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THE B&W **OWNERS GROUP**

Operator Support Committee

EMERGENCY OPERATING PROCEDURES TECHNICAL BASES DOCUMENT

Volume 3
Technical Bases

AmerGen Energy Company, LLC
Duke Energy Corporation
Entergy Operations, Inc.
FirstEnergy Nuclear Operating Company
Florida Power Corporation

74-1152414

FRAMATOME TECHNOLOGIES

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TECHNOLOGIES

TECHNICAL DOCUMENT

EMERGENCY OPERATING PROCEDURES
TECHNICAL BASES DOCUMENT

VOLUME 3

TECHNICAL BASES

74-1152414-09

Doc. ID - Serial No., Revision No.
for

The B&W Owners Group
Operator Support Committee

AmerGen Energy Company, LLC
Duke Energy Corporation
Entergy Operations, Inc.
FirstEnergy Nuclear Operating Company
Florida Power Corporation

BABCOCK & WILCOX
NUCLEAR POWER DIVISION

RECORD OF REVISION

NUMBER 74-1152414-01

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
01	III.C.2.3/4 III.C.3.3/6 III.C.3.3/9 IV.B.2.A.23/3	(PC 86-01) Guidance was added to prevent exceeding steam generator tube to shell compressive limits (tube hotter than shell).
01	IV.B.2.A.4/1 IV.B.2.A.4.1/1-3 IV.B.2.A.4.2/1-6 IV.B.2.B.4/1 IV.B.2.B.4.1/1-3 IV.B.2.B.4.2/1-6	(PC 86-02) Criteria for throttling HPI was clarified and emphasis was placed on not using pressurizer level as a requirement for throttling HPI. Titles for Sections IV.2.B.4.1 and IV.2.A.4.1 were revised to include PTS limit.
01	VI Entire Section	(PC 86-05) Reference list was upgraded to incorporate previously omitted references and include analyses that have been performed since initial issue of the TBD.
01	II.A.1.0/3	(PC 86-06) The philosophy concerning sequential use of backup equipment was not adequately discussed. The philosophy section was expanded to include the following philosophy: "The guidelines assume that any equipment can fail and that a multitudinous quantity of failures can occur. Therefore, the guidelines provide a defense in depth for both the components and the methods being used to mitigate the transients. That is if a component or method fails, the guidelines recommend a back up component or method. The list of backups should continue until all possible backups are identified. The recommended backups should be prioritized. such that the most effective equipment or methods is chosen first and the equipment or methods which can cause the most detrimental consequences are chosen last."
01	Figure III.B-1	Corrected typographical error.

BABCOCK & WILCOX
NUCLEAR POWER DIVISION

RECORD OF REVISION

NUMBER 74-1152414-01

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
01	III.A.1.1/2,3 III.A.1.2.1/2 III.A.2.1.1/1-3 III.A.2.2/1,2 III.A.2.2.5/1	(PC 86-07) Guidance was added on completing VSSV in conjunction with symptom identification and treatment.
01	II.B.3.2.3/1,2 III.B.1.2.B/1 III.D.1.1.1.A/1 III.D.2.2/1 III.D.3.2/1-7 III.G.3.7.3/1 IV.A.3.7/2,3	(PC 86-09) Guidance was added on expected SCM condition relative to overcooling occurrence.
01	III.E.1.1.2/5 III.E.2.5.10/1 III.E.3.3.1/4 III.E.3.3.1.1/1-3 III.E.3.3.1.4/1 III.E.3.3.3.2/3 III.E.3.4.1.2/2 III.E.3.4.3/1,2 III.E.3.6.1/1	(PC 86-10) Various changes were added to clarify the SGTR Chapter.
01	III.B.3.2.B/3 III.C.3.3.A.3/1 III.C.3.3.B.3/1 IV.B.2.A.2.3/3 IV.B.2.B.2.2/2	(PC 86-11) Guidance was added for failed open PORV during HPI cooling.
01	III.F.2.7/1 III.F.3.2/1	(PC 86-13) Guidance was added for operation of PORV during ICC.
01	III.G.3.3.1/3,4	(PC 86-14) Data was added to indicate the order of magnitude of cooldown times and required feedwater for NC cooldown.

Benton L Brooks — 4/20/88
Reviewed By — Date

[signature] — 4/20/88
Approved By — Date

RECORD OF REVISION

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
02	VI/References	(PC 87-10) Incorporated references which needed to be added for PC 86-9, 86-10, 86-14, 87-8, 87-9, 88-4, 87-3, 87-5, 88-5, 88-10, 89-06 and 89-11. Standardized reference format: Two authors and date of release from Document Control. Deleted unsatisfactory references.
02	III.D.1.1 IV.G	(PC 89-06 and PC 89-11) Guidance added for exiting PTS region and for determining which instrumentation to use with PTS limit. Also provided a new PTS limit for overcooling transients and emphasis on possible SG tube-to-shell delta T limit violations during an overcooling transient.
02	III.C.3.5 IV.E.2.3	(PC 87-3) Incorporates the results of OSC Task AS-4, Evaluation of Operator Actions to Reestablish Natural Circulation.
02	III.B.3.3 IV.C.4.4.3 V.B.9.0	(PC 87-08, PC 87-09 and PC 88-04) Modifies minimum AFW flowrates to reflect recent analyses and plant modifications (e.g. EFIC).

RECORD OF REVISION

NUMBER 74-1152414-02

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
02	III.C.2.2 III.C.2.3 III.C.3.2 III.C.3.3 III.G.2.2.7 III.G.3.9 III.G.3.9.1 III.G.3.9.2 III.G.3.9.3 III.G.3.9.4 III.G.3.9.5 IV.B.2.A.2.3 V.A.1.A.2 V.A.1.B.2	(PC 87-05 AND PC 88-10) Incorporates the results of OSC Task AS-5, HPI Cooling Analysis, covering RELAP5 analysis of HPI cooling with one or two pumps, high and low decay heat. Clarifies guidance on PORV operation during transition to HPI cooling. A third option, manual PORV cycling, is added. HPI/LPI Specific Rules were revised to eliminate PORV operation guidelines.
02	III.C.3.5 III.G.3.8.2 III.G.3.8.2.1 III.G.3.8.2.2 III.G.3.8.2.3 III.G.3.8.2.4 III.G.3.8.2.5 III.G.3.8.3 IV.A.3.1 IV.A.3.2 IV.A.3.4	(PC 88-05) Revise guidance on recognition and elimination of loop voids based on the analysis results of OSC Task AS-3, RCS Cooldown with Voids.
02	I/I.1	Introduction revised to incorporate the changes to the TBD for this revision.

Prepared by: B.A. Burki Date 5/15/90

Reviewed by: Glenn P. Moore Date 5/15/90

B&W NUCLEAR TECHNOLOGIES

BWNT-20005-3 (10/89)

NUMBER 74-1152414-03

RECORD OF REVISION

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
03	III.A Section 1.2	Incorporated PC-90-03 pertaining to guidance for a small break LOCA without HPI and a total loss of feedwater without HPI.
03	III.B Section 1.1 1.2 2.2 2.5 2.8 2.9 3.2 3.3 3.5 3.6	Incorporate PC-89-10 pertaining to guidance during a Station Blackout. Note: Revision 03 pages without revision bars have only different content from revision 02 pages due to text shift caused by text changes on preceding pages.
03	III.C Section 1.1 2.2 2.3 2.9 3.2 3.5	
03	New Chapter IV.H	
03	VI. Section 9.0	

Prepared by: [signature] Date 11-16-90

Reviewed by: [signature] Date 11/16/90

Reviewed by: [signature] Date 11/16/90

Approved by: [signature] Date 11/16/90

Released by: [signature] Date 11/20/90

BWNT-20005-3 (10/89)

B&W NUCLEAR TECHNOLOGIES

RECORD OF REVISION

NUMBER 74-1152414-04

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
04	Volume 1 Generic Emergency Operating Procedure (GEOG)	Original Issue

Prepared by: T. L. Book Jr. Date 12/7/90

Reviewed by: D. G. Newton Date 12-10-90

Reviewed by: B. L. Banks Date 12/10/90

Approved by: [illegible] Date 12/10/90

Approved by: [illegible] Date [illegible]

RECORD OF REVISION

NUMBER 74-1152414-05

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION

********* VOLUME 1 REVISIONS ********

05	II	(PC 89-05) Added DSS to list of Acronyms/Abbreviations.
05	III.A step 2.e	(PC 89-05) Added step to verify turbine trip and EFW actuation upon ATWS with loss of MFW.
05	III.A, III.B, III.F, RCP restart and SBLOCA/HPI Cooldown	(PC 90-08) Added the necessary details to incorporate guidance related to: a. Station Blackout b. SBLOCA w/out HPI c. LOFW w/out HPI

******** VOLUME 3 REVISIONS ********

05	List of Acronyms/Abbreviations	(PC 89-05) Added DSS.
05	III.A.1.2.1	(PC 89-05) Acknowledged the existence of Diverse Scram System (DSS).
05	III.A.2.2.1	(PC 89-05) Added reference to DSS and verification of actions if loss of main feedwater occurs during an ATWS.
05	III.A.3.1.A	(PC 89-05) Added reference to DSS.
05	III.B.2.8, III.B.2.9 and III.B.3.6	(PC 90-08) Added detail relative to cooldown rate when adequate SCM is lost and HPI is not available.
05	III.B.3.8	(PC 89-07) Deleted reference to Chapter III.E for saturated RCS DHRS operation.
05	III.E.2.6.1	(PC 89-07) Deleted second sentence of first paragraph.
05	III.E.2.6.2	(PC 89-05) Deleted saturated RCS DHRS operation. Added detail to maintain both LPI trains in the injection mode until SCM is restored.

