ENCLOSURE 3

WCAP-15690, Revision 00, "CE-NSSS LTOP Energy Addition Transient Analysis Methodology," May 2001

(Non-Proprietary)

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WCAP-15690, Rev 00

CE-NSSS LTOP Energy Addition Transient Analysis Methodology

CEOG Task 1174

May 2001

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1.0 INTRODUCTION

This document describes methods used for analysis of a pressure transient in a water-solid Reactor Coolant System (RCS) due to energy addition. The transient occurs when one reactor coolant pump (RCP) is started while the steam generator secondary inventories are at a higher temperature than the reactor coolant. Analysis of this transient using these methods supports evaluation of Low Temperature Overpressure Protection (LTOP) systems in the Combustion Engineering (C-E) designed Nuclear Steam Supply Systems (NSSSs). The LTOP system is used to protect the RCS pressure-temperature (P-T) limits from being exceeded by an overpressure event during heatup, cooldown, and shutdown operations.

The models and methodology described here are implemented in a utility computer program called OVERP which is used to find the pressure response of the water-solid system [ ]

Figure 1 is a flow diagram of the pressure transient calculation. First, the initial conditions and geometric parameters for the system are determined in a conservative way to provide input to the analytical calculation with OVERP. The code models [

]

The models are described in Section 2.0. The analysis methodology is described in Section 3.0. References are given in Section 4.0. The nomenclature used in the equations is described in Appendix A. Input and output for the OVERP computer code are described in Appendices B and C. Input and output for sample problems are provided in Appendix D.

2.0 MODEL

The model for the LTOP energy addition overpressurization event is based on [

]. It includes sufficient detail to model the pressure behavior of the RCS throughout the entire event including the time of peak pressure. [

] The resulting model is used to create a utility computer code OVERP that is used to calculate the system pressure for an LTOP energy addition transient.

2.1 Initial Conditions

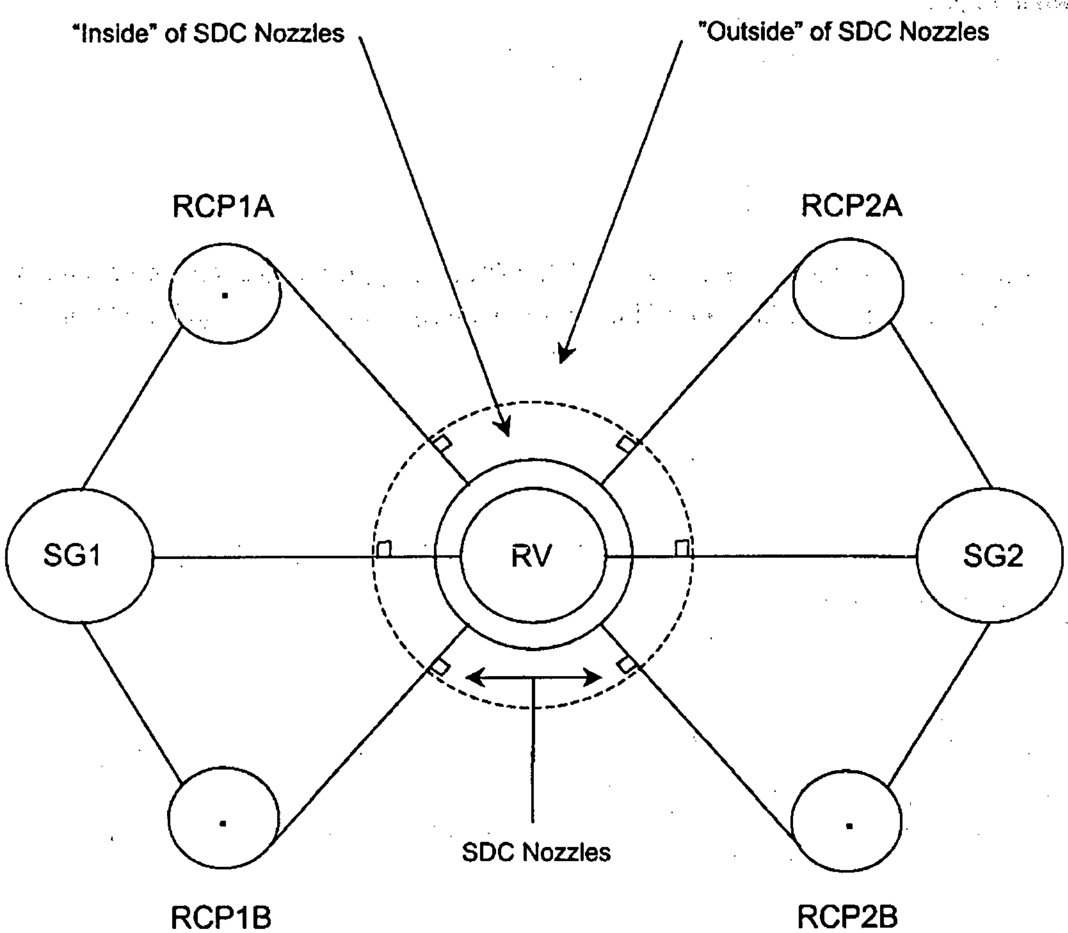
At the start of an energy addition LTOP transient, the RCS has been cooled down using the shutdown cooling (SDC) system. In this process, the reactor coolant exits the RCS through the SDC nozzles in the hot legs by means of the low pressure safety injection (LPSI) pumps, passes through the SDC heat exchangers, returns to the RCS through the safety injection/SDC nozzles in the cold legs, and circulates through the reactor vessel to the hot legs. This produces regions with two different states in the RCS:

