NPE MECH 4/1/81	PENNSYLVANIA POWER & LIGHT COMPANY CALCULATION SHEET	ER No. L00450
H.R. Clarke [signature]	PROJECT SUSQUEHANNA SES	Sht. No. 0 of 9
	[initials] checked	

CONTAINMENT STEAM BYPASS

OBJECTIVE: Assuming a small break accident with steam being completely bypassed directly into the wetwell air space, determine how much time is available without operator action before the wetwell design pressure of 53 psig is reached. Time $t=0$ is defined at the moment wetwell air space pressure reaches 30 psig.

NOTE: The fact that no credit was taken for heat sinks in this calculation is very conservative. An analysis similar to this calculation was performed by Sargent Lundy for LaSalle.* The Sargent Lundy analysis used the COMTEMPT computer code and investigated the sensitivity of the heat sink parameter. For LaSalle, a 50% reduction in heat sink capacity resulted in an 11 minute reduction (35%) in time allowed without operator action. It is safe to assume, therefore, that because of the similar Mark II geometries, SUSQUEHANNA would gain 10 to 20 minutes by taking credit for 100% of its heat sink capacity.

8104210467

* Reference LaSalle FSAR question C21.1

MARK II ASSUMPTIONS

1. The steam that leaks into the wetwell air space does not mix with the air already there.

2. No portion of the steam that has leaked into the wetwell air space condenses.

3. Only steam leaks into the wetwell; any air moving from the drywell into the wetwell goes through the vents.

4. For this small break analysis, all of the air initially in the drywell is cleared into the wetwell before the moment when the operator is alerted.

5. The flow of steam through leakage paths is considered incompressible.

6. The pressure differential across the leakage path is assumed constant and equal to the vent submergence hydrostatic pressure difference.

7. The wetwell air temperature when the operator is alerted to the occurance of bypass leakage is assumed to be equal to the initial wetwell temperature. At the time the drywell pressure is reduced due to operator action, the wetwell air temperature is assumed to be 50°F greater than the initial wetwell temperature.

Dept. NPE MECH	PENNSYLVANIA POWER & LIGHT COMPANY CALCULATION SHEET	ER No
Date 4/1 19 81		
Designed by HRC	PROJECT SUSQUEHANNA SES	Sht. No. 2 of 9
Approved by		
	INPUT PARAMETERS	

M_{NC} ≡ mass of non-condensible gas in drywell and wetwell 26,986 lbm

V_{DW} ≡ drywell volume (including vents) 239,337 ft^3

V_{WW} ≡ wetwell airspace volume (high water level) 148,590 ft^3

T_{DW} ≡ initial drywell temperature 135°F

T_{WW} ≡ initial wetwell temperature 90°F

ϕ_{DW} ≡ initial drywell relative humidity (minimum normal) 0.2

ϕ_{WW} ≡ initial wetwell relative humidity (minimum normal) 1.0

$P_{SAT}(T_{DW})$ ≡ pressure of saturated steam at T_{DW} 2.5375 psia

$P_{SAT}(T_{WW})$ ≡ pressure of saturated steam at T_{WW} 0.69813 psia

P_{DW} ≡ initial drywell pressure (maximum normal) 15.45 psia

P_{WW} ≡ initial wetwell pressure (maximum normal) 15.45 psia

ΔP_v ≡ pressure differential drywell/wetwell (high water level) 5.18 psi

P_{so} ≡ initial wetwell pressure (NRC operator action analysis) 44.7 psia (30 psig)

V_{so} ≡ volume of steam leaked into wetwell when pressure has reached P_{so} 23,639 ft^3

P_{SF} ≡ final wetwell pressure (NRC operator action analysis – SSES design) 67.7 psia (53

T_{WF} ≡ final wetwell temperature (when P_{SF} is reached) 140°F

V_{SF} ≡ volume of steam leaked into wetwell when pressure has reached P_{SF} 56,652 ft^3

$P_{SAT}(T_{WF})$ ≡ pressure of saturated steam at T_{WF} 2.8892 psia

$V_g(P_{SF})$ ≡ specific volume of saturated steam at P_{SF} 6.4036 ft^3/lbm

$V_g(P_{so})$ ≡ specific volume of saturated steam at P_{so} 9.4417 ft^3/lbm

R ≡ gas constant 53.34 $\frac{ft\ lbf}{lbm\ °R}$

t_r ≡ time delay between P_{so} and P_{SF} (30 psig to 53 psig)

