ATTACHMENT V

Consumers Power Company
Palisades Plant
Docket 50-255

PRESSURE RESPONSE EFFECT OF VLTOP WITH REPLACEMENT PORVs
(EA-FC-809-13, Rev. 1)

September 22, 1989

44 Pages

DESIGN REVIEW SIGNOFF

RECEIVED
SEP 21 1989
NUCLEAR LICENSING

EA: -FC-809-13 Rev 1 UFI: 950*40*40*06

TITLE: PRESSURE RESPONSE EFFECTS OF VLTOP WITH REPLACEMENT PORVs

PURPOSE:

ESTABLISH PERMISSABLE VLTOP ACTUATION SET POINTS

PROCEDURE UTILIZED:

HAND CALCULATIONS

SIMILARITIES WITH PREVIOUS DESIGNS:
BOTH MASS ADDITIONS AND V_f CHANGES WERE ADDRESSED IN PREVIOUS ANALYSES, BUT PREVIOUS ANALYSES ASSUMED A CONSTANT K, BULK MODULUS OF ELASTICITY.

SUMMARY OF RESULTS: See CURVES ATTACHED TO PARTS I & III

SPECIAL MEDIA ATTACHED (DRAWINGS, MICROFICHE, ETC)

___ NO ✓ YES - LIST OF ATTACHMENTS INCLUDED

FSAR UPDATE REQUIRED: ___ NO ✓ YES UPDATE ATTACHED ___ OR SHOULD BE COMPLETED AS PART OF FC PACKAGE

UPDATE ASSIGNED TO: ____________

REQUIRED COMPLETION DATE: ________

[signature] / 19 Sept 1989
PREPARED BY Date

[signature] / 9/20/89
PREPARER APPROVED BY Date

Timothy C. Duffy / 9/20/89
REVIEWED BY / Date

[signature] / 9/20/89
REVIEWER APPROVED BY Date

[signature] / 9/20/89
REPORT APPROVED BY Date

ENGINEERING ANALYSIS

Title: Pressure Response Effects of VLTOP with Replacement PORVs

Methodology:

The analysis is completed in four parts, described below. One part determines pressure overshoot, another the PORV flows, another the recommended LTOP set points, and the last, the Tech Specs limit.

Part I calculates the rate at which Pzr pressure would increase for permissable heating rates (PCS and Pzr), and mass addition rates. It also calculates an equivalent gpm for all effects, for use in Part III - Valve Opening Requirements. Mass addition rates both with and without HPSI are calculated over the 230 to 350 degree PCS temperature range.

Part II calculates the water flow for a single PORV to open full stroke, for use in Part III and Part IV.

Part III calculates the Appendix G pressure limits for PCS temperatures with allowance for temperature and pressure errors of 5 degrees and 30 psi respectively, and an allowance for pressure overshoot. These are the LTOP setpoints. The setpoints are plotted, and then a new plot of a smooth curve is prepared which envelopes all of the set points. This second curve is the recommended LTOP set point curve.

Part IV calculates the Appendix G pressure limits for PCS temperatures without temperature and pressure error, but with allowance for pressure overshoot. These values are plotted, and produce the LTOP Tech Specs Limit curve (3-4 in the T.S. change request).

During the preparation and review of this analysis, several questions were raised, and answered. The more significant of these are included below:

1) WHAT CONSERVATISMS ARE INCLUDED IN THE ANALYSIS?

   a) The longest PORV full stroke time was utilized in calculating time until required flow, for all cases, even though Pzr liquid would have to be saturated to produce such a stroke time. Times with subcooled liquid are computed to be substantially shorter.

   b) PORV flow figure used was that for only 310 psia in the pressurizer, regardless of LTOP set point. Further, PORV backpressure was assumed to be 115 psia continuously, even though it will likely be much lower initially, and cannot be sustained at that level due to the quench tank rupture disc's 90 psig set point.

c) Pressurizer heating rate was assumed to be 200 deg/hr, as permitted, but actual maximum heating rate when pressurizer is water-solid is substantially lower.

d) The Bulk Modulus of Elasticity, k, was not recalculated for every temperature above 200 degrees, but rather was 'stepped' down, such that over much of the temperature range it is higher than actual, resulting in calculation of a higher than actual rate of pressure increase.

e) No PORV flow is assumed to occur until the valve is full open; ie, flow is stepped, not ramped.

f) PCS volume is assumed to be that resulting from 29.3% average steam generator tube plugging, worsening the pressure increase rate over that with the current level of plugging (~25.5%)

2) WHY ARE THE POTENTIAL MEASUREMENT ERRORS NOT INCLUDED IN THE LTOP TECH SPECS LIMIT CURVE?

The T.S. curve represents the pressure at which the PORV must be actuated in order to prevent exceeding the Appendix G limit, considering the pressure overshoot during the time it takes for the valve to open. The amount by which the set point must be reduced below this value to offset potential error, drift, etc. may vary under the influence of calibration temperature, and instrument sensitivity. The requirement is that LTOP cicuitry set point be reached at the same time or before the T.S. limiting pressure is reached. With this approach, surveillance tests should never find an LTOP set point in excess of the T.S. limit.

3) WHY IS PROTECTION OF THE SDC SYSTEM NO LONGER PROVIDED BY THE PORVS?

The LTOP set point which would be necessary to protect the SDC system would be too low.

- SDC is designed for 500 psig
- The LPSI pumps can add as much as 197 psi to the system pressure
- The LPSI pump discharge is @ ~571.5 elev.
- Pzr pressure (LTOP pressure input) is measured @ ~650 elev.
- Elevation difference adds ~34 psi to indicated system pressure
- Potential pressure error of LTOP instrumentation (narrow range) is ~24 psi

The set point of LTOP to protect SDC system would therefore have to be (500 psig + 15) - 197 - 34 - 24 = 260 psia. Actual operating pressure would have to be reduced below this value to prevent inadvertent opening of PORVs, and to keep alarm (LTOP) cleared.

SDC system RVs will provide adequate protection against charging without letdown (133 gpm) in coincidence with PCS heating @ 40 deg/hr (25 gpm) and Pzr heating @ 60 deg/hr (9 gpm). RVs are 3164 (133 gpm), 3162 (5 gpm), 0402 (15 gpm), and 0403 (15 gpm). ER-PAL-89-040 will resolve their set points to account for elevation head and ensure SDC overpressure protection without reliance on the PORVs.

4) LTOP limit is shown a single curve for heating and cooling. Which is limiting?

Based on revised Appendix G limits (through 1.8E19 nvt), and on permissable rate of change, the LTOP limit is set by cooling constraints below ~280 deg F, and by heating constraints above ~290 deg F. The exact crossover point depends upon wether or not instrument error allowances are included, and is also affected by the assumed heating or cooling rate. For the rates assumed (maximum permissable rates for the PCS temperature), all pressure limits were from the 1/4t Appendix G calculations. Future changes in permissable rates, or in Appendix G limits could result in the 3/4t values being more limiting. Therefore, any change in permissable heating/cooling rates, or in vessel fluence, should prompt investigations into the posiblity of the 3/4t values being more limiting, and into a shift in the crossover point in which values are limiting (heating or cooling).

Part I - Pressure Increase Rates for Various PCS Heating Rates and Pump Start Combinations

Objective:

Determine the rate of Pressurizer pressure increase for inadvertent pump starts when PCS is water-solid as input to calculate Pzr presssure overshoot during LTOP actuation time.

Analysis Input:

a) Pzr heating rate = 200 degrees/hour.

b) PCS heating rates = 20 deg/hr up to 170 deg F. (ref 4)
40 deg/hr from 170 to 250 deg F.
60 deg/hr from 250 to 350 deg F.
100 deg/hr from 350 to 532 deg F.

c) Rate of Pzr presssure increase, psi/sec = K*(-dV/V), from ref 1,
where V = PCS volume = 10,311.7ft3, from ref 2 & 3, and
dV = Swell and mass additions, converted to ft3/sec, and
K = Bulk modulus of elasticity for water (see attacment 1)

d) dV is calculated for Swell from the relationship

dV = (Vf-Vf')/Vf*Vpcs/t or (Vf-Vf')/Vf*Vpzr/t ,

where Vf = fluid specific volume @ temp of interest, and
Vf'= fluid specific volume @ temp of interest + 10 deg, and
Vpcs, or Vpzr = the affected volume, and
t = the elapsed time for the temperature change, in seconds

Vpcs = PCS volume - Pzr volume = 8,808ft3, from ref 2

Vpzr = Pressurizer volume = 1,503.7, from ref 3

e) dV is calculated for mass additions from the relationship

dVchg, or dVhpsi = gpm / gal/ft3 / sec/min = ft3/sec,

where dVchg = charging flow = 133gpm, and
dVhpsi = High Pressure Safety Injection Flow from ref 6, and
gal/ft3 = 7.48, and
sec/min = 60

f) HPSI pumps delivery as a function of Pzr pressure is taken from reference 6.

g) Constants used in the analyses are:

A = Vpcs/t = 8,808/1,800 = 4.8933...ft3/sec over the range of 50 to 170 deg F

= 8,808/900 = 9.7866...ft3/sec for 170 to 250 deg

= 8,808/600 = 14.68 ft3/sec for 250 to 350 deg

= 8,808/360 = 24.466...ft3/sec for 350 & up

B = Vpzr/t = 1,503.7/180 = 8.3539 for all temperatures

C = K/V = 305,000/10,311.7 = 29.578052 psi/ft3 @ 50 deg F.
[C is recalculated each 10 deg F from 50 to 200 deg F, then @ 50 deg C intervals; see attachment 1]

K = Bulk modulus of elasticity for water; see attachment 1

Assumptions:

a) All HPSI pumps are disabled @ PCS temperatures <260 deg F (ref 4).

b) Steam Generator tube plugging will not reduce PCS volume below 10,311.7 ft3, which corresponds to 29.3% average fraction of tubes plugged (ref 2). [PCS volume with 23.68 & 24.49% SG 1 & 2 plugging respectively = 10,403.95ft3]

c) Inadvertent start of charging is in coincidence with isolation of letdown, maximum Pzr heating rate, and maximum PCS heating rates.

d) Inadvertent start of HPSI is in coincidence with inadvertent start of charging, maximum Pzr heating, and maximum PCS heating.

e) PCS is water-solid at beginning of transient.

f) PCS heating rates are the maximums permitted (ref 4).

g) No reduction in mass addition rate is taken as Pzr pressure rises above initial pressure.

h) Initial pressures are taken as equal to the shutdown cooling LTOP set point from 50 to 350 degrees, then taken as over 80 psi less than expected LTOP set points, to maximize HPSI delivery.

i) Pressurizer fluid is taken as being in equillibrium with the PCS until both are heated to 200 deg F; then, Pzr fluid is taken as being near saturation, to maximize volume change from Pzr heating.

j) Delivery from two HPSI pumps to the PCS is twice that from one HPSI pump.

