Sensitivity Analysis of Post-LOCA Containment Performance for Dresden Units 2/3

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Revision 0

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ATTACHMENT 1
CONTAINMENT SENSITIVITY ANALYSIS

Memorandum

ComEd

Date: March 11, 1997
NFS:BSA:97-034

To: Russell Freeman

Subject: Transmittal of Containment Post-LOCA Sensitivity Analysis

Attached please find for your use a copy of an NFS calculation entitled:

"Sensitivity Analysis of Post-LOCA Containment Performance for Dresden Units 2/3", BSA-D-97-03, revision 0.

This calculation has been prepared in response to NRC review questions regarding the Ultimate Heat Sink licensing amendment. This calculation demonstrates the sensitivity of changes in service water temperature on containment pressure and provides additional cases that support that a realistic calculation based on EOP guided operator response will result in continuous spray operation. In addition, the realistic cases provide support for the margin inherent in the vendor design calculations that form the basis of the licensing amendment.

This calculation has been prepared and reviewed in accordance with NFS procedures for the performance of controlled work. If you have any questions regarding this matter, please contact Mr. K. B. Ramsden on extension 3017.

Robert W. Tsai
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Enclosure

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Abstract

The purpose of this report is to document a series of calculations performed to support NPSH calculations for the Dresden ECCS pumps in Post-LOCA suppression pool heatup scenarios. The base Post-LOCA calculations were performed by General Electric. This calculation benchmarks a MATHCAD model to the vendor calculations and then develops a series of sensitivity cases to investigate nominal containment performance versus design limiting conditions and demonstrate the effect of service water temperature variation on suppression pool temperature and pressure.

This calculation is based on models previously developed to perform similar calculations, and extends the methodology developed to include the most recent vendor assumptions applied to analyses of this type. New benchmarks are provided to confirm the adequacy of the MATHCAD model for this application. This report has been written to stand alone and does not rely on previous calculations.

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1. Introduction

The intent of this calculation is to extend vendor calculations performed to evaluate Post-LOCA heatup as part of a licensing amendment currently under review by USNRC. During the review process it has become apparent that a simple, fast running model of suppression pool response is necessary to provide a valid technical basis for engineering judgements to be made regarding the effects of postulated variances from the design analysis assumptions. The questions that this report is directed towards addressing are two-fold: 1) What is the nominal post-LOCA containment performance anticipated, particularly with respect to operator actions supported by current operating procedures?, and 2) What is the sensitivity of the limiting long term case to postulated variations in service water temperature?

An analysis method has been developed that allows rapid and economic solution of a first order differential equation describing the post-blowdown behavior of the Dresden containment. This method uses the MATHCAD software package to perform Runge-Kutta numerical solution of this equation. A quasi-static balance is then performed at each solution step to obtain the drywell and wetwell airspace temperatures, determine the air mass of each volume, and ultimately the wetwell pressures for use in NPSH calculations. The analysis method developed has been benchmarked against the most recent General Electric SHEX-04 long term analyses which form the basis of the licensing amendment.

2. Methodology/Model Description and Assumptions

The following sections provide the theoretical basis for the MATHCAD model.

2.1 Analytical Solution of Post-LOCA Suppression Pool Temperature

The post-LOCA behavior of the suppression pool can be characterized as consisting of two distinct periods, the initial vessel blowdown and core reflood phase, and a long term heatup of the suppression pool during extended recirculation of the suppression pool water through the vessel. The first period adds a large amount of energy and mass to the suppression pool due to the inventory of the vessel as well as the feedwater addition. The recirculation phase has three major contributors to the energy addition to the pool, namely the decay heat, the sensible heat stored in the vessel thick metal volumes, and the ECCS pump heat. The LPCI/CCSW containment cooling subsystem acts as a sink, with heat removal dependent on the flows assumed and the temperature difference between service water (CCSW) and the suppression pool. This situation can be readily characterized by the following equation:

$$mc_p \frac{dT}{dt} = Q_{decay}(t) + Q_{pump} + Q_{sensheat} - K_{hx} * [T(t) - T_{sw}]$$

where:

m = the pool mass (initial plus mass added during blowdown phase)

c_p= the specific heat of water (1.0 used)

Q_{decay}= decay energy (based on ANS 5.1 1979 table used by GE)

Q_{pump}= pump motor horsepower converted to thermal energy (700 HP for LPCI, 800 HP for Core spray, and 2 CCSW pumps @ 500 HP each)

$Q_{sensheat}$= vessel metal mass sensible heat addition rate (approximately 70 MBTU added as an exponentially decreasing rate)

K_{HX}= LPCI heat exchanger performance based on flow rates of LPCI and CCSW (BTU/sec-F).

T_{SW}= CCSW temperature constant at 95 F.

This equation readily lends itself to solution with fourth order Runge-Kutta numerical methods. A solution of this type was developed utilizing the MATHCAD software package. The routines developed were then exercised for the base cases provided by GE as well as for the sensitivity studies requested.

2.2 Calculation of Suppression Pool Pressure

Once a model of the suppression pool temperature was developed, an expression for the suppression pool pressure was needed in order to provide necessary input data to the NPSH calculations. In the long term post-LOCA scenarios, the pressure of the suppression pool is determined by the distribution of air between the wetwell airspace and the drywell, and the partial pressures of water vapor in each region, which are dependent on temperature. The methods described below are based on calculation of quasi-static equilibrium conditions at the suppression pool temperatures already calculated. The scenarios assume the containment spray is operating in order to minimize the pressure. A diagram of the containment regions is provided in Figure 1. The wetwell airspace temperature is assumed to be equal to the spray temperature. The spray temperature can be determined based on the LPCI flow rate and heat exchanger K-value, and then expressions for the drywell and suppression pool temperatures can be developed as follows:

$$T_{ww} = T_{pool} - [K_{HX}(T_{pool} - T_{SW}) - Q_{pump}] / c_p m_{lpci}$$

Note that the pressure in the volumes is

$$P_{dw} = P_{air,dw} + P_{sat,Tdw}$$
$$P_{ww} = P_{air,ww} + P_{sat,Tww}$$

and

$$M_{a,dw} + M_{a,ww} = M_{total} = \text{constant}$$

Where M is the mass of air in the volumes.

By applying the ideal gas law to characterize the air partial pressure in the volumes the following expressions result:

$$P_{ww} - P_{dw} = P_{vb}$$

or

$$P_{a,ww} + P_{sat,Tww}] - [P_{a,dw} + P_{sat,Tdw}] = P_{vb}$$

rewriting based on the gas law

$$\left(\frac{[M_{a,ww}R(Tww+460)]}{V_{ww}} + P_{sat,Tww}\right) - \left(\frac{[M_{a,dw}R(Tdw+460)]}{V_{dw}} + P_{sat,Tdw}\right) = P_{vb}$$

now these equations can be solved for M_{aww}, yielding:

$$M_{a,ww} = \frac{144[P_{sat,Tdw} - P_{sat,Tww} + P_{vb}] + [M_{a,total}R(Tdw+460)/V_{dw}]}{[R(Tdw+460)/V_{dw}] + [R(Tww+460)/V_{ww}]}$$

Given this equation, the pressure in the wetwell can then be determined. The drywell temperature is estimated by the use of a mass weighted balance of the fluids mixing in the drywell, namely the recirculation from the break (equal to the core spray flow rate of 4500 gpm) and the drywell spray flow rate m_{lpcis}(95% of total LPCI flow) as follows:

$$Tdw = \frac{\{(T_{pool} - \frac{K_{hx}[T_{pool} - T_{sw}]}{c_p m_{lpcis}})m_{lpcis} + (T_{pool} + \frac{Q_{decay} + Q_{pump.cs} + Q_{senshl}}{c_p m_{cs}})m_{cs} * \eta\}}{m_{lpcis} + m_{cs} * \eta}$$

Where η is the fraction of the break recirculation fluid that is assumed to mix with the spray in the drywell atmosphere. This is consistent with the GE analysis. This is done to provide a conservatively low estimate of drywell temperature which minimizes the containment pressure predicted.

Note: This relationship is specifically true in the long term post-LOCA situation in which fluid exiting the vessel exhibits some degree of subcooling, it represents a constraint on the applicability of the model to other more generalized problems.

The saturation pressures are obtained by performing an interpolation of a parabolic spline fit of ASME data in the range of temperatures anticipated for this problem. (120-210 F) Data applied in the above equations is listed below:

R=53.34 (Gas Constant) ft-lbf/lbm-R

c_p =1.0

Fluid specific volume assumed constant = .0164 ft^3/lb

$M_{a,total}$=19284 lbm for nominal initial conditions DW 135F/20%RH

=16499 lbm for minimum non-condensible cases DW 150/100%RH

This reduction in initial air mass is consistent with the reductions applied by GE for use in the NPSH analysis previously performed, and represents the changes in air mass that would result from selection of model initial conditions minimizing the air volume. (higher humidity and temperature).

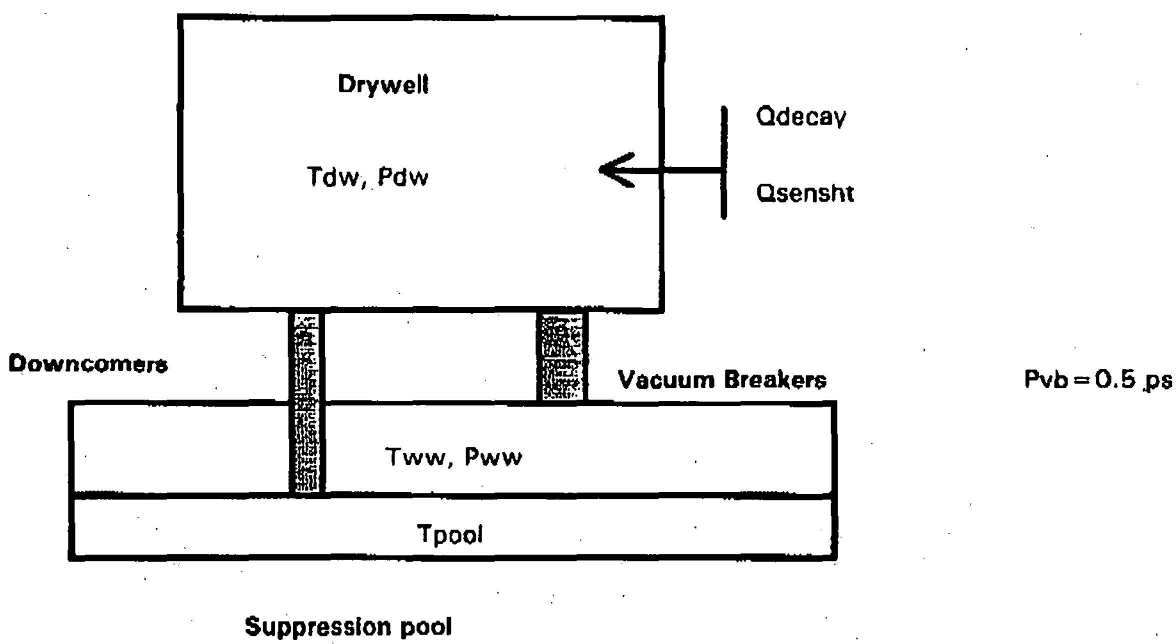


Figure 1 Containment Model

3. Calculations/Acceptance Criteria/Basedeck Changes

3.1 Background

The original design points for the LPCI heat exchangers were at a two LPCI flow of 10,700 gpm with two CCSW pump flow of 7000 gpm, and single LPCI flow of 5350 gpm and 3500 gpm single pump CCSW flow. In the updated calculations performed, the new "design" flow is at 5000 gpm LPCI / 7000 gpm CCSW for the limiting case. This case yields the lowest containment pressures with the highest corresponding suppression pool temperatures due to the injection of cold spray into the suppression pool airspace. The 1 LPCI/2CCSW pump cases yield the coldest temperatures exiting the LPCI HX, relative to a 1/1 or 2/2 case. Specific details of the cases performed are described below.

3.2 Benchmark cases

The first step in performing these calculations was to select benchmark cases and perform comparisons. These comparisons establish the validity of the model for use in subsequent sensitivity studies. The cases selected were GE cases 2A1 with assumed drywell mixing fractions of 20% and 100%. Reference 1. The flow rates and heat transfer capacities for these cases are provided in Table 1.

CASE	LPCI Flow gpm	CCSW Flow gpm	HX K Btu/sec-F
GE 2A1	5000	7000	307.4

Table 1 Heat Exchanger Parameters used in Benchmark Calculation

3.3 Sensitivity to service water temperature

These cases employ the base case 2A1 model used above, with a 20% drywell mixing fraction assumed. The service water is ranged from the initial value of 95F down to 75F in 5F increments. All other assumptions remain the same as the base case. The suppression pool initial temperature is assumed to be at 95F for all cases.

3.4 Nominal Containment Performance Calculation

Several cases are run for this case to provide an estimate of the most likely containment pressure that would exist in a DBA LOCA event based on operator response in accordance with existing Emergency Operating Procedures (EOPs). The operator would initiate sprays, first to the suppression pool, followed by the drywell spray upon reaching 9 psig containment pressure, or 281 F drywell temperature. The sprays would be manually secured upon pressure decreasing to 2 psig, and automatic isolation would occur at a drywell pressure of 1 psig. The cases that are run include the following:

1) Base case 2A1 with containment non-condensibles set to nominal values. This condition will then be used for the remaining nominal cases. This case provides the pressure that would be expected assuming spray operates continuously, but starting at a more likely initial condition.

2) Case 1 above repeated but with the assumption of 40% mixing in the drywell. This represents the situation of continuous spray, but with nominal initial conditions and best-estimate mixing. This is anticipated to be the most likely condition that the operator would see.

3) Case 2A1 with no spray assumed for entire event. This case provides an upper bound pressure that would be available if sprays were not utilized at all during the event. This covers the case in which subcooled break flow depressurizes the containment below the EOP spray initiation point prior to reaching the 10 minute time point where the operator would be initiating spray and or torus cooling. It should be noted that without spray or spillage of cold excess LPCI flow to the drywell, that repressurization will occur. This model calculates a quasi-static mass and pressure balance and will tend to overpredict the pressure somewhat in the initial phase of the event. Review of mass-release information for case 2A1 reveals that steam flow will be expected out past 4000 seconds, which supports that non-condensible transfer will continue at least through that time frame, and a saturated steam environment will prevail in the drywell.

4. Results

4.1 Benchmark Calculation Results

The results of the benchmark calculations are shown in Table 4. As can be seen, the MATHCAD model provides very good agreement with the GE base model. The results of the benchmark cases are shown in Figures 2, 3, 4, and 5. As can be seen, the temperature comparison is very good throughout the transient. The suppression pool pressure shows some small differences early in the transient, particularly for the 100% mixing case, which is believed to be a result of the quasi-static pressure calculation method employed. This model accounts for the effects of the spray flow and transfer of non-condensibles between the wetwell and drywell in basically an instantaneous fashion, which neglects the time element needed to accomplish the mass transfer. However, at the principal point of interest, the long term pressure peak, the agreement between the calculations is excellent. Therefore it is concluded that the MATHCAD model provides reasonable predictive capabilities, particularly at the long term peaks.

CASE	LPCI Flow gpm	CCSW Flow gpm	DW Mixing Fraction	Peak Pool Temp. F	Pressure at Peak psia
GE 2A1	5000	7000	20%	172.1	17.7
MCAD	5000	7000	20%	172.6	17.58
GE 2A1	5000	7000	100%	171.9	19.5
MCAD	5000	7000	100%	172.8	19.48