BW B&W NUCLEAR TECHNOLOGIES

BWNT-20005-3 (10/89)

RECORD OF REVISION

NUMBER 74-1152414-05

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
05	IV.B.3.3	(PC 90-04) Deleted entire section (3.3, 3.3.1 and 3.3.2) from TBD (deferred to Severe Accident Management Technical Bases).
05	IV.B.4.1	(PC 89-07) Deleted entire section. Replace with detail to maintain both LPI trains in the injection mode until SCM is restored.
05	IV.E.2.2	(PC 89-07) Deleted reference to DHRS and replace with referenece to LPI system.
05	VI	(PC 89-05) Added reference (design requirements for DSS and AMSAC).

Prepared by: J. L. Bord Jr. Date 8/5/91

Reviewed by: Dennis O Newton Date 8-5-91

Reviewed by: Bert L Brooks Date 8/5/91

Approved by: Glenn P Moore Date 8/8/91

********* VOLUME 1 REVISIONS ********

06	III.B, III.C, III.E, SS-1, Specific Rule 1, VI	(PC 86-08) Modified guidelines for starting RCPs with RV head and/or loop voids based on results of AS-6.
06	III.C, III.D, III.E, III.F, LBLOCA C/D, SBLOCA/HPI C/D, VI	(PC 88-07) Added guidelines for control of RB environment and integrity.
06	III.E	(PC 88-09) Modified guideline to reflect revised tube rupture guidance in Volume 3.
06	III.C, III.D, III.E	(PC 89-08) Added guidelines for HPI cooling with an inoperative PORV.
06	III.C	(PCs 90-01 & 86-04) Modified guidelines for MU/HPI cooling at Davis Besse.
06	All of Parts III, IV, V, and VI	(PC 91-04) Added and modified guidelines due to suggested changes resulting from the development of Volume 2.

******** VOLUME 2 REVISIONS ********

06	All sections.	(PC 90-05) Original issue of Volume 2.

******** VOLUME 3 REVISIONS ********

06	List of Acronyms/Abbreviations	(PCs 88-08, 88-11) Added BCC, CBP, HLL, PSV, RCITS, and RVL.
06	III.C, III.G, IV.A, V, VI	(PC 86-08) Modified guidelines for starting RCPs with RV head and/or loop voids based on results of AS-6 .
06	III.H, VI	(PC 88-07) Added new chapter to provide RB control guidance and new reference section (10) to the references in Part VI.
06	I.B, II.A, II.B, II.C, II.D	(PC 88-08) Added new chapter to address the overall TBD transient mitigation philosophy. Expanded discussions on symptom recognition and misdiagnosis and clarified relationship to severe accident guidance.

06	III.E, III.G, VI	(PC 88-09) Revised guidance for SGTR mitigation and provided guidance for implementing revised TRACC limit.
06	II.C, III.B, III.C, III.F, IV.I, VI	(PC 88-11) Added new chapter to discuss RC inventory measurement systems and revised guidance to reflect use of these systems.
06	III.A, III.E, III.G	(PC 89-04) Clarified interfaces with non-emergency procedures and treatment of forced shutdown for SGTR.
06	III.C, III.G	(PC 89-08) Added guidance for control of HPI cooling with an inoperative PORV.
06	IV.B	(PC 89-09) Revised guidance for transfer to RB sump.
06	III.C, III.G, IV.B, VI	(PCs 90-01, 86-04) Revised guidance for MU/HPI cooling for Davis Besse to reflect more recent analyses and design changes.
06	III.A	(PC 91-02) Corrected reference to appropriate steps during forced shutdown for SGTR.
06	II.B, III.A, III.B, III.C, III.F, III.G, IV.A, IV.B, IV.C, IV.E, V	(PC 91-04) Added and modified guidelines due to suggested changes resulting from the development of Volume 2.

Prepared by: T. L. Book Sr. Date 1/8/92

Reviewed by: (PC 88-09 only) Martin V Pearce Date 1/8/92

Reviewed by: Donna G Newton Date 1-9-92

Reviewed by: Brent J Book Date 1/9/92

Approved by: M Bak Date 1/9/92

BW B&W NUCLEAR TECHNOLOGIES

RECORD OF REVISION

NUMBER 74-1152414-07

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
	******** VOLUME 1 REVISIONS ********	
07	III.C/16.4 III.C/18.4 SS-2/8.4 SS-2/10.4 SS-3/9.5 SS-3/11.5	(PC 90-10) Revised guidance to allow operator to repeat a RC pump bump without waiting 15 minutes provided the RCS has stabilized with no heat transfer established.
07	III.B/18.3 III.B/18.4 III.C/3.0 III.C/10.1 III.C/15.1-15.2 III.C/3.0 Attch. 1 III.D/1.0 III.D/5.0 III.D/5.0 Attch. 1 III.E/8.0 III.E/10.2-10.3 III.E/11.2-11.3 III.E/13.0 FF/2.1 FF/6.3 FF/6.5 NC/2.1 NC/6.3 NC/6.5 HPI CD/1.0 HPI CD/21.2 SS-1/1.0 SS-1/2.1 SS-1/2.3 VI/2.0 VI/3.1 VI/3.2 (new) Figure 1 (deleted)	(PC 91-07) Incorporated relaxed PTS guidance which is less restrictive with regard to RCS pressures and temperatures.
07	III.B/3.0	(PC 91-08) Revised criteria for not raising the level in the affected or most affected SG to full flow from one HPIP. Clarified that both SGs are maintained available for heat transfer.

B&W NUCLEAR TECHNOLOGIES

RECORD OF REVISION

NUMBER 74-1152414-07

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
07	I/7 (paragraph deleted) III.A/10 III.B/4.0 III.B.4.2 (new section) III.B/8.6 III.B/9.5 III.B/19 III.C/3.2-3.3 III.C/3.5-3.7 III.C/3.9-3.10 III.C/12.0 (new caution) III.D/5.5 III.D/5.3 Attch. 1 III.D/5.4 Attch. 1 III.E/10.2 III.F/4.0 III.F/5.2 III.F/6-7 III.F/12.6-12.7 III.F/14.0 III.F/16.5 III.F/19.0 III.F/24.0 III./27.0 III.F/30.0 III.F/34.0 III.F/34.5-34.7 III.F/38.0-39.0 HPI CD/9.0 HPI CD/19.9 HPI CD/23.0 LBLOCA/5.0 HPI CD/2.1	(PC 92-06) Incorporated changes as agreed during 12/1-12/3/92 meeting with NRC reviewer of the TBD and as appended during the 1/14/93 OSC meeting.

******** VOLUME 2 REVISIONS ********

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
07	III.E/7.6	(PC 89-02) Added clarification on maximum allowable pressurizer cooldown rate during RCS depressurization.

RECORD OF REVISION

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
07	III.C/16.4 III.C/18.4 SS-2/8.4 SS-2/10.4 SS-3/9.5 SS-3/11.5	(PC 90-10) Revised guidance to allow operator to repeat a RC pump bump without waiting 15 minutes provided the RCS has stabilized with no heat transfer established.
07	III.B/15 III.B/18.3 III.B/18.4 III.C/3.0 III.C/3.1 (deleted) III.C/3.2 III.C/3.3 III.C/10.1 III.C/15.1 III.C/15.2 III.C/3.1 Attch. 1 (deleted) III.C/3.2 Attch. 1 III.C/3.8 Attch. 1 III.C/3.9 Attch. 1 III.C/3.10 Attch. 1 III.C/3.12 Attch. 1 III.D/1.0 III.D/5.1-5.4 III.D/5.1-5.5 Attch 1 III.E/8.0 III.E/10.2 III.E/10.4-10.6 III.E/11.2-11.3 III.E/13.1 III.F/21.0 III.F/29.0 FF/2.0 FF/6.3 FF/6.5 NC/2.0 NC/6.0 HPI CD/1.0 HPI CD/21.2 SS-1/1.1 SS-1/2.2 SS-1/2.3 VI/2.3 VI/3.0	(PC 91-07) Incorporated relaxed PTS guidance which is less restrictive with regard to RCS pressures and temperatures.

RECORD OF REVISION

NUMBER 74-1152414-07

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
07	III.B/3.1 III.E/6.1	(PC 91-08) Revised criteria for not raising the level in the affected or most affected SG to full flow from one HPIP. Clarified that both SGs are maintained available for heat transfer.
07	III.A/10.0 III.B/4.0 III.B/4.1 III.B/4.2 (new) III.B/8.6 III.B/9.5 III.B/19.0 III.C/3.2-3.3 III.C/3.5-3.7 III.C/3.9-3.10 III.C/12.0 III.D/5.5 III.D/5.3 Attch. 1 III.E/10.2 III.F/4.0 III.F/5.2 III.F/6.0 IIIF/7.0 III.F/12.6 III.F/12.7 III.F/14.0 III.F/16.5 III.F/19.0 III.F/21.1 III.F/24.0 III.F/27.0 III.F/30.0 III.F/34.0 III.F/38.0 III.F/39.0 HPI CD/9.0 HPI CD/19.0 HPI CD/23.0 LBLOCA/5.0	(PC 92-06) Incorporated changes as agreed during 12/1-12/3/92 meeting with NRC reviewer of the TBD and as appended during the 1/14/93 OSC meeting.

