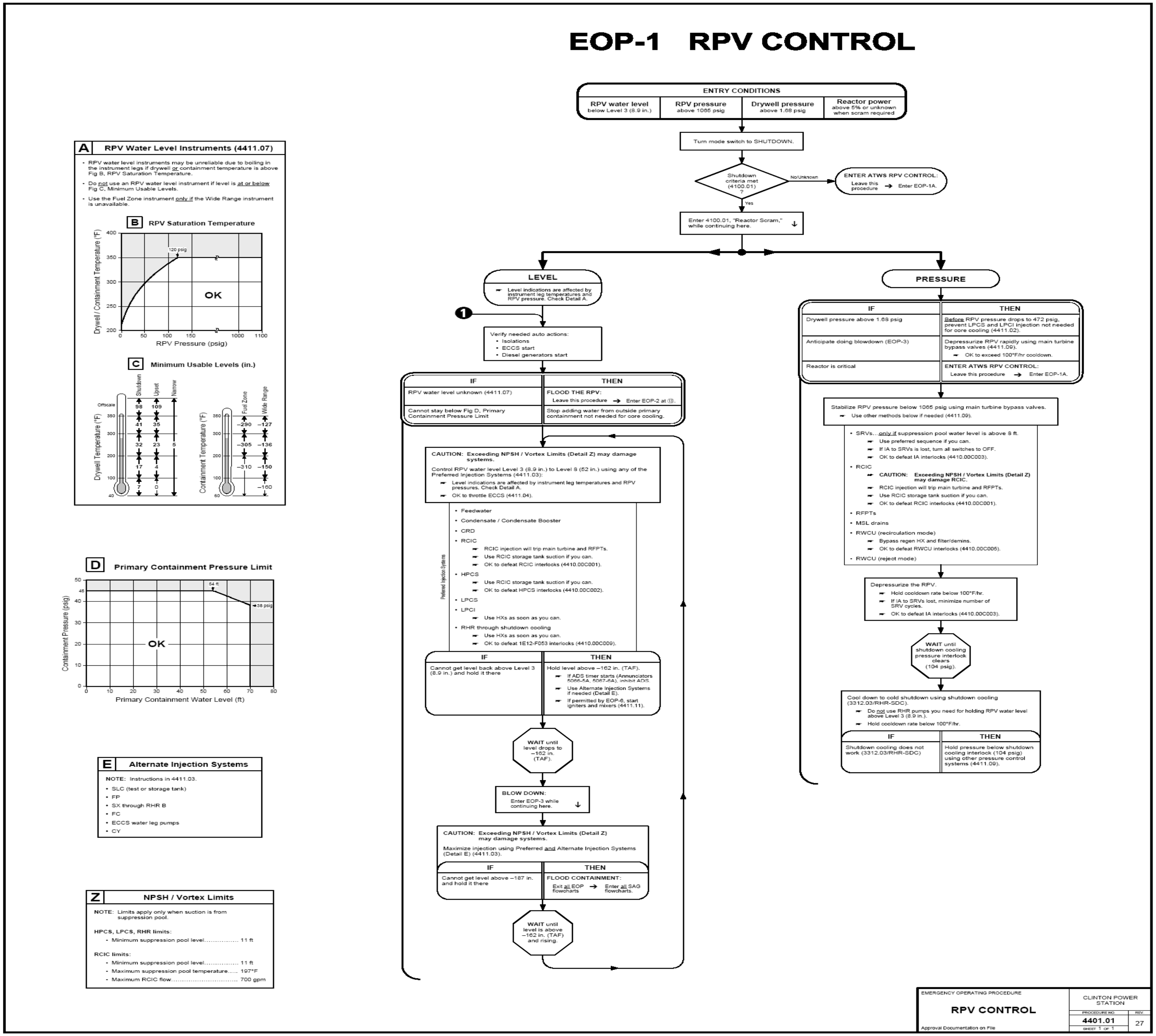
- Physical layout and components of interest
  - HPCS pump
  - HPCS utilizes two suction sources
    - RCIC water storage tank
      - Initial HPCS water supply
      - 285 feet of piping between tank outlet and RCIC storage tank suction valve
    - Suppression pool
      - Long-term HPCS water supply
      - 6 feet of piping between suppression pool and suppression pool suction valve
  - Valves
    - Suction valves (1E22-F001 and 1E22-F015)
      - Both in close proximity to HPCS pump
    - Injection valve (1E22-F004)
    - Minimum flow valve (1E22-F012)
      - Minimum flow goes into suppression pool

Emergency Operating Procedures (EOPs)

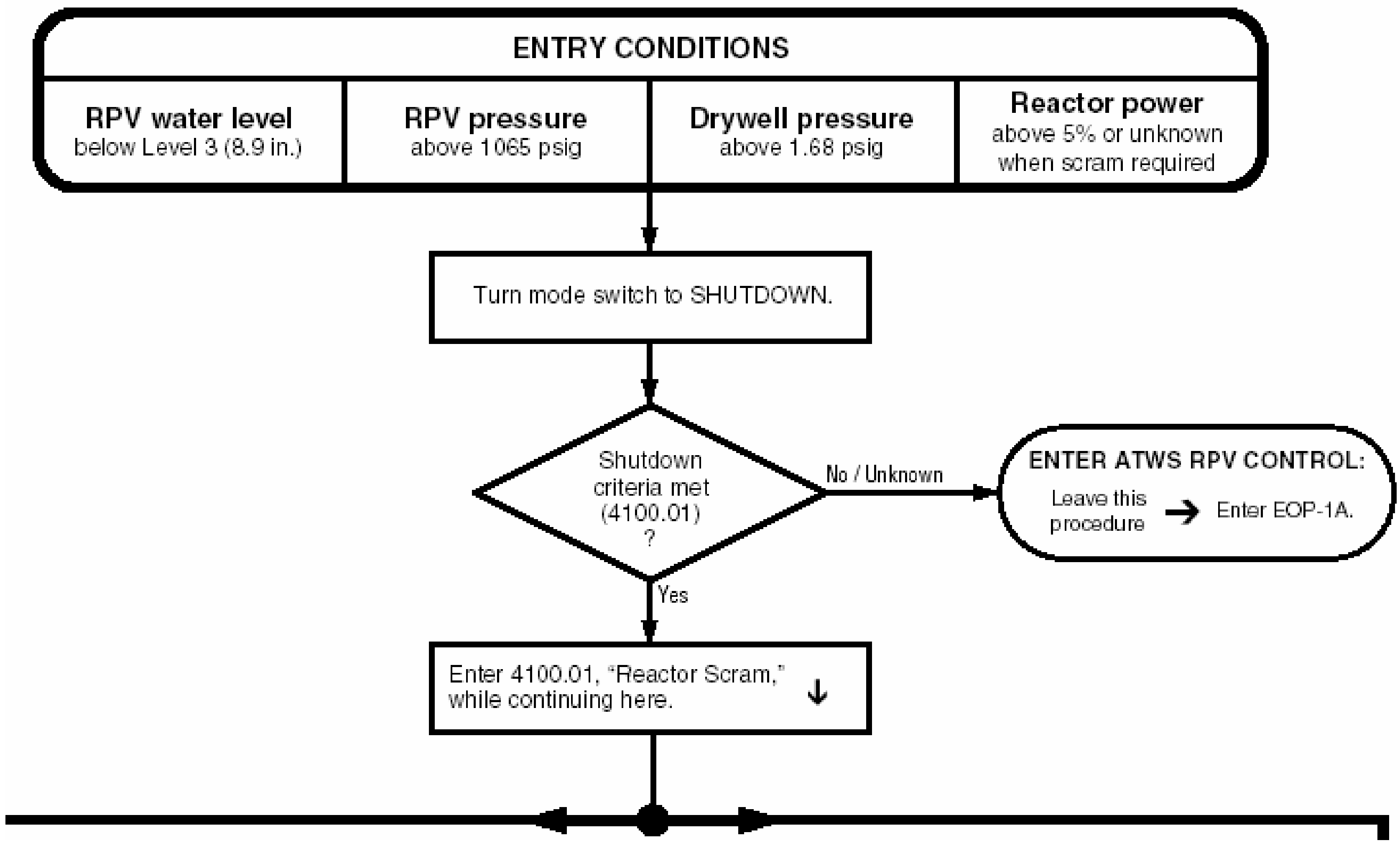
- EOP Usage Principles
  - Symptom based
  - Priority driven
- EOP-1 “RPV Control”
  - RPV level control leg
    - Direction provided to control water level between Level 3 and Level 8
    - Automatic operation of HPCS is from Level 2 to Level 8
    - Maintaining RPV level above Level 3 is important
      - Allows reactor scram to be reset
      - Prevent repeated receipt of Level 3 and 2 initiation signals

EOPs (cont.)