Table 2 Results of Benchmark Calculations

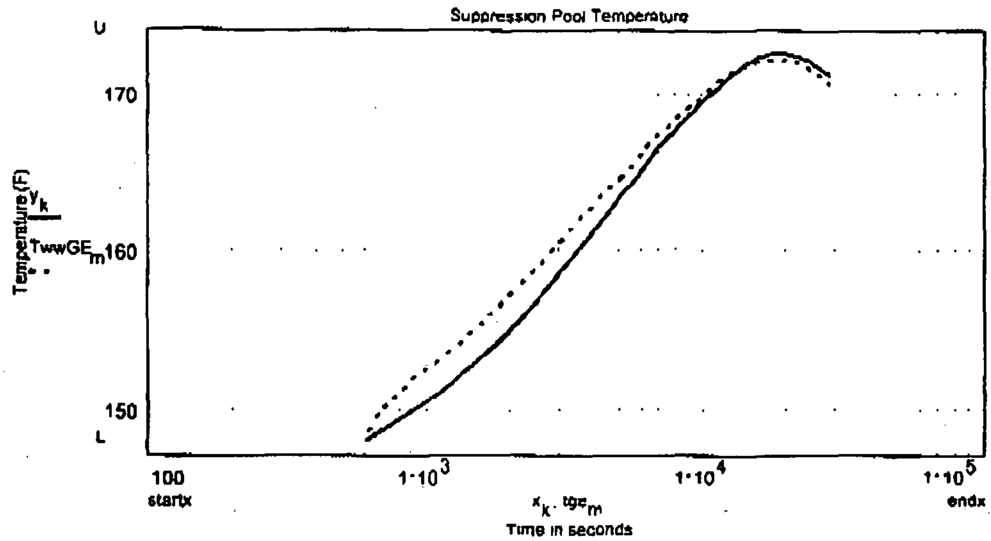


Figure 2 Benchmark 1 Suppression Pool Temperature Comparison 20% Case

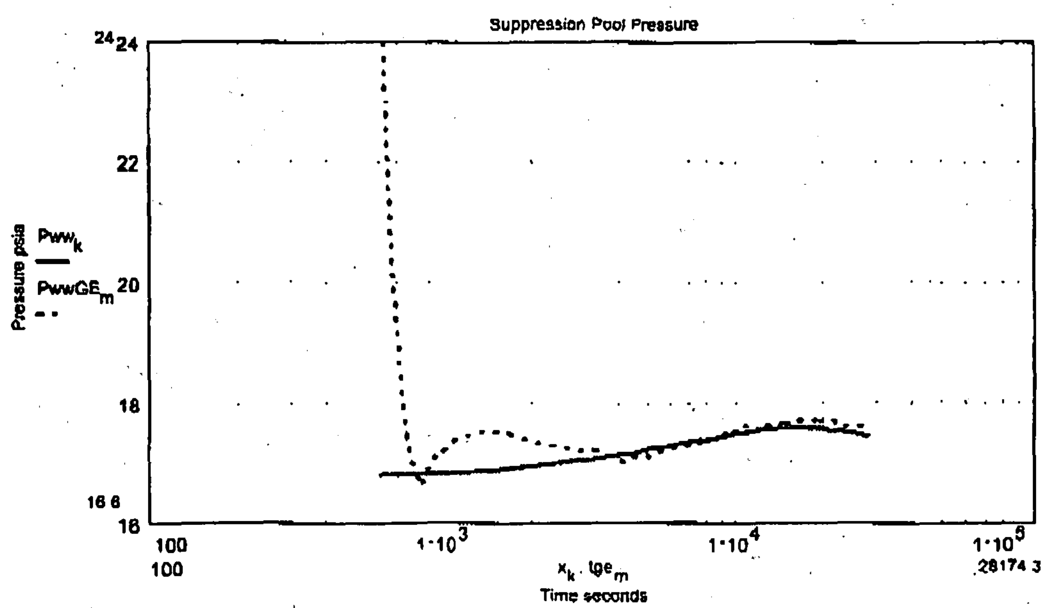


Figure 3 Benchmark 1 Suppression Pool Pressure Comparison 20% Case

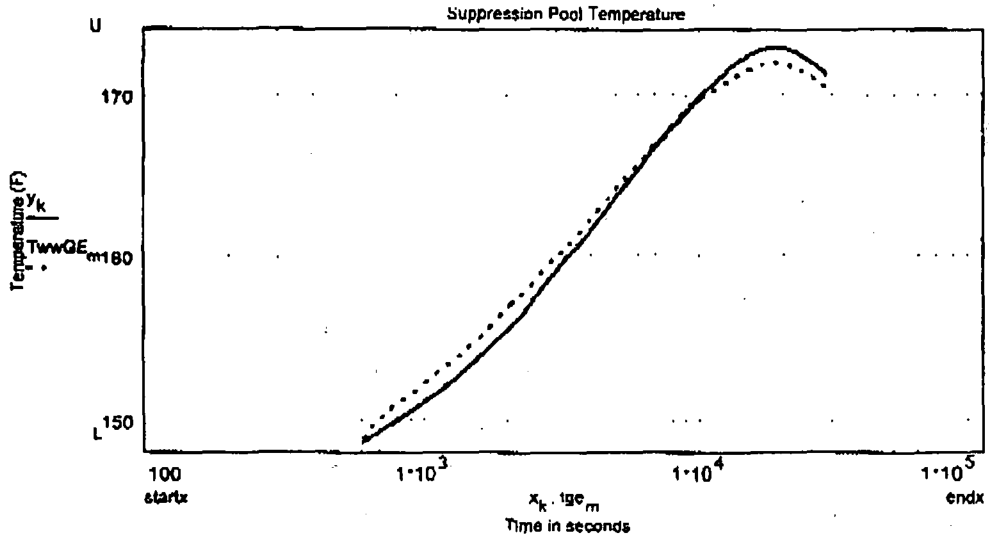


Figure 4 Benchmark 2 Suppression Pool Temperature Comparison 100% case

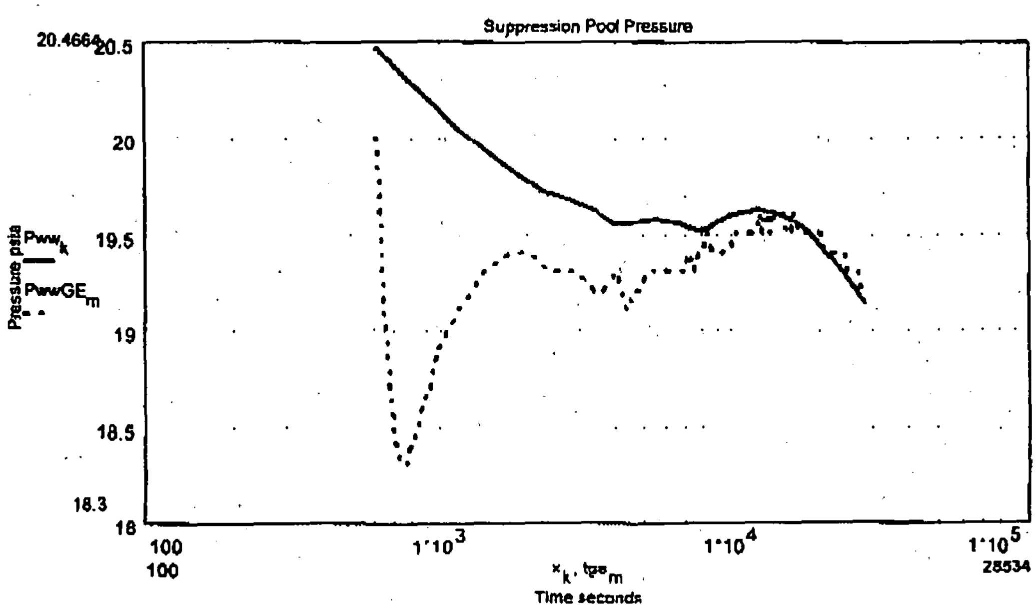


Figure 5 Benchmark 2 Suppression Pool Pressure Comparison 100% case

4.2 Sensitivity to Service Water Temperature Reduction

The model configured for the limiting Case 2A1 scenario, ie. low non-condensibles, low drywell mixing was applied for this sensitivity study. The initial pool temperature was assumed to be at the maximum allowable value of 95F. The service water temperature was reduced in a series of runs, covering a reduction to 75F in 5F increments. The effect of the reduction in service water temperature is to cause a reduction in both the maximum pool temperature and the available containment overpressure. There is a tendency to shift the time of maximum temperature earlier, since the LPCI HX heat removal rate is improved as the differential temperature between the CCSW and LPCI streams increases. The results are presented in the following table:

CASE	CCSW Temperature F	Peak Pool Temp. F	Pressure at Peak psia	Saturation Pressure at max T	ΔPsat/ Δ Peak Pressure
MCAD Base 2A1 20%	95	172.6	17.58	6.36	na
Sens-S3	90	170	17.23	5.9926	1.05
Sens-S4	85	167.7	16.9	5.6829	.996
Sens-S5	80	165.5	16.6	5.3992	.98
Sens-S6	75	163.5	16.33	5.1517	.967

Table 3 Results of Service Water Temperature Reduction

The change in saturation pressure and the relative change in saturation pressure vs peak pressure are provided to facilitate the assessment of the reduced temperatures on the NPSH calculations. As can be seen, the reduction in peak pressure is almost equal to the change in vapor pressure of the fluid. Therefore it can be concluded that there would be little or no effect on the NPSH calculations, since the net change between the two pressures is the primary input.

4.3 Nominal Containment Performance Cases

These cases examined the effects of nominal initial conditions, best estimate drywell mixing, and finally the effect of not using spray at all. The results of these cases are presented in the following table, along with the base case 2A1 results for comparison:

CASE	D/W Noncon-densibles	DW Mixing Fraction	Pressure at Peak Pool Temp psia
MCAD Base 2A1 20%	min	.20	17.58
Sens-S1	nominal	.20	19.93
Sens-S2	nominal	.40	20.54
Sens-S7	nominal	1.0/no spray	28.6

Table 4 Nominal Containment Performance Results

As can be seen from the results of the first two cases, the actual containment pressure, even under full spray flow assumptions, would be expected to be 2 to 3 psi higher than predicted by the limiting scenarios. The last case, covering a no spray scenario, would yield even higher pressures, and since these pressures would exceed the EOP spray initiation point (9 psig), and therefore the sprays can be expected to be initiated. The model indicated that pressures would be above 28 psia essentially from 600 seconds on. Note that this is an equilibrium based model, and that some re-pressurization time would be expected to occur once operators secure LPCI flow to the vessel and shift to pool cooling mode. The conclusion that high pressures would be expected is true however, and the time to reach it would be determined by the carryover fraction of air from the drywell to the suppression pool. Since the low pressure predicted by the first two "nominal" cases would exceed the 2 psig point at which the operator would act to terminate sprays, it can further be concluded that the spray will be initiated and maintained until well after the peak pool temperature is passed.

5. Conclusions/Discussion

A simple mathematical model based on first principles physics has been created and demonstrated to produce results consistent with vendor calculations. Sensitivity calculations performed using this model have provided several insights into post-LOCA containment performance. The effect of postulated service water temperature reductions has been demonstrated to be limited, with minimal impact on the ECCS pump NPSH calculations expected. The nominal containment performance predictions support that the operators would be expected to initiate and maintain spray flow throughout the post-LOCA period. Finally, the nominal cases run provide a reasonable basis for estimating the actual margin embedded due to conservative input assumptions in the design basis calculations performed by the vendor that comprise the analytical basis for the currently proposed license amendment.

6. References

1) GE Letter, Dresden Containment Analyses for Limiting Short Term LOCA Event, dated January 28, 1997 -TRF-123-00740, Attachment A, Containment Pressure and Temperature Analysis for Dresden NPSH Evaluations.

2) GE Letter, Dresden Containment Analyses for ComEd NPSH Evaluations. Transmittal of Digitized Suppression Pool Temperature and Suppression Chamber Pressure Time Histories, dated February 5, 1997 with attached EXCEL data files.

Appendix A -MATHCAD WORKSHEETS

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Benchmark Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, 20% mixing efficiency

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger and a term to account for sensible heat of the vessel metal

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

i 1..9

t_i	P_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7800	.01033
10200	.01012
20400	.008491
39600	.00706
61200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

$Q(x)\ \mathrm{linterp}(t,p,x)$

PHT is the pump heat input with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

$PHT\ (1\cdot 700 \cdot 1\cdot 800 \cdot 2\cdot 500)\cdot .70696$

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

$HXK\ 307.4$

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec. note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds

$$SENSHT\ \frac{10^{8}\cdot .70}{7200}$$

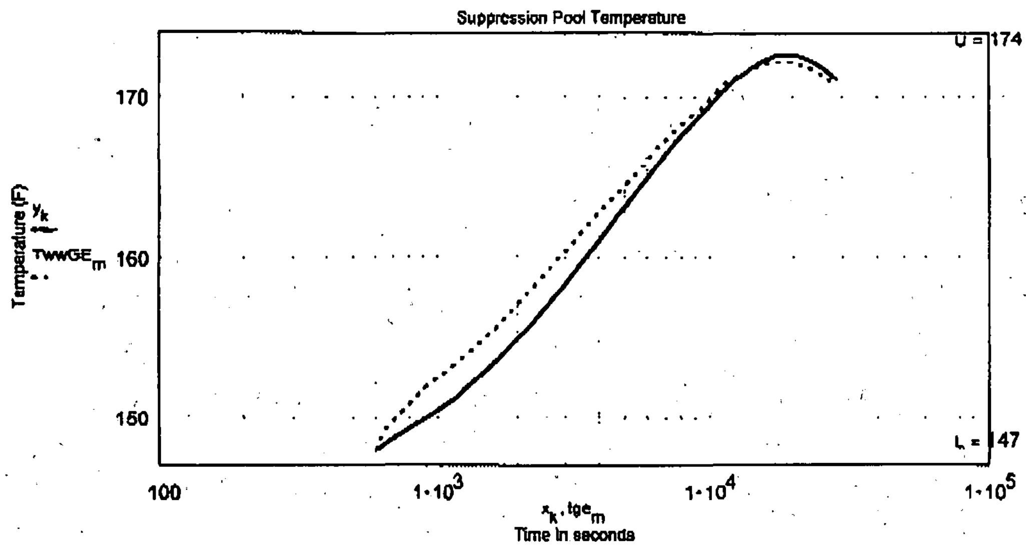
Enter the derivative of y as f(x,y). (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

$Tsw\ 95$

$$f(x,y)\ \frac{Q(x)\cdot 2578\cdot \frac{1000}{3600}\cdot 3413\cdot 1.0 \cdot PHT \cdot SENSHT\cdot e^{\frac{x}{7200}} \quad (y\ \ Tsw)\cdot HXK}{(124194)\cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y.

startx 600 endx 28000 n 50 intervals inity 148.



max(y) = 172.554

Note: GE Temperatures plotted from output data supplied by GE

Pressure Calculation

R 53.34

$LPCI \quad \frac{5000}{7.4805 \cdot .0164 \cdot 60}$

$CS \quad \frac{4500}{7.4805 \cdot .0164 \cdot 60}$

Vdw 158236

Ms 19284

Ma 16499 reduced air mass

η 0.2 mixing efficiency

Vww 108000

Qpmp 1·700·.70696 2·500·.70696 Qpmpc ·800 .70696

Pvb 0.5

$$Tatm_k \quad y_k \quad \frac{HXK \cdot y_k \quad Tsw \quad Qpmp}{LPCI} \cdot LPCI \cdot .95 \cdot \quad \frac{Q \; x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \cdot y_k \cdot \frac{Qpmpc}{CS} \cdot \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS} \cdot CS \cdot \eta}{LPCI \cdot .95 - CS \cdot \eta}$$

$$Twatm_k \quad y_k \quad \frac{HXK \cdot y_k \quad Tsw \quad Qpmp}{LPCI}$$

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

$Ts \quad S^{<0>}$

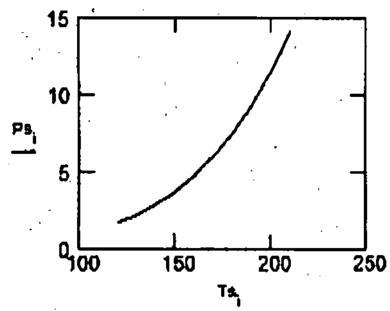
$Ps \quad S^{<1>}$

$i \quad 0..9$

vs pspline(Ts, Ps)

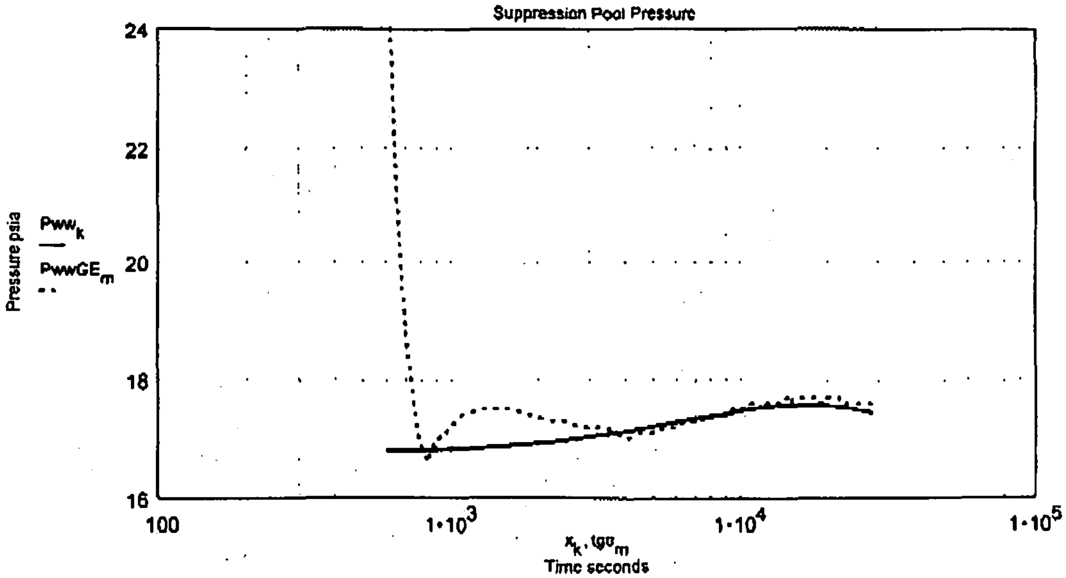
$Psat_k$ interp(vs, Ts, Ps, $Tatm_k$)

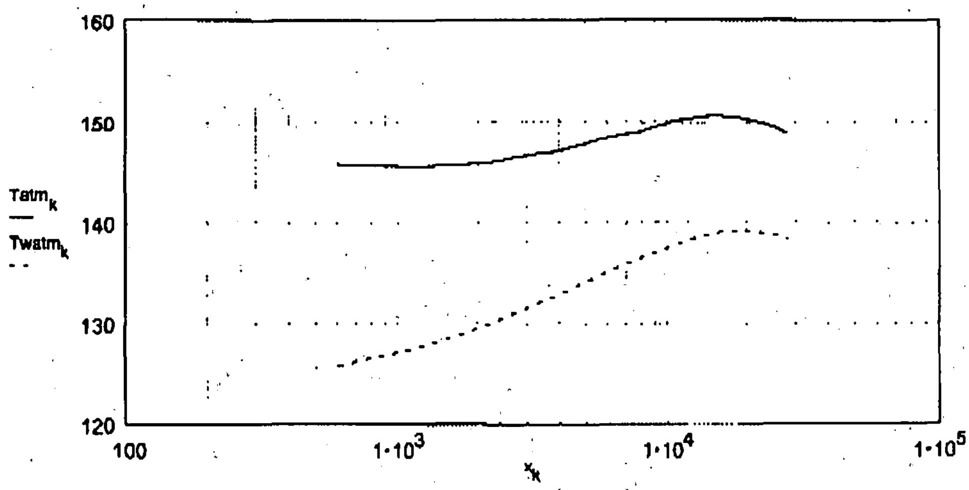
$Psatw_k$ interp(vs, Ts, Ps, $Twatm_k$)



$$Maww_k \quad \frac{144 \cdot \left(Psat_k \quad Psatw_k \cdot Pvb \cdot Ma \cdot R \cdot \frac{Tatm_k \cdot 460}{Vdw}\right)}{R \cdot \frac{Tatm_k \cdot 460}{Vdw} \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$


Suppression Pool Pressure
24
22
20
18
16
Pressure psia
Pww_k
$PwwGE_m$
100
1·10^3
1·10^4
1·10^5
x_k, tgo_m
Time seconds


160
150
140
130
120
$Tatm_k$
$Twatm_k$
100
1·10^3
1·10^4
1·10^5
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	16.798	125.785	145,888	148
	1148	16.841	127.48	145.669	151.096
	1696	16,901	128.89	145.86	153.972
	2244	16,957	130.07	146.105	155.828
	2792	17.023	131,107	146.574	157,723
	3340	17,077	132.019	146.911	159.387
	3888	17.118	132.808	147.119	160.83
	4436	17.168	133.497	147.498	162.088
	4984	17.216	134.122	147,884	163.229
	5532	17,258	134,688	148.209	164.259
	6080	17,294	135.192	148.476	165 183
	6628	17.325	135.642	148.685	166.006
	7176	17.35	136.039	148.839	166 73
	7724	17.37	136.384	148.941	167.36
	8272	17.398	136.69	149.167	167,919
	8820	17.423	136.975	149,4	168.44
	9368	17.447	137.241	149.616	168.926
	9916	17.47	137.489	149.816	169.38
	10464	17.491	137.72	149.988	169.801
	11012	17.509	137.931	150.127	170.187
	11560	17.524	138.123	150.249	170.538
	12108	17,538	138.297	150,353	170.856
	12656	17.55	138,454	150.44	171.143
	13204	17.561	138,594	150.511	171.399
	13752	17.569	138.719	150,587	171.626
	14300	17.577	138,820	150.607	171 826
	14848	17.582	138.923	150,633	171.999
	15396	17.586	139,004	150.646	172.147
	15944	17.589	139.071	150,644	172.27
	16492	17.59	139.126	150.63	172.37
	17040	17.59	139.169	150,604	172.448
	17588	17.589	139.199	150.585	172.504
	18136	17.586	139.218	150.515	172.539
	18684	17.582	139.227	150.454	172.554
	19232	17.577	139.224	150.382	172.55
	19780	17.571	139.212	150.299	172,527
	20328	17.564	139.19	150.206	172.487
	20876	17.558	139.16	150.131	172.432
	21424	17.551	139.125	150,056	172.368
	21972	17.544	139.086	149.976	172.296
	22520	17.537	139,042	149,892	172 217
	23068	17.529	138.994	149.803	172.129
	23616	17.521	138.942	149.711	172,035
	24164	17.512	138.887	149.615	171,933
	24712	17.503	138.828	149.516	171,825
	25260	17.494	138,765	149.413	171.71
	25808	17.484	138.699	149.306	171.59
	26356	17,474	138.63	149,197	171.463
	26904	17.464	138.557	149,084	171.331
	27452	17.453	138.482	148.968	171.193