1. The reactor coolant that is circulating through the SDC system including the reactor vessel (RV), the discharge cold legs from the safety injection/SDC nozzles to the RV, and the hot legs from the RV to the SDC nozzles (This part of the RCS is described as "inside" of the SDC system nozzles.) and
2. The reactor coolant that is not circulating including the remainder of the hot legs, and discharge cold legs, suction cold legs, the pressurizer and surge line, the RCPs, and the primary side of the steam generators (SG). (This part of the RCS is described as "outside" of the SDC system nozzles).

Figure 2 depicts this subdivision of the RCS at the start of the transient. The portion of the system "inside" of the SDC system nozzles is cooled by the SDC system to a temperature that is taken to be the initial coolant temperature for the transient. The portion of the RCS "outside" of the SDC system nozzles remains stagnant so its temperature is the same as that of the SG secondary side inventory. [

]

FIGURE 2



"Inside" of SDC Nozzles
"Outside" of SDC Nozzles
RCP1A
RCP2A
SG1
RV
SG2
SDC Nozzles
RCP1B
RCP2B

2.2 Nodalization

A [ ] is used to model the conservation equations and equations of state as shown in Figure 3. [

]

Properties at each of the above nodes are determined by appropriate energy balances. RCS pressure is computed as a function of total system energy content and specific volume. [

]

Figures 3 and 4 show the paths that the RCS coolant takes in the primary system when [ ]. These are:

[

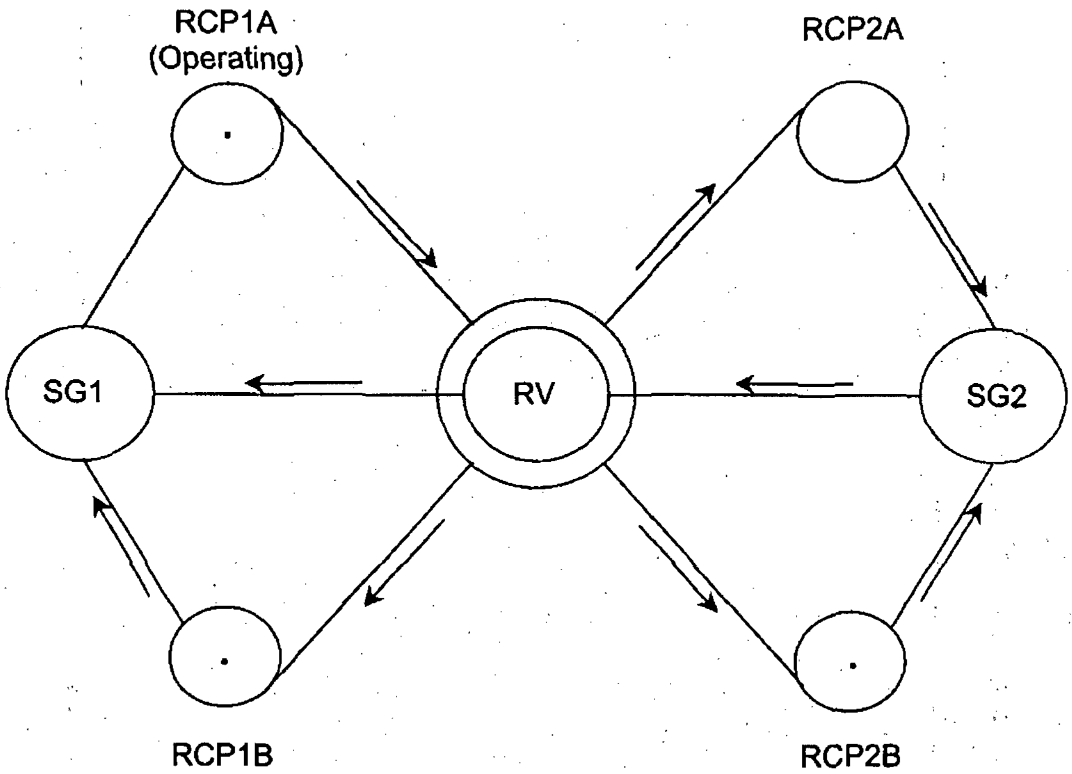
]

FIGURE 3

MODEL NODES FOR RCP START TRANSIENT

FIGURE 4

FLOW DIRECTION



2.3 Basis for OVERP Models

The LTOP model for the pressure behavior of a water-solid RCS due [ ] by consideration of the state of the system at the time the LTOP transient occurs. Several characteristics of the model features are presented below. These include [ ]

Finally, the basis for determining the state of each node is described.

Model Features

The analysis methodology includes [ ]

[

]

Basis for Determining the State of Each Node

The following statements define the basis for representing the state of each node. [

]

2.4 Derivation of Equations

Shown in Figure 1 is a flow diagram of the pressure transient calculation. The input for the OVERP code is determined as discussed in Section 3.0. This includes [

]

The transient is initiated by [

] Reference should be made to the calculational flow chart of Figure 1, depiction of the initial state of the RCS in Figure 2, the nodal diagram of Figure 3, and the flow directions in Figure 4. Time dependent variables are indicated by the subscripts "i", "i+1", and "i-1". Initial conditions are indicated by a zero subscript designation. Appendix A defines the nomenclature used in the equations.

2.4.1 SG1 NODE

As shown below, [ ] causes a volume element of primary coolant from the reactor vessel upper plenum region to displace a fluid element in SG1. The entering volume element instantaneously mixes with the primary coolant contained in the SG1 tubes. The resulting mixed fluid specific volume and temperature are found as follows:

AVERAGE SPECIFIC VOLUME, v_i^{P1}:

AVERAGE TEMPERATURE, T_{lmix}^{P1}:

[

]

[

] The iteration scheme is presented as follows:

STEAM GENERATOR HEAT TRANSFER ITERATION

[

[

2.4.2 REACTOR VESSEL ANNULUS NODE

[

]

2.4.3 REACTOR VESSEL CORE NODE

[

]

2.4.4 SG2 NODE

[

]