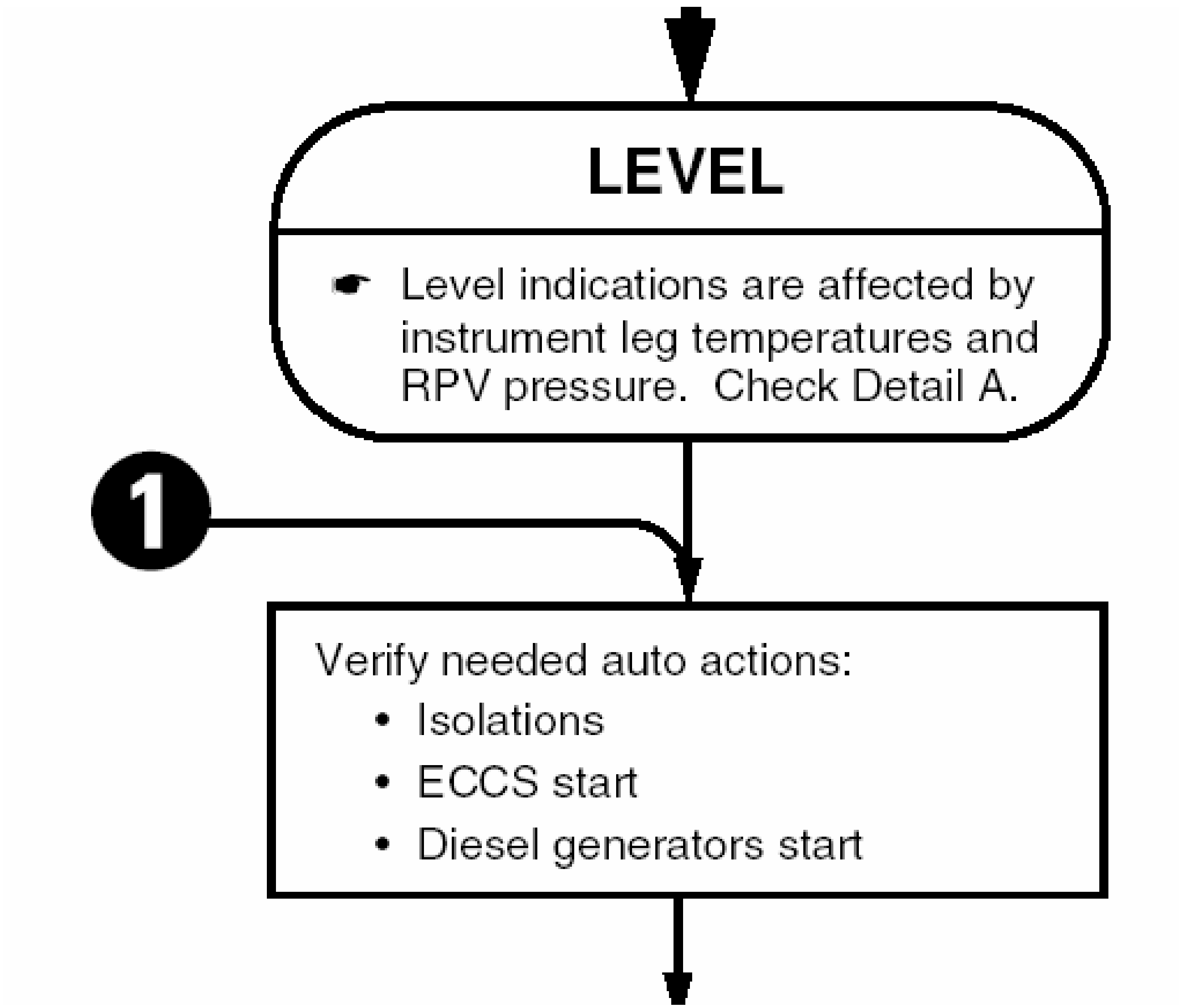
- HPCS injection valve throttling
  - Allows throttling using CPS 4411.04
  - Simple proceduralized action
  - Pre-staged EOP tools
- Operator training
  - Selected for initial and requalification training
  - Simulator
  - Job performance measure (JPM)