Constants on this page: A=_7.8933 B=8.3539 C=_29.8484 K=307.788
30.6135 315.675
31.2702 322.449

PCS tempeature 50_ Vf @ 310 psia = .01601 Vf'@ 60 & 310 psia = .01602
Pzr temp 50_ Vf @ 310 psia = .01601 Vf'@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3046*C =
9.0918 psi/sec

dVpcs = .00001/.01601*A = .0031 ft3/sec

dVpzr = .00001/.01601*B = .0052 ft3/sec

dVtot = .3046 ft3/sec

Equivalent gpm = (7.48*60*_.3046 ft3) = 136.7 gpm

PCS tempeature 60_ Vf @ 310 psia = .01602 Vf'@ 70 & 310 psia = .01603
Pzr temp 61_ Vf @ 310 psia = _____ Vf'@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3046*C =
9.3249 psi/sec

dVpcs = .00001/.01602*A = .0031 ft3/sec

dVpzr = .00001/.01602*B = .0052 ft3/sec

dVtot = .3046 ft3/sec

Equivalent gpm = (7.48*60*_.3046 ft3) = 136.7 gpm

PCS tempeature 70_ Vf @ 310 psia = .01603 Vf'@ 80 & 310 psia = .01606
Pzr temp 70 Vf @ ___psia = _____ Vf'@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3211*C =
10.0409 psi/sec

dVpcs = .00003/.01603*A = .0092 ft3/sec

dVpzr = .00003/.01603*B = .0156 ft3/sec

dVtot = .3211 ft3/sec

Equivalent gpm = (7.48*60*_.3211 ft3) = 144.1256 gpm

NOTES:

Constants on this page: A= 4.8933 B= 8.3539 C= 31.4939 K= 324,756
31.7177 327,063
31.9416 329,372

PCS tempeature 80° Vf @ 310 psia = .01606 Vf '@ 90° & 310 psia = .01608
Pzr temp 80° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00002/.01606*A = .0061 ft3/sec

dVpzr = .00002/.01606*B = .0104 ft3/sec

dVtot = .3128 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3128 *C =

9.8513 psi/sec

Equivalent gpm = (7.48*60* .3128 ft3) = 140.386 gpm

PCS tempeature 90° Vf @ 310 psia = .01608 Vf '@ 100° & 310 psia = .01611
Pzr temp 90° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00003/.01608*A = .0091 ft3/sec

dVpzr = .00003/.01608*B = .0156 ft3/sec

dVtot = .3210 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3210 *C =

10.1814 psi/sec

Equivalent gpm = (7.48*60* .3210 ft3) = 144.058 gpm

PCS tempeature 100° Vf @ 310 psia = .01611 Vf '@ 110° & 310 psia = .01615
Pzr temp 100° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00004/.01611*A = .0121 ft3/sec

dVpzr = .00004/.01611*B = .0207 ft3/sec

dVtot = .3291 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3291 *C =

10.5120 psi/sec

Equivalent gpm = (7.48*60* .3291 ft3) = 147.719 gpm

NOTES:

Constants on this page: A= 4.8933 B= 8.3539 C= 32.0995 K= 331,679
32.3891 333,987
32.1006 331,012

PCS tempeature 110° Vf @ 310 psia = .01615 Vf '@ 120° & 310 psia = .01619
Pzr temp 110° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00004/.01615*A = .0121 ft3/sec

dVpzr = .00004/.01615*B = .0207 ft3/sec

dVtot = .3291 ft3/sec

Equivalent gpm = (7.48*60* .3291 ft3) = 147.6959 gpm

RATE of Pzr Press rise=
dVtot*C = .3291 *C =
10.5856 psi/sec

PCS tempeature 120° Vf @ 310 psia = .01619 Vf '@ 130° & 310 psia = .01623
Pzr temp 120° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = ..2963ft3/sec

dVpcs = .00004/.01619*A = .0121 ft3/sec

dVpzr = .00004/.01619*B = .0206 ft3/sec

dVtot = .3290 ft3/sec

Equivalent gpm = (7.48*60* .3290 ft3) = 147.673 gpm

RATE of Pzr Press rise=
dVtot*C = .3290 *C =
10.656 psi/sec

PCS tempeature 130° Vf @ 310 psia = .01623 Vf '@___& 310 psia = .01628
Pzr temp 130° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00005/.01623*A = .0151 ft3/sec

dVpzr = .00005/.01623*B = .0257 ft3/sec

dVtot = .3371 ft3/sec

Equivalent gpm = (7.48*60* .3371 ft3) = 151.2905 gpm

RATE of Pzr Press rise=
dVtot*C = .3371 *C =
10.8211 psi/sec

NOTES:

Constants on this page: A= 4.8933 B= 8.3539 C= 31.8121 K= 328,037
31.5236 325,062
31.2350 322,086

PCS tempeature 140 Vf @ 310psia = .01628 Vf '@150&310psia = .01633
Pzr temp 140° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = NA gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00005/.01628*A = .0150ft3/sec

dVpzr = .00005/.01628*B = .0257ft3/sec

dVtot = .3370 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3370*C =
10.7207 psi/sec

Equivalent gpm = (7.48*60*.3370ft3) =151.2263 gpm

PCS tempeature 150° Vf @ 310psia = .01633 Vf '@160°&310psia = .01638
Pzr temp 150° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00005/.01633*A = .0150ft3/sec

dVpzr = .00005/.01633*B = .0256ft3/sec

dVtot = .3369 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3369*C =
10.6203 psi/sec

Equivalent gpm = (7.48*60*.3369 ft3) =151.191 gpm

PCS tempeature 160° Vf @ 310psia = .01638 Vf '@170°&310psia = .01644
Pzr temp 160° Vf @ ___psia = _____ Vf '@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00006/.01638*A = .0179 ft3/sec

dVpzr = .00006/.01638*B = .0306 ft3/sec

dVtot = .3448 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3448*C =
10.7698 psi/sec

Equivalent gpm = (7.48*60*.3448 ft3) =154.7462 gpm

NOTES:

Constants on this page: A= 9.7866 B= 8.3539 C= 30.9465 K= 319,111
30.6580 316,136
30.3695 313,161

PCS tempeature 170° Vf @ 310psia = .01644 Vf'@180°&310psia = .01649
Pzr temp 170° Vf @ ___psia = _____ Vf'@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

1) dVpcs = .00005/.01644*A = .0298 ft3/sec

dVpzr = .00005/.01644*B = .0254 ft3/sec

dVtot = .3515 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3515 *C =
10.8777 psi/sec

Equivalent gpm = (7.48*60* .3515 ft3) = 157.7564 gpm

PCS tempeature 180° Vf @ 310 psia = .01649 Vf'@190°&310psia = .01656
Pzr temp 180° Vf @ ___psia = _____ Vf'@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00007/.01649*A = .0415 ft3/sec

dVpzr = .00007/.01649*B = .0355 ft3/sec

dVtot = .3733 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3733 *C =
11.4569 psi/sec

Equivalent gpm = (7.48*60* .3733 ft3) = 167.5420 gpm

PCS tempeature 190° Vf @ 310 psia = .01656 Vf'@200&310psia = .01662
Pzr temp 190° Vf @ ___psia = _____ Vf'@___&___psia = _____

dVhpsi = N/A gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00006/.01656*A = .0355 ft3/sec

dVpzr = .00006/.01656*B = .0303 ft3/sec

dVtot = .3621 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .3621 *C =
10.9968 psi/sec

Equivalent gpm = (7.48*60* .3621 ft3) = 162.496 gpm

NOTES: 1) Increased PCS heating rate from 20°/hr to 40°/hr

Constants on this page: A= 9.7867 B= 8.3539 C= 30.0810 K= 310, 186
29.4131 303, 299

PCS tempeature 200° Vf @ 310 psia = .01662 Vf '@ 210° & 310 psia = .01669
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420° & 310 psia = .01893 1)

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00007/.01662*A = .0412 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4042 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .4042*C =
12.1587 psi/sec

Equivalent gpm = (7.48*60* .4042 ft3) = 181.4053 gpm

PCS tempeature 210° Vf @ 310 psia = .01669 Vf '@ 220° & 310 psia = .01676
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420° & 310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00007/.01669 *A = .0410 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4040 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .4040 *C =
11.8843 psi/sec

Equivalent gpm = (7.48*60* .4040 ft3) = 181.3361 gpm

PCS tempeature 220° Vf @ 310 psia = .01676 Vf '@ 230° & 310 psia = .01683
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420° & 310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00007/.01676*A = .0409 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4039 ft3/sec