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
	******** VOLUME 3 REVISIONS ********	
07	III.E.2.3.1/3 III.E.3.3.1/4 VI.5 (new references)	(PC 89-02) Provided clarification on controlling pressurizer cooldown rate during rapid RCS depressurization. Added six RCS Functional Specs to the reference list.
07	II.B.1/3 II.B.3.2.3/2 III.D.2.3/1 III.D.2.4/1 III.D.3.3/2 III.G.3.3.1/1 IV.C.3.2/1 IV.C.3.3/1 IV.C.4.4/1-2 IV.C.4.4.2/1	(PC 90-06) Revised guidance to ensure applicability during periods of low decay heat.
07	III.F.3.1/3	(PC 90-07) Revised discussion regarding identification of ICC conditions to note the expected existance of superheated core conditions during a large break LOCA.
07	III.F.2.1/2 III.F.3.1/2	(PC 90-09) Revise guidance to clarify ICC entry conditions with respect to possible instrument errors.
07	III.C.2.7.C/1 III.C.3.5.C/3 IV.A.3.3/1 IV.A.3.4/1	(PC 90-10) Revised guidance to allow operator to repeat a RC pump bump without waiting 15 minutes provided the RCS has stabilized with no heat transfer established.
07	III.C.2.3.A/4 III.C.3.3.A/3-4 III.G.3.9.1/6 III.G.3.9.1/9	(PC 91-03) Add guidance on addressing RCS heatup following loss of feedwater flow prior to establishing HPI flow and opening PORV.
07	IV.D.2.1.1/1	(PC 91-05) Added clarification that incore thermocouples may be used whenever forced RC flow does not exist.

RECORD OF REVISION

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
07	IV.J. (new section) VI/7 (new references)	(PC 91-06) Added generic guidance to cope with loss of shutdown cooling (DHR). New section IV.J was added.
07	II.D.2.3.5/1 III.B.1.1.2/3 III.B.2.6/1 III.B.3.4/1 III.C.1.1.1/6 III.C.1.1.2/4 III.C.2.2/4 III.C.2.3/2 III.C.2.3/5-6 III.C.2.3.A/9 III.C.2.3.B/1 III.C.2.3.B/7 III.C.2.3.B/10-11 III.C.3.2/3 III.C.3.2/7 III.C.3.3.A/5 III.C.3.3.B/2 III.C.3.3.B/6 III.C.3.5.B/1 III.D.1.1.1/5 III.D.1.1.2/1-2 III.D.2.2/1 III.D.3.2/5 III.D.3.5/3 III.E.2.2.2/4 III.E.3.3.1.3/1 III.G.2.2.2/2 III.G.3.1/1 III.G.3.8.2.1/1 III.G.3.8.2.2/7 III.G.3.9.1/4 III.G.3.9.1/10 III.G.3.9.1/12 III.G.3.9.1/14-16 III.G.3.9.2/3 III.G.3.9.2/29 III.G.3.9.2/31-32 IV.A.2.3/1 IV.A.3.0/2 IV.A.3.2/3 IV.A.3.7/2 IV.A.3.8/3	(PC 91-07) Incorporated relaxed PTS guidance which is less restrictive with regard to RCS pressures and temperatures.

BWNT-20005-3 (10/89)

BW B&W NUCLEAR TECHNOLOGIES

RECORD OF REVISION

NUMBER 74-1152414-07

REV. NO.	CHANGE SECT/PARA.	DESCRIPTION/CHANGE AUTHORIZATION
	IV.B.2.A.4.1/D (new) IV.D.2.2/1 (deleted) IV.E.2.3/3 IV.G (entire section) Figure IV.G-1 (deleted) V/3 VI/8 (new reference)	(PC 91-07) continued
07	III.E.2.2.2/2-3	(PC 91-08) Revised criteria for not raising the level in the affected or most affected SG to full flow from one HPIP. Clarified that both SGs are maintained available for heat transfer.
07	II.B.3.3/1 III.C.3.5/4 III.E.3.3.2.1/14 III.E.3.4.1.3/2 (new) III.E.3.4.4.2/5 (new) III.G.3.9/2 III.G.3.9.2/19 III.H.3.2.1/15-17 III.H.3.2.3/18 (new) IV.B.2.A.3.1/6 IV.B.7.1/1 IV.B.7.2/1 (deleted) IV.D.2.1.2/1	(PC 92-06) Incorporated changes as agreed during 12/1-12/3/92 meeting with NRC reviewer of the TBD and as appended during the 1/14/93 OSC meeting.

Prepared by: M. W. Eg... Date: 10-25-93

Reviewed by: Brt J Brk Date: 10/25/93

Reviewed by: David A Dorwstain Date: 10/25/93

Approved by: 71 Bale Date: 10/25/93

VOLUME 1 & 2 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	All Sections	Revision 8 is based primarily on validation of the GEOG and a Deviation Document Comparison (DDC) task. The B&WOG conducted two GEOG validation sessions on the FPC training simulator resulting in two sets of comments and their dispositions. These validations and the DDC task resulted in the following comment/disposition sources: – Validation session 1 comments (VC 1) – Validation session 2 comments (VC 2) – Document Deviation Comparison comments (DDC) Some changes are germane to the entire GEOG. These global changes are: – Revisions were made to various steps where compound/nested guidance existed. That is, where possible, compound/nested guidance has been revised such that only one succinct action is located in any one step. (VC 1: 8) – Extraneous notes and cautions were removed. – RB condition checks were changed from maintain to verify (DDC III.B.4.0). – Clarified guidance to maintain SCM near limit for PTS concerns. Revision 8 also incorporates three PCs.
08	III.A.1.0 and III.A.2.0	Revised to accommodate ATWS as an immediate action. VC 1: 1 and 51, DDC III.A, 2.0
08	III.A.1.0 SYMPTOM OCCURS DURING HEATUP OR COOL-DOWN	Revised to ensure rods manually inserted if enter GEOG from event other than reactor trip. VC 1: 29, VC 2: E.5.a
08	III.A.4.0 and III.A.5.0	Revised to reduce diversity between GEOG and owner's EPGs. DDC III.A, 4.0 and III.A, 5.0
08	III.A.6.0	Revised to include make up and letdown management. VC 1:12
08	III.A.7.0	Revised to explicitly state use of TBVs or ADVs. VC 1: 4
08	III.A.11.0	Deleted reference to NC.VC 1: 3, 9 and 10 DDC III.A, 11.0
08	III.B	Added reference to new Specific Rule 4.0, Feedwater/SG Control. VC 1: 7

VOLUME 1 & 2 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	III.B.3.3	Deleted reference to SG pressure control. If symptom of upset in primary to secondary heat transfer occurs, SG pressure control is addressed. Hence, not necessary. DDC III.B, 3.0
08	III.B.4.1.a	Revised to reduce diversity between GEOG and owner's EPGs. DDC III.B, 4.0
08	III.B.8.1 and III.B.9.1	Guidance to bypass secondary plant protection system moved to more appropriate location. VC 1: 75
08	III.B.8.2	Reference to NC deleted. Revised to clarify that TBVs and ADVs should be used to commence cooldown. Reference added to maintain tube to shell ΔTs within limits. VC 1: 76, VC 1: 65, VC 2: A.E.2
08	III.B.8.6	Deleted due to redundancy with step 9.4. VC 2: A.E.1
08	III.B.9.4	Changed WHENEVER to IF based on definition of terms. VC 1: 15
08	III.B.11.0	Added guidance to reduce cooldown rate if HPI cooldown established.
08	III.B.18.0	Revised to reduce diversity between GEOG and owner's EPGs. DDC III.B,18.0 Deleted caution and steps associated with solid plant during RCP start due to conflict of previous guidance and need to maintain SCM near limit due to PTS concern.
08	III.B.22.0	Revised guidance to allow plant to remain stable rather than force cooldown. DDC III.B,22.0
08	III.C Note following step 2.0	Added note to aid in preventing complications when attempting to restore feedwater. VC 1: 30
08	III.C.3.1 Note, III.C Attachment 1, 3.1 Note, III.D.5.0 Note, III.D Attachment 1, 5.1 Note, III.E.16.2.e Note	Note added to state that transition to III.B not necessary for loss of SCM caused by initiation of HPI cooling. VC 1: 32

VOLUME 1 & 2 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	III.C.8.1	Revised to reduce diversity between GEOG and owner's EPGs. Also, this change reduces operator burden, by using an easily discernable parameter, and still maintains the SGs as heat sinks. DDC III.C, 8.0
08	III.C.10.1 Note, III.E.17.2 Note, RCP 1.2 Note	Note added to state that certain conditions are preferred but not necessary. VC 2: E.6.e
08	III.C.17.0 Caution, EST 10.0 Note	Added caution to prevent reducing SG pressure below that required for operation of turbine driven EFW pump.
08	III.D.1.1	Added guidance to trip 4th RCP. DDC III.D, 3.0
08	III.D.1.2.c.1	Added guidance to isolate letdown. VC 2: E.4.a
08	III.D.3.1	Deleted guidance to trip EFW pumps and added guidance to control EFW. DDC III.D, 3.0
08	III.D.3.3 Note	Added detail to address actuation of isolation system. VC 1: 5
08	III.D.4.0, III.D.6.2	Revised to focus on determining overcooling (excessive primary to secondary heat transfer) symptoms as opposed to SG parameter stabilization. VC 1: 21
08	III.D.7.1 Note	Note added to draw focus on heat transfer recovery when heat transfer is challenged as opposed to recovering a SG when one is already removing heat. VC 1: 19
08	III.D.10.0, 11.0, 12.0 and 13.0	These new steps were added to ensure stability and SG protection following an EHT event. DDC III.D, 10.0 VC 2: E.4.c and AE.3
08	III.E.1.0 Caution	Added "immediate" since ATWS actions (step 2.0 of III.A) moved to immediate actions. VC 1: 60
08	III.E.2.1	Revised to minimize letdown flow. VC 1: 58
08	III.E.3.1	Deleted minimize letdown since moved to 2.1.