GE Data

tgc_m	$PwwGE_m$	$TwwGE_m$
616.8	24	148.6
631.8	22.4	148.9
649.2	21	149.3
669.2	19.6	149.6
686.2	19.2	149.7
099.2	18.7	149.9
712	18.3	150.1
722.8	18	150.2
735	17.7	150.3
749.8	17.4	150.5
764.6	17.1	150.6
781.1	16.9	150.8
798.4	16.8	150.9
813.7	16.7	151.1
831.5	16.6	151.2
848.5	16.8	151.4
865.3	16.9	151.6
880.9	16.9	151.7
894.9	17	151.8
907.4	17	151.9
922.9	17.1	152
935.7	17.1	152.1
949.2	17.1	152.2
963.2	17.1	152.3
977.2	17.2	152.3
991.4	17.2	152.4
1090.7	17.4	152.9
1308.2	17.5	154
1574.9	17.5	155.3
1857.8	17.4	156.5
2158.8	17.3	157.7
2454.3	17.3	158.7
2756.5	17.2	159.7
3055.6	17.2	160.5
3366.9	17.2	161.4
3675.9	17.1	162.1
4009.9	17	162.9
4354.2	17.1	163.5
4697.8	17.1	164.1
5026.4	17.1	164.6
5346.9	17.2	165.1
5666	17.2	165.6
5989	17.2	166.1
6317	17.3	166.6
6634.4	17.3	167
6968.3	17.3	167.3
7272	17.3	167.6
7513.6	17.4	167.9
7752	17.4	168.1
7995.8	17.4	168.3

$tgc_{(m \cdot 50)}$	$PwwGE_{(m \cdot 50)}$	$TwwGE_{(m \cdot 50)}$
8243	17.4	168.5
8493	17.4	168.7
8737.8	17.4	168.9
8989.2	17.4	169.1
9240.4	17.5	169.2
9495.7	17.5	169.4
9739	17.5	169.5
9988.8	17.5	169.8
10242.3	17.5	170
10489.8	17.5	170.2
10740.3	17.6	170.4
10993.5	17.6	170.6
11244.9	17.6	170.7
11495.2	17.6	170.8
11743.5	17.5	170.9
11993.5	17.6	171
12242.3	17.6	171.1
12492	17.6	171.2
12742	17.6	171.3
12992.5	17.6	171.4
13247.8	17.6	171.4
13500.4	17.6	171.5
13755.2	17.6	171.6
14009.9	17.6	171.7
14259.4	17.7	171.7
14511.9	17.7	171.8
14765.3	17.6	171.8
15019.8	17.7	171.9
15275.5	17.7	171.9
15531.3	17.7	172
15784.5	17.7	172
16036.3	17.7	172
16292.8	17.7	172
16543.9	17.7	172.1
16794.7	17.7	172.1
17045.2	17.7	172.1
17295.4	17.7	172.1
17546.4	17.7	172.1
17797.7	17.7	172.1
18051.2	17.7	172.1
18307.2	17.7	172.1
18560.7	17.7	172.1
18812.5	17.6	172.1
19067.8	17.7	172.1
19322.3	17.7	172.1
19576.8	17.7	172.1
19830.8	17.7	172.1
20081.3	17.7	172.1
20333	17.7	172
20585	17.7	172

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Benchmark Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, 100% mixing efficiency

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger,and a term to account for sensible heat of the vessel metal.

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

i 1..9

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7600	.01033
10200	.01012
20400	.008491
39600	.00706
61200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

Q(x) linterp(t, p, x)

PHT is the pump heat input with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

PHT (1·700 · 1·800 · 2·500)·.70698

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

HXK 307.4

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec; note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds.

$$SENSHT \quad \frac{10^{8} \cdot .70}{7200}$$

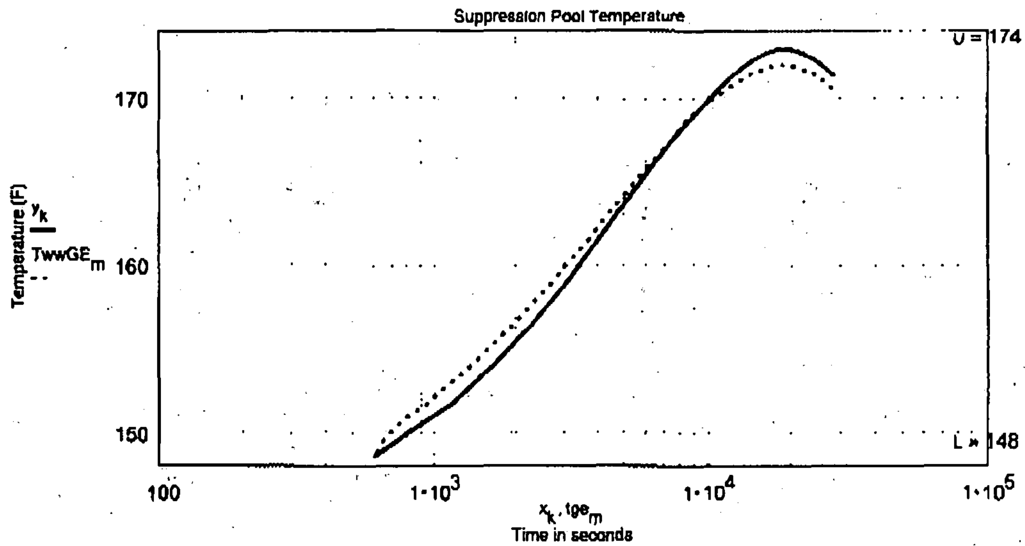
Enter the derivative of y as f(x,y): (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

Tsw 95

$$f(x,y) \quad \frac{Q(x)\cdot 2578 \cdot \frac{1000}{3600} \cdot 3413 \cdot 1.0 \cdot PHT \cdot SENSHT \cdot e^{\frac{x}{7200}} \quad (y \quad Tsw)\cdot HXK}{(124194)\cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration and the initial value of y

startx 600 endx 28000 n 50 intervals inity 148.6



max(y) = 172.846

Note: GE Temperatures plotted from output data supplied by GE

Pressure Calculation

$R \; 53.34$ $\qquad LPCI \; \frac{5000}{7.4805 \cdot .0164 \cdot 60}$ $\qquad CS \cdot \frac{4500}{7.4805 \cdot .0164 \cdot 60}$

$Vdw \; 158236$ $\qquad Ma \; 19284$

$Ma \; 16499$ reduced air mass $\qquad \eta \; 1$ mixing efficiency

$Vww \; 108000$ $\qquad Qpmp \; 1 \cdot 700 \cdot .70696 \cdot 2 \cdot 500 \cdot .70696$ $\; Qpmpc \cdot 800 \cdot .70696$

$Pvb \; 0.5$

$$Tatm_k \quad y_k \quad \frac{HXK \cdot y_k \quad Tsw \quad Qpmp}{LPCI} \cdot LPCI \cdot .95 \cdot \quad \frac{Q \; x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \cdot y_k \cdot \frac{Qpmpc}{CS} \cdot \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS} \cdot CS \cdot \eta}{LPCI \cdot .95 \cdot CS \cdot \eta}$$

$$Twatm_k \quad y_k \quad \frac{HXK \cdot y_k \quad Tsw \quad Qpmp}{LPCI}$$

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
100	9.34
200	11.526
210	14.123

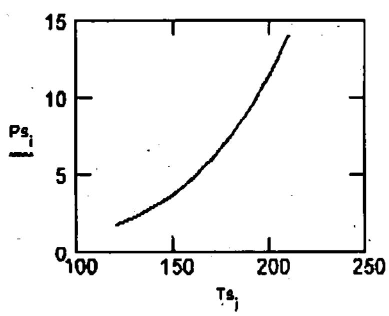
$Ts \quad S^{<0>}$

$Ps \quad S^{<1>}$

$i \quad 0..9$ $\qquad vs \quad pspline(Ts, Ps)$

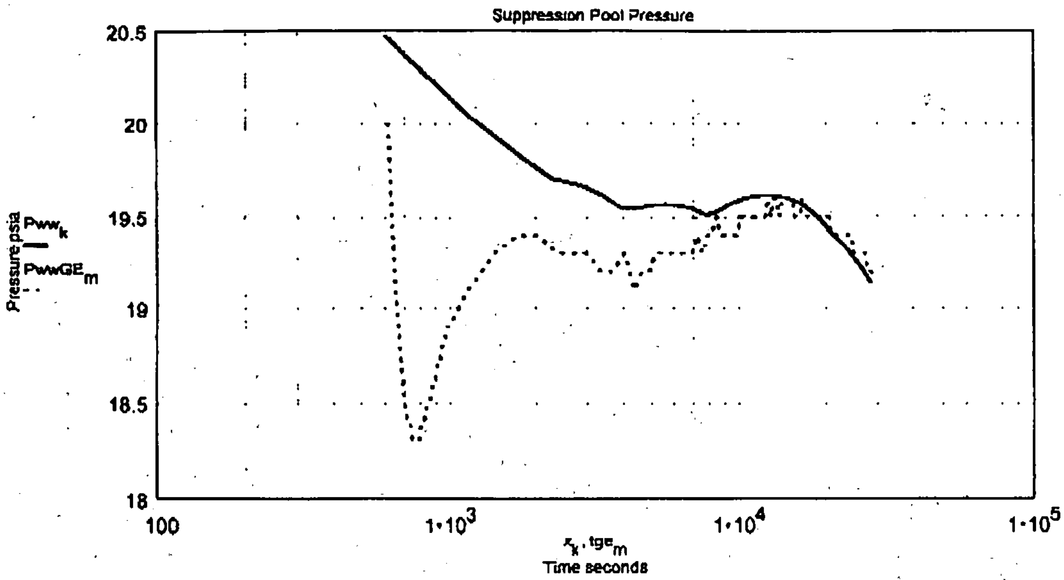
$Psat_k \quad interp(vs, Ts, Ps, Tatm_k)$

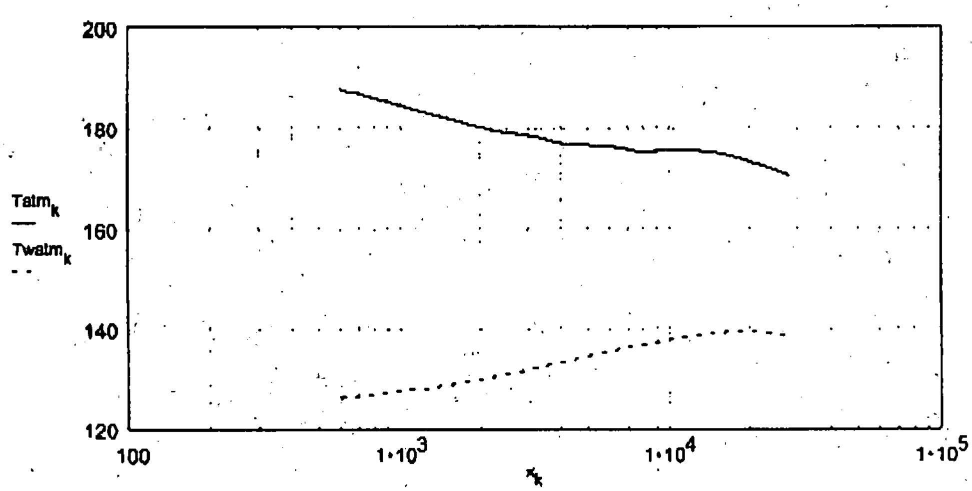
$Psatw_k \quad interp(vs, Ts, Ps, Twatm_k)$



$$Maww_k \quad \frac{144 \cdot \left(Psat_k \cdot Psatw_k \cdot Pvb\right) \cdot Ma \cdot R \cdot \frac{Tatm_k \cdot 460}{Vdw}}{R \cdot \frac{Tatm_k \cdot 460}{Vdw} \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$


Suppression Pool Pressure
20.5
20
19.5
19
18.5
18
100
1·10^3
1·10^4
1·10^5
Pressure psia
Pww_k
PwwGE_m
x_k, tge_m
Time seconds


200
180
160
140
120
100
1·10^3
1·10^4
1·10^5
Talm_k
Twalm_k
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	20.466	126.113	187.642	148.6
	1148	20.049	127.801	183,481	151.583
	1696	19.846	129.204	181,16	154.246
	2244	19.71	130.378	179.473	158.39
	2792	19.676	131.408	178.765	158.272
	3340	19.622	132,313	177.912	159.925
	3888	19.551	133.098	176.917	161.358
	4436	19.551	133.779	176.653	162.603
	4984	19.564	134,397	176.64	163.732
	5532	19.569	134.955	176.366	164.752
	6080	19.565	135.456	176.131	165.666
	6628	19.554	135,9	175.838	166.478
	7176	19.534	136,291	175,487	167.192
	7724	19.508	136.631	175.081	167.812
	8272	19.525	136.931	175,135	168.361
	8820	19.549	137.211	175.254	168.873
	9368	19.57	137.472	175,36	169.349
	9916	19.59	137.716	175.454	169.793
	10464	19.603	137.941	175.497	170.206
	11012	19.611	138.148	175.484	170.583
	11560	19.615	138.335	175.454	170.926
	12108	19.618	138.505	175.407	171.235
	12656	19.618	138,657	175.345	171.514
	13204	19.616	138.793	175.268	171.762
	13752	19.612	138.913	175.175	171.981
	14300	19,606	139.018	175.069	172.173
	14848	19.598	139.109	174.948	172.339
	15396	19.588	139.188	174.813	172.479
	15944	19.576	139.25	174.665	172.596
	16492	19,582	139.3	174.505	172.689
	17040	19.547	139.339	174.331	172.759
	17588	19.529	139.368	174.146	172.808
	18136	19.511	139.382	173.948	172.837
	18684	19.491	139.386	173.739	172.846
	19232	19.469	139,381	173.518	172,835
	19780	19,446	139.365	173,287	172.806
	20328	19,421	139.339	173.044	172.78
	20876	19,403	139.308	172,873	172.699
	21424	19,386	139,268	172.700	172.63
	21972	19.368	139.226	172.541	172.552
	22520	19.35	139.179	172.369	172.467
	23068	19,331	139,128	172.194	172 374
	23616	19.312	139.074	172.014	172.274
	24164	19.292	139.015	171.832	172.167
	24712	19.272	138.953	171,646	172.054
	25260	19.251	138.888	171.456	171.935
	25808	19.23	138.819	171.263	171.809
	26356	19 209	138 747	171.067	171.678
	26904	19.187	138.672	170.868	171.541
	27452	19.165	138.594	170.665	171.399

tge_m	$PwwGE_m$	$TwwGE_m$
608.6	20	148.6
619.1	19.7	149
630.1	18.4	149.2
644.7	19.1	149.5
658.7	18.9	149.7
674.4	18.7	149.9
691.7	18.5	150
705.4	18.4	150.2
720.4	18.4	150.3
738.7	18.3	150.5
757.4	18.3	150.6
774.9	18.3	150.8
793.2	18.4	150.9
811.1	18.4	151
830.1	18.5	151.1
847.1	18.5	151.2
865.9	18.6	151.3
884.4	18.6	151.4
902.4	18.7	151.5
919.9	18.7	151.6
937.4	18.8	151.7
953.9	18.8	151.8
971.1	18.9	151.9
990.4	18.9	152.1
1152.4	19.1	153
1425.6	19.3	154.3
1719.1	19.4	155.6
2022.2	18.4	156.8
2333	19.3	157.9
2647.5	19.3	158.9
2969.7	19.3	159.9
3314	19.2	160.7
3626.4	19.2	161.5
3977.5	19.3	162.3
4299.4	19.1	163
4559.6	19.2	163.5
4838.1	19.2	164
5121.9	19.3	164.5
5404.9	19.3	165
5688.7	19.3	165.4
5976.6	19.3	165.8
6265.9	19.3	166.2
6554.5	19.3	166.6
6855.9	19.3	166.9
7146.5	19.4	167.2
7438	19.3	167.5
7717.7	19.4	167.9
8012	19.4	168.3
8309	19.5	168.6
8603.7	19.4	168.8

$tge_{(m + 50)}$	$PwwGE_{(m + 50)}$	$TwwGE_{(m + 50)}$
8899.1	19.4	169.1
9201.2	19.4	169.3
9493.5	19.4	169.4
9787.9	19.4	169.6
10094.9	19.5	169.8
10390	19.5	169.9
10687.7	19.5	170.1
10991.7	19.5	170.2
11282.2	19.5	170.3
11591.7	19.5	170.5
11882.9	19.5	170.6
12180.1	19.5	170.7
12479.4	19.6	170.8
12772	19.5	170.9
13072.5	19.6	171
13365.5	19.6	171.1
13664.6	19.5	171.2
13959.1	19.6	171.3
14260.6	19.6	171.4
14551.1	19.6	171.4
14844.5	19.6	171.5
15140.5	19.6	171.6
15436.6	19.5	171.6
15740.9	19.5	171.7
16037.4	19.5	171.7
16342.4	19.6	171.8
16650.1	19.6	171.8
16946.3	19.5	171.8
17243.8	19.5	171.8
17536.8	19.5	171.9
17840.1	19.5	171.9
18144.9	19.5	171.9
18451.9	19.5	171.9
18755.1	19.5	171.9
19050.5	19.5	171.9
19342	19.5	171.9
19640	19.5	171.9
18932.4	19.5	171.8
20227.4	19.5	171.8
20531.3	19.4	171.8
20825.5	19.4	171.8
21129.8	19.4	171.7
21419.9	19.4	171.7
21726.4	19.4	171.6
22018.6	19.4	171.6
22317.9	19.4	171.6
22623.9	19.4	171.5
22925.9	19.4	171.5
23231.1	19.4	171.4
23534.3	19.4	171.4

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS

Sensitivity Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, 20% mixing efficiency, Service water temp=90

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger, and a term to account for sensible heat of the vessel metal.