RATE of Pzr Press rise=
dVtot*C = .4039 *C =
11.8792 psi/sec

Equivalent gpm = (7.48*60* .4039 ft3) = 181.2591 gpm

NOTES: 1) Pzr Temp assumed @ near saturation

Constants on this page: A= 9.7867 (14.68) B= 8.3539 C= 29.4131 K= 303.295

PCS tempeature 230° Vf @ 310 psia = .01683 Vf '@ 240° & 310 psia = .01691
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420° & 310 psia = .01853

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00008/.01691*A = .0463 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4093 ft3/sec

Equivalent gpm = (7.48*60*.4093 ft3) = 183.7836 gpm

RATE of Pzr Press rise= dVtot*C = .4093*C = 12.0417 psi/sec

PCS tempeature 240° Vf @ 310 psia = .01691 Vf '@ 250° & 310 psia = .01699
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420° & 310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00008/.01691*A = .0463 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4093 ft3/sec

Equivalent gpm = (7.48*60*.4093 ft3) = 183.6938 gpm

RATE of Pzr Press rise= dVtot*C = .4093*C = 12.0388 psi/sec

PCS tempeature 250° Vf @ 310 psia = .01699 Vf '@ 260° & 310 psia = .01707
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420° & 310 psia = .01853

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

1) dVpcs = .00008/.01699*A = .0691 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4321 ft3/sec

Equivalent gpm = (7.48*60*.4321 ft3) = 193.9265 gpm

RATE of Pzr Press rise= dVtot*C = .4321*C = 12.7094 psi/sec

NOTES:

1) Begin heating PCS @ 60°/hr; (A = 14.68)

Constants on [redacted] page: A= 14.68 B= 8.3539 C= 29.4131 K= 303.299

PCS tempeature 260° Vf @ 310 psia = .01707 Vf '@ 270 & 310 psia = .01716
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420 & 310 psia = .01893

dVhpsi = 1,220gpm/7.48/60 = 2.7184ft3/sec 1)

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01707*A = .0774 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1588 ft3/sec

Equivalent gpm = (7.48*60* 3.1588 ft3) = 1417.69 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1588 *C =
92.91 psi/sec

PCS tempeature 270° Vf @ 310 psia = .01716 Vf '@ 280° & 310 psia = .01725
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420 & 310 psia = .01893

dVhpsi = 1,220gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01716*A = .0770 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1584 ft3/sec

Equivalent gpm = (7.48*60* 3.1584 ft3) = 1,417.4868 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1584*C =
92.8981 psi/sec

PCS tempeature 280° Vf @ 310 psia = .01725 Vf '@ 290° & 310 psia = .01734
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@ 420 & 310 psia = .01893

dVhpsi = 1,220gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01725*A = .0766 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1580 ft3/sec

Equivalent gpm = (7.48*60* 3.1580 ft3) = 1,417.3065 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1580 *C =
92.8863 psi/sec

NOTES: 1) Both HPSI pumps operable: See page 20 for rates of Pzr Press increase w/o HPSI from 260° to 350°

Constants on this page: A= 14.68 B= 8.3539 C= 29.4131 K= 303,299
23.5188 292,519

PCS tempeature 290° Vf @ 310psia = .01734 Vf'@300&310 psia = .01743
Pzr temp 410° Vf @ 310psia = .01878 Vf'@420&310psia = .01853

dVhpsi = 1,220 gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01734*A = .0762 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1576 ft3/sec

Equivalent gpm = (7.48*60* 3.1576 ft3) = 1,417.1281 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1576*C =
92.8746 psi/sec

PCS tempeature 300° Vf @310 psia = .01743 Vf'@310°&310 psia = .01753
Pzr temp 410° Vf @ 310 psia = .01878 Vf'@420&310psia = .01853

dVhpsi = 1,220 gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00010/.01743*A = .0842 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1656 ft3/sec

Equivalent gpm = (7.48*60* 3.1656 ft3) = 1,420.7314 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1656*C = 1)
93.110 psi/sec

PCS tempeature 310° Vf @ 310 psia = .01753 Vf'@320°&310psia = .01764
Pzr temp 410° Vf @ 310 psia = .01878 Vf'@420&310 psia = .01893

dVhpsi = 1,220 gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01753*A = .0921 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1735 ft3/sec

Equivalent gpm = (7.48*60* 3.1735 ft3) = 1,424.2741 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1735*C =
79.6374 psi/sec

NOTES: 1) C revised as K changed from 303,299 to 292,519

Constants on this page: A= 14.68 B= 8.3539 C= 23.5188 K= 242.519

PCS tempeature 320° Vf @ 310 psia = .01764 Vf' @ 330° & 310 psia = .01775
Pzr temp 410° Vf @ 310 psia = .01878 Vf' @ 420° & 310 psia = .01893

dVhpsi = 1,220 gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01764*A = .0915 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1729 ft3/sec

Equivalent gpm = (7.48*60*3.1729 ft3) = 1,424.0163 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1729*C =
74.6238 psi/sec

PCS tempeature 330° Vf @ 310 psia = .01775 Vf' @ 340° & 310 psia = .01786
Pzr temp 410° Vf @ 310 psia = .01878 Vf' @ 420° & 310 psia = .01853

dVhpsi = 1,220 gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01775*A = .0910 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1724 ft3/sec

Equivalent gpm = (7.48*60*3.1724 ft3) = 1,423.7617 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1724*C =
74.6105 psi/sec

PCS tempeature 340° Vf @ 310 psia = .01786 Vf' @ 350° & 310 psia = .01797
Pzr temp 410° Vf @ 310 psia = .01878 Vf' @ 420° & 310 psia = .01853

dVhpsi = 1,220 gpm/7.48/60 = 2.7184 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01786*A = .0904 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = 3.1718 ft3/sec

Equivalent gpm = (7.48*60*3.1718 ft3) = 1,423.5103 gpm

RATE of Pzr Press rise=
dVtot*C = 3.1718 *C =
74.5973 psi/sec

NOTES:

Constants on this page: A= 24.4667 B= 8.3539 C= 23.5188 K= 242.519 1)

PCS tempeature 350° Vf @ 700 psia = .01794 Vf'@ 360 & 700 psia = .01806
Pzr temp 490° Vf @ 700 psia = .02020 Vf'@ 500 & 700 psia = .02043

2) dVhpsi = 950 gpm/7.48/60 = 2.1168 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

1) dVpcs = .00012/.01794*A = .1637 ft3/sec

1) dVpzr = .00023/.02020*B = .0951 ft3/sec

dVtot = 2.6719 ft3/sec

RATE of Pzr Press rise= dVtot*C = 2.6719*C = 62.8404 psi/sec

Equivalent gpm = (7.48*60* 2.6719 ft3) = 1,199.1571 gpm

PCS tempeature 360° Vf @ 900 psia = .01804 Vf'@ 370 & 900 psia = .01816
Pzr temp 520° Vf @ 900 psia = .02089 Vf'@ 530 & 900 psia = .02117

dVhpsi = 780 gpm/7.48/60 = 1.738 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00012/.01804*A = .1627 ft3/sec

dVpzr = .00028/.02089*B = .1120 ft3/sec

dVtot = 2.3090 ft3/sec

RATE of Pzr Press rise= dVtot*C = 2.3090*C = 54.3043 psi/sec

Equivalent gpm = (7.48*60* 2.3090 ft3) = 1,036.2666 gpm

PCS tempeature 370° Vf @ 1,100 psia = .01814 Vf'@ 380 & 1,100 psia = .01827
Pzr temp 540° Vf @ 1,100 psia = .02141 Vf'@ 550 & 1,100 psia = .02173

dVhpsi = 550 gpm/7.48/60 = 1.2255 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00013/.01814*A = .1753 ft3/sec

dVpzr = .00032/.02141*B = .1249 ft3/sec

dVtot = 1.822 ft3/sec

RATE of Pzr Press rise= dVtot*C = 1.822*C = 42.8513 psi/sec

Equivalent gpm = (7.48*60* 1.822 ft3) = 817.7136 gpm

NOTES: 1) Begin heating PCS @ 100°/hr, and increase Pzr Press from 310 psia to 700 psia

2) HPSI must be operable at this temp. & above.

Constants on this page: A= 24.4667 B= 8.3539 C= 23.5188 K= 242,519
17.0722 176,043

PCS tempeature 380° Vf @ 1,200psia = .01826 Vf '@390°&1,200psia = .01839
Pzr temp 550° Vf @ 1,200psia = .02170 Vf '@560°&1,200psia = .02205

dVhpsi = 350 gpm/7.48/60 = .7799 ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00013/.01826*A = .1742 ft3/sec

dVpzr = .00035/.02170*B = .1347 ft3/sec

dVtot = 1.3851 ft3/sec

Equivalent gpm = (7.48*60* 1.3851 ft3) = 621.6510 gpm

RATE of Pzr Press rise=
dVtot*C = 1.3851*C =
32.5769 psi/sec

PCS tempeature 390° Vf @ 1,400psia = .01837 Vf '@400°&1,400psia = .01850
Pzr temp 570° Vf @ 1,400psia = .02234 Vf '@580&1400psia = .02275