VOLUME 1 & 2 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	III.E.6.1	Significantly revised to make easier to follow; now compatible with same guidance in III.B. VC 2: E.6.d
08	III.E.6.2.c	Replaced ΔT with stable. DDC III.E,6.0
08	III.E.7.0 - 14.0	Completely restructured old steps 7 and 8 to new steps 7-14 (which requires renumbering rest of III.E). Reason for restructuring is to effect "depressurization prior to cooldown" VC 1:15, 61,62,68,69,70,71 and 72
08	III.E.15.3.c Note	Added note that depressurizing to <1000 psig does not mean to violate the SCM limit. VC 1: 63
08	III.E.17.3.c	Deleted caution and steps associated with solid plant during RCP start due to conflict of previous guidance and need to maintain SCM near limit due to PTS concern.
08	III.E.	Deleted old step 13.0. VC 1: 64
08	III.F	Added reference to H2 monitoring and control at several steps throughout this section. VC 2: E.2.c DDC III.F, 9.0 Deleted second part of caution addressing suction source prior to sump switchover at several steps throughout this section. VC 1: 42
08	III.F.7.0	Deleted old 7.0; redundant with guidance of old step 8.0, which is now step 7.0. VC 2: E.2.d
08	III.F.9.0	Added caution and steps to further depressurize SGs in region 3. DDC III.F, 11.0
08	Cooldown sections: SBLOCA COOLDOWN HPI COOLDOWN (HPIC)	The original SBLOCA/HPI cooldown section was split into two discrete sections. VC 1:22,23,34,35,36,37,39,48 and 50. These sections utilize currently existing guidance; hence, new guidance has not been added. Generally, the only exception to this is addition of H2 monitoring and control guidance and guidance to secure RBS when appropriate. VC 2: E.2.c DDC III.F, 9.0

VOLUME 1 & 2 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	SBLOCA 4.0	Added guidance to maintain tube/shell ΔT limits. VC 2: E.2.b
08	SBLOCA 7.0	Guidance added due to restructuring; allows exit if conditions are satisfactory.
08	LBLOCA COOLDOWN (LBLOCA)	Added guidance to monitor and control H2. VC 2: E.2.c DDC III.F, 9.0
08	LBLOCA 1.0	Revised step 1.0 to just verify actuations (no specifics) and deleted reference to VSSV (old step 1.1). VC 1:52 Added substep 1.2 to cross–tie LPI if only one pump is available. This also required an addition to the caution before step 4 (old step 5) regarding piggyback operation. VC 1:55
08	LBLOCA 3.0	Deleted old step 3.0 (redundant) and renumbered rest of section accordingly. VC 1:54
08	Equipment restoration subsections: RCP RESTART ESTABLISH PRIMARY TO SECONDARY HEAT TRANSFER TO ONE OR BOTH SGs (EST HT)	The original RCP restart subsection has been restructured to facilitate its use with the revised restoration of heat transfer subsection.The original equipment restoration subsections included two subsections dealing with restoration of heat transfer. These have been restructured and consolidated into one subsection.
08	RCP RESTART (RCP) 1.0	Step was revised to reflect desired RCP start conditions, including a caution, not included in original version.
08	RCP 3.0 and 4.0.	Guidance added due to restructuring; allows exit if conditions are satisfactory.
08	EST HT 1.0 Note	Note was added do define the term "affected SG".
08	EST HT 1.1	Added reference to Specific Rule 4.0. VC 1:7
08	EST HT 2.0	Provides route to RCP for attempt of RCP start.
08	EST HT 6,0, 7.0 and 17.0	Guidance added due to restructuring; allows exit if conditions are satisfactory.
08	Specific Rule 2.0	Added two rules and supporting note regarding pump runout and minimum flow requirements. DDC Specific Rule 2.0

VOLUME 1 & 2 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	New Specific Rule 4.0	New rule added to reduce diversity between GEOG and owner's EPGs.
08	Specific Rule 3.0	This revision includes PC 94-06: Revised the PTS guidance to provide operator guidance should the requirement to limit the cooldown rate to a 50F/hour linear cool-down rate be violated. Corrected typographical error and added note to support reduced cooldown rate of 50F/hr.
08	All sections containing flow charts.	This revision includes PC 94-05: Flowcharts were revised using flowcharting software.

VOLUME 3 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	All sections containing flow charts.	This revision includes PC 94-05: Flowcharts were revised using flowcharting software.
08	I.B page I.B.4	Added statement about instrument error corrections not within the scope of the TBD. VC 1: 25
08	II.B.3.3	Delete reference to 50F - 60F delta T. DDC III.E, 6.0
08	III.A.1.1, III.A.2.2.1 and III.A.3.1	This revision addresses ATWS concerns. It maintains main turbine operation, if possible, during ATWS until the reactor is shutdown. VC 1: 1 and 51 DDC III.A,2.0
08	III.B.3.4, III.C.3.5.A, III.G.3.8.2.2, and IV.A.3.7	Change SCM increase, for RCP start, from 70F to 20F. VC 1: 25
08	III.B.3.6	Clarified that, when SCM is lost and there is no HPI, the SGs should be steamed at maximum rate possible (to maximize cooldown and depressurization of RCS) even if there is no measurable SG level. VC 2: AE.2
08	III.B.3.8	Added detail relative to reason TBD uses LPI operational discharge pressure for trigger to transition to LBLOCA cooldown guidance. DDC III.B, 6.0
08	III.C.3.5, III.C.3.5.C and III.C.3.5.D	Changed RCS pressure reduction criteria from delta Tsat to 1600 psig RCS pressure. DDC III.C, 8.0
08	III.F.3.4	Added guidance to reduce SG pressure in region 3. DDC III.F, 11.0
08	III.C.2.2	Added discussion that addresses the acceptability of initiating HPI cooling before reaching HPI cooling criteria. VC 2: E.3.b DDC III.C, 8.0
08	III.H.3.2.3	Add discussion relative to use of H2 monitors. DDC III.F, 9.0
08	IV.A.3.8	Clarified to only raise pressure for solid RCS conditions (prior to RCP start) if PTS not invoked.
08	IV.B.3.1	Clarified LPI cross-connect.

VOLUME 3 REVISIONS

REV NO.	CHANGE SECT/PARA.	DESCRIPTION / CHANGE AUTHORIZATION
08	IV.C.4.0	Added more discussion on identifying a dry SG. VC 1: 20
08	IV.C.4.4.3	Discussion added to support Specific Rule 4.0
08	IV.A.2.5	Added reference to plant specific core lift limit.
08	IV.G.2.5	This revision includes PC 94-06: Revised the PTS guidance to provide operator guidance should the requirement to limit the cooldown rate to a 50F/hour linear cool-down rate be violated.
08	IV.C.4.4.3	This revision includes PC 95-04: Clarification that minimum EFW flow required for loss of SCM takes precedence if it conflicts with maximum EFW flow for dry SG.

Prepared by:	J. L. Book	Date:	11/18/96
Reviewed by:	DA Downtain	Date:	11/18/96
Reviewed by:	Brent Booth	Date:	11/18/96
Approved by:	[illegible]	Date:	11/18/96

Rev. No.	Section Paragraph.	PC No.	Description/Change Authorization

****** VOLUME 1 CHANGES ******

Volume 1 (GEOG) was re-written in an effort to further minimize TBD-EOP deviations. Along with specific changes that would fulfill this intent, Volume 1 was streamlined in areas where a high degree of prescription was not necessary.

Rev. No.	Section Paragraph.	PC No.	Description/Change Authorization
09	III.C III.D III.E IV.A IV.B IV.C VI 4.0	PC 86-17 PC 87-07 PC 92-04	Added guidance for SG tube to shell differential temperature limits. Added dry SG recovery guidance.
09	VI 2.0	PC 87-01 PC 88-02	Revised criteria for termination of HPI and isolation of CFTs to account for small break sizes and to clarify CFT control. Revised criteria for termination of HPI to eliminate requirement for 20 minute hold after verifying LPI flow.
09	I	PC 87-02	Added a bullet to Volume 1 Part I to explain the intent of the guidelines to proceed through the appropriate actions without undue delay and to primarily mitigate transients from the control room when possible.
09	III.D	PC 89-01	Added guidance for situations where a forced cooldown is occurring due to an unisolable steam leak, but the rate of RC temperature change is less than the T.S. limit and the operator can control SG level and RCS pressure.
09	III.C III.D III.E IV.A IV.B IV.C VI 1.3 VI 4.0	PC 91-09	Added concern for feeding a SG with an unisolable steam leak in areas of personnel access or key equipment to Rule 4.0. Referenced Rule 4.0 in more areas.
09	III.B III.E IV.A IV.C	PC 93-01	Revised the guidance for saturated cooldown using SGs to clarify that normal T.S. cooldown rate limits are not applicable, nor is the 50°F/HR voided RV head limit. Revised the guidance for SG control during SGTR and any cooldown without forced flow to ensure that available SGs are maintained as heat sinks.
09	II III.F Fig. 1	PC 93-02 PC 94-01	Revised ICC guidance to interface with/transition to Severe Accident Management Guidance. Revised guidance for RCP operation during ICC to remove RCP bumps and starts and added RCP trip prior to transfer to severe accident guidance.
09	I	PC 94-03	Modified to make it clearer that GEOG does not directly apply to the utility EOPs; rather that the TBD as a whole are used in conjunction with the plant specific writer's guide to provide transient mitigation guidance.