EOP-1 RPV CONTROL
ENTRY CONDITIONS
RPV water level below Level 3 (8.9 in.)
RPV pressure above 1065 psig
Drywell pressure above 1.68 psig
Reactor power above 5% or unknown when scram required
Turn mode switch to SHUTDOWN.
Shutdown criteria met (4100.01) ?
No/Unknown
ENTER ATWS RPV CONTROL:
Leave this procedure → Enter EOP-1A.
Yes
Enter 4100.01, "Reactor Scram," while continuing here.
LEVEL
Level indications are affected by instrument leg temperatures and RPV pressure. Check Detail A.
1
Verify needed auto actions:
• Isolations
• ECCS start
• Diesel generators start
IF
THEN
RPV water level unknown (4411.07)
FLOOD THE RPV:
Leave this procedure → Enter EOP-2 at ⑬.
Cannot stay below Fig D, Primary Containment Pressure Limit
Stop adding water from outside primary containment not needed for core cooling.
CAUTION: Exceeding NPSH / Vortex Limits (Detail Z) may damage systems.
Control RPV water level Level 3 (8.9 in.) to Level 8 (52 in.) using any of the Preferred Injection Systems (4411.03):
Level indications are affected by instrument leg temperatures and RPV pressures. Check Detail A.
OK to throttle ECCS (4411.04).
Preferred Injection Systems
• Feedwater
• Condensate / Condensate Booster
• CRD
• RCIC
RCIC injection will trip main turbine and RFPTs.
Use RCIC storage tank suction if you can.
OK to defeat RCIC interlocks (4410.00C001).
• HPCS
Use RCIC storage tank suction if you can.
OK to defeat HPCS interlocks (4410.00C002).
• LPCS
• LPCI
Use HXs as soon as you can.
• RHR through shutdown cooling
Use HXs as soon as you can.
OK to defeat 1E12-F053 interlocks (4410.00C009).
IF
THEN
Cannot get level back above Level 3 (8.9 in.) and hold it there
Hold level above –162 in. (TAF).
If ADS timer starts (Annunciators 5066-5A, 5067-6A), inhibit ADS.
Use Alternate Injection Systems if needed (Detail E).
If permitted by EOP-6, start igniters and mixers (4411.11).
WAIT until level drops to –162 in. (TAF).
BLOW DOWN:
Enter EOP-3 while continuing here.
CAUTION: Exceeding NPSH / Vortex Limits (Detail Z) may damage systems.
Maximize injection using Preferred and Alternate Injection Systems (Detail E) (4411.03).
IF
THEN
Cannot get level above –187 in. and hold it there
FLOOD CONTAINMENT:
Exit all EOP flowcharts → Enter all SAG flowcharts.
WAIT until level is above –162 in. (TAF) and rising.
PRESSURE
IF
THEN
Drywell pressure above 1.68 psig
Before RPV pressure drops to 472 psig, prevent LPCS and LPCI injection not needed for core cooling (4411.02).
Anticipate doing blowdown (EOP-3)
Depressurize RPV rapidly using main turbine bypass valves (4411.09).
OK to exceed 100°F/hr cooldown.
Reactor is critical
ENTER ATWS RPV CONTROL:
Leave this procedure → Enter EOP-1A.
Stabilize RPV pressure below 1065 psig using main turbine bypass valves.
Use other methods below if needed (4411.09).
• SRVs... only if suppression pool water level is above 8 ft.
Use preferred sequence if you can.
If IA to SRVs is lost, turn all switches to OFF.
OK to defeat IA interlocks (4410.00C003).
• RCIC
CAUTION: Exceeding NPSH / Vortex Limits (Detail Z) may damage RCIC.
RCIC injection will trip main turbine and RFPTs.
Use RCIC storage tank suction if you can.
OK to defeat RCIC interlocks (4410.00C001).
• RFPTs
• MSL drains
• RWCU (recirculation mode)
Bypass regen HX and filter/demins.
OK to defeat RWCU interlocks (4410.00C005).
• RWCU (reject mode)
Depressurize the RPV.
Hold cooldown rate below 100°F/hr.
If IA to SRVs lost, minimize number of SRV cycles.
OK to defeat IA interlocks (4410.00C003).
WAIT until shutdown cooling pressure interlock clears (104 psig).
Cool down to cold shutdown using shutdown cooling (3312.03/RHR-SDC).
Do not use RHR pumps you need for holding RPV water level above Level 3 (8.9 in.).
Hold cooldown rate below 100°F/hr.
IF
THEN
Shutdown cooling does not work (3312.03/RHR-SDC)
Hold pressure below shutdown cooling interlock (104 psig) using other pressure control systems (4411.09).
A RPV Water Level Instruments (4411.07)
• RPV water level instruments may be unreliable due to boiling in the instrument legs if drywell or containment temperature is above Fig B, RPV Saturation Temperature.
• Do not use an RPV water level instrument if level is at or below Fig C, Minimum Usable Levels.
• Use the Fuel Zone instrument only if the Wide Range instrument is unavailable.
B RPV Saturation Temperature
Drywell / Containment Temperature (°F)
400
350
300
250
200
120 psig
OK
0
50
100
150
1000
1100
RPV Pressure (psig)
C Minimum Usable Levels (in.)
Shutdown
Upset
Narrow
Offscale
Drywell Temperature (°F)
350
300
200
100
40
98
109
41
35
32
23
5
17
4
7
0
Fuel Zone
Wide Range
Containment Temperature (°F)
350
300
200
100
60
–290
–127
–305
–136
–310
–150
–160
D Primary Containment Pressure Limit
Containment Pressure (psig)
50
45
40
30
20
10
0
54 ft
38 psig
OK
0
10
20
30
40
50
60
70
80
Primary Containment Water Level (ft)
E Alternate Injection Systems
NOTE: Instructions in 4411.03.
• SLC (test or storage tank)
• FP
• SX through RHR B
• FC
• ECCS water leg pumps
• CY
Z NPSH / Vortex Limits
NOTE: Limits apply only when suction is from suppression pool.
HPCS, LPCS, RHR limits:
• Minimum suppression pool level................ 11 ft
RCIC limits:
• Minimum suppression pool level................ 11 ft
• Maximum suppression pool temperature..... 197°F
• Maximum RCIC flow................................ 700 gpm
EMERGENCY OPERATING PROCEDURE
RPV CONTROL
Approval Documentation on File
CLINTON POWER STATION
PROCEDURE NO.
4401.01
SHEET 1 OF 1
REV.
27

Entry Conditions



EOP-1, Part B Level/ Automatic Actions



EOP-1, Part C Level Overrides

IF	THEN
RPV water level unknown (4411.07)	**FLOOD THE RPV:** Leave this procedure → Enter EOP-2 at ⑬.
Cannot stay below Fig D, Primary Containment Pressure Limit	Stop adding water from outside primary containment not needed for core cooling.

EOP-1, Part D Level Control Systems

CAUTION: Exceeding NPSH / Vortex Limits (Detail Z) may damage systems.

Control RPV water level Level 3 (8.9 in.) to Level 8 (52 in.) using any of the Preferred Injection Systems (4411.03):

- ☛ Level indications are affected by instrument leg temperatures and RPV pressure. Check Detail A.
- ☛ OK to throttle ECCS (4411.04).

Preferred Injection Systems

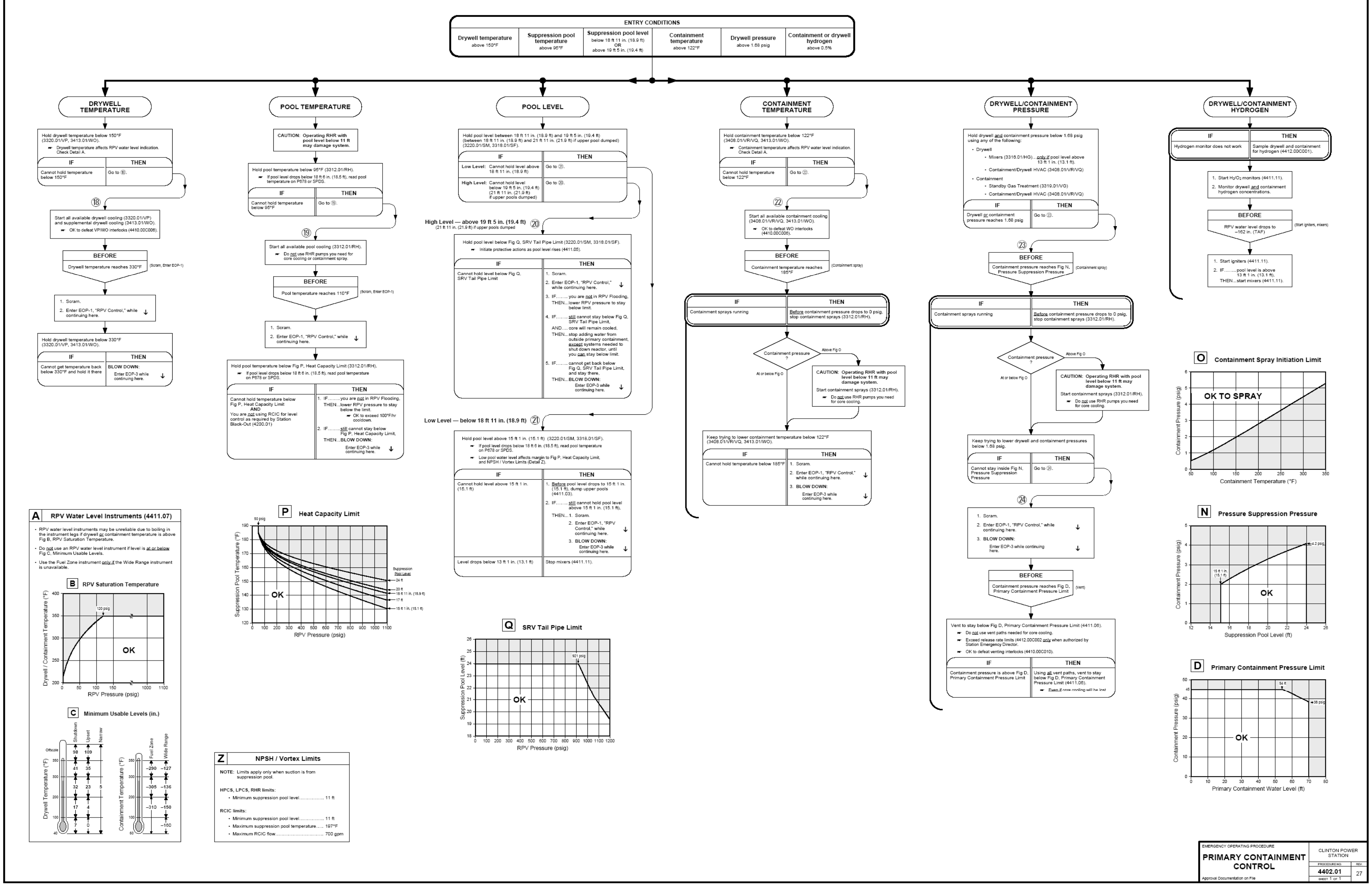
- Feedwater
- Condensate / Condensate Booster
- CRD
- RCIC
  - ☛ RCIC injection will trip main turbine and RFPTs.
  - ☛ Use RCIC storage tank suction if you can.
  - ☛ OK to defeat RCIC interlocks (4410.00C001).
- HPCS
  - ☛ Use RCIC storage tank suction if you can.
  - ☛ OK to defeat HPCS interlocks (4410.00C002).
- LPCS
- LPCI
  - ☛ Use HXs as soon as you can.
- RHR through shutdown cooling
  - ☛ Use HXs as soon as you can.
  - ☛ OK to defeat 1E12-F053 interlocks (4410.00C009).