AVERAGE SPECIFIC VOLUME, v_i^{P2}:

AVERAGE TEMPERATURE, T_{lmix}^{P2} :

[

]

SG2 HEAT TRANSFER ITERATION

[

]

UPDATED SG2 PRIMARY SPECIFIC VOLUME, v_i^{P2}:

[

]

2.4.5 REACTOR VESSEL UPPER PLENUM NODE

[

]

2.4.6 RCS ENTHALPY CHANGE DURING TIME INCREMENT

[

]

2.4.7 RCS PRESSURE UPDATE

[

]

2.4.8 RELIEF VALVE DISCHARGES

[

]

[

]

[

]

2.4.9 SUMMARY OF EQUATIONS

[

]

[

]

3.0 METHODOLOGY

The computer code OVERP is used to analyze the energy addition overpressure event under water-solid conditions. The input parameters and code output are described in Appendices B and C respectively. A general discussion of considerations in selecting design inputs is given in Section 3.1. The OVERP input preparation process including adjustments for conservatism, etc. is described in Section 3.2. The analysis procedure is summarized in Section 3.3.

3.1 General Considerations for Selecting Design Inputs

3.1.1 RCS Location for Pressure

The code represents transient primary pressure [

]

3.1.2 Passive Heat Sources and Sinks

Steam generator [

]

[

]

3.1.3 Active Heat Sources

The following active energy inputs to the [

]

3.1.4 Relief Valve Discharge Model

The equations used by OVERP to calculate the discharge rate from [

]

[

]

3.1.5 Single Failure

[
]

3.1.6 Fluid Mixing in SG Tubes

The model used in the OVERP Code models the [

]

3.2 OVERP Input Preparation

In addition to title information that is used to describe the case, there are [

] This discussion provides the basis for selecting the inputs and indicates how some inputs affect the final results.

[

]

[

]

[

]

[

]

[

]

[

]

[

]

[

]

3.3 Analysis Procedure

The LTOP energy addition analysis is [

]

4.0 REFERENCES

1. 1967 ASME Steam Tables, The American Society of Mechanical Engineers, N. Y. (1967).

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APPENDIX A

NOMENCLATURE

The following nomenclature applies to the equations derived in Section 2.0 and use of the resulting equations in the subsequent discussion. Also listed for each item is the FORTRAN variable name used in the code OVERP.

Note: Symbol subscripts and superscripts were chosen from the following considerations:

1. <u>Superscripts</u> indicate a time variant parameter; the particular time increment is indicated for these variables by <u>subscripts</u> such as "i", "i-1" and "i+1". Initial conditions are indicated by a zero subscript designation.
2. Parameters which remain constant throughout the calculation use only subscript designations.

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APPENDIX B

OVERP INPUT DESCRIPTION

The input for the OVERP computer code is described below. It is organized as 13 records of input structured per the requirements of the FORTRAN formats used in the OVERP coding. The description of the contents in each record include:

1. The Record number and the FORTRAN FORMAT specification for the record
   a) 80A1 means 80 alpha-numeric characters
   b) I5 means a right adjusted integer entered in a field 5 characters wide
   c) F10.0 means a real number entered in a field 10 columns wide with the decimal point assumed to be in the right-most column unless an explicit decimal point is entered
2. The Item number for each variable on the Record (except for Records 1-5)
3. The FORTRAN variable name used in the code
4. The columns used to enter each variable in the record
5. A summary description for each input variable including the units
6. A more detailed description of the variable

APPENDIX C

OVERP OUTPUT DESCRIPTION

The output from the OVERP utility code consists of three parts: a card image listing of the input, a listing of each input variable with a brief description, and a listing of the output from the transient.

The initial input listing includes a header indicating the input card/record number, a label for each column in the input record and the code name with the version identification. The input is in card image format with the card/record number at the beginning of each line of input.