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

i 1..9

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7800	.01033
10200	.01012
20400	.008491
39600	.00706
61200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

$Q(x)$ linterp(t, p, x)

PHT is the pump heat input, with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

$PHT\ (1\cdot 700 \cdot 1\cdot 800 \cdot 2\cdot 500)\cdot .70696$

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

HXK 307.4

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec, note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds.

$$SENSHT\ \frac{10^{8}\cdot .70}{7200}$$

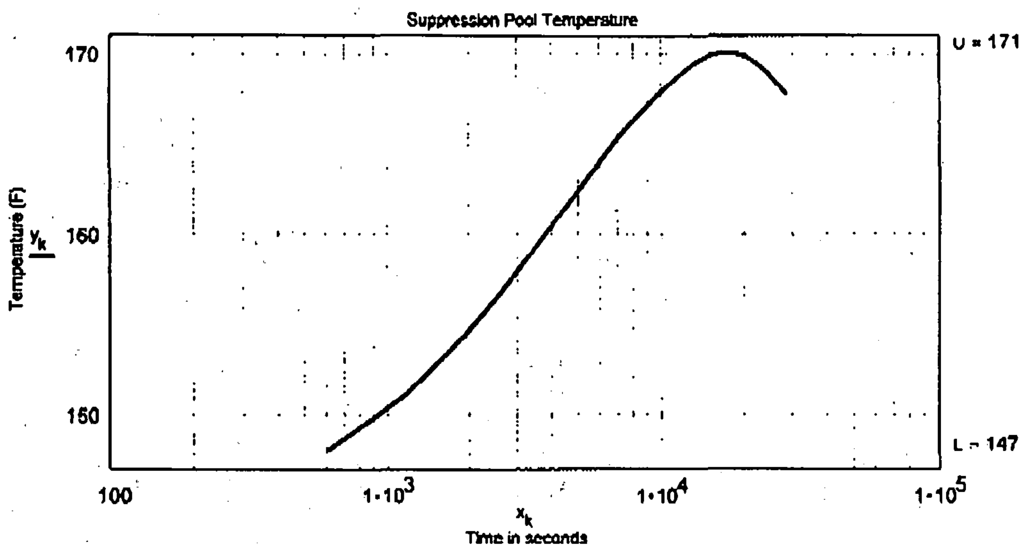
Enter the derivative of y as f(x,y) (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

Tsw 90

$$f(x,y)\ \frac{Q(x)\cdot 2578\cdot \frac{1000}{3600}\cdot 3413\cdot 1.0 \cdot PHT \cdot SENSHT\cdot e^{\frac{x}{7200}} \quad (y \quad Tsw)\cdot HXK}{(124194)\cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y.

startx 600 endx 28000 n 60 intervals inity 148.



max(y) = 170.043

Pressure Calculation

R 53.34

LPCI $\frac{5000}{7.4805 \cdot .0164 \cdot 60}$

CS $\frac{4500}{7.4805 \cdot .0164 \cdot 60}$

Vdw 168236

Ma 19284 nominal air mass

Ma 16499 reduced air mass

η 0.2 mixing efficiency

Vww 108000

Qpmp $1 \cdot 700 \cdot .70696 \quad 2 \cdot 500 \cdot .70696$

Qpmpc $\cdot 800 \cdot .70696$

Pvb 0.5

$$Tatm_k \quad y_k \quad \frac{HXK \cdot y_k \quad \frac{Tsw}{LPCI} \quad Qpmp \cdot LPCI \cdot .95 \cdot Q\,x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \cdot y_k \cdot \frac{Qpmpc}{CS} \cdot \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS} \cdot CS \cdot \eta}{LPCI \cdot .95 - CS \cdot \eta}$$

$$Twatm_k \quad y_k \quad HXK \cdot y_k \quad \frac{Tsw}{LPCI} \quad Qpmp$$

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables.

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

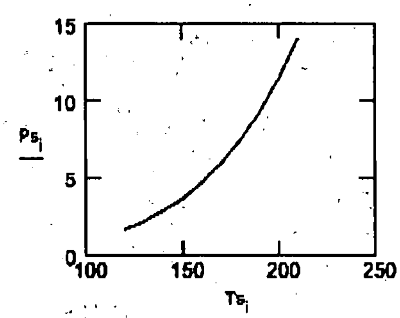
$Ts \quad S^{<0>}$

$Ps \quad S^{<1>}$

$i \quad 0..9$ $\quad vs \quad pspline(Ts, Ps)$

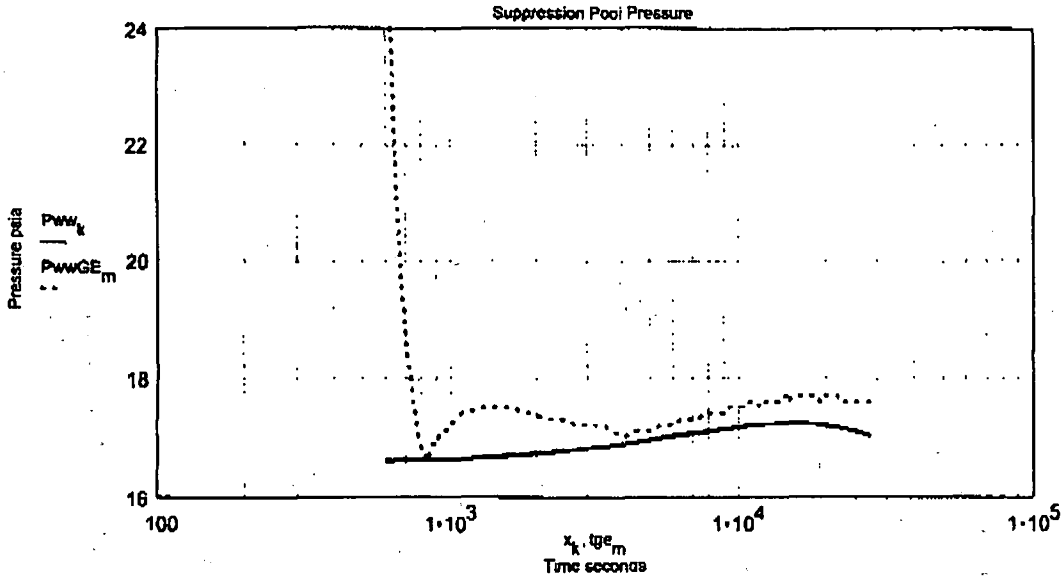
$Psat_k \quad interp(vs, Ts, Ps, Tatm_k)$

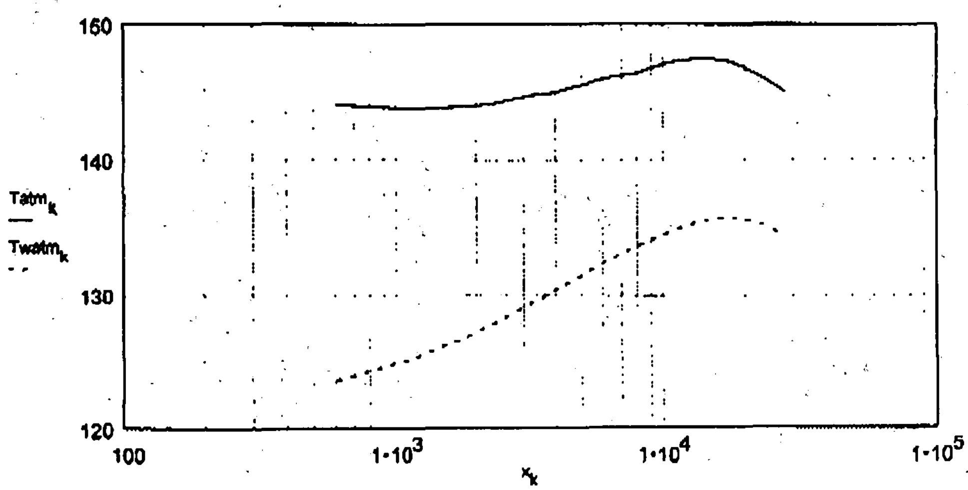
$Psatw_k \quad interp(vs, Ts, Ps, Twatm_k)$



$$Maww_k \quad \frac{144 \cdot Psat_k \quad Psatw_k \cdot Pvb \quad Ma \cdot R \cdot \frac{Tatm_k \cdot 460}{Vdw}}{R \cdot \frac{Tatm_k \cdot 460}{Vdw} \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$


Suppression Pool Pressure
Pressure psia
Pww_k
$PwwGE_m$
24
22
20
18
16
100
$1 \cdot 10^3$
$1 \cdot 10^4$
$1 \cdot 10^5$
x_k, tge_m
Time seconds


$Tatm_k$
$Twatm_k$
160
140
130
120
100
$1 \cdot 10^3$
$1 \cdot 10^4$
$1 \cdot 10^5$
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tetm_k$	y_k
	600	16.609	123.522	143.986	148
	1148	16.645	125.158	143.699	150.988
	1696	16.696	126.51	143.825	153.458
	2244	16.745	127.634	144.006	155.511
	2792	16.802	128.615	144.412	157.304
	3340	16.849	129.472	144.688	158.87
	3888	16.883	130.209	144.836	160.215
	4436	16.925	130.846	145.157	161.379
	4984	16.966	131.42	145.485	162.427
	5532	17.001	131.934	145.754	163.366
	6080	17.03	132.392	145.965	164.202
	6628	17.055	132.794	146.121	164.937
	7176	17.074	133.144	146.222	165.577
	7724	17.088	133.444	146.272	166.124
	8272	17.108	133.705	146.448	166.601
	8820	17.129	133.947	146.632	167.043
	9368	17.148	134.17	146.8	167.451
	9916	17.165	134.377	146.952	167.828
	10464	17.18	134.587	147.078	168.175
	11012	17.193	134.738	147.172	168.488
	11560	17.203	134.891	147.25	168.768
	12108	17.212	135.027	147.311	169.016
	12656	17.22	135.146	147.355	169.234
	13204	17.225	135.25	147.385	169.423
	13752	17.23	135.339	147.4	169.585
	14300	17.233	125.413	147.401	160.721
	14848	17.234	135.474	147.388	169.832
	15396	17.234	135.521	147.382	169.918
	15944	17.233	185.556	147.324	169.982
	16492	17.231	135.578	147.274	170.023
	17040	17.227	135.589	147.212	170.043
	17588	17.222	135.589	147.138	170.043
	18136	17.217	135.579	147.054	170.023
	18884	17.21	135.557	146.96	169.984
	19232	17.202	135.528	146.855	169.928
	19780	17.193	135.486	146.74	169.854
	20328	17.183	135.436	146.617	169.763
	20876	17.175	135.379	146.511	169.659
	21424	17.166	135.318	146.406	169.547
	21972	17.156	135.253	146.297	169.428
	22520	17.147	135.184	146.184	169.302
	23068	17.137	135.111	146.068	169.17
	23616	17.126	135.035	145.948	169.031
	24164	17.116	134.956	145.825	168.886
	24712	17.105	134.874	145.7	168.736
	25260	17.093	134.788	145.571	168.58
	25808	17.082	134.7	145.44	168.419
	26356	17.07	134.609	145.306	168.253
	26904	17.058	134.518	145.189	168.082
	27452	17.046	134.42	145.03	167.907

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Sensitivity Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, 20% mixing efficiency, Service water temp=85

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger,and a term to account for sensible heat of the vessel metal

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

i 1..9

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7600	.01033
10200	.01012
20400	.008491
39600	.00706
61200	.006308

Q(x) defines a linear interpolation of the above vectors for use in the calculation

Q(x) linterp(t, p, x)

PHT is the pump heat input, with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

$$PHT \quad (1\cdot 700 \cdot 1\cdot 800 \cdot 2\cdot 500)\cdot .70696$$

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

HXK 307.4

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec, note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds.

$$SENSHT \quad \frac{10^6\cdot .70}{7200}$$

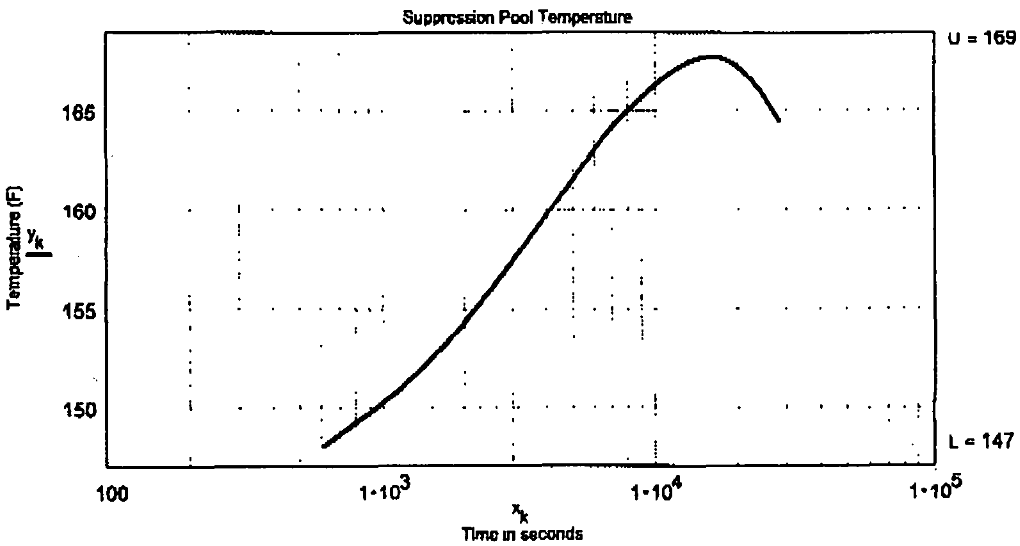
Enter the derivative of y as f(x,y) (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

Tsw 85

$$f(x,y) \quad \frac{Q(x)\cdot 2578\cdot \frac{1000}{3600}\cdot 3413\cdot 1.0 \cdot PHT \cdot SENSHT\cdot e^{\frac{x}{7200}} \quad (y \quad Tsw)\cdot HXK}{(124194)\cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y

startx 600 endx 28000 n 50 intervals inity 148.



max(y) = 167.693

Pressure Calculation

R 53.34

$LPCI \cdot \frac{5000}{7.4805 \cdot .0164 \cdot 60}$

$CS \frac{4500}{7.4805 \cdot .0164 \cdot 60}$

Vdw 158236

Ma 19284 nominal air mass

Ma 16499 reduced air mass

η 0.2 mixing efficiency

Vww 108000

Qpmp 1·700·.70696 - 2·500·.70696

Qpmpc 800·.70696

Pvb 0.5

$Tatm_k \quad y_k \quad HXK \cdot y_k \quad Tsw \quad \frac{Qpmp}{LPCI} \cdot LPCI \cdot .95 \cdot Q\, x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \cdot y_k \cdot \frac{Qpmpc}{CS} \cdot \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS} \cdot CS \cdot \eta \;/\; LPCI \cdot .95 \cdot CS \cdot \eta$

$Twatm_k \quad y_k \quad HXK \cdot y_k \quad Tsw \quad \frac{Qpmp}{LPCI}$

This File estimates Psat based on temperature input It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables.

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

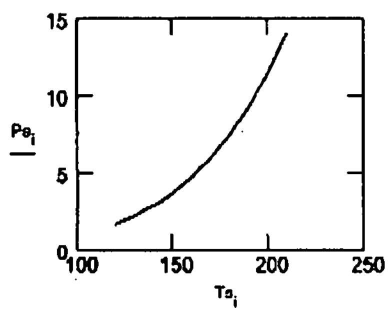
$Ts \;\; S^{<0>}$

$Ps \;\; S^{<1>}$

$i \;\; 0..9$ $\qquad vs \;\; pspline(Ts, Ps)$

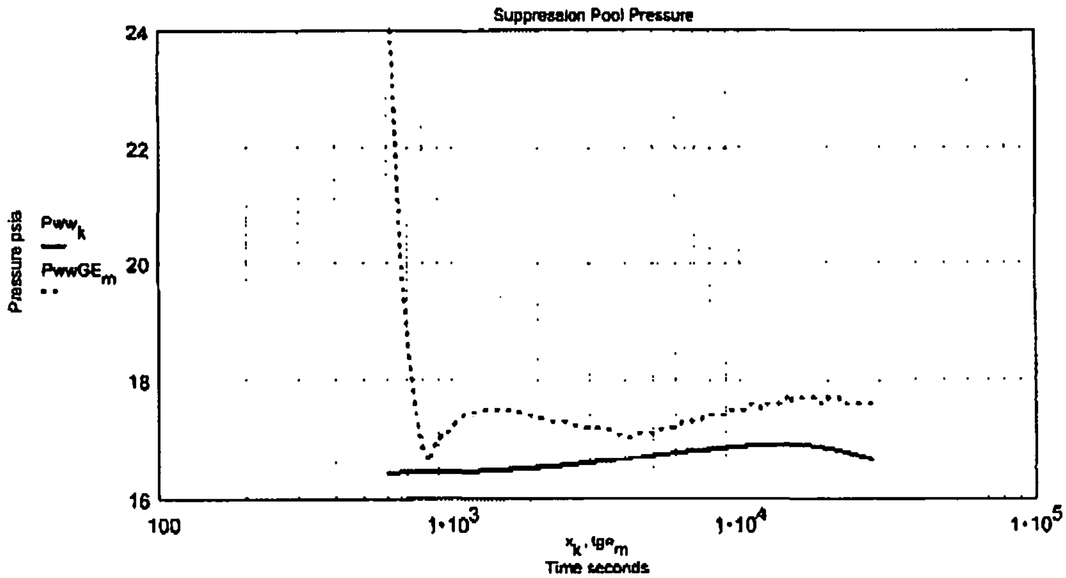
$Psat_k \;\; interp(vs, Ts, Ps, Tatm_k)$