1) dVhpsi = 0 gpm/7.48/60 = ——— ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00013/.01837*A = .1731 ft3/sec

dVpzr = .00041/.02234*B = .1533 ft3/sec

dVtot = .6227 ft3/sec

Equivalent gpm = (7.48*60* .6227 ft3) = 279.4753 gpm

RATE of Pzr Press rise=
dVtot*C = .6227*C =
14.6456 psi/sec

PCS tempeature 400° Vf @ 1,500psia = .01849 Vf '@410°&1,500psia = .01863
Pzr temp 580° Vf @ 1,500psia = .02270 Vf '@590°&1,500psia = .02315

dVhpsi = 0 gpm/7.48/60 = ——— ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00014/.01849*A = .1853 ft3/sec

dVpzr = .00045/.02270*B = .1656 ft3/sec

dVtot = .6472 ft3/sec

Equivalent gpm = (7.48*60* .6472 ft3) = 290.466 gpm

RATE of Pzr Press ~~rise~~= 2)
dVtot*C = .6472*C =
11.0492 psi/sec

NOTES: 1) Pzr Press > HPSI Shutoff head ... no further contribution from HPSI

2) C revised as K changed from 242,519 to 176,043

Constants on this page: A= 24.4667 B= 8.3539 C= 17.0722 K= 176,043

PCS tempeature 410° Vf @ 1,500psia = .01863 Vf '@420°& 1,500psia = .01878
Pzr temp 580° Vf @ 1,500psia = .02270 Vf '@590°&1,500psia = .02315

dVhpsi = 0 gpm/7.48/60 = —— ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00015/.01863*A = .1970 ft3/sec

dVpzr = .00045/.02270*B = .1656 ft3/sec

dVtot = .6589 ft3/sec

Equivalent gpm = (7.48*60* .6589 ft3) = 295.7117 gpm

RATE of Pzr Press rise=
dVtot*C = .6589 *C =
11.2487 psi/sec

PCS tempeature 420° Vf @1,600psia = .01877 Vf '@430°&1,600psia = .01892
Pzr temp 590° Vf @ 1,600psia = .02309 Vf '@600°&1600psia = .02359

dVhpsi = 0 gpm/7.48/60 = —— ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00015/.01877*A = .1955ft3/sec

dVpzr = .00050/.02309*B = .1809 ft3/sec

dVtot = .6727ft3/sec

Equivalent gpm = (7.48*60* .6727 ft3) = 301.9189 gpm

RATE of Pzr Press rise=
dVtot*C = .6727*C =
11.4849 psi/sec

PCS tempeature 430° Vf @1,800psia = .01890 Vf '@440°&1800psia = .01905
Pzr temp 610° Vf @ 1,800psia = .02400 Vf '@620°&1800 psia = .02465

dVhpsi = 0 gpm/7.48/60 = —— ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00015/.01890*A = .1942ft3/sec

dVpzr = .00065/.02400*B = .2263 ft3/sec

dVtot = .7168 ft3/sec

Equivalent gpm = (7.48*60* .7168 ft3) = 321.6908 gpm

RATE of Pzr Press rise=
dVtot*C = .7168 *C =
12.2370 psi/sec

NOTES:

Constants on this page: A=24.4667 B=8.3539 C=17.0772 K=176.043

PCS tempeature 440° Vf @ 1800psia = .01905 Vf'@450°&1800psia = .01922
Pzr temp 610° Vf @ 1800psia = .02400 Vf'@620°&1800psia = .02465

dVhpsi = 0 gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00017/.01905*A = .2183 ft3/sec

dVpzr = .00065/.02400*B = .2263 ft3/sec

dVtot = .7409 ft3/sec

Equivalent gpm = (7.48*60*.7409 ft3) = 332.5533 gpm

RATE of Pzr Press rise=
dVtot*C = .7409*C =
12.6494 psi/sec

PCS tempeature 450° Vf @ 1800psia = .01922 Vf'@460°&1800psia = .01939
Pzr temp 610° Vf @ 1800psia = .02400 Vf'@620°&1800psia = .02465

dVhpsi = 0 gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00017/.01922*A = .2164 ft3/sec

dVpzr = .00065/.02400*B = .2263 ft3/sec

dVtot = .7390 ft3/sec

Equivalent gpm = (7.48*60*.7390 ft3) = 331.6663 gpm

RATE of Pzr Press rise=
dVtot*C = .7390*C =
12.6165 psi/sec

PCS tempeature ___ Vf @ ___psia = _____ Vf'@___&___psia = _____
Pzr temp ___ Vf @ ___psia = _____ Vf'@___&___psia = _____

dVhpsi = ____gpm/7.48/60 = ______ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .000__/.01___*A = ______ft3/sec

dVpzr = .000__/.0____*B = ______ft3/sec

dVtot = ______ft3/sec

Equivalent gpm = (7.48*60*_______ft3) = _____gpm

RATE of Pzr Press rise=
dVtot*C = ______*C =
______psi/sec

NOTES:

Constants on this page: A= 14.68 B= 8.3539 C= 29.4131 K= 303,299

FOLLOWING APPLICABLE WITH NO HPSI PUMPS OPERABLE 1)

PCS tempeature 260° Vf @ 310 psia = .01707 Vf '@270°&310 psia = .01716
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420°& 310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01707*A = .0774 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4404 ft3/sec

Equivalent gpm = (7.48*60* .4404 ft3) = 197.6515 gpm

RATE of Pzr Press rise= dVtot*C = .4404 *C = 12.9535 psi/sec

PCS tempeature 270° Vf @ 310 psia = .01716 Vf '@ 280°&310 psia = .01725
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420°&310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01716*A = .0770 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4400 ft3/sec

Equivalent gpm = (7.48*60* .4400 ft3) = 197.472 gpm

RATE of Pzr Press rise= dVtot*C = .4400*C = 12.9418 psi/sec

PCS tempeature 280° Vf @310 psia = .01725 Vf '@290°& 310 psia = .01734
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420°&310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01725*A = .0766 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4396 ft3/sec

Equivalent gpm = (7.48*60* .4396 ft3) = 197.2725 gpm

RATE of Pzr Press rise= dVtot*C = .4396 *C = 12.93 psi/sec

NOTES: 1) See page 13 for rates of Pzr Press Increase w/HPSI

Constants on this page: A= 14.68 B= 8.3539 C= ~~29.4131~~ 23.5788 K= ~~303,299~~ 242,519

PCS tempeature 290° Vf @ 310 psia = .01734 Vf '@300&310 psia = .01743
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420°&310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00009/.01734*A = .0762 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4392 ft3/sec

Equivalent gpm = (7.48*60* .4392 ft3) = 197.113 gpm

RATE of Pzr Press rise=
dVtot*C = .4392*C =
12.9182 psi/sec

PCS tempeature 300° Vf @ 310 psia = .01743 Vf '@310°&310 psia = .01753
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420°&310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00010/.01743*A = .0842 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4472 ft3/sec

Equivalent gpm = (7.48*60* .4472 ft3) = 200.7034 gpm

RATE of Pzr Press rise=
dVtot*C = .4472*C =
13.1535 psi/sec

PCS tempeature 310° Vf @ 310 psia = .01753 Vf '@320°&310 psia = .01764
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420°&310 psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01753*A = .0921 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4551 ft3/sec

Equivalent gpm = (7.48*60* .4551 ft3) = 204.2489 gpm

RATE of Pzr Press rise= 1)
dVtot*C = .4551*C =
10.7034 psi/sec

NOTES: 1) C revised as K changed from 303,299 to 242,519

Constants on this page: A= 14.68 B= 8.3539 C= 23.5188 K= 242.519

PCS tempeature 320° Vf @ 310 psia = .01764 Vf '@330&310psia = .01775
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420&310psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01764*A = .0915 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4545 ft3/sec

RATE of Pzr Press rise= dVtot*C = .4545*C = 10.6893 psi/sec

Equivalent gpm = (7.48*60* .4545 ft3) = 203.9796 gpm

PCS tempeature 330° Vf @ 310 psia = .01775 Vf '@340&310psia = .01786
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420&310psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01775*A = .0910 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4540 ft3/sec

RATE of Pzr Press rise= dVtot*C = .4540*C = 10.6775 psi/sec

Equivalent gpm = (7.48*60* .4540 ft3) = 203.7552 gpm

PCS tempeature 340° Vf @ 310 psia = .01786 Vf '@350&310psia = .01797 1)
Pzr temp 410° Vf @ 310 psia = .01878 Vf '@420&310psia = .01893

dVhpsi = N/A gpm/7.48/60 = ______ ft3/sec

dVchg = 133gpm/7.48/60 = .2963ft3/sec

dVpcs = .00011/.01786*A = .0904 ft3/sec

dVpzr = .00015/.01878*B = .0667 ft3/sec

dVtot = .4534 ft3/sec

RATE of Pzr Press rise= dVtot*C = .4534*C = 10.6634 psi/sec

Equivalent gpm = (7.48*60* .4534 ft3) = 203.4859 gpm

NOTES:
1) From 350° and above, HPSI pumps are operable

Conclusions:

Pressurizer pressure rate of change is defined for the assumptions taken.

References:

1) FLUID MECHANICS, Daugherty and Franzini, 7th edition, c. 1977

2) ANF-88-107, Palisades LOCA-ECCS Analysis for 2530 Mwt Operation with Increased Radial Peaking and 29.3% Steam Generator Tube Plugging

3) Palisades Plant Functional Description M10, Primary Coolant System, rev 1

4) Palisades Plant Technical Specifications Change Request, 1989, affecting HPSI Operability Requirements, and PCS Heating and Cooling Rates

5) ASME Steam Tables, 4th edition, c. 1979

6) Letter to DJVandeWalle, CPCo, from WDMeinert, CE, 1 Jan 79, P-CE-4538; Attachment 1, HPI SYSTEM DELIVERY - ONE HPI PUMP THROUGH FOUR HPI VALVES

Consumers Power
POWERING MICHIGAN'S PROGRESS

PALISADES NUCLEAR PLANT
ENGINEERING ANALYSIS WORK SHEET

Title PRESSURE RESPONSE EFFECTS OF VLTOP WITH REPLACEMENT PORVs.

INITIATION AND REVIEW

Rev #	Description	Initiated By	Initiated Date	Initiator Appd By	Review Method Check (✓) Alt Calc	Det Rvw	Qual Test	Technically Reviewed By	Date	Reviewer Appd By
0	Original Issue									

CALCULATE THE BULK MODULUS OF ELASTICITY FOR WATER AT 10°F INTERVALS FROM 50°F TO 200°F, AND AT 50°C INTERVALS FROM 200°F TO 450°F.