The second portion of the input starts with the same header used for the card image listing of the input. This is followed by the case title information (normally four lines followed by a blank line) centered on the output page. Labels are provided for a brief description of each input variable name, the value, and the units in three columns. For each of the 38 variables described in Appendix B, the variable description, value, and units are listed.

The third part of the output lists the transient results. The first three lines give titles for each column including units. The following output items are listed:

FORTRAN Name	Description	Units
LINENO	Line number in output table	--
TIME	Elapsed time during transient (including TIMEI) (Initial time TIMEI for first edit)	Seconds
PRCS	RCS pressure	psia
HRCS	RCS enthalpy	Btu/lbm
TPC(1)	Primary coolant temperature in SG1	°F
TSC(1)	Secondary coolant temperature in SG1	°F
TPC(2)	Primary coolant temperature in SG2	°F
TSC(2)	Secondary coolant temperature in SG2	°F
QPSUM(1)	Heat transferred from secondary to primary by SG1	Btu
QPSUM(2)	Heat transferred from secondary to primary by SG2	Btu
QVSUM	Integrated energy loss through relief valve	Btu
MRCSZ	Total inventory (Mass) in RCS	lbm

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APPENDIX D

SAMPLE PROBLEMS FOR TYPICAL ANALYSIS

OVERP input and output for two sample problems are provided here. The first sample problem has a PORV for pressure relief. The second problem has a SDC system safety relief valve (SRV) for pressure relief. A description of the input for the OVERP utility code is given in Appendix B. A summary of the output from OVERP is given in Appendix C.

D.1 Sample Problem with PORV

The input file for this case is listed in Table D.1-1. The output from OVERP for the PORV sample problem is shown in Table D.1-2.

Table D.1-1

Input for Sample Problem with PORV

Table D.1-2

Output for Sample Problem with PORV

D.2 Sample Problem with SRV

The input file for this case is listed in Table D.2-1. The output from OVERP for the SRV sample problem is shown in Table D.2-2.

Table D.2-1

Input for Sample Problem with SRV

Table D.2-2

Output for Sample Problem with SRV

WCAP-15690, Rev. 0

Westinghouse Electric Company, LLC
P.O. Box 355
Pittsburgh, PA 15230-0355

ENCLOSURE 4

Letter from A. Meeden (APS) to J. Olszewski (Westinghouse), "APS Palo Verde Units 1, 2 and 3 PTLR Plant Data Request," Letter No. 448-00708, dated October 17, 2007

A subsidiary of Pinnacle West Capital Corporation

Palo Verde Nuclear
Generating Station

Mr. Alfred Meeden
NSSS Mechanical
Design Section
Leader (Acting)

Tel: (623) 393-6582
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Mail Station 7543
PO Box 52034
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Mr. James S. Olszewski
Customer Projects Manager
Westinghouse Electric Company
Nuclear Services
4350 Northern Pike Road
Monroeville, PA 15146

Letter No. 448-00708
Date: October 17, 2007

Subject: **APS Palo Verde Units 1, 2, and 3 PTLR Plant Data Request**

Reference: 1. Westinghouse Letter Number CVER-07-70, dated 10/09/07

2. Westinghouse Letter Number LTR-NEM-07-483, Rev. 01, dated 06/13/07

Attachments: APS, Palo Verde Quality Assured Plant Datasheet

Dear Mr. Olszewski:

In response to your Reference 1 letter request for plant data to support the Pressure-Temperature Limits Report (PTLR), the attached signed datasheet is provided for your use and information. This information has been reviewed and found appropriate for preparation of a Palo Verde PTLR in accordance with Westinghouse's Proposal Letter, Reference 2.

Should you have any questions or require additional information, please contact me (623-393-6582) or Eugene Montgomery (623-393-6930).