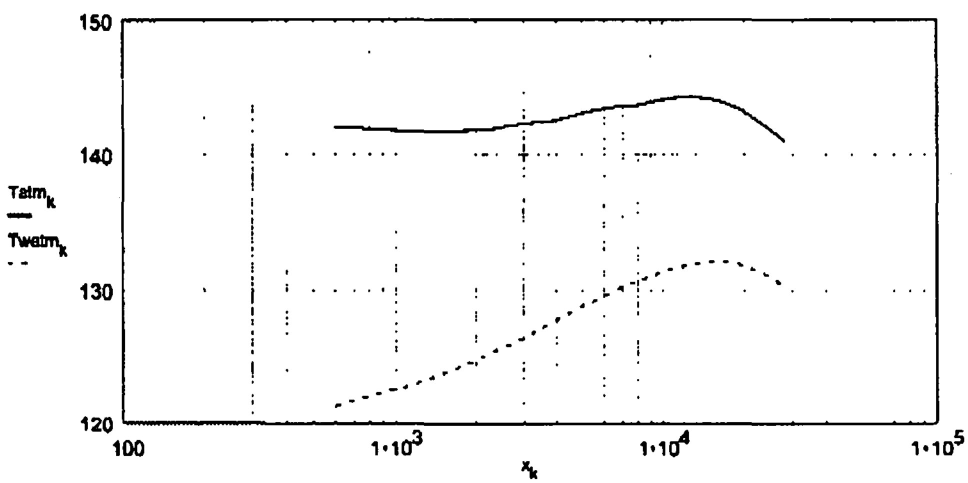
$Psatw_k \;\; interp(vs, Ts, Ps, Twatm_k)$



$$Maww_k \quad \frac{144 \cdot Psat_k \;\; Psatw_k \cdot Pvb \cdot Ma \cdot R \cdot \frac{Tatm_k \cdot 460}{Vdw}}{R \cdot \frac{Tatm_k \cdot 460}{Vdw} \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$


Suppression Pool Pressure
24
22
20
18
16
Pressure psia
Pww_k
$PwwGE_m$
100
$1\cdot10^3$
$1\cdot10^4$
$1\cdot10^5$
x_k, tge_m
Time seconds


150
140
130
120
$Tatm_k$
$Twatm_k$
100
$1\cdot10^3$
$1\cdot10^4$
$1\cdot10^5$
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	16.427	121.259	142.083	148
	1148	16.455	122.838	141,73	150.88
	1696	16.499	124.13	141.791	153.244
	2244	16.54	125.197	141,907	155.193
	2792	16.59	126.123	142.251	156.885
	3340	16.629	126.926	142.485	158.352
	3888	16.657	127.61	142.553	159.601
	4436	16.692	128.195	142.815	160.669
	4984	16.726	128.718	143.086	161.624
	5532	16.755	129.183	143,298	162,473
	6080	16.778	129.591	143.455	163.22
	6628	16.796	129.947	143.556	163.869
	7176	16.81	130,25	143.605	164,423
	7724	16.819	130.504	143.604	164,887
	8272	16.834	130.721	143,729	165.283
	8820	16.849	130.919	143,864	165,645
	9368	16.862	131.1	143.983	165.975
	9916	16.875	131.264	144,089	166.276
	10464	16,885	131.414	144.168	166.548
	11012	16.892	131.545	144,217	166.788
	11560	16,898	131.659	144.25	166.997
	12108	16.903	131,757	144,258	167.175
	12656	16.906	131.839	144,271	167.325
	13204	16.908	131.906	144.259	167.448
	13752	16.908	131.959	144.233	167.544
	14300	16.907	131.998	144.194	167.616
	14848	16.905	132.024	144.143	167.664
	15396	16.901	132.038	144.079	167.689
	15944	16.897	132.04	144.004	167.693
	16492	16.891	132.031	143.917	167.676
	17040	16,885	132.01	143.82	167.638
	17588	16,877	131.979	143.712	167.582
	18136	16.869	131,939	143.593	167.507
	18684	16,859	131.888	143.465	167.415
	19232	16.849	131.828	143.328	167.306
	19780	16.837	131.759	143.182	167.18
	20328	16.825	131.682	143.027	167.039
	20876	16.814	131.598	142.891	166.886
	21424	16.803	131.511	142.756	166.726
	21972	16,792	131.42	142.617	166.56
	22520	16.78	131.326	142.476	166.388
	23068	16.768	131.229	142,332	166.21
	23616	16.756	131.128	142.185	166.028
	24164	16.744	131.028	142.038	165.84
	24712	16.731	130.92	141.884	165.647
	25260	16.718	130.812	141.729	165.45
	25808	16.705	130.702	141.573	165.248
	26356	16.692	130.589	141.415	165.043
	26904	16.679	130.474	141.254	164.833
	27452	16.665	130.358	141.091	164.62

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Sensitivity Case: 1/2 nominal CCSW GE Case 2a1,
4500 gpm CS flow, 20% mixing efficiency, Service water temp=80 x+R

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger,and a term to account for sensible heat of the vessel metal.

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

i 1..9

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7800	.01033
10200	.01012
20400	.008491
39600	.00706
61200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

Q(x) linterp(t, p, x)

PHT is the pump heat input, with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

PHT (1·700 · 1·800 · 2·500)·.70696

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

HXK 307.4

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec, note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds

$$SENSHT = \frac{10^{8}\cdot .70}{7200}$$

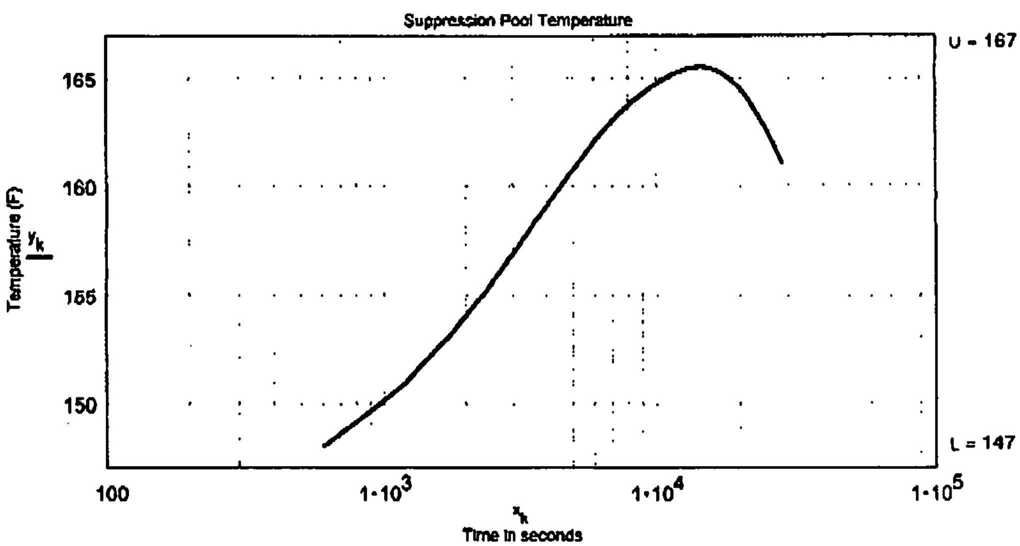
Enter the derivative of y as R(x,y): (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

Tsw 80

$$R(x,y) = \frac{Q(x)\cdot 2578\cdot \frac{1000}{3600}\cdot 3413\cdot 1.0 + PHT + SENSHT\cdot e^{-\frac{x}{7200}} - (y - Tsw)\cdot HXK}{(124194)\cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y

startx 600 endx 28000 n: 50 intervals inity 148.



max(y) = 165.511

Pressure Calculation

R 53.34

LPCI $\frac{5000}{7.4805 \cdot .0164 \cdot 60}$

CS $\frac{4500}{7.4805 \cdot .0164 \cdot 60}$

Vdw 158236

Ma 19284 nominal air mass

Ma 16499 reduced air mass

η 0.2 mixing efficiency

Vww 108000

Qpmp 1·700·.70696 · 2·500·.70696

Qpmpc 800·.70696

Pvb 0.5

$$Tatm_k \; y_k \; \frac{HXK \cdot y_k \; Tsw \quad Qpmp}{LPCI} \cdot LPCI \cdot .95 \cdot \; \frac{Q \; x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \cdot y_k \cdot \frac{Qpmpc}{CS} \; \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS} \cdot CS \cdot \eta}{LPCI \cdot .95 \cdot CS \cdot \eta}$$

$$Twatm_k \; y_k \; \frac{HXK \cdot y_k \; Tsw \quad Qpmp}{LPCI}$$

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables.

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

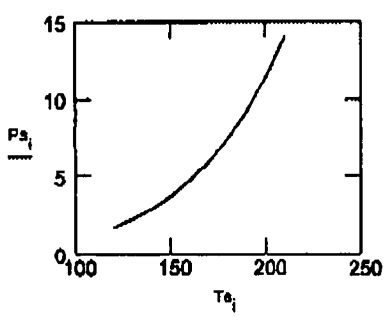
$Ts \quad S^{<0>}$

$Ps \quad S^{<1>}$

$i \quad 0..9$ $\qquad$ vs pspline(Ts, Ps)

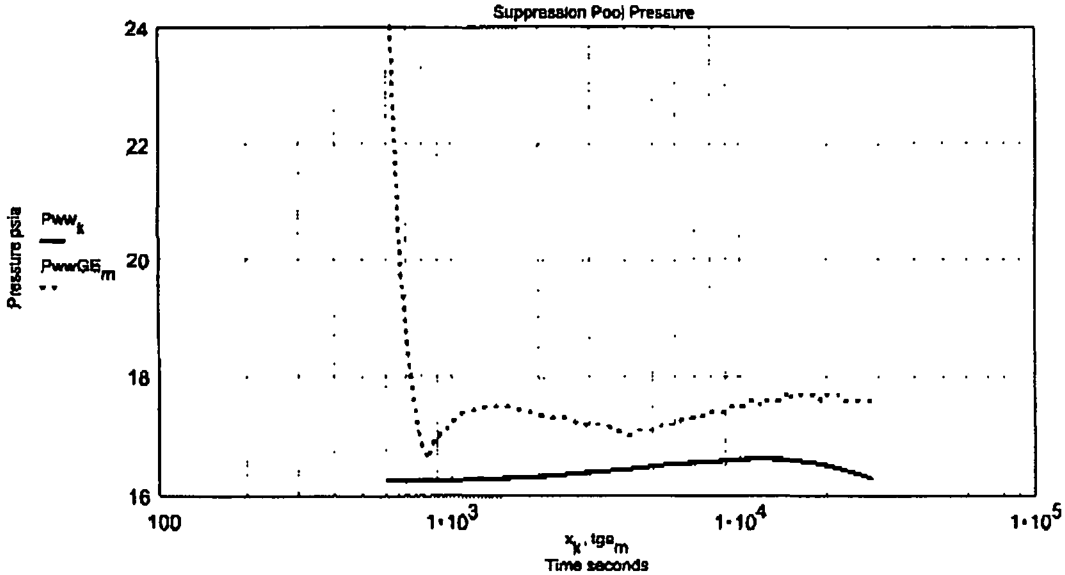
$Psat_k \quad$ interp(vs, Ts, Ps, $Tatm_k$)

$Psatw_k \quad$ interp(vs, Ts, Ps, $Twatm_k$)

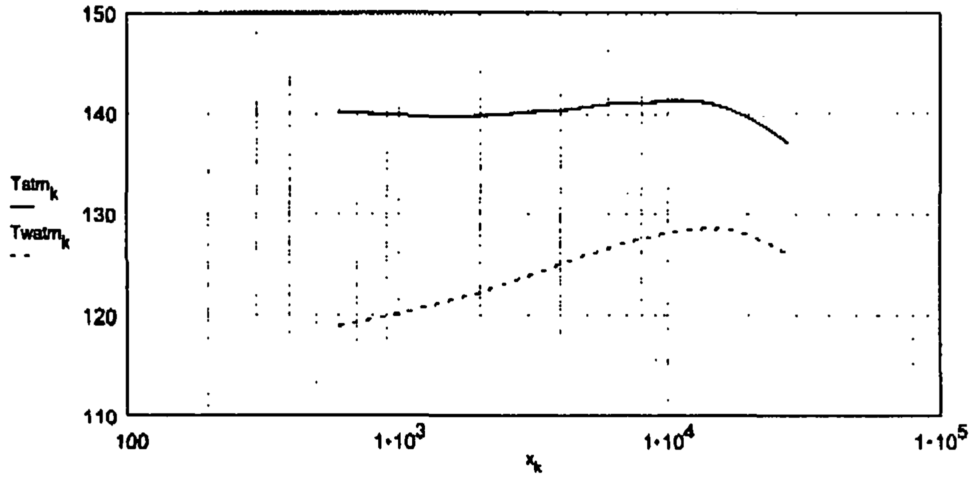


$$Maww_k \quad \frac{144 \cdot \left(Psat_k \quad Psatw_k \cdot Pvb\right) \cdot Ma \cdot R \cdot \frac{Tatm_k \cdot 460}{Vdw}}{R \cdot \frac{Tatm_k \cdot 460}{Vdw} \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$



Suppression Pool Pressure
Pressure psia
Pww_k
PwwGE_m
24
22
20
18
16
100
1·10^3
1·10^4
1·10^5
x_k, tge_m
Time seconds



Tatm_k
Twatm_k
150
140
130
120
110
100
1·10^3
1·10^4
1·10^5
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	16.251	118.896	140.181	148
	1148	16.272	120.514	139.761	150.772
	1696	16.309	121.75	139.756	153.03
	2244	16.343	122.761	139.808	154.876
	2792	16.386	123.632	140.089	156.467
	3340	16.418	124.38	140.242	157.834
	3888	16.44	125.011	140.269	158.986
	4436	16.469	125.544	140.473	159.96
	4984	16.496	126.016	140.687	160.822
	5532	16.519	126.431	140.843	161.58
	6080	16.536	126.791	140.944	162.238
	6628	16.549	127.099	140.992	162.8
	7176	16.558	127.356	140.968	163.27
	7724	16.561	127.584	140.935	163.65
	8272	16.572	127.737	141.01	163.965
	8820	16.582	127.891	141.095	164.247
	9368	16.59	128.029	141.167	164.5
	9916	16.598	128.152	141.226	164.724
	10464	16.603	128.261	141.258	164.922
	11012	16.607	128.352	141.262	165.089
	11560	16.609	128.427	141.251	165.226
	12108	16.609	128.486	141.226	165.336
	12656	16.608	128.531	141.188	165.416
	13204	16.606	128.562	141.132	165.472
	13752	16.603	128.579	141.066	165.503
	14300	16.599	128.583	140.988	165.511
	14848	16.593	128.575	140.898	165.496
	15396	16.587	128.555	140.796	165.46
	15944	16.579	128.524	140.684	165.404
	16492	16.571	128.483	140.561	165.328
	17040	16.561	128.431	140.427	165.234
	17588	16.551	128.369	140.285	165.121
	18136	16.54	128.299	140.132	164.992
	18684	16.528	128.219	139.971	164.846
	19232	16.516	128.13	139.801	164.684
	19780	16.502	128.033	139.623	164.507
	20328	16.488	127.928	139.437	164.315
	20876	16.475	127.818	139.271	164.113
	21424	16.462	127.704	139.106	163.905
	21972	16.449	127.587	138.938	163.692
	22520	16.436	127.468	138.768	163.474
	23068	16.422	127.346	138.596	163.251
	23616	16.409	127.221	138.422	163.024
	24164	16.395	127.095	138.246	162.793
	24712	16.381	126.966	138.068	162.558
	25260	16.366	126.830	137.888	162.32
	25808	16.352	126.703	137.706	162.078
	26356	16.338	126.569	137.523	161.832
	26904	16.323	126.433	137.339	161.584
	27452	16.309	126.296	137.153	161.333

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Sensitivity Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, 20% mixing efficiency, Service water temp=75

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger,and a term to account for sensible heat of the vessel metal.

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

$i\ 1..9$

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7800	.01033
10200	.01012
20400	.008491
39600	.00706
81200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

$Q(x)\ \mathrm{linterp}(t,p,x)$

PHT is the pump heat input, with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

$PHT\ (1\cdot700 \cdot 1\cdot800 \cdot 2\cdot500)\cdot.70696$

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

$HXK\ 307.4$

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec, note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds

$$SENSHT\ \frac{10^{8}\cdot.70}{7200}$$

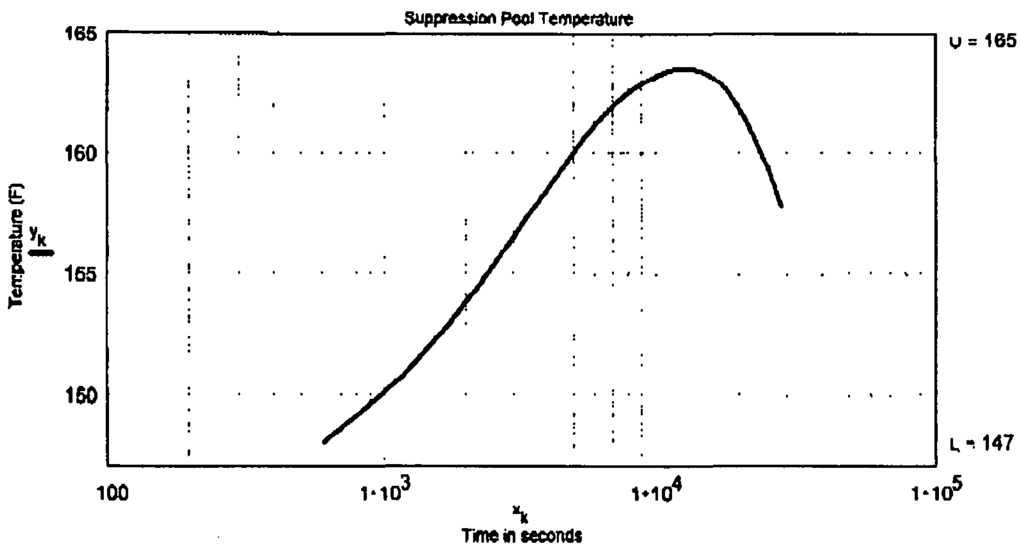
Enter the derivative of y as f(x,y): (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

$T_{sw}\ 75$

$$f(x,y)\ \frac{Q(x)\cdot2578\cdot\frac{1000}{3600}\cdot3413\cdot1.0 + PHT + SENSHT\cdot e^{-\frac{x}{7200}} \quad (y\ \ T_{sw})\cdot HXK}{(124194)\cdot62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y.

startx 600 endx 28000 n 50 intervals inity 148.



max(y) = 163.508

Pressure Calculation

$R\ 53.34$ $\quad LPCI\ \frac{5000}{7.4805 \cdot .0164 \cdot 60}$ $\quad CS \cdot \frac{4500}{7.4805 \cdot .0164 \cdot 60}$

$Vdw\ 158236$ $\quad Ma\ 19284$ nominal air mass

$Ma\ 16499$ reduced air mass $\quad \eta\ 0.2$ mixing efficiency

$Vww\ 108000$ $\quad Qpmp\ 1 \cdot 700 \cdot .70696 - 2 \cdot 500 \cdot .70696$ $\quad Qpmpc\ 800 \cdot .70696$