FOR TEMPERATURES FROM 50°F TO 200°F, values are interpolated from table 1.1 of reference 1. For TEMPERATURES FROM 200°F TO 450°F, values are calculated from data in table C.2 of reference 5.

Table 1.1 has values for 32°, 68°, 120°, and 200°, so interpolation is necessary for 10° incremental values. Also, table 1.1 has values for 15psia, and 1500psia, so another interpolation is required for 310psia. The two interpolated values must in turn be interpolated to arrive at value for temperature and pressure of interest.

310psia represents .1987 of the range from 15psia to 1500psia
$(310-15)/(1500-15) = .1987$

FINAL INTERPOLATED VALUES ARE DERIVED FROM TABLE 1.1 AS FOLLOWS:

a) INTERPOLATE FOR DESIRED TEMP @ 15psia
b) " " " " @ 1500psia
c) " " 310psia @ Desired Temp.

PCS TEMP	K@ 32°/15psi	K@ 68°/15psi	K@ */15psi	K@ 32°/1500	K@ 68°/1500	K@ */1500	K@ */310 psia	Reference Comments
*								Rev 1
50	292,000	320,000	306,000	300,000	330,000	315,000	307,788	
60	292,000	320,000	313,778	300,000	330,000	323,333	315,675	
	68°/15psi	120°/15psi		68°/1500	120°/1500			
70	320,000	332,000	320,462	330,000	342,000	330,462	322,449	
80	320,000	332,000	322,769	↓	↓	332,769	324,756	
90	↓	↓	325,077			335,077	327,064	
100			327,385			337,385	329,372	
110			329,692			339,692	331,679	
120			332,000			342,000	333,987	
	120°/15psi	200°/15psi		120°/1500	200°/1500			
130	332,000	308,000	329,000	342,000	319,000	339,125	331,012	
140	↓	↓	326,000	↓	↓	336,250	328,037	
150			323,000			333,375	325,062	
160			320,000			330,500	322,086	
170			317,000			327,625	319,111	
180			314,000			324,750	316,136	
190			311,000			321,875	313,161	
200			308,000			319,000	310,186	

CALCULATING K from ref 5 table C.2 data, K =

$P_1 - P_2 / ((V_1 - V_2)/V_1)$ * (1 atmosphere in psia)

where P_1 and P_2 are in atmospheres, and V_1 and V_2 are specific volumes of water at the respective pressures.

From reference 5, conversion factor from bar to psi = 14.5037738

@ 100°C, K = (25 − 225)/((1.04245 − 1.03248)/1.04245)*14.5037738
= −303,299

@ 150°C, K = −200/((1.08938 − 1.07635)/1.08938)*14.5037738 = 242,519

@ 200°C, K = −200/((1.15551 − 1.13647)/1.15551)*14.5037738 = 176,043

@ 250°C, K = −200/((1.24941 − 1.21751)/1.24941)*14.5037738 = 113,612

ENGINEERING ANALYSIS

Title: Pressure Response Effects of VLTOP with Replacement PORVs
Part II - PORV FLOW versus TIME for NEW PORVs (Target Rock)

Objective:

Determine the water flow after reaching full stroke position for the new PORVs, as input to calculate pressurizer pressure overshoot during LTOP actuation.

Analysis Input:

a) PORV Cv = 219 at full stroke (ref 1)

b) PORV main disc slew (stroke) time = 0.20 seconds (ref 5)

c) PORV solenoid and pilot chamber reaction time = 1.68 seconds (ref 5)

d) Instrument channel reaction time = .2 seconds (ref 3)

e) PORV full stroke effective area = 5.7732 square inches (ref 2)

f) PORV lift and effective area versus time from reference 5.

g) PORV flow = Cv*Sqrt dP

Assumptions:

a) Available dP = Pressurizer pressure - Quench Tank pressure

b) Quench Tank pressure = 100 psig (90 psig RuD setting +10 psi margin)

c) PORV stroke time will lessen with increasing subcooling; ie, longest response time(1.68 seconds) with associated stroke time (0.20 seconds) from the computer model will envelope times with lower pressurizer temperatures. That is, time for full valve stroke will be less with sufficient subcooling of the fluid in the PORV control chamber.

Calculations:

Begin of page following

PORV FLOW versus TIME

(From Reference 5)

1) Graph Time	2) Lift mils	3) Effect. Area	4) Effect. Area /F.S.Eft Ar.	5) Cv (219*4)	6) Sqrt dP @310 s.p	7) Sqrt dP @700 s.p	8) Sqrt dP @900 s.p

9) Adjusted Time	10) Total Time	Flow = Cv*Sqrt dP ----> = 5) * 6) = 5) * 7) = 5) * 8)	11) Flow @ 310 sp	12) Flow @ 700 sp	13) Flow @ 900 sp

N/A

1) Graph Time	2) Lift mils	3) Effect. Area	4) Effect. Area /F.S.Eft Ar.	5) Cv (219*4)	6) Sqrt dP @310 s.p	7) Sqrt dP @700 s.p	8) Sqrt dP @900 s.p

9) Adjusted Time	10) Total Time	Flow = Cv*Sqrt dP ----> = 5) * 6) = 5) * 7) = 5) * 8)	11) Flow @ 310 sp	12) Flow @ 700 sp	13) Flow @ 900 sp

1) Graph Time	2) Lift mils	3) Effect. Area	4) Effect. Area /F.S.Eft Ar.	5) Cv (219*4)	6) Sqrt dP @310 s.p	7) Sqrt dP @700 s.p	8) Sqrt dP @900 s.p

9) Adjusted Time	10) Total Time	Flow = Cv*Sqrt dP ----> = 5) * 6) = 5) * 7) = 5) * 8)	11) Flow @ 310 sp	12) Flow @ 700 sp	13) Flow @ 900 sp

1) Graph Time	2) Lift mils	3) Effect. Area	4) Effect. Area /F.S.Eft Ar.	5) Cv (219*4)	6) Sqrt dP @310 s.p	7) Sqrt dP @700 s.p	8) Sqrt dP @900 s.p
N/A	1,000	5.7732	1.0	219	13.96		

9) Adjusted Time	10) Total Time	Flow = Cv*Sqrt dP ----> = 5) * 6) = 5) * 7) = 5) * 8)	11) Flow @ 310 sp	12) Flow @ 700 sp	13) Flow @ 900 sp
1,880	2,080		3,057 GPM		

40

PORV FLOW versus TIME

RESULTS

TIME msec	STROKE mils	EFFECTIVE AREA (interp sq in)	Cv (from Area)	VdP Pzr @ 310	flow (gpm)	VdP Pzr @ 700	flow (gpm)	VdP Pzr @ 900	flow gpm
2,080	1,000	5.7732	219	13.96	3,057	<----not evaluated---->			

(ONLY FULL VALVE STROKE CONSIDERED IN THIS REVISION)

Conclusions:

The expected PORV flow versus dP identified above is conservatively calculated due to the assumptions made.

References:

1) Target Rock Test Data, Fascimile Transmitted 11 July 1989, 1345

2) Target Rock Test Data, Fascimile Transmitted 26 July 1989, 1453

3) Combustion Engineering Proposal for Variable Set Point LTOP, Proposal #88-240-AIA, Section II.4, page 6

4) Palisades Instrument Index, M-311, sheet 01-31

5) Letter, L. E. Demick, MPR Asc. Inc, to J. L. Topper, CPCo, 12 September 1989, #98-108-07, COMPUTED STROKE TIMES forPALISADES REPLACEMENT

6) Letter, L. E. Demick, MPR Asc. Inc, to J. L. Topper, CPCo, 18 September 1989, #98-108-09, VALIDATION of DYNAMIC MODELING APPROACH and PROGRAM for the REPLACEMENT PORVs at PALISADES NUCLEAR POWER PLANT.

MPR ASSOCIATES, INC.

September 12, 1989
98-108-07

Mr. James L. Topper
Consumers Power Company
1945 West Parnall Road
Jackson, MI 49201

Subject: Computed Stroke TImes for Palisades Replacement Power Operated Relief Valves

Reference: GWO 8304, File -011, -317.0

Dear Mr. Topper:

In accordance with our telephone conversation of September 12, 1989 and my subsequent discussion with Mr. Ashworth of CPCo, we have computed the expected opening stroke times for the Palisades replacement Target Rock Power Operated Relief Valves (PORV) for several LTOP set points assuming saturation conditions in the pressurizer. These computations included the effects of the RCS pressure ramp rates that have been calculated by CPCo personnel at these LTOP set points. The following summarizes the results of the computations and identifies the conditions analyzed.

Pressure Set Point (psia)	Pressurizer Temp (°F)	Ramp Rate (psi/sec)	Coil Energize Time (sec)	Depressurize Time (sec)	Slew Time (sec)	Total Time (sec)
330.0	426.1	93.0	0.23	1.45	0.20	1.88
500.0	467.1	93.0	0.26	1.41	0.16	1.83
1000.0	544.6	63.0	0.32	0.97	0.10	1.39

These analyses assume no subcooling in the fluid at the LTOP set point and, therefore, represent an upper limit on the temperature conditions of the pressurizer when the setpoint pressure is reached. We consider this assumption to be very conservative yet the analyses indicate that the valve will open within 2 seconds. As indicated in prior analyses any subcooling of the fluid will reduce the total valve response time.

This information will be included in the final report. If you have any questions or require further information please give me a call.

Sincerely,

L. E. Demick

1050 CONNECTICUT AVENUE, N.W. WASHINGTON, D.C. 20036 202-659-2320

MPR ASSOCIATES, INC.