Rev. No.	Section Paragraph.	PC No.	Description/Change Authorization
09	III.D	PC 94-04	Added SG trickle feed as a core cooling method to GEOG.
09	I	PC 95-05	Added clarification on symptom priorities.
09	IV.A	PC 96-01	Revised and expanded guidance for boron precipitation prevention.
09	IV.A IV.B	PC 96-02	Removed transition to DHRS operations. Considered by OSC as beyond the scope of GEOG.
09	III.C IV.B IV.C V.A	PC 96-03	Added caution to V.A, RCP restart to ensure criteria to preclude a potential for recriticality are satisfied. All other RCP start guidelines state IF AVAILABLE. Volume 2 says that IF AVAILABLE includes considerations and limits due to dilution.
09	IV.A IV.B VI 5.0	PC 96-05	Revised the guidelines to address approach to criticality during transient mitigation.
09	III.B IV.A	PC 97-01	All reference to the Rules in GEOG has been standardized by listing the Rules that apply to a step instead of wording the rule as part of the action. Moved routing step 4.0 in III.B sooner to transition to LOCA cooldown sooner from LSCM.
09	I	PC 97-02	Clarify GEOG-EOP relationship and step sequencing.
09	III.C	PC 98-02	Revised guidance to prevent continuation of guidance path until either HPI or SCM are restored.
09	II VI 4.0	PC 99-01	Implemented new plant specific minimum total EFW flow rates and SG level loss of SCM setpoints based on new SBLOCA analyses that use inputs supplied by each B&WOG member. Supercedes PC 91-01 and its interim guidance.
09	VI 3.0	N/A	Revised PTS rule to require minimum subcooling regardless of why PTS is invoked.

Rev No.	Section/ Paragraph	PC No.	Description/Change Authorization
			****** **VOLUME 2 CHANGES** ******
			Volume 2 was re-written/revised as necessary to support the changes (i.e., further reduce TBD-EOP deviations and streamline Volume 1 guidance) made to Volume 1.
09	III.C III.D III.E IV.A IV.B IV.C VI 4.0	PC 86-17 PC 87-07 PC 92-04	Added guidance for SG tube to shell differential temperature limits. Added dry SG recovery guidance.
09	VI 2.0	PC 87-01 PC 88-02	Revised criteria for termination of HPI and isolation of CFTs to account for small break sizes and to clarify CFT control. Revised criteria for termination of HPI to eliminate requirement for 20 minute hold after verifying LPI flow.
09	III.D	PC 89-01	Added guidance for situations where a forced cooldown is occurring due to an unisolable steam leak, but the rate of RC temperature change is less than the T.S. limit and the operator can control SG level and RCS pressure.
09	III.C III.D III.E IV.A IV.B IV.C VI 1.3 VI 4.0	PC 91-09	Added concern for feeding a SG with an unisolable steam leak in areas of personnel access or key equipment to Rule 4.0. Referenced Rule 4.0 in more areas.
09	III.B III.E IV.A IV.C	PC 93-01	Revised the guidance for saturated cooldown using SGs to clarify that normal T.S. cooldown rate limits are not applicable, nor is the 50°F/HR voided RV head limit. Revised the guidance for SG control during SGTR and any cooldown without forced flow to ensure that available SGs are maintained as heat sinks.
09	II III.F	PC 93-02 PC 94-01	Revised ICC guidance to interface with/transition to Severe Accident Management Guidance. Revised guidance for RCP operation during ICC to remove RCP bumps and starts and added RCP trip prior to transfer to severe accident guidance.
09	III.D	PC 94-04	Added SG trickle feed as a core cooling method to GEOG.
09	All	PC 95-05	Modified to stress symptom priorities in numerous locations.
09	IV.A	PC 96-01	Revised and expanded guidance for boron precipitation prevention.
09	IV.A IV.B	PC 96-02	Removed transition to DHRS operations. Considered by OSC as beyond the scope of GEOG.

Rev No.	Section/ Paragraph	PC No.	Description/Change Authorization
09	III.B III.C III.E IV.B IV.C V.A	PC 96-03	Added caution to V.A, RCP restart to ensure criteria to preclude a potential for recriticality are satisfied. All other RCP start guidelines state IF AVAILABLE. Volume 2 says that IF AVAILABLE includes considerations and limits due to dilution.
09	IV.A IV.B VI 5.0	PC 96-05	Revised the guidelines to address approach to criticality during transient mitigation.
09	III.B IV.A	PC 97-01	All reference to the Rules in GEOG has been standardized by listing the Rules that apply to a step instead of wording the rule as part of the action. Moved routing step 4.0 in III.B sooner to transition to LOCA cooldown sooner from LSCM.
09	All	PC 97-02	Clarify GEOG-EOP relationship and step sequencing. A brief statement of any sequence requirements imposed by the TBD has been added to each bases.
09	III.C	PC 98-02	Revised guidance to prevent continuation of guidance path until either HPI or SCM are restored.
09	II VI 4.0	PC 99-01	Implemented new plant specific minimum total EFW flow rates and SG level loss of SCM setpoints based on new SBLOCA analyses that use inputs supplied by each B&WOG member. Supercedes PC 91-01 and its interim guidance.
09	VI 3.0	N/A	Revised PTS rule to require minimum subcooling regardless of why PTS is invoked.

Rev No.	Section/ Paragraph	PC No.	Description/Change Authorization
			****** VOLUME 3 CHANGES ******
09	III.C III.D III.E III.G IV.A IV.C IV.K (New) V 4.0 VI 8.0	PC 86-17 PC 87-07 PC 92-04	Added guidance for SG tube to shell differential temperature limits. Added dry SG recovery guidance. Added 14 references to VI 8.0.
09	III.F IV.A IV.B V 2.0 VI 8.0	PC 87-01 PC 88-02	Revised criteria for termination of HPI and isolation of CFTs to account for small break sizes and to clarify CFT control. Revised criteria for termination of HPI to eliminate requirement for 20 minute hold after verifying LPI flow.
09	III.D III.G	PC 89-01	Added guidance for situations where a forced cooldown is occurring due to an unisolable steam leak, but the rate of RC temperature change is less than the T.S. limit and the operator can control SG level and RCS pressure.
09	III.C III.D III.E III.G IV.C V 4.0	PC 91-09	Added concern for feeding a SG with an unisolable steam leak in areas of personnel access or key equipment to Rule 4.0.
09	III.B III.E III.F III.G VI 2.0	PC 93-01	Revised the guidance for saturated cooldown using SGs to clarify that normal T.S. cooldown rate limits are not applicable, nor is the 50°F/HR voided RV head limit. Revised the guidance for SG control during SGTR and any cooldown without forced flow to ensure that available SGs are maintained as heat sinks.
09	I.B II.C II.D III.F IV.A IV.E IV.H IV.I VI 6.0	PC 93-02 PC 94-01	Revised ICC guidance to interface with/transition to Severe Accident Management Guidance. Revised guidance for RCP operation during ICC to remove RCP bumps and starts and added RCP trip prior to transfer to severe accident guidance.
09	III.G IV.C V 4.0	PC 94-04	Clarified SG trickle feed as a core cooling method.

Rev No.	Section/ Paragraph	PC No.	Description/Change Authorization
09	II.A II.B	PC 95-05	Added clarification on symptom priorities.
09	III.B III.G IV.B	PC 96-02	Precautions were added when attempting to establish DHRS operations subsequent to LOCA or HPIC.
09	II.C III.B III.C III.G III.H IV.A IV.E IV.H IV.I VI 8.0	PC 96-03	Added restrictions and criteria for RCP restart following potential RCS dilution conditions to prevent recriticality.
09	II.C V 5.0	PC 96-05	Revised the guidelines to address approach to criticality during transient mitigation.
09	III.E	PC 98-03	Revised the radiation limit for continued steaming to the atmosphere in SGTR to make TBD guidance consistent with UFSAR.
09	III.B IV.C V 4.0 VI 2.0	PC 99-01	Implemented new plant specific minimum total EFW flow rates and SG level loss of SCM setpoints based on new SBLOCA analyses that use inputs supplied by each B&WOG member. Supercedes PC 91-01 and its interim guidance.
09	IV.B IV.G V 3.0	N/A	Revised PTS rule and supporting bases to require minimum subcooling regardless of why PTS is invoked. This change was necessary as a result of recent methodology changes in determining plant specific P-T limits.

Rev No.	Section/ Paragraph	PC No.	Description/Change Authorization

****** **VOLUME 4 CHANGES** ******

This volume was added to provide TBD implementation guidance, including documenting the TBD change process, the EOP V&V process, the GEOG V&V process and important TBD related OSC-NRC interactions.