$Pvb\ 0.5$

$$Tatm_k \quad y_k \quad \frac{HXK \cdot y_k \quad Tsw \quad Qpmp \cdot \quad \cdot LPCI \cdot .95 \cdot \quad Q\ x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \cdot y_k \cdot \frac{Qpmpc}{CS} \cdot \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS} \cdot CS \cdot \eta}{LPCI \cdot .95 \cdot CS \cdot \eta}$$

$$Twatm_k \quad y_k \quad HXK \cdot y_k \quad \frac{Tsw}{LPCI} \quad Qpmp$$

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

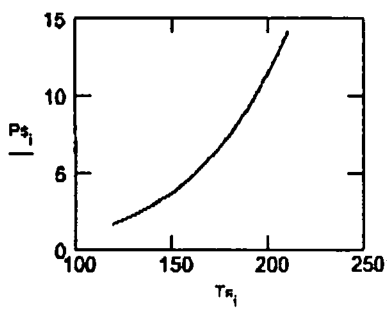
$Ts \quad S^{<0>}$

$Ps \quad S^{<1>}$

$i \quad 0..9$ $\qquad$ $vs \quad pspline(Ts, Ps)$

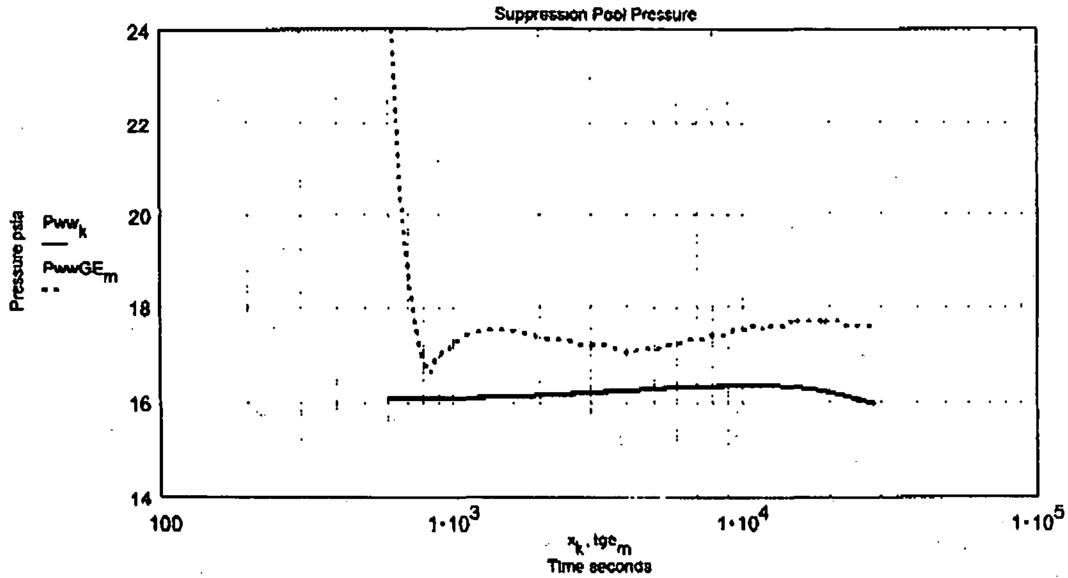
$Psat_k \quad interp(vs, Ts, Ps, Tatm_k)$

$Psatw_k \quad interp(vs, Ts, Ps, Twatm_k)$

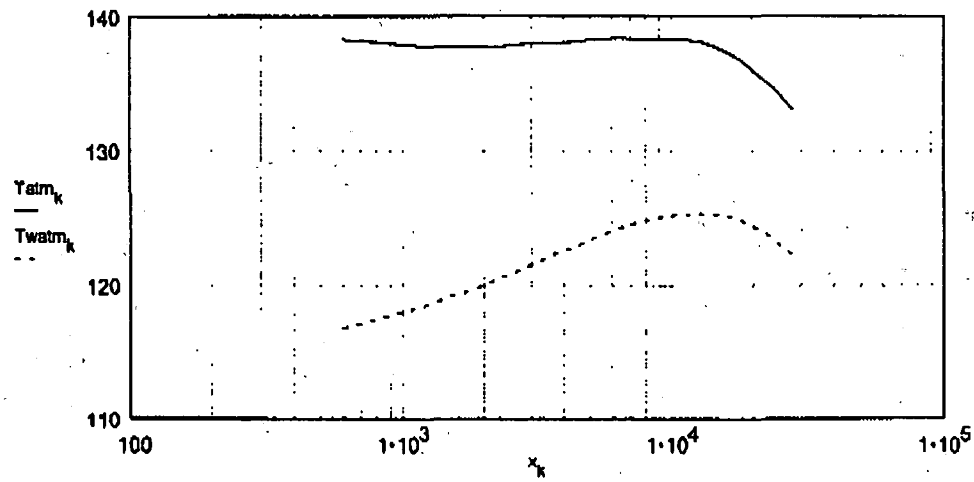


$$Maww_k \quad \frac{144 \cdot (Psat_k \quad Psatw_k + Pvb) \cdot Ma \cdot R \cdot \frac{Tatm_k \cdot 460}{Vdw}}{R \cdot \frac{Tatm_k \cdot 460}{Vdw} + R \cdot \frac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$



Suppression Pool Pressure
Pressure psia
Pww_k
$PwwGE_m$
24
22
20
18
16
14
100
$1\cdot10^3$
$1\cdot10^4$
$1\cdot10^5$
x_k, tge_m
Time seconds



140
130
120
110
$Tatm_k$
$Twatm_k$
100
$1\cdot10^3$
$1\cdot10^4$
$1\cdot10^5$
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	16.081	116.734	138.279	148
	1148	16.096	118.192	137.792	150.664
	1696	16.126	119.37	137.721	152.816
	2244	16.154	120.324	137.709	154.559
	2792	16.19	121.14	137.928	156.048
	3340	16.216	121.834	138.019	157.317
	3888	16.232	122.412	137.986	158.371
	4436	16.254	122.893	138.131	159.251
	4984	16.276	123.314	138.287	160.02
	5532	16.293	123.679	138.387	160.687
	6080	16.305	123.991	138.434	161.257
	6628	16.313	124.251	138.428	161.731
	7176	16.317	124.462	138.371	162.116
	7724	16.316	124.624	138.287	162.413
	8272	16.321	124.792	138.291	162.647
	8820	16.327	124.883	138.327	162.849
	9368	16.331	124.959	138.35	163.024
	9916	16.334	125.04	138.361	163.172
	10464	16.338	125.107	138.348	163.296
	11012	16.335	125.159	138.307	163.39
	11560	16.333	125.195	138.252	163.456
	12108	16.33	125.216	128.183	163.494
	12656	16.326	125.223	138.101	163.508
	13204	16.321	125.217	138.006	163.498
	13752	16.314	125.199	137.9	163.462
	14300	10.307	125.168	137.782	163.406
	14848	16.298	125.126	137.653	163.329
	15396	16.289	125.072	137.513	163.232
	15944	16.279	125.009	137.363	163.115
	16492	16.268	124.935	137.204	162.981
	17040	16.258	124.852	137.035	162.829
	17588	16.244	124.76	136.858	162.66
	18136	16.231	124.659	136.672	162.476
	18684	16.217	124.549	136.477	162.276
	18232	16.202	124.432	136.275	162.062
	19780	16.187	124.307	136.065	161.833
	20328	16.171	124.175	135.847	161.592
	20876	16.157	124.037	135.65	161.34
	21424	16.142	123.897	135.458	161.084
	21972	16.127	123.754	135.259	160.824
	22520	16.112	123.609	135.06	160.559
	23068	16.097	123.463	134.86	160.292
	23616	16.082	123.314	134.659	160.021
	24164	16.067	123.164	134.456	159.748
	24712	16.052	123.013	134.252	159.469
	25260	16.037	122.859	134.046	159.189
	25808	16.021	122.705	133.84	158.907
	26356	16.006	122.549	133.632	158.622
	26904	15.991	122.392	133.424	158.335
	27452	15.975	122.234	133.214	158.048

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Sensitivity Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, 20% mixing efficiency, nominal ICs

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger and a term to account for sensible heat of the vessel metal.

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

$i := 1..9$

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7800	.01033
10200	.01012
20400	.008491
39600	.00706
61200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

$Q(x)\ \mathrm{linterp}(t, p, x)$

PHT is the pump heat input, with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

$PHT\ \ (1 \cdot 700\ ,\ 1 \cdot 800\ \cdot\ 2 \cdot 500) \cdot .70696$

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

$HXK\ \ 307.4$

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec, note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds

$$SENSHT\ \ \frac{10^{8} \cdot .70}{7200}$$

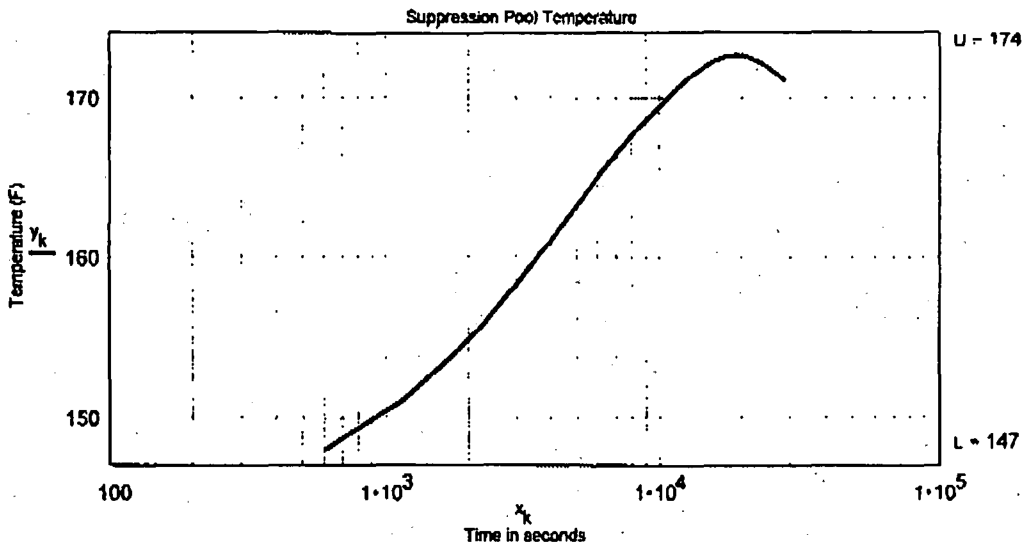
Enter the derivative of y as f(x,y): (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet yielding a pool volume of 124194 ft3)

$Tsw\ \ 95$

$$f(x,y)\ \ \frac{\left(Q(x) \cdot 2578 \cdot \frac{1000}{3600} \cdot 3413 \cdot 1.0\ \cdot\ PHT\ \cdot\ SENSHT \cdot e^{\frac{x}{7200}}\ \ (y\ \ Tsw) \cdot HXK\right.}{(124194) \cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y

startx 600 endx 28000 n - 50 intervals inity 148.



max(y) = 172.554

Pressure Calculation

R 63.34

LPCI $\frac{5000}{7.4805 \cdot .0164 \cdot 60}$

CS $\frac{4500}{7.4805 \cdot .0164 \cdot 60}$

Vdw 168236

Ma 16499 reduced air mass

Ma 19284 nominal air mass

η 0.2 mixing efficiency

Vww 108000

Qpmp 1 700·.70696 · 2·500·.70696

Qpmpc · 800·.70696

Pvb 0.5

$Tatm_k$ y_k HXK· y_k Tsw Qpmp LPCI ·LPCI·.95 · Q x_k ·2578·1000· $\frac{3413}{3600 \cdot CS}$ · y_k · $\frac{Qpmpc}{CS}$ · $\frac{SENSHT \cdot \sigma}{CS}$ $\frac{x_k}{7200}$ ·CS·η

LPCI·.95 · CS·η

$Twatm_k$ y_k HXK· y_k Tsw Qpmp LPCI

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables.

S :=

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

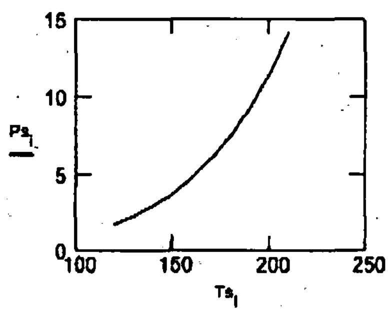
$Ts := S^{\langle 0 \rangle}$

$Ps := S^{\langle 1 \rangle}$

$i := 0..9$ $\quad vs := pspline(Ts, Ps)$

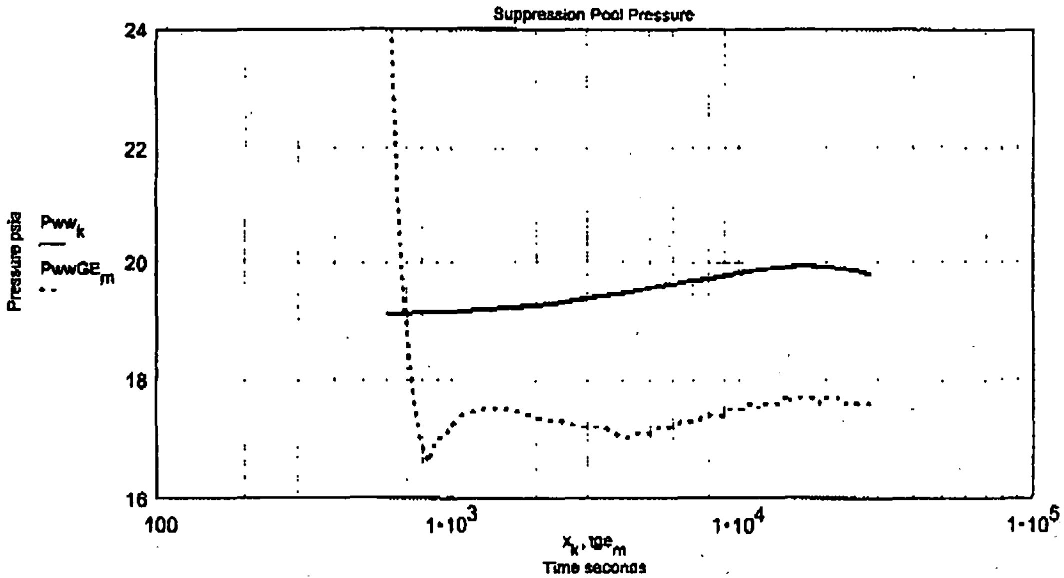
$Psat_k := interp(vs, Ts, Ps, Tatm_k)$

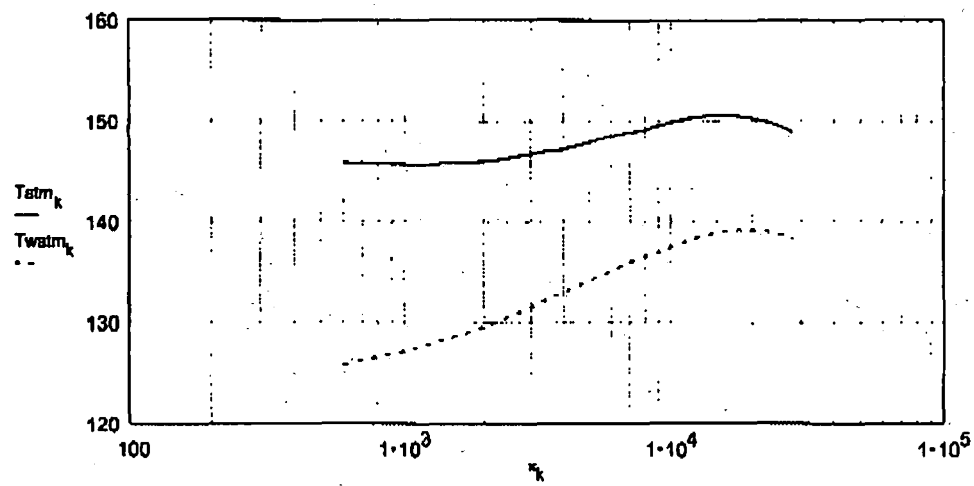
$Psatw_k := interp(vs, Ts, Ps, Twatm_k)$



$$Maww_k := \frac{144 \cdot (Psat_k - Psatw_k - Pvb) - Ma \cdot R \cdot \frac{Tatm_k + 460}{Vdw}}{R \cdot \frac{Tatm_k + 460}{Vdw} - R \cdot \frac{Twatm_k + 460}{Vww}}$$

$$Pww_k := Maww_k \cdot R \cdot \frac{Twatm_k + 460}{Vww \cdot 144} + Psatw_k$$


Suppression Pool Pressure
24
22
20
18
16
Pressure psia
Pww_k
$PwwGE_m$
100
1·10^3
1·10^4
1·10^5
x_k, tge_m
Time seconds


160
150
140
130
120
$Tstm_k$
$Twatm_k$
100
1·10^3
1·10^4
1·10^5
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	19.114	125.785	145.888	148
	1148	19.159	127.48	145.669	151.096
	1696	19.221	128.89	145.88	153.672
	2244	19.28	130.07	146.105	155.828
	2792	19.348	131.107	146.574	157.723
	3340	19.404	132.019	146.911	159.387
	3888	19.448	132.808	147.119	160.83
	4436	19.499	133.497	147.498	162.088
	4984	19.549	134.122	147.884	163.229
	5532	19.593	134.686	148.209	164.259
	6080	19.63	135.192	148.476	165.183
	6628	19.662	135.642	148.685	166.006
	7176	19.689	136.039	148.839	166.73
	7724	19.709	136.384	148.941	167.38
	8272	19.737	136.69	149.167	167.919
	8820	19.764	136.975	149.4	168.44
	9368	19.79	137.241	149.616	168.926
	9916	19.814	137.489	149.816	169.38
	10464	19.835	137.72	149.988	169.801
	11012	19.853	137.931	150.127	170.187
	11560	19.87	138.123	150.249	170.538
	12108	19.884	138.297	150.353	170.856
	12656	19.897	138.454	150.44	171.143
	13204	19.907	138.594	150.511	171.399
	13752	19.916	138.719	150.567	171.626
	14300	19.924	138.820	150.607	171.820
	14848	19.93	138.923	150.633	171.899
	15396	19.934	139.004	150.646	172.147
	15944	19.936	139.071	150.644	172.27
	16492	19.938	139.126	150.63	172.37
	17040	19.938	139.169	150.604	172.448
	17588	19.936	139.199	150.565	172.504
	18136	19.934	139.218	150.515	172.539
	18684	19.93	139.227	150.454	172.554
	19232	19.924	139.224	150.382	172.55
	19780	19.918	139.212	150.299	172.527
	20328	19.911	139.19	150.208	172.487
	20876	19.904	139.16	150.131	172.432
	21424	19.898	139.125	150.056	172.368
	21972	19.89	139.086	149.976	172.298
	22520	19.883	139.042	149.892	172.217
	23068	19.875	138.994	149.803	172.129
	23616	19.866	138.942	149.711	172.035
	24164	19.857	138.887	149.615	171.933
	24712	19.848	138.828	149.516	171.825
	25260	19.838	138.765	149.413	171.71
	25808	19.828	138.699	149.308	171.59
	26356	19.818	138.63	149.197	171.463
	26904	19.807	138.557	149.084	171.331
	27452	19.796	138.482	148.968	171.193

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Sensitivity Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, 40% mixing efficiency, nominal ICs

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger, and a term to account for sensible heat of the vessel metal.