IF	THEN
Cannot get level back above Level 3 (8.9 in.) and hold it there	Hold level above -162 in. (TAF). ☛ If ADS timer starts (Annunciators 5066-5A, 5067-6A), inhibit ADS. ☛ Use Alternate Injection Systems if needed (Detail E). ☛ If permitted by EOP-6 or EOP-7, start igniters (4411.11).

EOPs (cont.)

- EOP-6 "Primary Containment Control"
  - Suppression pool level control leg
  - Actions prioritized relative to importance
    - Establishing/maintaining adequate core cooling higher priority than taking action to exit pool level leg entry conditions
  - HPCS suction transfer is expected to occur

EOP-6 PRIMARY CONTAINMENT CONTROL



EOPs (cont.)

POOL LEVEL

Hold pool level between 18 ft 11 in. and 19 ft 5 in. (between 18 ft 11 in. and 21 ft 11 in. if upper pool dumped) (3220.01/SM, 3318.01/SF).

IF		THEN
Low Level:	Cannot hold level above 18 ft 11 in.	Go to a .
High Level:	Cannot hold level below 19 ft 5 in. (21 ft 11 in. if upper pools dumped)	Go to p .

EOPs (cont.)

High Level — above 19 ft 5 in.
(21 ft 11 in. if upper pools dumped)

p

Hold pool level below Fig Q, SRV Tail Pipe Limit (3220.01/SM, 3318.01/SF).

☛ Initiate protective actions as pool level rises (4411.05).

IF	THEN
Cannot hold level below Fig Q, SRV Tail Pipe Limit	1. Scram. 2. Enter EOP-1, "RPV Control," while continuing here. ⇓ 3. IF............ you are not in RPV Flooding, THEN.......lower RPV pressure to stay below limit. ☛ OK to exceed 100°F/hr cooldown. 4. IF............ still cannot stay below Fig Q, SRV Tail Pipe Limit, AND.........core will remain cooled, THEN.......stop adding water from outside primary containment, except systems needed to shutdown reactor, until you can stay below limit. 5. IF............ cannot get back below Fig Q, SRV Tail Pipe Limit, and stay there, THEN.......**BLOW DOWN:** Enter EOP-3 while continuing here. ⇓

History of Vortexing Issue

Russell Peak

CPS Site Engineering Director

History of Vortexing Issue

- February 1994 Self Assessment identified setpoint for RCIC and HPCS systems suction transfer from RCIC water storage tank to suppression pool did not consider vortexing
  - Generated Calculation IP-M-0384 which was approved March 1994
    - Addressed vortexing concern by raising the analytical limit by 1.6 inches
- NRC Inspection Report 94004 dated April 22, 1994 documents inspectors evaluation of calculation IP-M-0384
  - Concluded that calculation was very thorough
  - No further concerns noted

History of Vortexing Issue (cont.)

- December 1995 submitted Technical Specification change
  - Raised the RCIC water storage tank low level (HPCS suction transfer) allowable value by +2.5 inches to account for vortexing
  - Approved by the NRC in April 1996 (Amendment 104)
- This is the point in time when CPS considered the vortexing issue resolved

History of Vortexing Issue (cont.)

- Mid-1998 self-identified issues related to generic setpoint methodology
  - Revised calculations to further address instrument uncertainties
  - Early 1999 NRC reviewed adequacy of setpoint program
    - Concluded sufficient margin exists between field settings and respective allowable values and analytical limits (Closed restart issue)
- 2001 Setpoint Calculations Upgrade Project
  - TS change approved September 2005 (Amendment 168)
  - Raised allowable value by 0.5 inches to +3.0 inches (+3.31 inches above top of pipe inside diameter)

History of Vortexing Issue (cont.)

- Actions prior to the December 2005 NRC Safety System Design and Performance Capability inspection were reasonable to address vortexing

Scale Model Vortex Testing and Results

Russell Peak

CPS Site Engineering Director

Scale Model Vortex Testing

- Scale Model Vortex Testing
- Testing Results
- Statistical Analysis of Testing Results
- Modeling Analysis
- Conservatisms Applied
- RELAP Analysis Results

Scale Model Vortex Testing Background

- Scale model testing performed to ensure site specific geometric conditions at CPS were captured
  - Accurately determine hydraulic behavior and determine minimum submergences to avoid air entrainment
- Alden Labs chosen to perform testing
  - Recognized industry expert on model testing
  - Leading fluids engineering laboratory
  - Used by Nuclear Regulatory Commission for NUREG/CR-2760 studies

Scale Model Description

- Used geometric scale of 1:3.051
- Allowed control of the Froude, Reynolds, and Weber numbers
  - Froude number of model and CPS are equivalent because gravity and inertial forces are predominant
  - Reynolds number in model kept high to minimize viscous scale effect
  - Weber number in model kept high to make surface tension effects negligible

Scale Model Description (cont.)

- Initial water level was 4 ft. in the model
  - Representative of >12 ft. above the top of the nozzle in the tank and used since air entrainment due to air-drawing vortices is likely to occur at lower water levels in the tank
- Video cameras (3) utilized to capture the dynamic effects
- Viewing boxes utilized to capture visual effects of air entrainment
  - Constructed to observe conditions at the outlet nozzle
  - Constructed to observe conditions in the pipe just downstream of the nozzle
- Third party (i.e., MPR) review of model scaling

Scale Model Description (cont.)