Dept. NPE MECH Date 4/1 1981 Designed by HRC Approved by	PENNSYLVANIA POWER & LIGHT COMPANY CALCULATION SHEET PROJECT SUSQUEHANNA SES MNC	ER No Sht. No. 3 of 9

$$M_{NC} = \frac{\left(P_{DW} - \phi_{DW}\, P_{SAT}(T_{DW})\right) V_{DW}}{R\, T_{DW}} + \frac{\left(P_{WW} - \phi_{WW}\, P_{SAT}(T_{WW})\right) V_{WW}}{R\, T_{WW}}$$

$$M_{NC} = \frac{\left(15.45 \frac{lbf}{in^2} - 0.2\left(2.5375 \frac{lbf}{in^2}\right)\right)\left(239{,}337\ ft^3\right)\left(144 \frac{in^2}{ft^2}\right)}{\left(53.34 \frac{ft\ lbf}{lbm\ {}^\circ R}\right)\ (135+460)\ {}^\circ R} +$$

$$\frac{\left(15.45 \frac{lbf}{in^2} - 1.0\left(0.69813 \frac{lbf}{in^2}\right)\right)\left(148{,}590\ ft^3\right)\left(144 \frac{in^2}{ft^2}\right)}{\left(53.34 \frac{ft\ lbf}{lbm\ {}^\circ R}\right)\ (90+460)\ {}^\circ R}$$

$$M_{NC} = 16227 + 10{,}759$$

$$\underline{M_{NC} = 26{,}986\ lbm}$$

Dept. NPE MECH	**PENNSYLVANIA POWER & LIGHT COMPANY** **CALCULATION SHEET**	ER No
Date 4/1 19 81		
Designed by HRC	PROJECT SUSQUEHANNA SES	Sht. No. 4 of 9
Approved by		
	ΔP_v	

$$\Delta P_v = \rho H \left(\frac{g}{g_c}\right)$$

ρ = density of water at $T_{ow} = 90°F$

ρ = 62.12 lbm / ft³

$\frac{g}{g_c}$ = constant 1.0 $\frac{lbf}{lbm}$

H = vent submergence

H = 12 ft

$$\Delta P_v = \left(62.12 \frac{lbm}{ft^3}\right)\left(12\ ft\right)\left(1.0\ \frac{lbf}{lbm}\right)\left(\frac{1.0\ ft^2}{144\ in^2}\right)$$

$\underline{\Delta P_v = 5.18\ psi}$

Dept. NPE MECH	PENNSYLVANIA POWER & LIGHT COMPANY CALCULATION SHEET	ER No
Date 4/1 1981		
Designed by HRC	PROJECT SUSQUEHANNA SES	Sht. No. 5 of 9
Approved by		
	P_{so}, V_{so}	

P_{so} = 30 psig per NRC assumption

P_{so} = 44.7 psia

$$V_{so} = V_w - \frac{M_{NC}\ R\ T_{ww}}{P_{so} - P_{SAT}(T_{ww})}$$

$$V_{so} = 148{,}590\ ft^3 - \frac{(26986\ lbm)\left(53.34\ \frac{ft\ lbf}{lbm\ {}^\circ R}\right)(90+460)^\circ R}{\left(44.7\ \frac{lbf}{in^2} - 0.69813\ \frac{lbf}{in^2}\right)\left(\frac{144\ in^2}{1.0\ ft^2}\right)}$$

V_{so} = 148,590 − 124,945

V_{so} = 23645 ft^3

Dept. NPE MECH

Date 4/1 19 81

Designed by HRC

Approved by

PENNSYLVANIA POWER & LIGHT COMPANY
CALCULATION SHEET

PROJECT SUSQUEHANNA SES

P_{SF}, T_{WF}, V_{SF}

ER No

P_{SF} = final wetwell pressure = SSES wetwell design pressure

P_{SF} = 53 psig

P_{SF} = 67.7 psia

T_{WF} = final assumed wetwell airspace temperature

$T_{WF} = T_{WW} + 50°F$

$T_{WF} = 90°F + 50°F$

$T_{WF} = 140°F$

$$V_{SF} = V_{WW} - \frac{(26786\ \text{lbm})\left(53.34\ \frac{\text{ft lbf}}{\text{lbm °R}}\right)(140+460)\ \text{°R}}{\left(67.7\ \frac{\text{lbf}}{\text{in}^2} - 2.8872\ \frac{\text{lbf}}{\text{in}^2}\right)\left(144\ \frac{\text{in}^2}{\text{ft}^2}\right)}$$