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

i 1..9

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7800	.01033
10200	.01012
20400	.008491
39600	.00706
61200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

$Q(x) \quad \text{linterp}(t, p, x)$

PHT is the pump heat input, with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

$PHT \quad (1 \cdot 700 + 1 \cdot 800 + 2 \cdot 500) \cdot .70696$

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

$HXK \quad 307.4$

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec, note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds

$$SENSHT \quad \frac{10^8 \cdot .70}{7200}$$

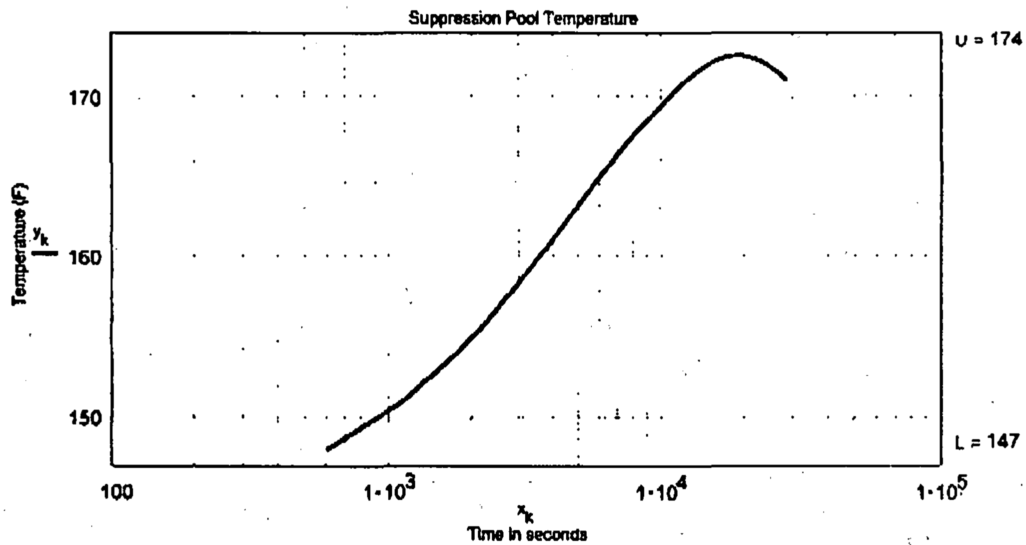
Enter the derivative of y as f(x,y): (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

$Tsw \quad 95$

$$f(x,y) \quad \frac{Q(x) \cdot 2578 \cdot \frac{1000}{3600} \cdot 3413 \cdot 1.0 + PHT + SENSHT \cdot e^{-\frac{x}{7200}} - (y - Tsw) \cdot HXK}{(124194) \cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y.

startx 600 endx 28000 n - 50 intervals inity 148.



max(y) = 172.554

Pressure Calculation

R 53.34

LPCI $\frac{5000}{7.4805 \cdot .0164 \cdot 60}$

CS $\frac{4500}{7.4805 \cdot .0164 \cdot 60}$

Vdw 158238

Ma 16499 reduced air mass

Ma 19284 nominal air mass

η 0.4 mixing efficiency

Vww 108000

Qpmp 1·700·.70696 , 2·600·.70696

Qpmpc 800·.70696

Pvb 0.5

$Tatm_k \quad y_k \quad HXK \cdot y_k \quad \frac{Tsw}{LPCI} \quad Qpmp \cdot \quad \cdot LPCI \cdot .95 \cdot \quad Q\ x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \quad \frac{}{LPCI \cdot .95 \cdot CS \cdot \eta} \cdot y_k \cdot \frac{Qpmpc}{CS} \quad \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS} \cdot CS \cdot \eta$

$Twatm_k \quad y_k \quad HXK \cdot y_k \quad \frac{Tsw}{LPCI} \quad Qpmp$

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

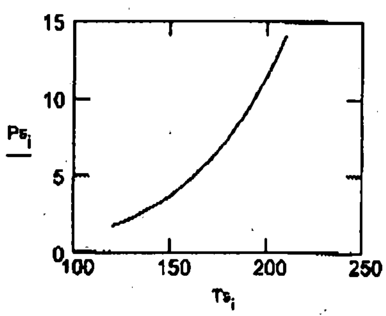
$Ts \quad S^{<0>}$

$Ps \quad S^{<1>}$

$i \quad 0..9$ $\qquad vs \quad pspline(Ts, Ps)$

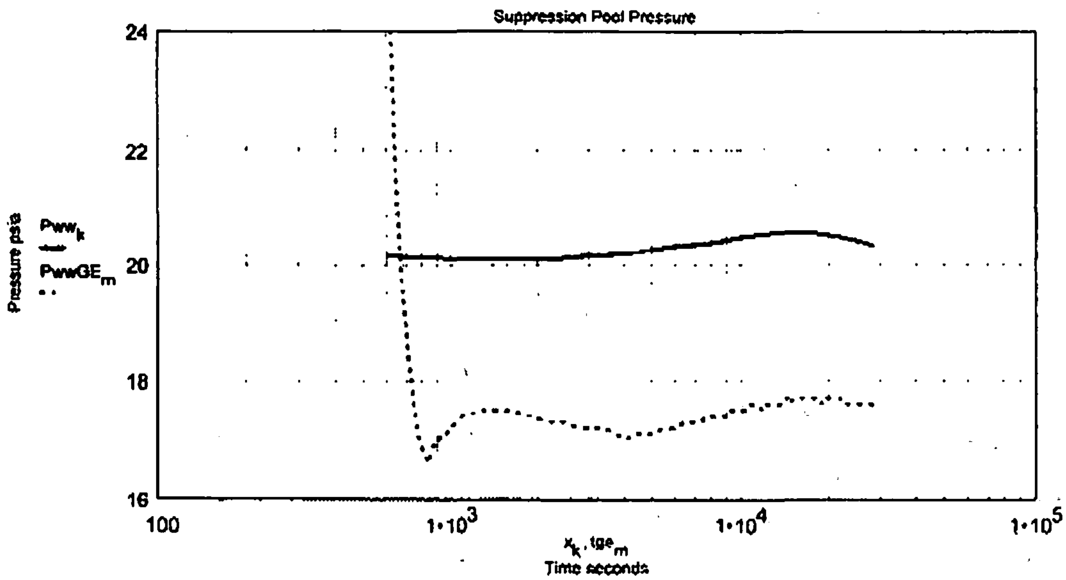
$Psat_k \quad interp(vs, Ts, Ps, Tatm_k)$

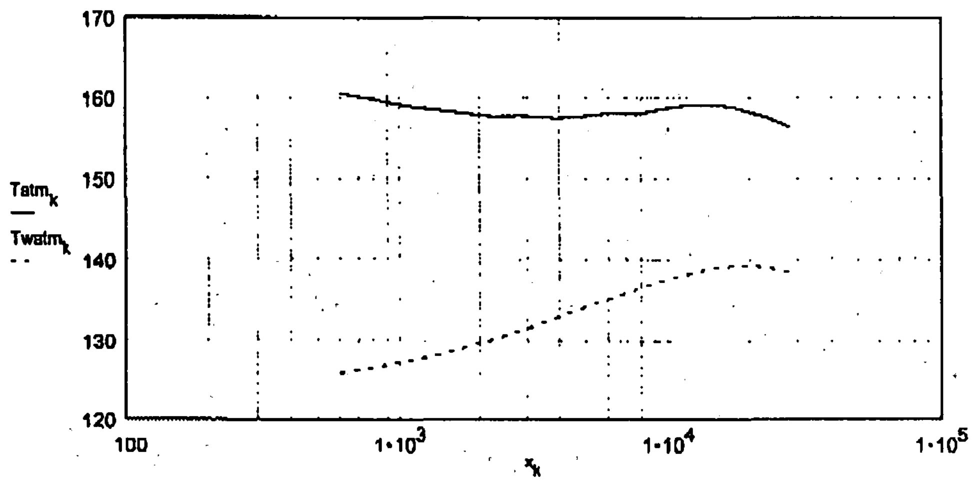
$Psatw_k \quad interp(vs, Ts, Ps, Twatm_k)$



$$Maww_k \quad \frac{144 \cdot \left(Psat_k \quad Psatw_k \cdot Pvb\right) \cdot Ma \cdot R \cdot \frac{Tatm_k \cdot 460}{Vdw}}{R \cdot \frac{Tatm_k \cdot 460}{Vdw} \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$


Suppression Pool Pressure
24
22
20
18
16
Pressure psia
Pww_k
PwwGE_m
100
1·10^3
1·10^4
1·10^5
x_k, tge_m
Time seconds


170
160
150
140
130
120
Tatm_k
Twatm_k
100
1·10^3
1·10^4
1·10^5
x_k

	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Variable	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	20.162	126.785	160.487	148
	1148	20.096	127.48	158.859	151.096
	1696	20.093	128.89	158.187	153.672
	2244	20.104	130.07	157.733	155.628
	2792	20.147	131,107	157.79	157 723
	3340	20.176	132.019	157.71	159.387
	3888	20.19	132.808	157.496	160.83
	4436	20.229	133.497	157.652	162.088
	4984	20.27	134.122	157.885	163,229
	5532	20.304	134,686	158.017	164.259
	6080	20.331	135.192	158,109	165,183
	6628	20.352	135.642	158.143	166,006
	7176	20.366	136.039	158,122	166.73
	7724	20.375	136.384	158.047	167.36
	8272	20.4	136.69	158.215	167.919
	8820	20.427	136.975	158.411	168.44
	9368	20.452	137,241	158,591	168.926
	9916	20.476	137.489	158.755	169.38
	10464	20.495	137.72	158,884	169.801
	11012	20.511	137.931	158.972	170.187
	11560	20.525	138.123	159,043	170.538
	12108	20.536	138.297	159.096	170.856
	12656	20.546	138,454	159.133	171.143
	13204	20.553	138.594	159,153	171.399
	13752	20.559	138.719	159.159	171.626
	14300	20.563	138.828	159.149	171.826
	14848	20.565	138.923	159,126	171.999
	15396	20.566	139.004	159.088	172.147
	15944	20.564	139.071	159,037	172.27
	16492	20.562	139.126	158.973	172.37
	17040	20.557	139.169	158,898	172.448
	17588	20.551	139.199	158.808	172.504
	18136	20.544	139.218	158,707	172.539
	18684	20.536	139.227	158,596	172.554
	19232	20.526	139.224	158.473	172.55
	19780	20.515	139.212	158,339	172.527
	20328	20.503	129.19	158,195	172.487
	20876	20.493	129.16	158,088	172.432
	21424	20.483	139.125	157.983	172,368
	21972	20.473	139,088	157.873	172.298
	22520	20.462	139.042	157,78	172.217
	23068	20.451	138.994	157.642	172.129
	23616	20.439	138.942	157,52	172.035
	24164	20.427	138.887	157.395	171.933
	24712	20.415	138.828	157.267	171.825
	25260	20.402	138.765	157.134	171.71
	25808	20.389	138.699	156.999	171.59
	26356	20.375	138,63	156.86	171.463
	26904	20.361	138.557	156.718	171,331
	27452	20.347	138.482	156.573	171.193

DRESDEN SUPPRESSION POOL HEATUP CALCULATIONS
Benchmark Case: 1/2 nominal CCSW GE Case 2a1, 4500 gpm CS flow, no spray case, nominal ICs

This calculation is based on the use of a Runge-Kutta solution method to numerically evaluate the first order differential equation describing the behavior of the suppression pool following the completion of the blowdown from the vessel. It uses boundary conditions taken from new GE calculations. These are the decay heat, pool temperature at 600 seconds, the K value for the heat exchanger,and a term to account for sensible heat of the vessel metal.

The following vectors represent the decay heat input to the problem. These are based on the GE supplied data and represent a ANS-5.1-1979 standard values

i 1..9

t_i	p_i
600	.02212
1000	.01956
2000	.01599
4000	.01273
7800	.01033
10200	.01012
20400	.008491
39600	.00706
81200	.006306

Q(x) defines a linear interpolation of the above vectors for use in the calculation

$Q(x)$ linterp(t, p, x)

PHT is the pump heat input with CCSW and LPCI considered to be 500 and 700 HP and the Core Spray at 800 HP, converted to BTU/SEC

$PHT \ (1 \cdot 700 + 1 \cdot 800 + 2 \cdot 500) \cdot .70696$

HXK is the heat removal rate of the LPCI HX in BTU/Sec-F, based on GE calculations at revised HX capacity

HXK 307.4

SENSHT is the sensible heat stored in the thick metal structures, added to the pool in exponential fashion as BTU/sec, note that this term is adjusted to provide a reasonable match to vendor base calculations, with the total sensible heat being approximately 100 MBTU, assuming a fraction remaining at 600 seconds

$$SENSHT \ \frac{10^6 \cdot .70}{7200}$$

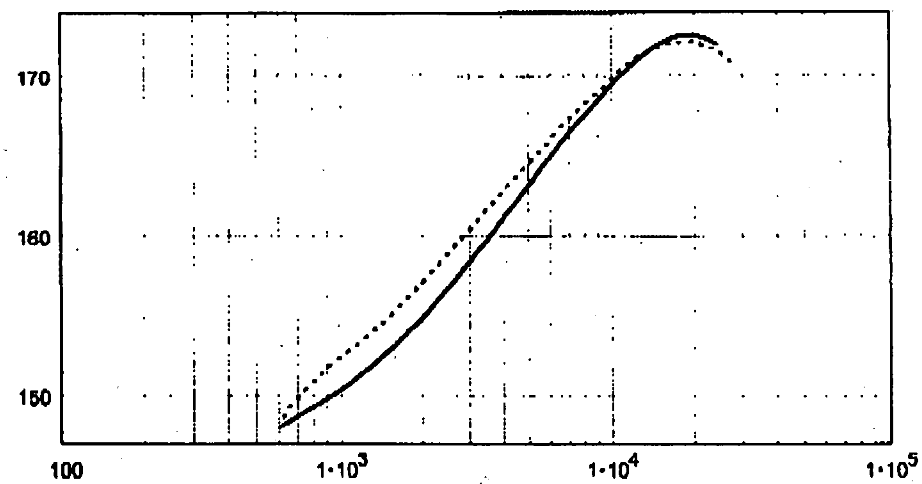
Enter the derivative of y as f(x,y) (Note that x=time(seconds and y=Temperature) Pool Volume is based on final volumes provided by GE in base calculations (vapor space of 108000 cubic feet, yielding a pool volume of 124194 ft3)

Tsw 95

$$f(x,y) \ \frac{Q(x) \cdot 2578 \cdot \frac{1000}{3600} \cdot 3413 \cdot 1.0 + PHT + SENSHT \cdot e^{-\frac{x}{7200}} - (y - Tsw) \cdot HXK}{(124194) \cdot 62.054}$$

Enter starting and ending values of x, the number of intervals for the integration, and the initial value of y.

startx 600 endx 24000 n · 50 intervals inity 148



U ~ 174

L = 147

max(y) ~ 172.556

Note: GE Temperatures plotted from output data supplied by GE.

Pressure Calculation

R 53.34

$LPCI = \frac{5000}{7.4805 \cdot .0164 \cdot 60}$

$CS = \frac{4500}{7.4805 \cdot .0164 \cdot 60}$

Ma 16499 reduced air mass

Vdw 158236

Ma 19284 nominal air mass

Vww 108000

$Qpmp = 1 \cdot 700 \cdot .70696 - 2 \cdot 500 \cdot .70696$ Qpmpc = 800 · .70696

Pvb 0.5

$Tatm_k \quad Q \; x_k \cdot 2578 \cdot 1000 \cdot \frac{3413}{3600 \cdot CS} \cdot y_k \quad \frac{Qpmpc}{CS} \quad \frac{SENSHT \cdot e^{\frac{x_k}{7200}}}{CS}$

Note change to account for no spray in drywell and wetwell. Airspace temperature then set by breakflow in drywell and pool temp in wetwell.

$Twatm_k \quad y_k \quad \frac{HXK \cdot y_k \quad Tsw}{LPCI} \quad Qpmp \qquad Twatm_k \cdot y_k$

This File estimates Psat based on temperature input. It is a curve fit interpolation between 120 and 200 degrees of data from the 1967 ASME tables.