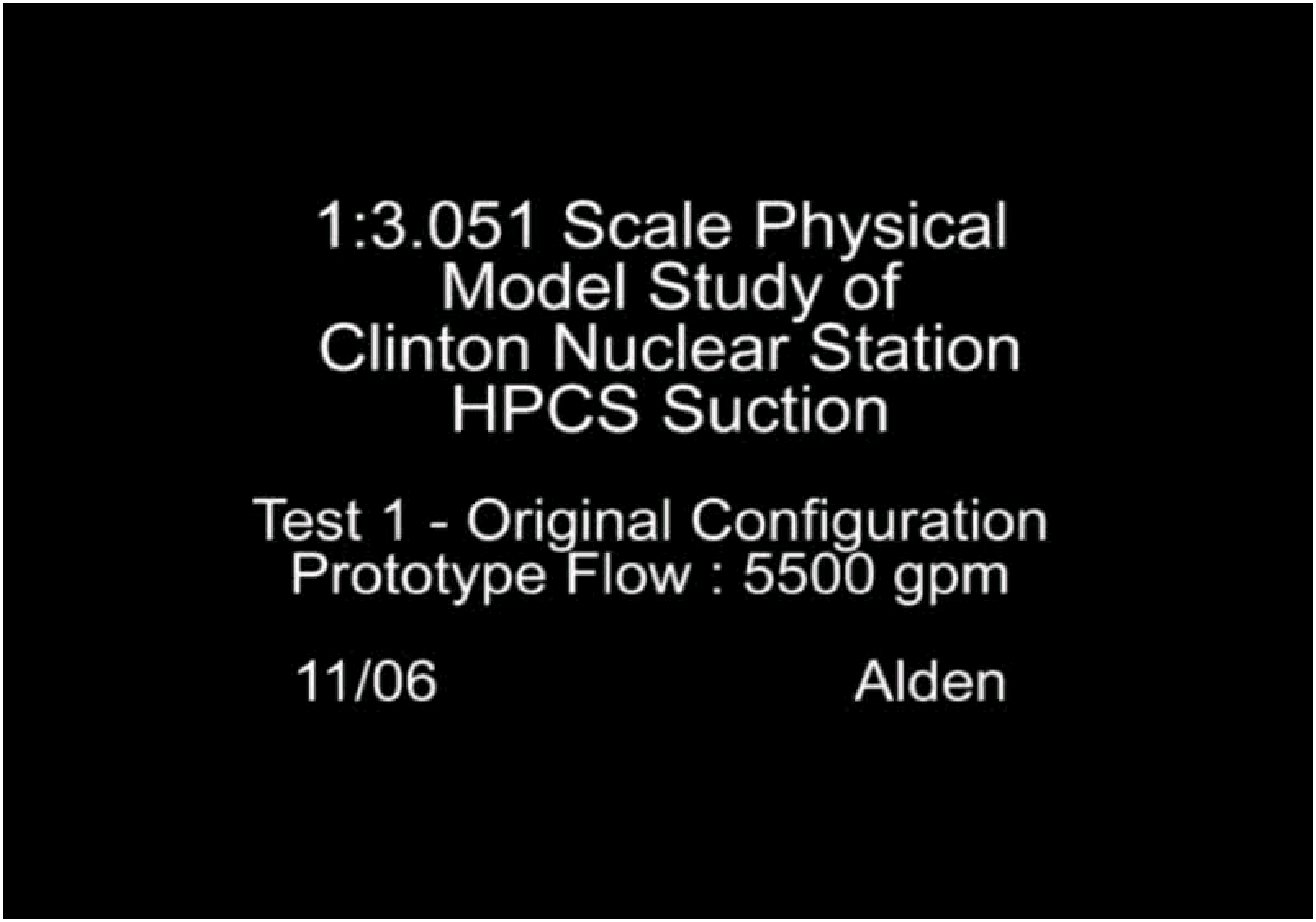
- Physical modeling included tank and outlet piping five (5) diameters downstream of where the nozzle attaches to the tank
- Elliptical outlet nozzle configuration modeled
- Tank internal obstructions (tank heater and HPCS test return) were modeled in the affected quadrant
  - Modeled due to their close proximity to the suction nozzle which could influence the flow patterns

Scale Model Vortex Testing

- Testing witnessed on site at Alden Labs
  - Clinton Power Station personnel
  - Independent third party reviewer (MPR Associates)
  - Nuclear Regulatory Commission (NRR)
- Testing included transient water level conditions
  - Simulating field conditions for selected flows
  - No return flow to the tank representative of field conditions

Scale Model Vortex Testing (cont.)

- Flows selected were 5500 gpm (3 runs), 3000 gpm (3 runs) and 4250 gpm (1 run)
  - Three runs performed at both the high and lower flow rates to demonstrate repeatability of results
    - High flow (5500 gpm bound pump run-out flow rates)
    - Low flow (3000 gpm) representative of flow rates seen after a scram (based on reactor pressure)
  - One run performed at a flow rate in the middle of these two to ensure consistency of data collection


1:3.051 Scale Physical
Model Study of
Clinton Nuclear Station
HPCS Suction
Test 1 - Original Configuration
Prototype Flow : 5500 gpm
11/06
Alden

Results of Testing

- No vortexing was observed as tank level decreased
- Localized surface depression at outlet nozzle forms as tank level decreased to level of nozzle
- Air entrainment occurs (air enters nozzle) when localized drawdown reaches top of nozzle
- Air entrainment is initiated at different levels corresponding to different flow rates
  - Sensitive to flow rate
- No air entrainment occurs prior to localized surface depression level reaching the top of the nozzle

Results of Testing (cont.)

- Onset of air entrainment at 5500 gpm occurs at an average value (average of 3 runs) of 4.5 plant inches above the top of the exit pipe
- Onset of air entrainment at 3000 gpm occurs at an average value (average of 3 runs) of 2.6 plant inches above the top of the exit pipe
- Onset of air entrainment at 4250 gpm occurs at 3.7 plant inches above the top of the exit pipe
- Air entrainment fraction could not be directly measured
  - Air flow characteristic observed was bubbly flow and not slug flow
    - Puts an upper limit of 24% air entrainment based on the RELAP flow map

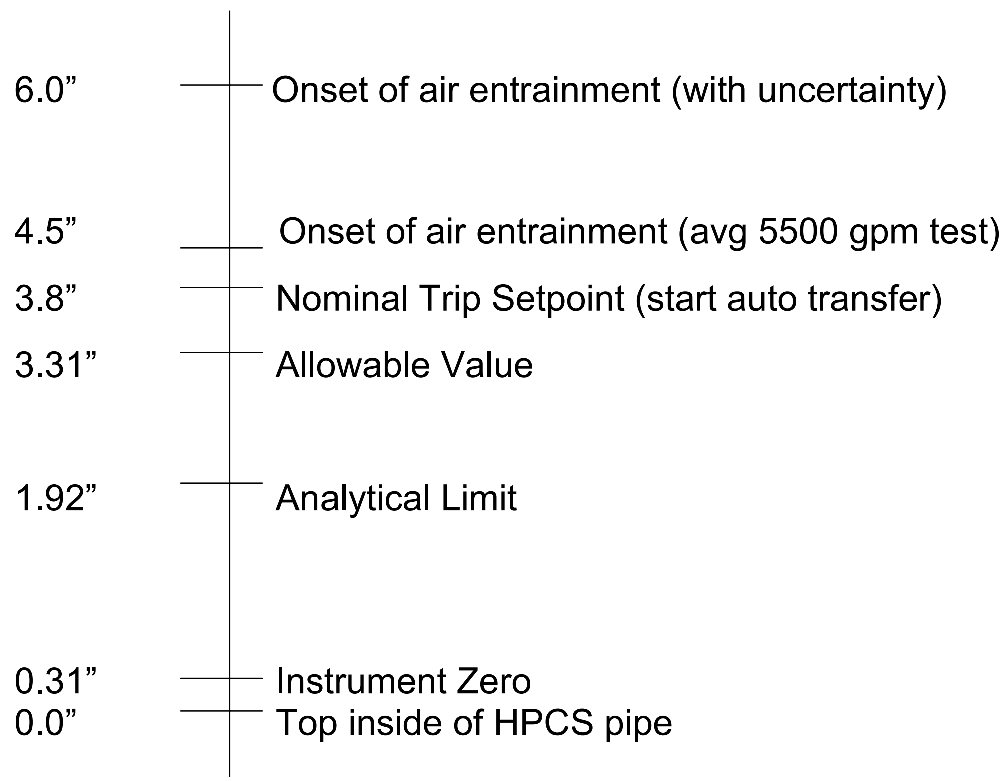
Statistical Analysis of Testing Results

- Data from the 6 test data points at the high and low flow test conditions were pooled to determine the uncertainty to apply
  - Instrument uncertainty and distribution uncertainty were used
  - The points meet the NUREG-1475 requirements for pooling data points
  - 1 sided distribution bounds 95% of real distribution with 95% confidence
  - Data from 4250 gpm not included in the pooling since there was only one point (i.e., no spread)
- Using this approach, air entrainment would occur at 6 plant inches for the 5500 gpm flow case

Statistical Analysis of Testing Results
(cont.)

- 6 inches is higher than the trip setpoint by approximately 2.2 inches

RCIC Tank Elevations



Modeling Analysis Inputs

- To determine impact on HPCS pump, the test results were used as inputs for a RELAP model of the suction piping
  - Model accounts for air traveling down the 285 feet of 16 inch diameter suction piping while the tank level continues to decrease to the suction transfer trip setpoint at which point the valve from the suppression pool strokes open
- RELAP calculated the void transport and the hydraulic effect of the suppression pool valve opening

Conservative Inputs to RELAP Analysis

- Onset of air entrainment is 6 inches above the exit pipe based on statistical considerations
  - Conservative because 6 inches is greater than the average value of 4.5 inches and this would allow for additional time for air ingestion to the pump
- Allowable value for suction transfer level point was used rather than the nominal trip setpoint
  - Conservative because value is less than the nominal trip setpoint and thus the time to transfer to the pool will be later

Conservative Inputs to RELAP Analysis
(cont.)