$V_{SF} = 148,590 - 92,541$

$V_{SF} = 56\,049\ \text{ft}^3$

Dept. NPE MECH

Date 4/1 1981

Designed by HRC

Approved by

PENNSYLVANIA POWER & LIGHT COMPANY
CALCULATION SHEET

PROJECT SUSQUEHANNA SES

$A/\sqrt{K}$, $\bar{\dot{m}}_{SB}$

ER No

$$\frac{A}{\sqrt{K}} = \bar{\dot{m}}_{SB}\sqrt{\frac{V_g(P_{SF}) + V_g(P_{SO})}{4\, g_c\, \Delta P_v}}$$

$$\frac{A}{\sqrt{K}} = \bar{\dot{m}}_{SB}\sqrt{\frac{6.4036\ \frac{ft^3}{lbm} + 9.4417\ \frac{ft^3}{lbm}}{4\left(32.2\ \frac{ft}{sec^2}\right)\left(5.18\ \frac{lbf}{in^2}\right)\left(\frac{144\ in^2}{1\ ft^2}\right)\left(\frac{lbm}{lbf}\right)}}$$

$$\frac{A}{\sqrt{K}} = \bar{\dot{m}}_{SB}\sqrt{.00016493}$$

$$\underline{\frac{A}{\sqrt{K}} = .01284\ \bar{\dot{m}}_{SB}} \qquad \underline{\underline{OR}} \qquad \underline{\bar{\dot{m}}_{SB} = 77.88\ \frac{A}{\sqrt{K}}}$$

$\frac{A}{\sqrt{K}}$ ft^2

$\bar{\dot{m}}_{SB}$ $\frac{lbm}{sec}$

Dept. NPE MECH

Date 4/1 19 81

Designed by HRC

Approved by

PENNSYLVANIA POWER & LIGHT COMPANY
CALCULATION SHEET

PROJECT SUSQUEHANNA SES

$\bar{\dot{m}}_{SB}$, t_D

ER No

$\bar{\dot{m}}_{SB} \equiv$ average steam mass flow for a small break accident

$t_D \equiv$ time delay between P_{SO} and P_{SF} (30 psig and 53 psig)

$$\bar{\dot{m}}_{SB} = \frac{1}{t_D}\left(\frac{V_{SF}}{V_g(P_{SF})} - \frac{V_{SO}}{V_g(P_{SO})}\right)$$

$$\bar{\dot{m}}_{SB} = \frac{1}{t_D}\left(\frac{56{,}052\ ft^3}{6.4036\ ft^3/lbm} - \frac{23{,}639\ ft^3}{9.4417\ ft^3/lbm}\right)$$

$$\bar{\dot{m}}_{SB} = \frac{1}{t_D}\left(8753\ lbm - 2504\ lbm\right)$$

$$\bar{\dot{m}}_{SB} = \frac{1}{t_D}(6249) \quad \text{OR} \quad t_D = \frac{1}{\bar{\dot{m}}_{SB}}(6249)$$

$\bar{\dot{m}}_{SB}$ $\frac{lbm}{sec}$

t_D sec

CASE 1

$$\frac{A}{\sqrt{K}} = .05 \text{ ft}^2 \quad \text{NRC Standard Review Plan}$$

$$\bar{\dot{m}}_{SB} = 77.88 \frac{A}{\sqrt{K}} = 77.88(.05)$$

$$\bar{\dot{m}}_{SB} = 3.894 \text{ lbm/sec}$$

$$t_D = \frac{1}{\bar{\dot{m}}_{SB}}(6249) = \frac{1}{3.894}(6249)$$

$$t_D = 1605 \text{ sec}$$

$$t_D = 26.75 \text{ minutes}$$

CASE 2

$$\frac{A}{\sqrt{K}} = .0535 \text{ ft}^2 \quad \text{Calculation for SSES by GE}$$

$$\bar{\dot{m}}_{SB} = 77.88 \frac{A}{\sqrt{K}} = 77.88(.0535)$$

$$\bar{\dot{m}}_{SB} = 4.167 \text{ lbm/sec}$$

$$t_D = \frac{1}{\bar{\dot{m}}_{SB}}(6249) = \frac{1}{4.167}(6249)$$

$$t_D = 1500 \text{ sec}$$

$$t_D = 25 \text{ minutes}$$

CONTAINMENT HIGH PRESSURE
BYPASS LEAKAGE TEST

ATTACHEMENT 2 TO PLA 742