Sincerely,

Sushil K Daftuar
SUSHIL K. DAFTUAR
for Alfred Meeden
NSSS Section Leader (Acting)
Mechanical Design Engineering

Kielty, Sherry A (Z87336)

Digitally signed by Kielty, Sherry A (Z87336)
DN: cn=Kielty, Sherry A(Z87336)
Reason: Verified as a true copy of original
Date: 2008.01.31 09:30:37 -07'00'

Attachment 1 – APS, Palo Verde Quality Assured Plant Datasheet

Please review the datasheets below, markup and/or comment, and provide a signed data transmittal letter back to Westinghouse that clearly indicates the information has been verified in accordance with the applicable APS Palo Verde Quality Assurance Program and is appropriate for use in preparation of a plant specific PTLR. (Attach additional comment sheets as necessary.) **Return signed datasheets to Westinghouse via Fax: (860) 683-6129, or Email PDF file to: paul.b.kramarchyk@us.westinghouse.com**

Item	Plant Reference Document List	Date, Revision No., Amendment No., and/or other unique identifier
1.	Updated Final Safety Analysis Report Unit 1, Unit 2, and Unit 3	Revision 14 - List A June 2007
2.	Technical Specifications Unit 1, Unit 2, and Unit 3	Unit 1 Operating License - through Amendment No. 168 Unit 2 Operating License - through Amendment No. 168 Unit 3 Operating License - through Amendment No. 168 Implementation: August 21, 2007
3.	13-N001-6.02-650-2, "PV Units 1,2,3 RCS P-T Limits at 8 & 32 EFPY" (See Ref. 2 above, this document is Ref. 5 within Westinghouse Proposal Letter, LTR-NEM-07-483, Rev. 01)	Revision 2, March 7, 1997 Latest version in SWMS reflects all changes made by APS. Calculation inputs/references are to be revised for instrument uncertainty as listed in items 10 and 11 below.
4.	CN-PS-03-42, "Evaluation of Impact of RSGs and Power Uprate on LTOP" (See Ref. 2 above, this document is Ref. 6 within Westinghouse Proposal Letter, LTR-NEM-07-483, Rev. 01)	Revision 0, December 12, 2003 Latest version in SWMS reflects calculation changes made by APS in item #3. Calculation inputs/references are to be revised for instrument uncertainty as listed in items 10 and 11 below.
5.	Technical Specification BASES PVNGS Units 1, 2, and 3	Revision 45, August 29, 2007
6.	Technical Requirements Manual PVNGS Units 1, 2, and 3	Revision 42, July 12, 2007

* Reclassified to non-proprietary with concurrence from Westinghouse. gaM 3/19/09
ARM 3/19/09

Attachment 1 — APS, Palo Verde Quality Assured Plant Datasheet

Item	Plant Reference Document List	Date, Revision No., Amendment No., and/or other unique identifier
7.	WCAP-16374-NP, "Analysis of Capsule 230 (degrees) from Arizona Public Service Company Palo Verde Unit 1 Reactor Vessel Radiation Surveillance Program"	Revision 0, February 2005
	WCAP-16524-NP, "Analysis of Capsule 230 (degrees) from Arizona Public Service Company Palo Verde Unit 2 Reactor Vessel Radiation Surveillance Program"	Revision 0, February 2006
	WCAP-16449-NP, "Analysis of Capsule 230 (degrees) from Arizona Public Service Company Palo Verde Unit 3 Reactor Vessel Radiation Surveillance Program"	Revision 0, August 2005