- Linear flow characteristic used for suppression pool suction gate valve
  - Conservative because yields a lower flow value from pool than if non-linear flow characteristics of gate valve used
- Stroke time for suppression pool gate valve was the bounding value of all past test data collected at the station (21 seconds)

Conservative Inputs to RELAP Analysis
(cont.)

- 24% air entrainment used to represent air volume in piping after air entered nozzle
  - Conservative because this is upper bound for observed bubbly flow for air entrainment in RELAP analysis model
  - Above this, slug flow is exhibited and we did not see this flow phenomena during the testing

RELAP Analysis Results

- Results show that no significant air entrainment will reach pump
- As suppression pool valve opens, the head drives the water from the pool through the 20 inch line
  - Slows the water/air mixture in the 16 inch line from the tank
- The void transient ends when the suppression pool valve has stroked full open

The analysis demonstrates that the HPCS pump would not see significant air entrainment

Scale Model Vortex Testing Conclusions

- Scale model testing provided useful plant specific insights
- Previous calculations did not account for geometric conditions necessary for vortex formation
- Test results combined with RELAP evaluation show that significant air entrainment will not reach pump prior to completion of transfer
- Demonstrates HPCS was capable of performing its safety function

Risk Assessment

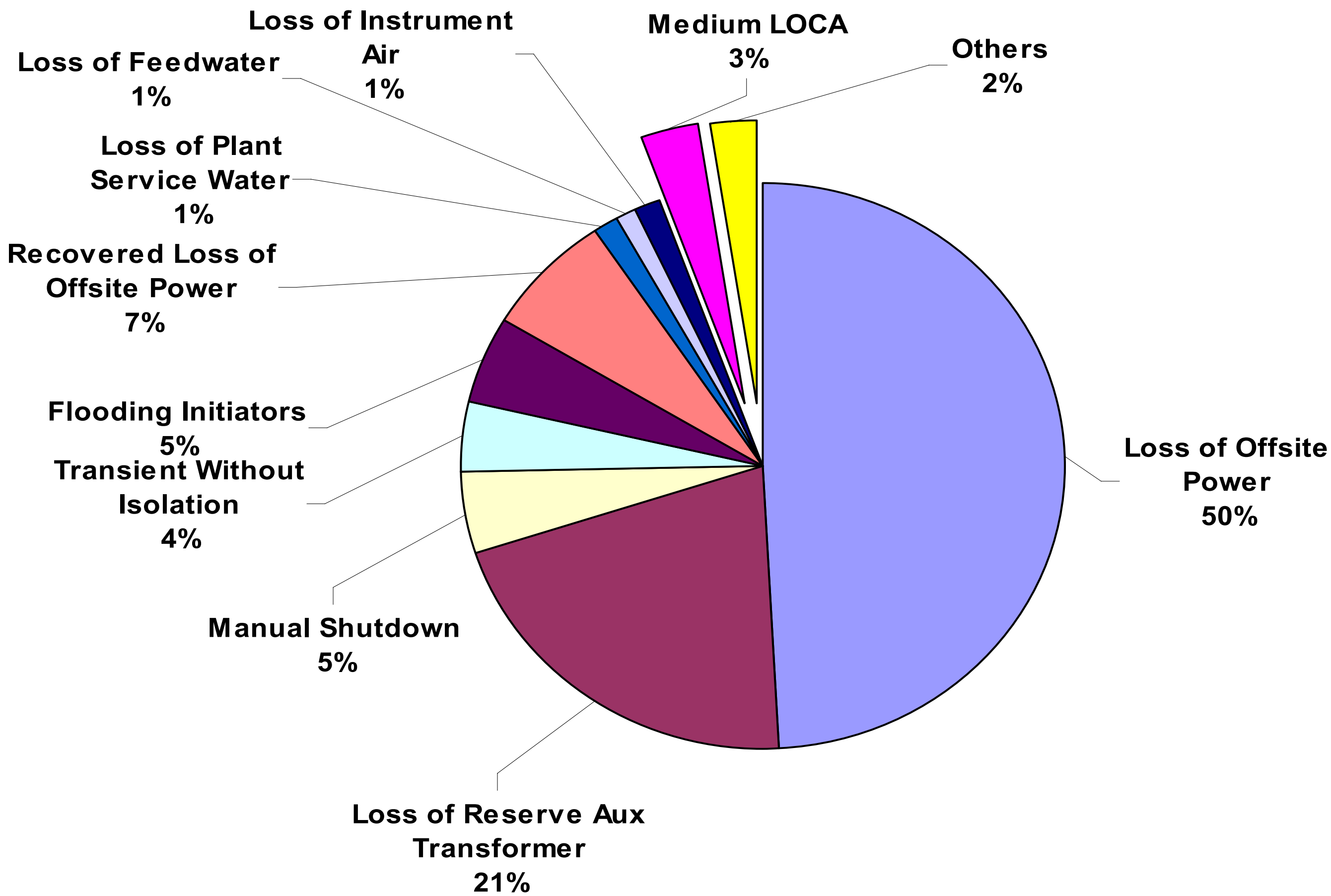
Greg Krueger

Corporate Risk Management Manager

Phase 3 SDP Risk Assessment Approach

- The Clinton internal events PRA model of record used to evaluate potential impact of HPCS pump air entrainment
- Calculated change in CDF considered the impact of potential operator actions and system response during a range of events
- Operator response and event scenario impacts were explored
  - HPCS injection valve throttling
  - HPCS suction transfer to the suppression pool

Clinton PRA Model CDF Distribution



Total CDF = 1.16E-05/yr

Risk Assessment Boundary Conditions

- HPCS is capable of mitigating core damage in most PRA scenarios and therefore is important during transient and LOCA events
- HPCS is considered risk significant due to its high flow capacity over a full range of reactor pressures
  - The risk achievement worth (RAW) is approximately 16 in the current PRA model
  - The RAW represents the increase in CDF that occurs when HPCS is removed from service or not credited in the PRA for accident mitigation

Risk Assessment Boundary Conditions (Cont.)

- The PRA model requires both HPCS suction sources
  - RCIC water storage tank
  - Suppression pool
- The suppression pool volume is required for long-term success of HPCS in the PRA
  - Failure of HPCS to transfer from the tank to the pool is a modeled failure of HPCS
- Tank level instrumentation, capable of automatically transferring the suction source, is modeled in the PRA
- Operator action to manually transfer suction is qualitatively modeled

Risk Assessment Boundary Conditions (Cont.)

- The PRA models HPCS system failures occurring at the beginning of the event
- Potential air entrainment, operator actions, and transfer of suction to suppression pool; however, occur at various times during an accident scenario
  - Without this time dependent assessment during response to an event, the initial significance of potential air entrainment could result in an overly conservative SDP result

Risk Assessment

- The CPS internal events PRA model (CL06A) was used in risk evaluation
- Baseline calculated risk values are:
  - CDF: 1.16E-05/yr
  - LERF: 5.25E-07/yr
- All core damage scenarios in the PRA that credit HPCS as a mitigation system were evaluated for the potential impact of air entrainment on system operation
- Used standard SDP practice of one year exposure period to assess risk

Risk Assessment (Cont.)

- The calculated result is considered conservative due to the following simplifications:
  - Operator throttling of the HPCS flow is the only credited action
  - No credit for tank or pool instrumentation automatically transferring HPCS from the tank to the suppression pool
  - No credit for manual transfer of HPCS suction to the suppression pool
  - No credit for HPCS minimum flow adding volume to suppression pool which would accelerate transfer of HPCS suction automatically to the suppression pool

Risk Assessment (cont.)