Rev No.	Section/ Paragraph	PC No.	Description/Change Authorization
09	All	PC 97-02	Initial issue of Volume 4. Clarifies relationship between GEOG and plant EOPs and discusses step sequencing.
09	All	PC 94-03	Volume 4, the GEOG Implementation Guide, has been developed to convey information and expectations on the interpretation, implementation and use of the GEOG beyond that found in the TBD, Volumes 1 through 3. This volume provides generic guidance on the preparation and performance of the EOP V&V process. This volume provides lessons learned from EOP inspections to help counter the divergent nature of plant specific generated EOPs. The B&WOG OSC believes that in preparing and disseminating the information in Volume 4, the EOP programs of the B&WOG members will be improved both individually and collectively.
09	III 4.0	PC 92-05	Added generic position for safety system bypass or override following actuation.

Prepared by: B. L. Brooks Date: 3/31/00

Reviewed by: (PC 86-17/87-07/92-04 only) Date: 4/3/00

Reviewed by: (PCs 87-01/88-02/96-02/99-01 only) Date: 4/3/00

Reviewed by: James R. (PC 96-03 only) Date: 4/5/00

Reviewed by: T.L. Book Date: 4/5/00

Reviewed by: D. T. Scott Date: 4/5/00

Released by: ~~R. W. Dorman~~ M.W. Ewing Date: 4/5/00

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List of Acronyms/Abbreviations

AAC	-	Alternate AC
ADV	-	Atmospheric Dump Valve
AFW	-	Auxiliary or Emergency Feedwater
ANO-1	-	Arkansas Nuclear One Unit 1
ATOG	-	Abnormal Transient Operating Guidelines
ATWS	-	Anticipated Transient Without Scram
BAAS	-	Boric Acid Addition System
BCC	-	Boiler-Condenser Cooling
BHUT	-	Bleed Holdup Tank
BWST	-	Borated Water Storage Tank
CBP	-	Condensate Booster Pump
CF	-	Core Flood
CFT	-	Core Flood Tank
CR-3	-	Crystal River Unit 3
DB	-	Davis Besse
DG	-	Diesel Generator
DH	-	Decay Heat
DHR	-	Decay Heat Removal
DHRS	-	Decay Heat Removal System
DSS	-	Diverse Scram System
ECC	-	Emergency Core Cooling
ECCS	-	Emergency Core Cooling System
EFW	-	Emergency Feedwater
EOP	-	Emergency Operating Procedures
ERV	-	Electromatic Relief Valve
FA	-	Fuel Assemblies
FW	-	Feedwater
GPM	-	Gallons per Minute
HLL	-	Hot Leg Level
HPI	-	High Pressure Injection
HPV	-	High Point Vent
I/C	-	Incore
ICC	-	Inadequate Core Cooling
ICS	-	Integrated Control System
IST	-	Integrated Systems Tests
LCO	-	Limiting Condition for Operation
LOCA	-	Loss of Coolant Accident
LOFW	-	Loss of Feedwater
LOOP	-	Loss of Offsite Power
LPI	-	Low Pressure Injection
MFW	-	Main Feedwater
MU	-	Makeup

MSSV	-	Main Steam Safety Valve
NDT	-	Nil-Ductility Transition
NNI	-	Non-Nuclear Instrumentation
NPSH	-	Net Positive Suction Head
NSS	-	Nuclear Steam Supply
NSSS	-	Nuclear Steam Supply System
NUMARC	-	Nuclear Management and Resources Council
ONS 1	-	Oconee Nuclear Station Unit 1
ONS 2	-	Oconee Nuclear Station Unit 2
ONS 3	-	Oconee Nuclear Station Unit 3
OTSG	-	Once Through Steam Generator
PCT	-	Peak Clad Temperature
PORV	-	Pressurizer Power or Pilot Operated Relief Valve
PSIG	-	Pounds per Square Inch Gauge
PSV	-	Pressurizer Safety Valve
P-T	-	Pressure versus Temperature
PTS	-	Pressurized Thermal Shock
Pzr	-	Pressurizer
RB	-	Reactor Building or Containment
RBCU	-	Reactor Building Cooling Units
RBS	-	Reactor Building Spray
RC	-	Reactor Coolant
RCBT	-	Reactor Coolant Bleed Tank
RCITS	-	Reactor Coolant Inventory Trending Systems
RCP	-	Reactor Coolant Pump
RCS	-	Reactor Coolant System
RPS	-	Reactor Protection System
RTD	-	Resistance Temperature Detector
RV	-	Reactor Vessel
RVL	-	Reactor Vessel Head Level
SAG	-	Severe Accident Guidelines
SBLOCA	-	Small Break Loss of Coolant Accident
SBO	-	Station Blackout
SCM	-	Subcooling Margin
SER	-	Safety Evaluation Report
SF	-	Spent Fuel
SFAS	-	Safety Features Actuation System
SFRCS	-	Steam/Feed Rupture Control System
SG	-	Steam Generator
SGTR	-	Steam Generator Tube Rupture
SPND	-	Self Powered Neutron Detector
T_{ave}	-	Reactor Coolant Average Temperature
TAP	-	Transient Assessment Program
TBD	-	Emergency Operating Procedure Technical Bases Document

TBV	-	Turbine Bypass Valve
T/C	-	Thermocouple
T_c	-	Reactor Coolant System Cold Leg Temperature
T_{cold}	-	Reactor Coolant System Cold Leg Temperature
T_h	-	Reactor Coolant System Hot Leg Temperature
T_{hot}	-	Reactor Coolant System Hot Leg Temperature
TRACC	-	Tube Rupture Alternate Control Criteria
TMI-1	-	Three Mile Island Unit 1
T_{sat}	-	Saturation Temperature
VSSV	-	Vital System Status Verification

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Part I

INTRODUCTION

Part I

INTRODUCTION

This document was developed primarily to establish a technical bases format that provides an efficient vehicle for document maintenance and periodic updates to address new issues and operational methods on a generic bases.

BACKGROUND

The B&W Owners Group developed vendor guidelines in a plant specific format called Abnormal Transient Operating Guidelines (ATOG). The ATOG documents were used to develop symptom- oriented procedures for compliance with Item I.C.1 of NUREG-0737. The NRC reviewed the Oconee version of ATOG and issued a Safety Evaluation Report in 1983 that endorsed the guidelines for implementation and identified additional items to be addressed in the longer term

This document, the EOP Technical Bases Document (TBD) was developed to provide a single, generic set of guidelines to encompass the ATOG scope and the new scope resulting from closure of the ATOG SER open items. In addition, the TBD is the document used for upgrading the guidance for new issues and improved methods.

The expanded TBD guidance is based primarily on new analyses that, where appropriate, used computer simulations that have been benchmarked against Integral System Test data.

Chapter I.A

Purpose of This Document

There are four main purposes for developing this Technical Bases Document (TBD). These purposes are summarized as follows:

PURPOSE #1 - To provide the bases for operator actions for mitigating abnormal transients using plant symptoms.

WHY - To assist utilities in maintaining emergency operating procedures (EOP).

HOW -
- By describing the basic heat transfer symptoms and control functions used to diagnose and mitigate abnormal transients.
- By giving operating guidance for key equipment and systems used for core cooling based on:
  a. equipment design limitations and
  b. expected system performance.
- By giving guidance for restoring stable plant conditions.
- By giving guidance for diagnosing symptoms.
- By providing the bases for recommended guidance.

PURPOSE #2 - To provide a consistent technical bases for operation of nuclear plants with B&W supplied NSS systems.

WHY -
- To facilitate regulatory review.
- To provide a common ground for utilities to exchange operating experience and ideas.

HOW - By providing a document applicable to all nuclear plants with B&W supplied NSS Systems.

PURPOSE #3 - To provide an efficient vehicle for document maintenance.

WHY -
- So that the document will not require changing every time small plant modifications are made.
- So that timely changes can be made.
- So that changes can be made economically.
- So that the document will be kept up to date and therefore have high credibility.
- To address new issues and operating methods (e.g., IST results, ATOG SER open issues, TAP results, etc.).

HOW - By providing one generic document applicable to all nuclear plants with B&W NSS systems.

- By making a "high level" document. The document discussions will avoid plant specific design detail. Document discussions will tend to be in terms of operational functions, which are common among all, plants with B&W NSS systems.

- The document format is designed so that revised pages can be inserted with minimum perturbation to the remainder of the document.

- Related topics tend to be discussed in one localized section of the document.

PURPOSE #4 – To consolidate related information.

WHY - So that material is easily referenced.
- So that related facts can be easily drawn from the document.
- So that related facts are not overlooked.

HOW - By formatting concisely and rigidly.

Chapter I.B

Scope of This Document

1.0 Introduction

The Technical Bases Document (TBD) provides generic operational guidance for recognizing and mitigating abnormal transients. It is intended for use in developing and maintaining plant specific emergency operating procedures (EOPs). The TBD covers mitigation of plant transients and subsequent plant stabilization by achieving one of the following conditions:

- Normal, stable plant state where non-emergency procedures apply
- Decay heat removal system (DHRS) operation; the TBD provides guidance for plant cooldown under abnormal conditions and transition to DHRS operation.
- Stable, controlled plant conditions that can be maintained until station management determines the course of further operation.

The scope of the TBD covers transient initiation from all plant modes other than DHRS operation. The guidance covers plant conditions during transient mitigation up to and including partial core uncovery. Conditions of partial core uncovery, which do not lead to severe accidents, are known as Inadequate Core Cooling (ICC). With the exception of some design bases LOCA scenarios, if the TBD guidance is implemented successfully, a transient will not lead to ICC. However, guidance for ICC mitigation has been provided for completeness and to extend the severe accident prevention space of the TBD guidance.