September 18, 1989
98-108-09

Mr. James L. Topper
Consumers Power Company
1945 West Parnall Road
Jackson, MI 49201

Subject: Validation of Dynamic Modeling Approach and Program for the Replacement Power Operated Relief Valves at Palisades Nuclear Power Plant

Reference: GWO 8304, File -011, -317.0

In accordance with our telephone conversation of September 18, 1989, the purpose of this letter is to confirm our confidence in the accuracy and validity of the computer program and the approach, which have been used to calculate the opening and closing times for the replacement PORV's to be installed in Palisades this fall. This confidence is based in part on the results of calculations of the stroke times of similar valves in tests performed by EPRI at Wyle facilities in Norco, California. These calculations, reported in a letter to CPCo dated September 15, 1989 (98-108-08), showed good correlation with the test data. Variations between the calculated and test data were also generally in the conservative direction, e.g., calculated opening times for the water tests were generally slower than the test data.

We have also calculated the response of the Palisades replacement valves over a wide range of fluid conditions and consider the variations to be consistent with expectations for this valve design, e.g., more rapid response for steam conditions than for sub-cooled water and more delayed response for saturated water conditions. These data were reported to CPCo in letters dated September 7, 1989 (98-108-06) and September 12, 1989 (98-108-07).

We intend to include complete documentation of the validation basis for the computer program and the valve models in our final report on the replacement valve stroke time analyses. In the meantime if you have any questions concerning these matters or require further information, please give me a call.

Sincerely,

L. E. Demick

ENGINEERING ANALYSIS

Title: Pressure Response Effects of VLTOP with Replacement PORVs
Part III - Recommended LTOP Set Points for Variable LTOP Protection

Objective:

Determine the LTOP set points to preclude exceeding Appx. G Limits, considering :

- Permissable heating/cooling rates
- Signal processing time
- PORV response time
- Instrument inaccuracies, calibration errors, and drift
- Potential Quench Tank backpressure

Analysis Inputs:

a) Pressurizer temperature rate of change is 200 degrees F/hr

b) Primary Coolant System temperature rate of change is:
20 deg/hr when < 170 degrees F
40 deg/hr when 170 to 250 degrees F
60 deg/hr when 250 to 350 degrees F
100 deg/hr when 350 degrees F and greater

c) Appendix G limits from EA-A-PAL-89-98

d) Instrument inaccuracies, calibration errors, and drift are less than 5 degrees and 30 psi (reference 5)

e) Volume change, equivalent gpm, Bulk Modulus of Elasticity, and pressure increase rates from Part I of this analysis

f) Time for PORV flow to equal equivalent gpm from Part II of this analysis

g) Appendix G Limit Equations from reference 4

Assumptions:

a) Signal Processing Delay is 200 milliseconds (reference 3)

b) PORV response time is 1680 milliseconds (reference 6)

c) PORV full stroke opening time is 200 milliseconds (reference 6)

d) PORV Cv at partial stroke is proportional to effective area

e) Quench Tank pressure will not exceed 100 psig

HPSI pumps are inoperable when shutdown cooling is onstream

g) HPSI pumps are inoperable when PCS is < 260 deg F

Calculations:

Equation 1, Heating Limited

Plim = (17.206x(26.78+(1.233xExp(.0145x(T-86-dT1/4)))))-84

Equation 2, Cooling Limited

Plim = (17.206x(26.78+(1.233xExp(.0145x(T-86+dT1/4)))))-(5.85xdTmax)-84

Where Plim = Recommended set point in PSIG before allowance for over-shoot,
T = PCS temperature, degrees F

dT1/4 for	Heating	Cooling	dTmax for Cooling
20deg/hr	6.3	4.4	10.1
40deg/hr	12.4	9.0	20.5
60deg/hr	18.2	13.9	31.8
100deg/hr	30.0	23.6	54.0

<---from Part I------------------------> <Part II>(7x8) PSIG PSIA

1 PCS Temp degF	2 Htg/Clg Rate deg/hr	3 Pumps Oper-able	4 dV/sec Cu.ft	5 Equiv gpm	6 K	7 Rate of Press Increas psi/sec	8 Time for PORV flo =Equival gpm in sec's	9 Press O'sht psi	10 Appx G Limit -Temp& Press Errors	11 Max Perm Set Pnt
50	20	3 Chg.	.3046	137	309,[illegible]	9.0918	2.1	19	331	326
60			.3046	137	315,675	9.3249		20	333	327
70			.3211	144	322,4[illegible]	10.0409		21	336	329
80			.3128	140	324,7[illegible]	9.8513		21	338	331
90			.3210	144	327,063	10.1814		21	342	335
100			.3291	148	329,372	10.5120		22	345	337
110			.3291	148	331,679	10.5856		22	350	342
120	↓	↓	.3290	148	333,987	10.656	↓	22	355	347

<---from Part I						--->	<Part II>	(7x8)		
1	2	3	4	5	6	7	8	9	10	11
PCS Temp degF	Htg/Clg Rate deg/hr	Pumps Oper-able	dV/sec Cu.ft	Equiv gpm	K	Rate of Press Increas psi/sec	Time for PORV flo =Equival gpm in sec's	Press O'sht psi	Appx G Limit -Temp& Press Errors	Max Perm Set Pnt
130	20	3Chg	.3371	151	331,012	10.8211	2.1	23	361	352
140			.3370	151	328,037	10.7207		23	367	358
150			.3369	151	325,062	10.6203		22	375	367
160			.3448	155	322,086	10.7698		23	384	375
170	40		.3515	158	319,111	10.8777		23	339	330
180			.3737	168	316,136	11.4569		24	351	341
190			.3621	162	313,161	10.9968		23	366	357
200			.4042	181	310,186	12.1587		26	383	371
210			.4040	181	303,299	11.8843		25	403	392
220			.4039	181		11.8792		25	426	415
230			.4093	184		12.0447		25	452	441
240			.4093	184		12.0388		25	482	471
250	60		.4321	194		12.7094		27	471	458
260		3Chg	.4404	198		12.9535		27	514	501
260		+2HPSI	3.1588	1,418		92.91		195	514	333
270		3Chg	.4400	197		12.9418		27	565	552
270		+2HPSI	3.1584	1,417		92.8981		195	565	384
280		3 Chg	.4396	197		12.93		27	623	610
280		+2HPSI	3.1580	1,417		92.8863		195	623	442
290		3 Chg	.4392	197		12.9182		27	691	678
290		+2HPSI	3.1576	1,417		92.8746		195	691	510
300		3 Chg	.4472	201		13.1535		28	740	726
300		+2HPSI	3.1656	1,421		93.110		196	740	558
310		3 Chg	.4551	204	242,5[illegible]	10.7034		22	796	788
310		+2HPSI	3.1735	1,424		74.6374		157	796	653
320		3 Chg	.4545	204		10.6893		22	862	894
320		+2HPSI	3.1729	1,424		74.6238		157	862	719
330		3Chg	.4540	204		10.6775		22	937	929
330		+2HPSI	3.1724	1,424		74.6105		157	937	794
340		3 Chg	.4534	203		10.6634		22	1,025	1,017
340		+2HPSI	3.1718	1,424		74.5973		157	1,025	882
350	100	3Chg+2HPSI	2.6719	1,199		62.8404		132	1,008	890
360			2.309	1,036		54.3043		114	1,107	1,007
370			1.822	818		42.8513		90	1,220	1,144
380			1.3851	622		32.5769		68	1,352	1,298
390			.6227	279		14.6456		31	1,504	1,487
400			.6472	290	176,043	11.0492		23	1,680	1,671
410			.6589	296		11.2487		24	1,884	1,874
420			.6727	302		11.4849		24	2,119	2,109
430			.7168	322		12.2370		26	2,390	2,378
440			.7409	333		12.6494		27	2,704	2,691
450			.7390	332		12.6165		27	3,068	3,055

440

Conclusions:

Attachment 1 graphs the results of these calculations, and illustrates values (Actual Set Point) which will envelope these calculated values.

References:

1) Target Rock Test Data, Fascimile Transmitted 11 July 1989, 1345

2) Target Rock Test Data, Fascimile Transmitted 26 July 1989, 1453

3) Combustion Engineering Proposal for Variable Set Point LTOP, Proposal #88-240-AIA, Section II.4, page 6