- Operator action to throttle HPCS flow was considered
  - Operator prioritization of response actions
  - EOP-1 allows throttling of HPCS
  - Throttling becomes compelling for scenarios in which long-term HPCS operation is required, because of RPV level swings
  - Air entrainment not expected to occur when HPCS throttled
    - Transients do not require significant HPCS flow (200 to 700 gpm)
    - Flow rates below those necessary for air entrainment

Risk Assessment (cont.)

- HPCS system failure due to RCIC water storage tank suction air entrainment is mitigated by the following plant and operator responses
  - Upon recognition that extended HPCS operation will be required, throttling HPCS flow becomes high priority
  - The time it takes to empty the RCIC storage tank also delays the time that HPCS suction air entrainment may occur
    - This timing provides input to the operator success rate for other responses

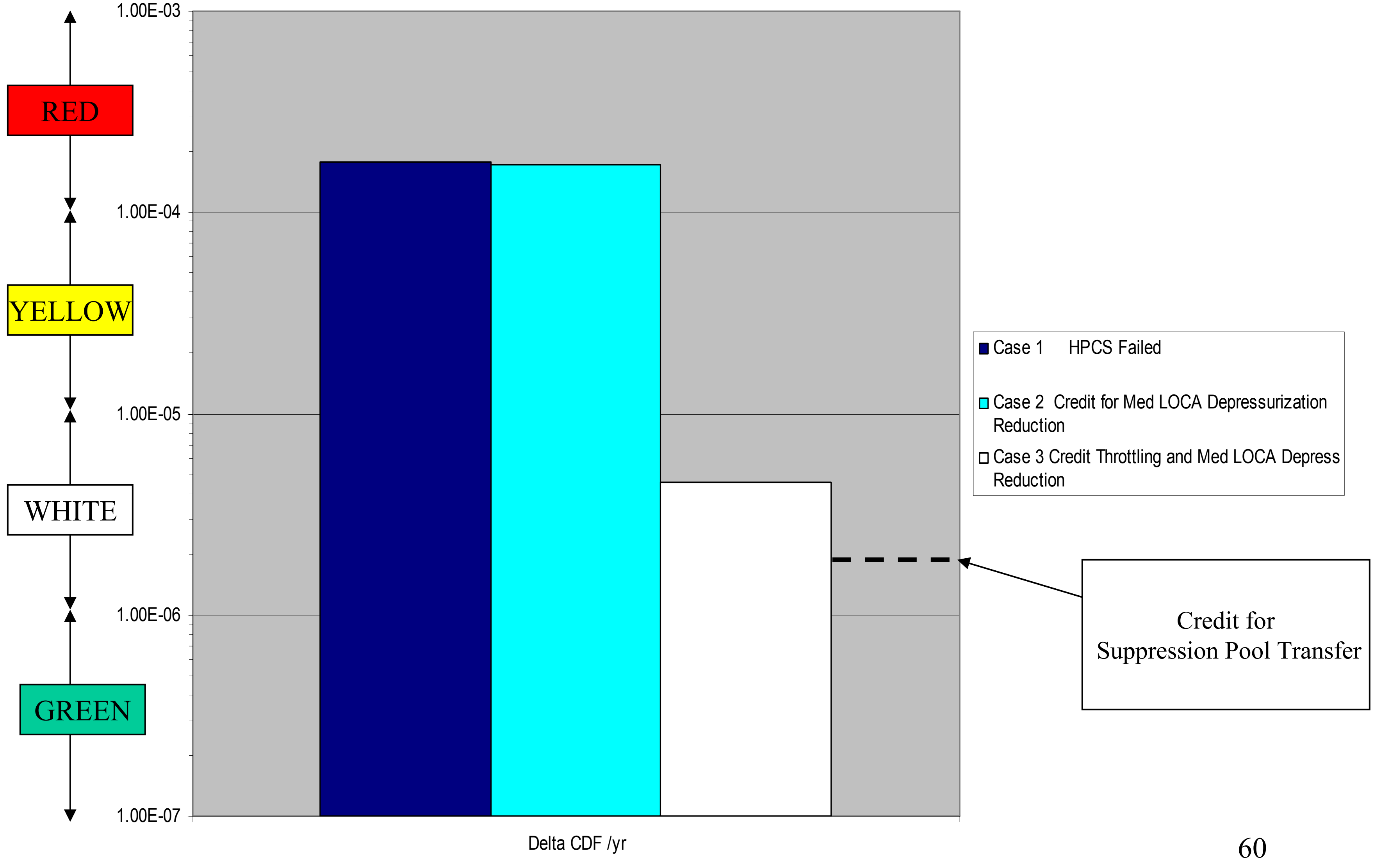
Risk Assessment (cont.)

- Operator success for throttling based on:
  - RPV water level control directed by EOPs
  - Simple procedurally directed actions
  - Staged equipment to perform the action
  - Operator trained and evaluated
  - Time available to perform the action is on the order of hours
- Throttling is applied to transient cases

Risk Assessment (cont.)

- Scenarios other than transients (e.g., medium LOCA) do not credit throttling
- Failure of HPCS due to air entrainment is not applied to medium LOCA scenarios involving depressurization
  - Nature of medium LOCA is that break flow depressurizes the reactor
  - Depressurization below low pressure injection pressure occurs before HPCS air entrainment can occur

Risk Assessment Results (cont.)



Risk Assessment Results (cont.)

- Quantification of external events models was not performed but an estimation using previously docketed information was used
  – External events such as fires, floods, and seismic events result in transient-type conditions, therefore the change in risk is similar to that calculated from the internal events model
  – Fire result dominates risk and therefore the change in CDF from external events only considers fires

Risk Assessment Results (cont.)

- Total CDF associated with fires is 3.26 E-6/yr (from the IPEEE Fire PRA)
  - The change in fire CDF is estimated to be 3.49 E-6/yr
- The total SDP CDF is the summation of the risk from internal and external events is:

  4.59E-6 + 3.49E-6 = 8.08E-6/yr (White band)
- This result is conservative due to the previously mentioned simplifications
  - Qualitatively accounting for those simplifications would drive the result lower in the White band
- LERF does not drive the results

Risk Assessment Conclusions

- Risk assessment conservatively assumes that air entrainment does occur at RCIC water storage tank low level
- The risk significance associated with air entrainment in the RCIC water storage tank is in the White band
  - Inclusion of external events contribution does not change the color
- Consideration of additional system responses and operator actions would reduce the risk significance lower in the White band