S

120	1.6927
130	2.223
140	2.8892
150	3.7184
160	4.7414
170	5.9926
180	7.511
190	9.34
200	11.526
210	14.123

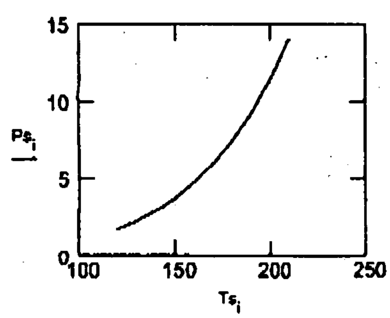
$Ts \quad S^{<0>}$

$Ps \quad S^{<1>}$

$i \quad 0..9$ $\qquad vs \quad pspline(Ts, Ps)$

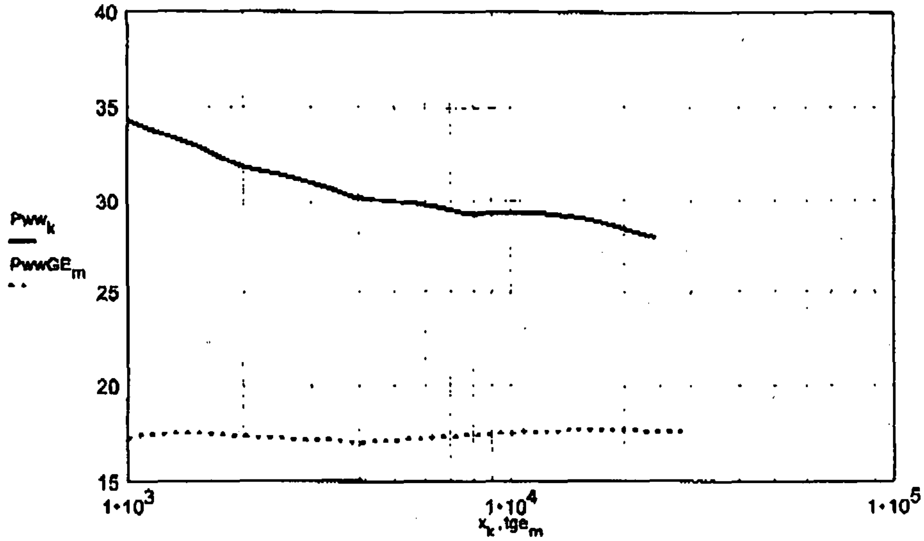
$Psat_k \quad interp(vs, Ts, Ps, Tatm_k)$

$Psatw_k \quad interp(vs, Ts, Ps, Twatm_k)$

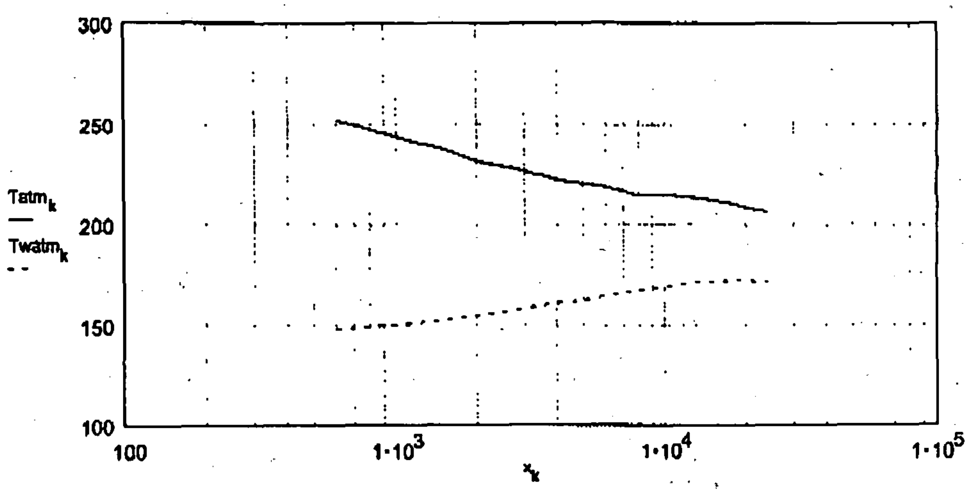


$$Maww_k \quad \frac{144 \cdot Psat_k \quad Psatw_k \cdot Pvb \cdot Ma \cdot R \cdot \dfrac{Tatm_k \cdot 460}{Vdw}}{R \cdot \dfrac{Tatm_k \cdot 460}{Vdw} \cdot R \cdot \dfrac{Twatm_k \cdot 460}{Vww}}$$

$$Pww_k \quad Maww_k \cdot R \cdot \frac{Twatm_k \cdot 460}{Vww \cdot 144} \cdot Psatw_k$$

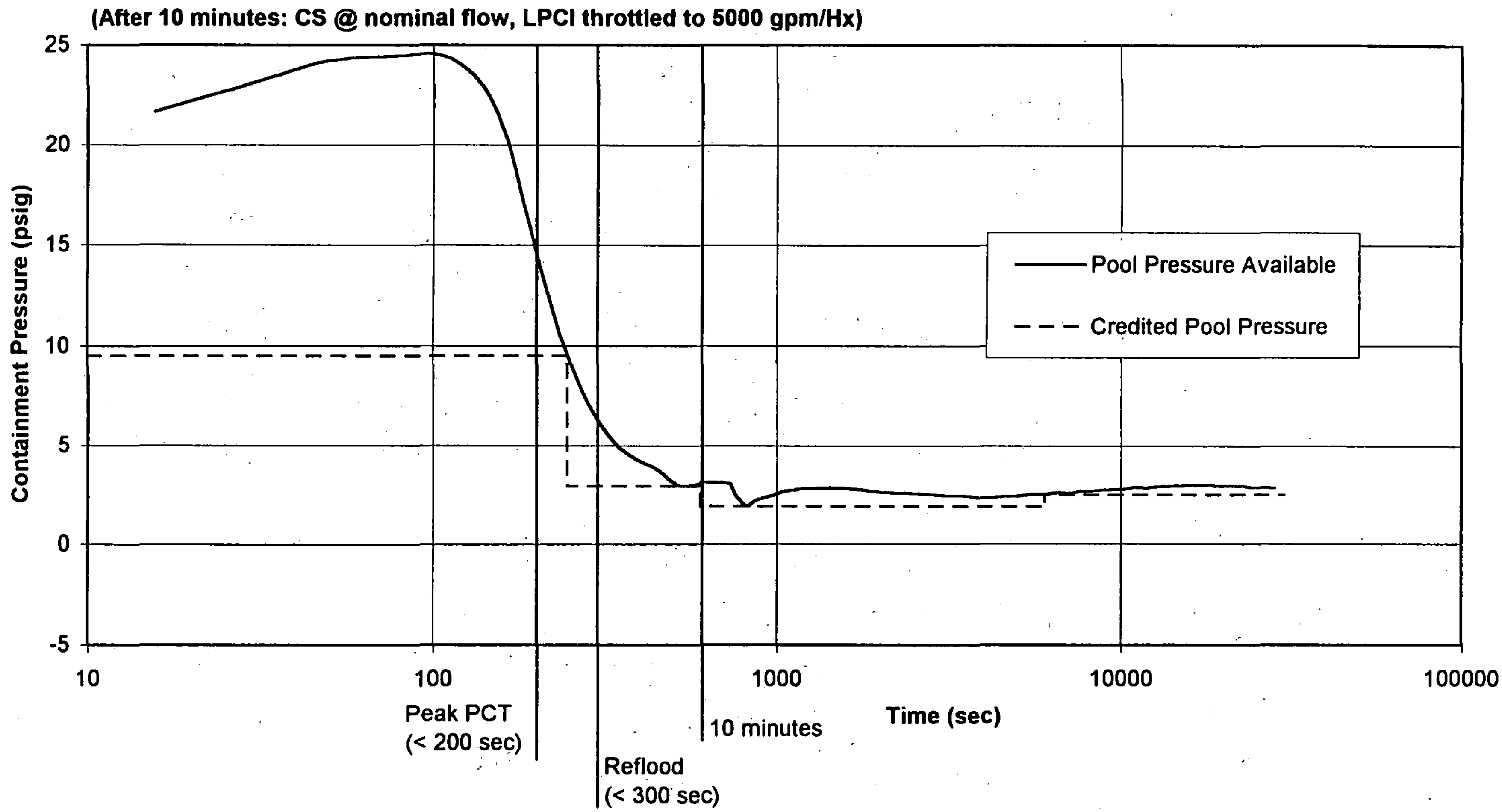


max(Pww) = 36.188



	Time sec	WW Press psia	WW air T deg F	DW Temp deg F	WW Pool T deg F
Varible	x_k	Pww_k	$Twatm_k$	$Tatm_k$	y_k
	600	36.188	148	251.99	148
	1068	33.995	150.684	242.547	150.684
	1536	32.899	152.966	237.287	152.966
	2004	31.79	154.929	231.794	154.929
	2472	31.447	156.65	229.707	156.65
	2940	31.077	158.199	227.497	158.199
	3408	30.683	158.583	225.165	159.583
	3876	30.265	160.805	222.714	160.805
	4344	30.103	161.89	221.538	161.89
	4812	30.026	162.887	220.806	162.887
	5280	29.936	163.803	220.027	163.803
	5748	29.833	164.64	219.202	164.64
	6216	29.718	165.401	218.331	165.401
	6684	29.591	166.088	217.414	166.088
	7152	29.453	166.704	216.453	166.704
	7620	29.303	167.251	215.448	167.251
	8088	29.201	167.739	215.033	167.739
	8556	29.288	168.196	215.001	168.196
	9024	29.312	168.628	214.964	168.628
	9492	29.334	169.034	214.921	169.034
	9960	29.353	169.417	214.872	169.417
	10428	29.357	169.777	214.751	169.777
	10896	29.344	170.11	214.551	170.11
	11364	29.328	170.419	214.34	170.419
	11832	29.309	170.702	214.118	170.702
	12300	29.285	170.962	213.886	170.962
	12768	29.258	171.199	213.643	171.199
	13236	29.228	171.415	213.39	171.415
	13704	29.195	171.609	213.127	171.609
	14172	29.158	171.784	212.853	171.784
	14640	29.118	171.938	212.569	171.938
	15108	29.076	172.074	212.275	172.074
	15576	29.03	172.192	211.971	172.192
	16044	28.981	172.292	211.657	172.292
	16512	28.93	172.375	211.334	172.375
	16980	28.876	172.442	211.001	172.442
	17448	28.819	172.493	210.658	172.493
	17916	28.76	172.529	210.307	172.529
	18384	28.698	172.55	209.946	172.55
	18852	28.634	172.556	209.575	172.556
	19320	28.567	172.549	209.196	172.549
	19788	28.499	172.528	208.808	172.528
	20256	28.428	172.494	208.412	172.494
	20724	28.374	172.449	208.118	172.449
	21192	28.328	172.398	207.871	172.398
	21660	28.281	172.34	207.62	172.34
	22128	28.233	172.276	207.368	172.276
	22596	28.185	172.206	207.112	172.208
	23064	28.136	172.131	206.855	172.131
	23532	28.088	172.051	206.594	172.051

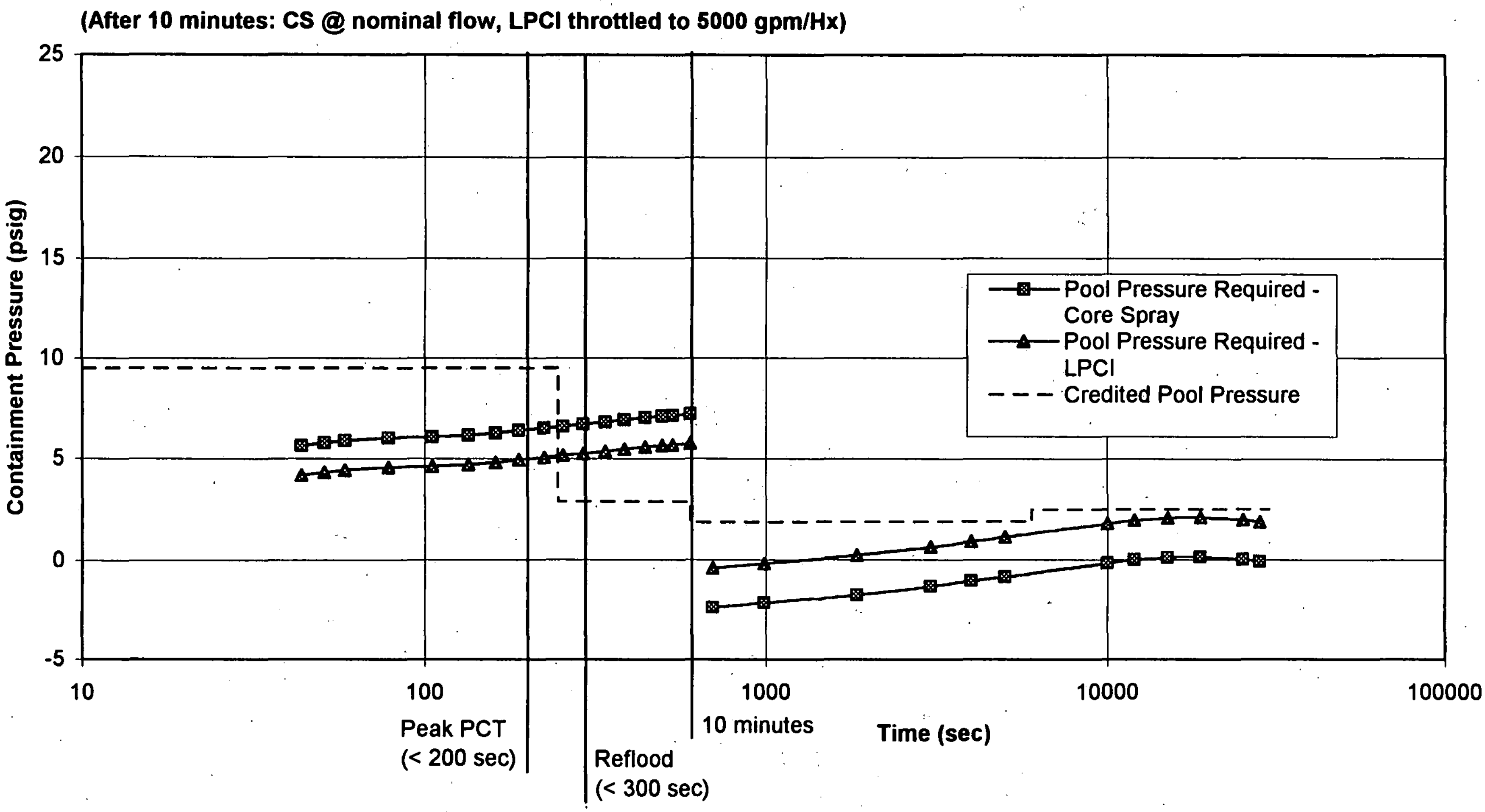
ATTACHMENT 2
AVAILABLE AND CREDITED CONTAINMENT OVERPRESSURE



DRESDEN STATION
UNITS 2 & 3

MINIMUM CONTAINMENT PRESSURE AVAILABLE AND CREDITED CONTAINMENT PRESSURE FOR PUMP NPSH

FIGURE 1



DRESDEN STATION
UNITS 2 & 3

CREDITED CONTAINMENT PRESSURE FOR PUMP NPSH

FIGURE 2

ATTACHMENT 3
OPERATOR ACTIONS

During the Design Basis LOCA, the operator is credited with actions at the ten minute mark into the accident. The operator works through all applicable Dresden Emergency Operating Procedures (DEOP) concurrently. During the following explanation, the operator is responding to the Design Basis Loss of Coolant Accident where a reactor vessel water level of only two-thirds core height can be achieved and the reactor vessel is depressurized. The purpose of the following is to outline what containment parameters exist and the guidance provided to govern the control room operator actions.

Primary Containment Control EOP

The operator would enter this procedure based on the following entry conditions during a Loss of Coolant Accident:

- Drywell Temperature above 160 degrees F
- Torus Bulk Temperature above 95 degrees F
- Drywell Pressure above 2.0 psig

During conduct of this procedure, his responsibilities include addressing all conditions in order to bring the above Drywell Temperature and Pressure and Torus Bulk Temperature parameters to within normal operating values. To address these parameters, the operator will take the following actions:

Suppression Pool Bulk Temperature: The operator will use all available suppression pool cooling to maintain the pool temperature below 95 degrees F. The operator will use only those LPCI pumps which do not have to be run continually in the injection mode for core cooling. At ten minutes into the accident scenario, the vessel will be reflooded to two-thirds core height, LPCI pumps will be diverted to suppression pool cooling and Containment Cooling Service Water Pumps will be operated to begin containment and suppression pool cooling.

Drywell Temperature and Pressure: The operator will first use the available drywell coolers to maintain pressure below 2.0 psig and if drywell pressure can not be maintained below this value the operator will spray the suppression pool. The operator will initiate drywell sprays to control these parameters prior to drywell temperature reaching 281 degrees F or when drywell pressure exceeds 9 psig. If the Suppression Pool bottom pressure can not be maintained within the containment design limits, the primary containment is then vented to atmosphere. The EOPs direct the operation of the torus and drywell sprays be terminated when torus pressure or drywell pressure decreases to the high drywell pressure scram setpoint to assure that the primary containment pressure is not reduced below atmospheric. Maintaining a positive suppression chamber pressure precludes air from being drawn in through the vacuum breakers to de-inert the primary containment, assures that a positive margin to the negative design pressure of the primary containment exists, and also permits resetting the scram and primary containment isolation logic, thereby enabling the operator to perform action specified in other parts of the EOPs without defeating the associated interlocks.

Reactor Control

The operator would enter this procedure based on the following entry conditions during a Loss of Coolant Accident:

- Reactor Vessel Water Level below the low water level setpoint of 8 inches
- Drywell Pressure of 2.0 psig

The operator will try to restore and maintain reactor vessel level. Since only two-thirds core height can be achieved during this accident, the operator will line up and inject with the available safety and non safety related systems that can supply water in order to restore vessel level to the normal operating band. Since reactor vessel water level can not be maintained above the top of the active fuel, the operator is directed to Emergency Depressurize the reactor and then enter the Primary Containment Flooding DEOP. This DEOP has the operator use the available safety and non-safety related systems to flood the containment to ensure core submergence.

Recognition of Pump Cavitation

Loss of pump NPSH may be detected through one or more indications of degraded system performance. As available NPSH decreases, these indications may include:

- System flow rate less than expected for the backpressure to which the system is discharging (i.e., Reactor Vessel, Suppression pool pressure).
- Decreased suction pressure (local indication only)
- Decreased pump motor current indications (local ammeter, control room indication for Emergency Diesel Generator power).
- Frequent unanticipated adjustment of system discharge valves. For example, given steady state conditions is reached, the discharge valve must be periodically adjusted to increase flow.
- Inability to control and maintain parameters such as Reactor Vessel water level, containment pressure, drywell temperature, suppression pool temperature and suppression pool level within the bounds of the specified EOP action levels and limits.
- Abnormally low discharge pressure indication for a given flow: As available NPSH decreases, suction pressure decreases which produces a lower than normal pump discharge pressure for a given flow rate.
- Erratic and dramatic fluctuations in discharge pressure, flow, and pump motor current indications
- Indications of the minimum flow valve cycling on low flow conditions.
- Annunciation and subsequent reset of ECCS pump at pressure alarms and ECCS pump pressure low alarms.

The Licensed Operator training program includes approved training material on the indications to recognize the loss of NPSH to the ECCS pumps. The training material is evaluated using operator diagnostic capabilities during various plant transients presented on the Dresden Simulator.

Summary

The EOPs are structured such that the operator need not diagnose the cause in order to deal with the event properly. They are a symptom based procedure, such that the operator takes actions on symptoms. With a symptom based procedure, the entire spectrum of plausible events must be covered by the procedure. As the conditions degrade, the operator would proceed through the procedure taking steps on the severity of the symptoms. All the actions specified in the procedures are within the system and operators capability. The EOPs cover a broad spectrum of events and many events are well beyond the design based events that were assumed in the FSAR. Therefore, the EOPs specify the best actions to be taken based on the symptoms available to the operator in the control room. Based upon data from the containment sensitivity analysis (attachment 1): 1) plant parameters would lead the operators to initiate containment spray within the first 10 minutes following a design basis LOCA and 2) the spray is expected to be maintained for the duration of the accident scenario.

The operator's actions are governed by the plant parameter's which exist during the accident. The operator may perform actions in two different EOP procedures concurrently in order to address many parameters (drywell pressure, temperature, reactor vessel water level) which must be brought back to within the normal operating band.