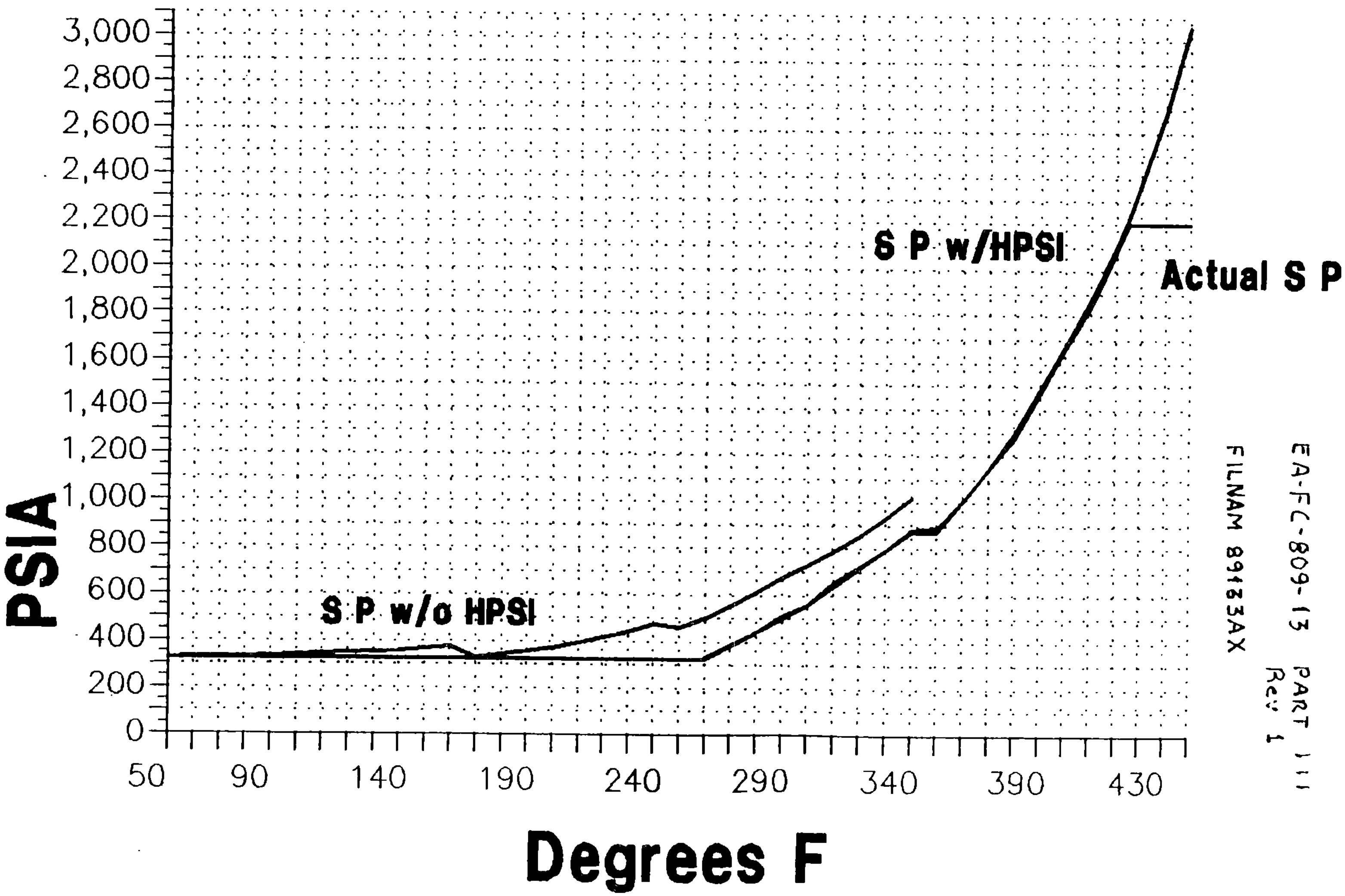
4) EA-A-PAL-89-98, Palisades Pressure and Temperature Limits

5) EA-FC-809-19, LTOP Temperature and Pressure Loop Errors

6) Letter, L. E. Demick, MPR Asc. Inc, to J.L. Topper, CPCo, 12 September 1989, #98-108-07, COMPUTED STROKE TIMES for PALISADES REPLACEMENT PORVs

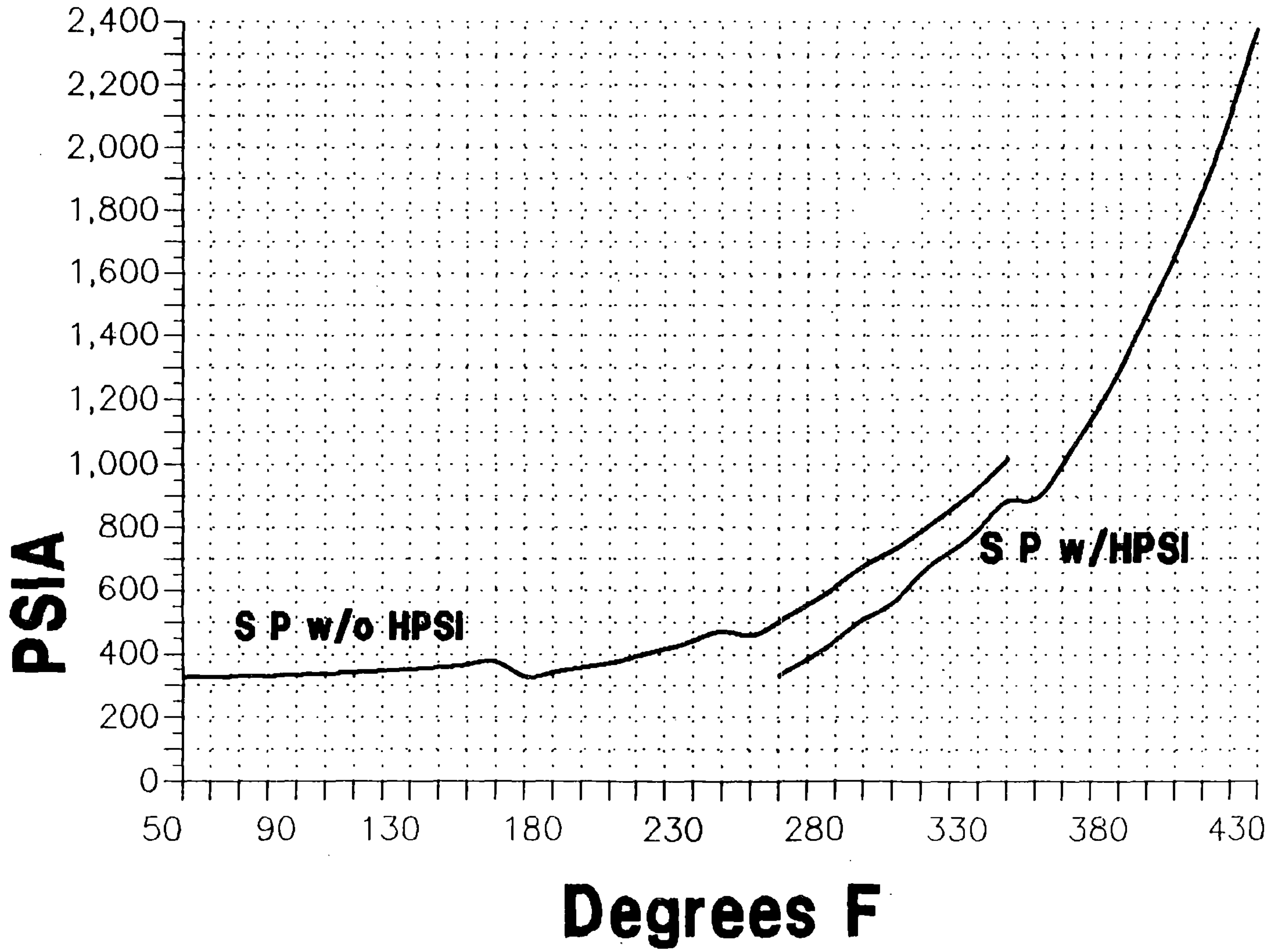
7) Letter, L. E. Demick, MPR Asc. Inc, to J.L. Topper, CPCo, 18 September 1989, #98-108-09, VALIDATION of DYNAMIC MODELING APPROACH and PROGRAM for the REPLACEMENT PORVs at PALISADES NUCLEAR POWER PLANT

LTOP SETPOINTS



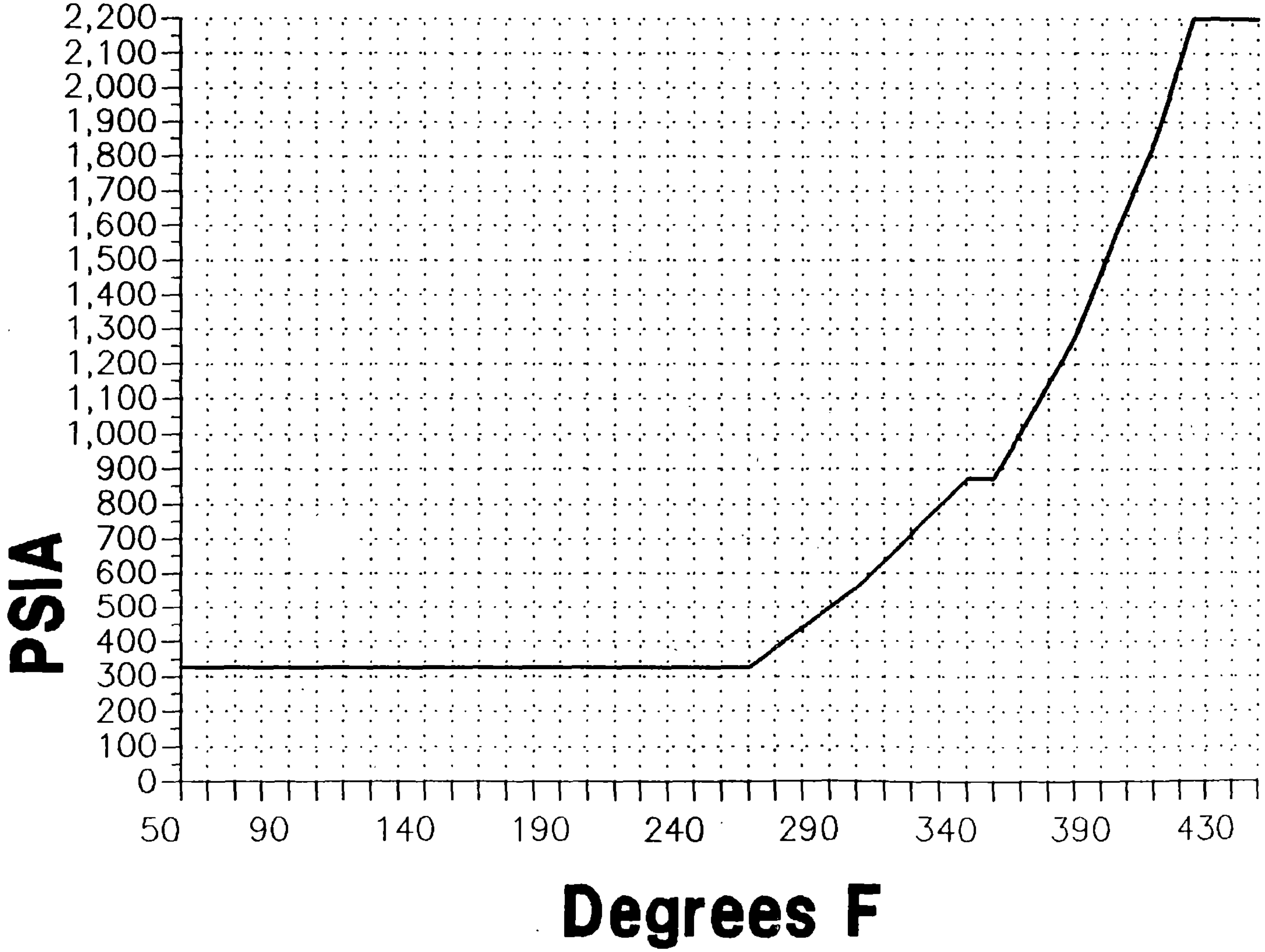
EA-FC-809-13 PART III
Rev 1
FILNAM 8913AX

LTOP SETPOINTS



EA-FC-809-13 Part III
FILNAM 89133Br1 Rev 1

ACTUAL LTOP SET POINTS w/SDC ISOLATED



EA-FC-809-13 Part III
FILNAM 8913Cr1 Rev 1

ENGINEERING ANALYSIS

Title: Pressure Response Effects of VLTOP with Replacement PORVs

Part IV - Limiting Pressures versus Temperatures for Tech Specs

Objective:

Calculate the pressure at which PORVs must be actuated as a function of PCS temperature to prevent exceeding the applicable Appendix G limit.