The TBD does not cover severe accidents. The TBD guidance, upon which plant specific EOPs are based, is focused on "preventing the occurrence of a severe accident". Guidance that addresses severe accident mitigation has a different focus than EOPs. Severe accident guidance focuses on:

- Quenching and cooling the overheated core material
- Protecting remaining (uncompromised) fission product barriers
- Restoring compromised fission product barriers
- Minimizing fission product release

Once a severe accident occurs, it will not be known what equipment is/will be available or the effect mitigating actions will have on subsequent plant conditions (i.e., the uncertainties associated with severe accident mitigation are very large). Because of this, it is not possible to prepare highly prescriptive procedures, e.g., like the EOPs, to deal with severe accidents. Therefore, severe accident mitigation is addressed by plant specific guidelines, not procedures. These plant specific Severe Accident Guidelines (SAGs) are typically located in the Technical Support Center (TSC) and intended for use by an expert team trained in their use. Once the severe accident is mitigated (the severe accident mitigation time interval is expected to be about 12 to 24 hours), continued operations, e.g., long term cooling of core material, maintaining fission product boundaries, eventual site recovery, will be implemented in accordance with site emergency plans. The guidance in the TBD does not consider the complications that may arise from a damaged core, and therefore no longer applies after the transition to the SAG.

2.0 Control and Purpose of the TBD

The TBD is continually revised and upgraded as necessary to address new issues within the TBD scope and enhanced methods derived from lessons learned.

The TBD comprises four volumes. The purpose and content of each volume is as follows:

Volume 1, entitled Generic Emergency Operating Guidelines (GEOG), provides a functional example of how the TBD guidance can be covered in a procedure. The purpose of the GEOG is to demonstrate how the broad, high level guidance of Volume 3 of the TBD can be structured in a logical sequence to accomplish the objectives of transient mitigation. The GEOG does not cover all of the options supported by Volume 3. Where options exist in Volume 3, the GEOG uses the vendor-preferred option. This does not lessen the viability of the remaining options; rather, the use of the preferred option in the GEOG was done solely to simplify the guideline. The GEOG comprises the following:

Part I: Introduction

Description of the GEOG and appropriate precautions and limitations on use of the GEOG.

Part II: Acronym List

Part III: Diagnosis and Mitigation

Guidance for accomplishing transient mitigation. Part III is structured similar to Part III of Volume 3 for consistency, e.g., III.B in both volumes addresses loss of subcooling margin. The exceptions are cooldown guidance (in Part IV of Vol. 1) and RB control (contained within the appropriate sections of Part III of Vol. 1).

Part IV: Cooldown Guidelines

Guidelines for abnormal cooldown modes, primarily based on the guidance in III.G of volume 3.

Part V: Repetitive Actions

Guidance for tasks that may be applicable in several mitigation or cooldown sections, such as transfer of ECCS suction to the RB sump.

Part VI: Rules

Rules for the guidelines. The scope of Part VI has been limited to those guideline actions that are always applicable regardless of when the criteria occur.

Part VII: Figures

Volume 2, entitled Generic Emergency Operating Guidelines Bases, provides the bases for each step of the example guidelines in Volume 1. The bases cover the following aspects of each step:

Indicators and Controls:

The indications and controls that should be used to accomplish the step are listed.

Purpose:

The objective of the step is stated.

Bases:

The bases for the step is briefly discussed. This includes the bases for actions carried out in the step and the bases for any setpoints delineated by the step. Errors associated with instruments are plant specific, and therefore are not included in the TBD. Also, some values used in the TBD are intended to be approximate (e.g., establishing a 50°FΔT) and thus do not require error adjustment to accommodate instrument string inaccuracies. GEOG parameters that require error adjustment are identified.

Sequence:

Provides any step sequence requirements imposed by the TBD.

TBD Section References:

The applicable portions of Volume 3 are identified allowing the user to readily locate the full bases information. This acts as a link between volumes 1 and 3.

Volume 3, entitled Emergency Operating Procedures Technical Bases, provides the detailed technical bases for the TBD. Volume 3 provides a description of and philosophy behind symptom-oriented transient mitigation, the bases for treatment of symptoms and abnormal plant cooldown modes, and specific guidance for the operation of key systems and components. The bases is derived from the collective knowledge gained from plant operations (including actual transient data), conservative licensing analysis codes, and realistic plant modeling codes benchmarked to integral systems test data. The bases began with the Abnormal Transient Operating Guidelines (ATOG) and have been modified and expanded through extensive analyses and through feedback obtained from use of EOPs derived from ATOG. Volume 3 comprises the following:

Part I: Introduction, purpose, and scope description.

Part II: Description of the philosophy of the symptom approach to transient mitigation, the use of the RCS pressure/temperature relationship for symptom recognition and plant control, and the five control functions that affect the heat transfer process.

Part III: Guidance and bases for mitigating the symptoms of abnormal transients, steam generator tube ruptures, and inadequate core cooling. Guidance for plant cooldowns in other than the normal two loop forced circulation mode. Guidance for reactor building control.

Part IV: Guidance for the use of key systems and components in transient mitigation. Bases for the reactor vessel pressure/temperature limits.

Part V: Rules that apply throughout transient mitigation.

Part VI: References used in the development of the TBD.

Volume 4, entitled GEOG Implementation Guide, provides vendor and B&WOG expectations for Utility implementation of the guidance provided in the TBD, including verification and validation requirements, positions developed on key EOP issues, and what is expected when a plant EOP deviates from the TBD.

Volume 4 comprises the following:

Part I:	Introduction
Part II:	Vendor Implementation Philosophy and Expectations
Part III:	B&WOG OSC Positions on EOP Related Issues
Part IV:	Considerations On Error Correcting Values Used in the GEOG
Part V:	Deviations and Their Justification
Part VI:	Generic EOP Verification and Validation Guideline (GVVG)
Part VII:	TBD Change Control Process
Part VIII:	Verification and Validation of GEOG
Part IX:	History of NRC Interaction with B&WOG on ATOG and TBD Issues
Part X:	References

Part II

SYMPTOM APPROACH TO ABNORMAL TRANSIENT DIAGNOSIS AND MITIGATION

Chapter II.A

Philosophy of Symptom Approach

1.0 Introduction

This chapter describes the symptom approach, why the symptom approach should be used and what the symptoms are. The symptom approach avoids drawbacks inherent in the event oriented approach for transient diagnosis and mitigation.

The event oriented approach uses mitigating procedures which are tailored for each initiating event. Inherent complications with event oriented procedures surfaced in the aftermath of the March 1979 accident at the Three Mile Island Unit 2 Nuclear Plant. The complications are:

a) Writing a procedure to address every conceivable initiating event is impractical. In addition every possible initiating event cannot be defined; some will be overlooked. Consequently, for some events there will be no procedure.

b) Operators will have to try to follow more than one procedure simultaneously if multiple failures occur. Procedures may not be structured to facilitate simultaneous use.

c) The operator must immediately and correctly diagnose the initiating event. The type of event is not always immediately apparent, especially if multiple failures occur. Consequently, the operator may lose valuable time following wrong procedures. In addition, once the error is discovered the operator will need to transfer from the wrong procedure to the correct procedure. Immediate decisions will need to be made without the aid of a procedure as to which steps should be reversed and which should not when transferring to the new procedure.

A new type of procedure was implemented to avoid these complications. The procedure uses the symptom approach. This approach requires the operator to monitor directly observable symptoms of upsets in heat transfer from the core to the SG, then mitigate the abnormal transient by re-stabilizing the same or an alternate heat transfer process.

One fundamental axiom of this symptomatic approach is the use of the best available equipment to mitigate a transient regardless of the safety classification of that equipment. When abnormal conditions develop, the operator is directed to attempt regaining control of the control function (see Chapter II.C) in question by first using the system or equipment best suited for that purpose. If that fails, he is directed to the next system or equipment that can restore control, etc. This approach continues until either control is regained or all available equipment has failed. In the latter case, the operator would proceed to another mode to maintain core cooling with this loss of control function. For example, for a loss of main feedwater (SG inventory control function), if the operator cannot restore main feedwater, he will establish (or verify) emergency feedwater flow. If this system is also unavailable, he will attempt to feed the steam generators from any available source. If no source of feedwater is available, then secondary inventory control cannot be regained. The operator will proceed to HPI cooling to maintain decay heat removal.

This "defense in depth" philosophy ensures that the operator will utilize the best equipment available should the preferred equipment fail, regardless of the reason. Because of this philosophy, it is not necessary for the operator to know what failed or why.

2.0 Stable core heat removal is the basic goal of transient mitigation.

The normal method of core cooling is by transferring core heat to the RC, then transferring the heat from the RC to the secondary steam system via the SGs. If the rate of heat transfer from one medium to the next is equal, then stable heat transfer exists. When this process is disrupted a transient occurs.

The symptom approach uses an upset in heat transfer symptom as a symptom of an abnormal transient. Consequently, to mitigate an abnormal transient the operator must correct or circumvent the upset. Knowing the cause of the upset or whether it is caused by one failure or a combination of failures is not important to the ability to mitigate the abnormal transient.

Restoring and maintaining controlled core cooling is the top priority throughout these guidelines. Consideration is given to optimizing the use of methods and equipment, but whenever conflicts exist between optimum control methods and assured core cooling, the assurance of core cooling takes precedence.