Conclusions

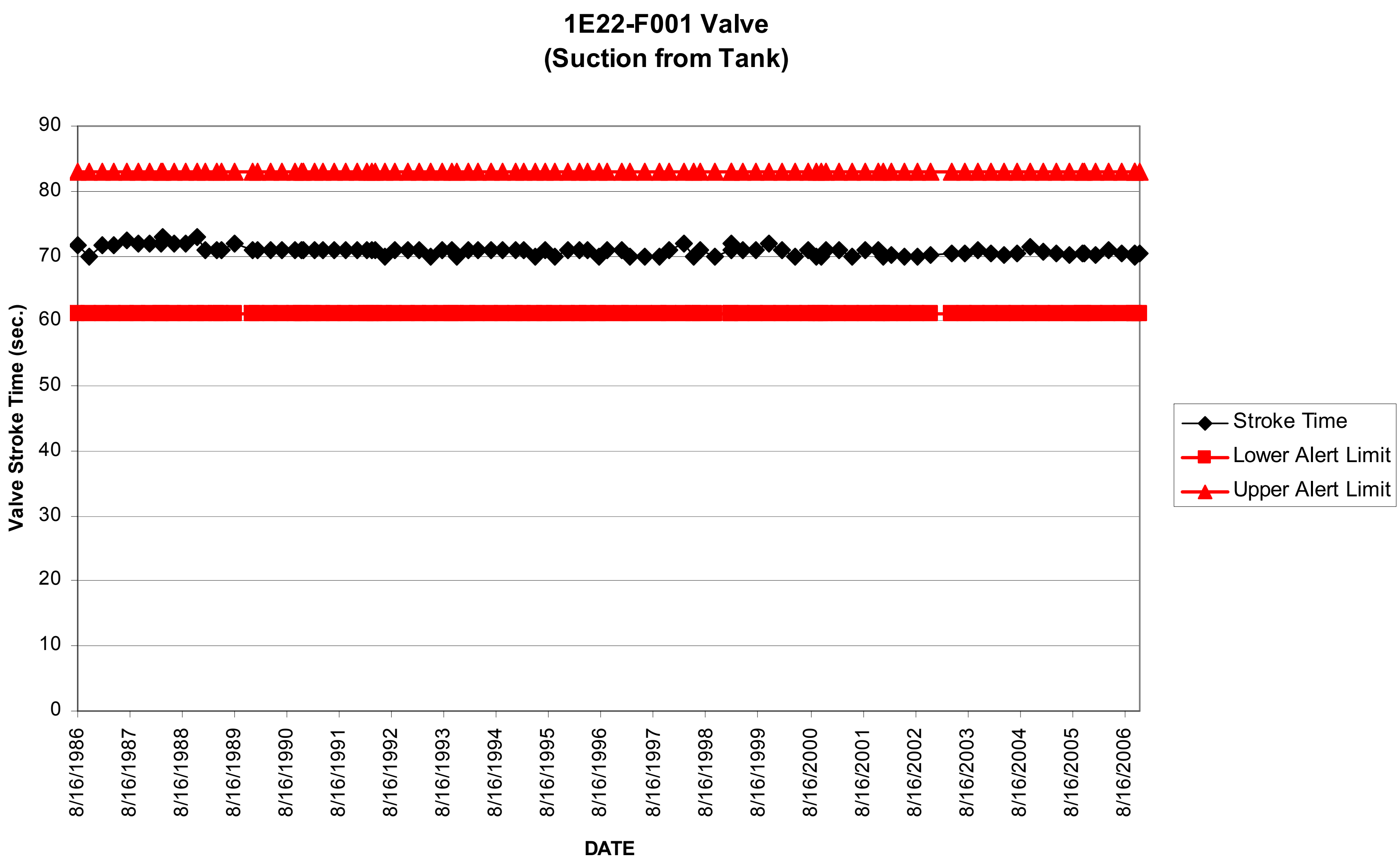
Michael McDowell

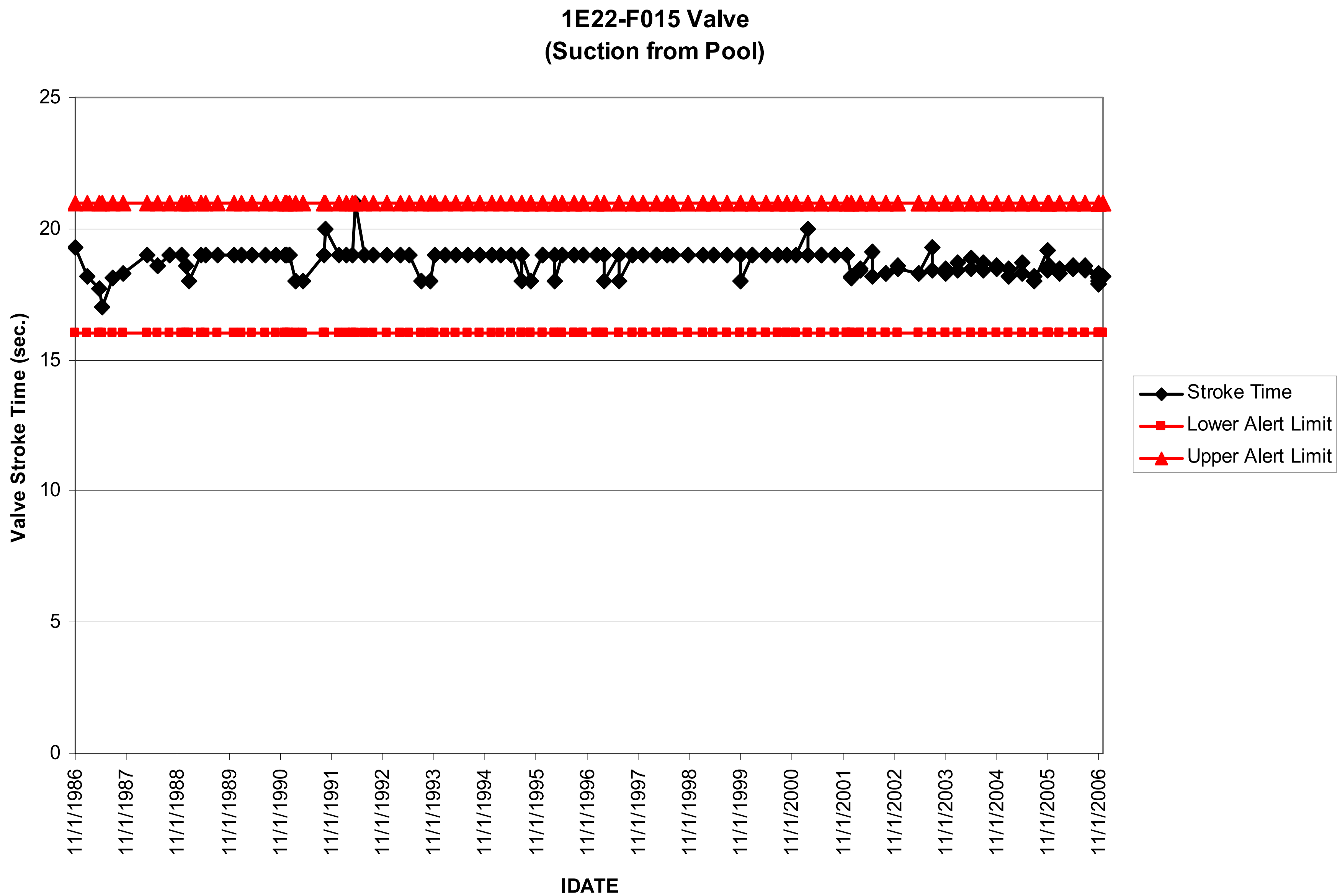
CPS Plant Manager

Conclusions

- Scale model testing results demonstrate HPCS would have been capable of performing safety function
  - As a result Finding would be of very low safety significance (i.e., Green)
- CPS also completed a risk assessment neglecting scale model testing insights
  - Results show that risk consequences are of low to moderate safety significance (i.e., White)

Backup Slides


1E22-F001 Valve
(Suction from Tank)
Valve Stroke Time (sec.)
90
80
70
60
50
40
30
20
10
0
8/16/1986
8/16/1987
8/16/1988
8/16/1989
8/16/1990
8/16/1991
8/16/1992
8/16/1993
8/16/1994
8/16/1995
8/16/1996
8/16/1997
8/16/1998
8/16/1999
8/16/2000
8/16/2001
8/16/2002
8/16/2003
8/16/2004
8/16/2005
8/16/2006
DATE
Stroke Time
Lower Alert Limit
Upper Alert Limit



1E22-F015 Valve
(Suction from Pool)
Valve Stroke Time (sec.)
25
20
15
10
5
0
11/1/1986
11/1/1987
11/1/1988
11/1/1989
11/1/1990
11/1/1991
11/1/1992
11/1/1993
11/1/1994
11/1/1995
11/1/1996
11/1/1997
11/1/1998
11/1/1999
11/1/2000
11/1/2001
11/1/2002
11/1/2003
11/1/2004
11/1/2005
11/1/2006
IDATE
Stroke Time
Lower Alert Limit
Upper Alert Limit

Sensitivity Study of Input Parameters

- RELAP analysis was run with a suppression pool suction valve stroke time of 28 seconds
  - All other inputs remained the same
  - This stroke time represents the design stroke time of the valve
- Results showed 4% air entrainment at the pump suction