Attachment 1 — APS, Palo Verde Quality Assured Plant Datasheet

Item	Plant Reference Document List	Date, Revision No., Amendment No., and/or other unique identifier
8.	C E Report TP-V-MCM-004, "Program for Arizona Public Service Company Palo Verde Station Unit 1 Irradiation Surveillance of Reactor Vessel Materials"	Revision 1, July 31, 1981
	C E Report TP-V-MCM-005, "Program for Arizona Public Service Company Palo Verde Station Units 2 & 3 Irradiation Surveillance of Reactor Vessel Materials"	Revision 0, September 27, 1982
	C E Report TR-V-MCM-002, "Summary Report on Manufacture of Test Specimens and Assembly of Capsules for Irradiation Surveillance of Palo Verde Unit 1 Reactor Vessel Materials"	Revision 0, July 14, 1982
	ABB C E Report TR-V-MCM-010, "Summary Report on Manufacture of Test Specimens and Assembly of Capsules for Irradiation Surveillance of Palo Verde Unit 3 Reactor Vessel Materials"	Revision 0, November 5, 1992
	ABB C E Report TR-V-MCM-004, "Summary Report on Manufacture of Test Specimens and Assembly of Capsules for Irradiation Surveillance of Palo Verde Unit 2 Reactor Vessel Materials"	Revision 0, June 30, 1983

Attachment 1 — APS, Palo Verde Quality Assured Plant Datasheet

Item	Design Input Data Description	Nominal Value
9.	Material adjusted nil-ductility temperatures at 1/4 thickness and 3/4 thickness for 54 EFPY[1]	For 32 EFPY 116°F at 1/4 thickness 103°F at 3/4 thickness
10.	Instrument uncertainty pressure corrections:[1] 13-JC-SI-205 "Pressurizer Pressure (Restricted Range) Total Loop Uncertainty and Setpoints" 13-JC-RC-209 "Pressurizer Pressure Wide Range Instrument Uncertainty and Setpoint Calculation"	The values for pressurizer pressure instrument uncertainty (+/- 27.6 psi narrow range <750 psia and +/-70 psi wide range >750 psia respectively) from these calculations remain bounding. Revision 7, April 7, 2000 Revision 10, October 10, 2003
11.	Instrument uncertainty temperature corrections:[1] 13-JC-RC-202 "RCS Hot and Cold Leg Temperature Instrument Uncertainty Calculation" 13-JC-RC-203 RCS Cold Leg Temperature Instrument Setpoint and Uncertainty Calculation"	Use +13.2°F instead of +11° F over the complete temperature range as a bounding value. Revision 8 January 8, 2004 Revision 7 August 11, 2000
12.	Atmospheric pressure[1]	14.2 psia
13.	Highest flange region initial RT_{NDT}[1]	60°F
14.	Highest piping, pumps, valves initial RT_{NDT}[1]	40°F

Attachment 1 — APS, Palo Verde Quality Assured Plant Datasheet

Item	Design Input Data Description	Nominal Value
15.	Operating pressure[1]	2250 psia
16.	In-service hydrostatic test pressures[1]	625 psia and 2475 psia
17.	ASME Code criteria fracture toughness[1]	Year 2003 crack initiation toughness K_{IC}
18.	Flange P-T limits	From ASME Section XI Code Appendix G Criteria

Notes – Design Input Data Description:

(1) Reference for these data is APS Log No. 13-N001-6.02-650-2, "PV Units 1,2,3 RCS P-T Limits at 8 & 32 EFPY", 1989 CE calculation note 625192-MPS-5CALC-001 rev.00.

Attachment 1 – APS, Palo Verde Quality Assured Plant Datasheet

The signatures below indicate that the data above has been verified to be correct in accordance with the applicable APS Palo Verde Quality Assurance Program and is appropriate for use in preparation of a plant specific PTLR per Reference 1 and Reference 2.

Prepared By: Eugene F. Montgomery

Digitally signed by Eugene F. Montgomery
DN: cn=Eugene F. Montgomery, c=US, o=Design Engineering, ou=9711, email=eugene.montgomery@aps.com
Reason: I am the author of this document
Date: 2007.10.04 16:58:45 -07'00'

Print / Signature

Date: __________

Reviewed By: Ramakant Indap

Digitally signed by Ramakant Indap
DN: cn=Ramakant Indap, c=US, o=Inservice Inspection, ou=9737, email=Ramakant.Indap@aps.com
Reason: I have reviewed this document
Date: 2007.10.17 10:56:00 -07'00'

Print / Signature

Date: __________