Analysis Inputs:

1) Pressure overshoot during LTOP actuation, from Part III of this analysis

2) Appendix G limits from reference 1

Assumptions:

1) PCS heating and cooling rates will be limited to -

20deg/hr at PCS temperatures $\leq$ 170 deg F
40deg/hr at PCS temperatures from 170 to 250 deg F
60deg/hr at PCS temperatures from 250 to 350 deg F
100deg/hr at PCS temperatures of 350 F and greater

2) Pressurizer heating and cooling rates will be 200deg/hr for all PCS temperatures

Calculations:

The following equations define the Appx G limit, as corrected for elevation difference between the limiting RPV weld and the pressurizer, and for the dP created by operation of the Primary Coolant Pumps.

a) Heating Limited -

Plim = (17.206x(26.78+(1.233xEXP(.0145x(T-81-dT1/4)))))-54

b) Cooling Limited -

Plim =

$(17.206\times(26.78+(1.233\times Exp(.0145\times(T-81+dT1/4)))))-(5.85\times dTmax)-54$

Where T = PCS temperature, and

	@20deg/hr	40deg/hr	60deg/hr	100deg/hr
dT1/4 for heating =	6.3	12.4	18.2	30.0
dT1/4 for cooling =	4.4	9.0	13.9	23.6
dTmax for cooling =	10.1	20.5	31.8	54

The above equations indicate that cooling is more limiting than heating for temperatures at or below 285 deg F; ie, calculated values from 280 to 290 deg for 60deg/hr rate of change are as follows:

	Heating	Cooling
280	698.6	685.6
281	702.9	692.4
282	707.2	699.2
283	711.6	706.2
284	716.07	713.3
285	720.5932	720.5719
286	725.1	727.8
287	729.8	735.2
288	734.5	742.7
289	739.3	750.4
290	744.1	758.1

Therefore, limiting values will be calculated with the heating equation from 290 degrees and greater, and with the cooling equation from 280 degrees and less.

		equ. b	equ. a	from Part III				
1	2	3	4	5		6		7
PCS Temp degF	Rate of Chng	Limit cooling psiG	Limit heating psiG	Overshoot w/o HPSI psi	w/HPSI psi	LTOP T.S. Limit w/o HPSI psiA	w/HPSI psiA	Comments
50	20°/hr	362	419	19		357		Overshoot based on initial Pzr Press of 310 psia
60		364	421	20		358		
70		367		21		360		
80		370		21		363		
90		373		21		366		

0 1 PCS Temp degF	2 Rate of Chng	equ. b 3 Limit cooling psiG	equ. a 4 Limit heating psiG	from Part III 5 Overshoot w/o HPSI psi	w/HPSI psi	6 LTOP T.S. Limit w/o HPSI psiA	w/HPSI psiA	7 Comments
100	20°/hr	377		22		369		
110	↓	382		22		374		
120		387		22		379		
130		394		23		385		
140		401	452	23		392		
150		409	459	22		401		
160		419	468	23		410		
170	40°/hr	375	471	23		366		
180		388		24		378		
190		404		23		395		
200		423		26		411		
210		444		25		433		
220		468		25		457		
230		497		25		486		
240		529	585	25		518		
250	60°/hr	522	596	27		509		
260		569			195		388	
270		623			195		442	
280		686	699		195		505	
290		758	744		195		563	
300			797		196		615	
310			858		157		715	Change in value of K
320			928		157		785	
330			1,009		157		866	
340		1,330	1,103		157		960	
350	100°/hr	1,567	1,085		132		967	Initial Press assumed 700 psia
360		1,798	1,191		114		1,091	" " " 900 "
370			1,314		90		1,238	" " " 1,100 "
380			1,455		68		1,401	" " " 1,200 "
390			1,619		31		1,602	1,400 "
400			1,808		23		1,799	Change K; Press to 1500 psia
410			2,027		24		2,017	
420			2,280		24		2,270	Press to 1600 psia
427			2,480		25		2,469	
428			2,510		25		2,499	
429			2,541		26		2,529	CODE SAFETIES PROTECT
430		4,800	2,572		26		2,560	Press to 1800 psia

NOTE:

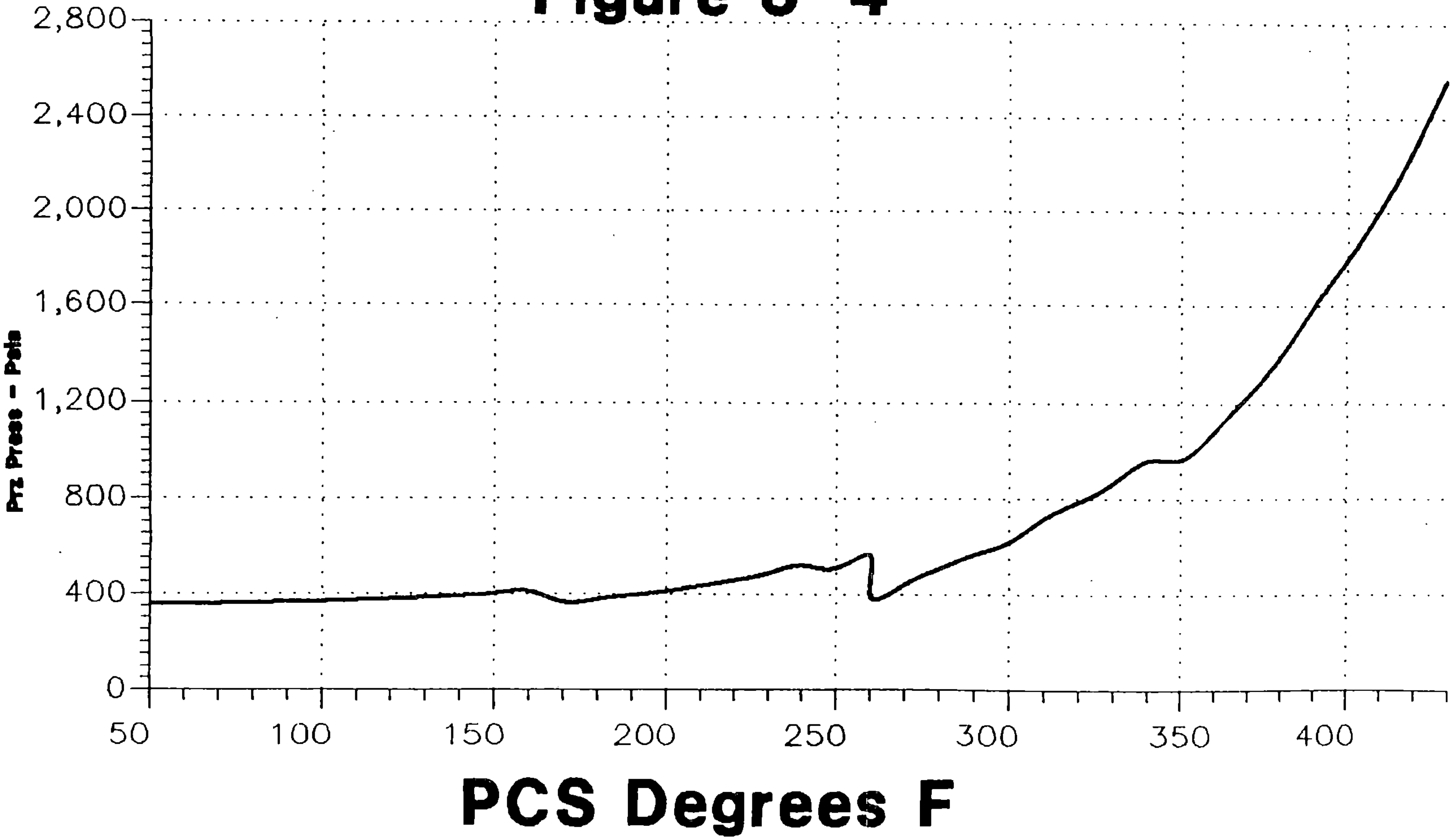
3/4 t values are not limiting for the rates of change of interest, being higher in every instance, for the rates of temperature change assumed, and for the RPV fluence through 1.8E19 nvt.

References:

1) PCS Pressure Temperature limits, August 89 revision, EA-A-PAL-89-98

LTOP LIMIT CURVE

Figure 3-4



3-25c

Ammend. No.

EA-FC-809-13
Part IV Rev 1
FILNAM 89134Cr1