The philosophy used for transient mitigation involves four basic steps:

- recognition of the symptom
- termination of the transient
- stabilization of core heat removal
- restoring equipment, systems, and plant configuration

In some instances the transient may not be completely terminated. In these instances, such as a tube rupture, the transient is minimized to allow controlled core cooling and RCS cooldown to the point where termination can occur.

Transient mitigation should not be unnecessarily prolonged. Therefore, the guidance generally assumes that mitigation actions are taken from the control room. While actions that can be readily accomplished in the plant are acceptable, termination of transients should not be inordinately delayed to allow localized actions. If another course of action is available from the control room it should be taken. If, for example, excessive heat transfer exists and attempts to reduce or terminate feedwater from the control room are unsuccessful using remote operated valves, then the pump(s) supplying the feedwater should be tripped rather than wait for local valve operation. Feedwater can be restored following the valve lineup or using another feedwater system. Obviously, this approach is situational dependent; pump trip may not be required for a relatively slow cooling transient where RCS pressure is under control and flooding of the SG is not imminent. These types of decisions are subjective and therefore require some degree of operator judgement.

3.0 Three symptoms of upsets in heat transfer are used

The three symptoms of upsets in heat transfer are:

a) loss of subcooling margin

b) inadequate primary to secondary heat transfer

c) excessive primary to secondary heat transfer

3.1 Loss of subcooling margin:

The core transfers heat to the RC. As long as the core is covered with RC, sufficient heat transfer from the core will occur to keep the core adequately cooled. As long as the RC is subcooled the core will be covered. Therefore, the operator should assume that if a sufficient margin to saturation does not exist, the core has a potential of not being adequately cooled. The operator should take appropriate actions to assure adequate core cooling, including restoring the margin to subcooling. (Refer to Chapter III.B, Loss of Subcooling Margin.)

3.2 Inadequate/excessive primary to secondary heat transfer.

If too little or too much heat is transferred to the SGs the heat transfer process is upset. The RC transfers heat to the secondary system via the SG. If not enough heat is transferred the RC will increase in temperature. If too much heat is transferred the RC will decrease in temperature. Therefore, if the operator detects uncontrolled heat-up or cooldown symptoms he should take the appropriate actions to stop the overheating or overcooling.

The corrective actions to counter the loss of subcooling margin, inadequate heat transfer and excessive heat transfer are designed so that the upset in heat transfer can be corrected independent of the initiating event. Consequently, the heat transfer process can be stabilized without correcting the failure or failures. Once the heat transfer process is stabilized core cooling is assured and time is available for identifying and correcting the failure.

The three symptoms have features (discussed in Chapter II.B) making them readily recognizable. Consequently, the operator should be able to quickly ascertain the upset and commence mitigating actions.

3.3 Priority of Symptoms

Treatment for a loss of SCM has the highest priority of the three symptoms of upsets in heat transfer because as long as the RCS remains subcooled, adequate core cooling is assured. Once core cooling is assured, the next concern is to control primary to secondary heat transfer. Therefore, treatment of a lack of primary to secondary heat transfer, along with its counterpart, excessive primary to secondary heat transfer are second priority symptoms.

4.0 Steam Generator Tube Rupture

A steam generator tube rupture (SGTR) is an event that the operator should identify and treat as a specific event in addition to treating the symptoms. An exception is made in treating the SGTR as an event in addition to upsets in heat transfer because the SGTR has unique indications allowing it to be easily identified and because by treating the SGTR also as an event, the operator can significantly reduce radiation release, improve core cooling and minimize waste water management problems. Consequently, this event is addressed separately in Chapter III.E.

Chapter II.B

P-T Relationship to Monitor Symptoms

1.0 Introduction

This chapter discusses how symptoms are monitored.

The main tool used to monitor symptoms of changes in primary to secondary heat transfer is the Pressure-Temperature (P-T) relationship as shown in Figure II.B-1. Changes in heat transfer are observed by monitoring variable pressure and temperature measurements. These pressure and temperature variables are:

a) Reactor Coolant Hot Leg Temperature (each loop),

b) Reactor Coolant Pressure,

c) Reactor Coolant Cold Leg Temperature (each leg),

d) Incore Thermocouple Temperature,

e) Steam Generator Pressure (each SG).

In addition, the relationship of these variable measurements to fixed limits associated with the variable pressure and temperature measurements are also monitored. These fixed limits are:

a) Saturation Line,

b) RC Subcooling Margin Limit,

c) Post-Trip Window.

By monitoring these variable parameters and limits, their relationship can be readily observed allowing a quick transient diagnosis.

Continual monitoring of the P-T variables provides a real time relationship of the variable measurements which demonstrates both the present plant conditions and the trend in plant conditions. Knowing the present plant conditions enables the operator to take actions applicable to the existing conditions. The trending information is valuable in diagnosing the transient, predicting what actions may need to be taken, determining how quickly they need to be taken, judging whether or not the mitigating actions are working, and determining when the plant has reached a stable condition.

2.0 Fixed P-T Relationship

2.1 Saturation Line

The saturation line indicates the pressure and temperature combination where water changes to steam and vice versa. This is applicable to both primary and secondary conditions.

2.2 Subcooling Margin Limit

The subcooling margin (SCM) limit presents pressure and temperature combinations which are more subcooled than the saturation line. The intent of this limit is to assure that the RC is subcooled. The extra subcooling (i.e., the area between the saturation line and the SCM limit) is chosen based on the ability to accurately measure the RC pressure and temperature (instrument errors) and for pressure and temperature variations from the point of measurement (e.g., the elevation head). If the SCM limit is violated, the assumption should be made that the RC is no longer subcooled even though it may be. This limit applies only to RC conditions.

2.3 Post-Trip Window

The post-trip window encloses an area of the P-T relationship where the RC pressure and temperature combination will normally stay after a trip. The minimum RC temperature and pressure boundaries of the window were compiled from a review of actual reactor trips and computer simulations. The normal post-trip cooling of the RC by the secondary system should not cause the RC pressure and temperature to go outside the post-trip window.

The maximum RC pressure is based on the pressurizer power operated relief valve (PORV) pressure setpoint. Following a reactor trip the RC pressure will not normally increase to the PORV setpoint. However, if it does rise to the PORV setpoint, the relief valve should prevent the RC pressure from exceeding its setpoint.

The upper temperature limit is based on the high temperature reactor trip setpoint and/or the SCM limit. A normal reactor trip will result in an overall decrease in RC temperature.

3.0 Variable P-T Relationship

The variable parameters are used to provide the following information.

3.1 Recognizing Abnormal Transient Conditions

During normal post-trip transient conditions during power operation, the primary to secondary heat transfer process is a stable process. The process is upset when the reactor trips, causing a transient condition as a normal transition occurs to a post trip stable heat transfer condition. This normal transition could mask a simultaneous abnormal transient. However, these conditions can be recognized during the post trip transient.

The shape of the RC P-T trace for a normal transient following reactor trip from power operation when the pre-trip T_{ave} is above post-trip T_{ave} is similar to the one shown in Figure II.B-1. The magnitude of the transient becomes smaller as the initial power level decreases. The dip of the curve is due to cooldown of the RCS to near T_{sat} of the SGs for the turbine bypass valve (TBV) setpoint. The cooldown results in coolant shrinkage, which results in a pressurizer outsurge and pressure reduction. After the RCS reaches a temperature slightly above T_{sat} of the SGs, the RCS will repressurize and stabilize due to the MU pumps partially refilling the pressurizer and due to energizing of the pressurizer heaters. Depending on prior power history, the low point of the dip will have different values, but the characteristic shape of the trace will remain the same when the reactor trips when the RC T_{ave} is greater than the post-trip T_{ave}.

If the transient is normal, the RC temperature vs. RC pressure relationship will stabilize at one of two locations inside the post-trip window depending on RCP status. When the RCPs are off T_{cold} will be essentially the same as the SG temperature but T_{hot} will be greater. The value of T_{hot} will depend on the amount of decay heat. When the RCPs are running, Thot and T_{cold} will stabilize within a few degrees of each other after trip and T_{cold} will be within a few degrees above the SG temperature.

In the secondary system, the steam pressure will initially rise to the TBV or MSSV setpoint and steam temperature will decrease to saturation temperature.

A P-T plot for a normal trip is shown in Figure II.B-1. Some parameter changes associated with a normal trip are as follows:

1) Hot and cold leg temperatures stabilize in 2-3 minutes.

2) RC pressure stabilizes in 5 to 6 minutes.

3) T_{cold} will be nearly equal to saturated steam temperature indicating that RC is transferring heat to the steam generators.

4) Steam pressure stabilizes in 2 to 3 minutes.

5) RC SCM increases.

3.1.1 Post-Trip Window

The post-trip window is an aid for determining if systems are operating correctly after a trip. If the RC temperature and pressure path goes outside the post trip window then an abnormal transient is probably occurring. The post trip window is not an absolute determinant as to whether or not an abnormal transient is occurring. However, if the pressure vs temperature plot goes outside the post-trip window the transient is likely abnormal and the operator should proceed with abnormal transient mitigation procedures.

Conversely, if the RC pressure and temperature plot remains inside this window or if the transient path goes outside this window slightly but returns, then the transient is likely going as expected and the core cooling with SG heat transfer is correct. The operator need only verify proper plant conditions exist to identify any abnormal transient which may be masked by the normal plant RC pressure and temperature behavior or which needs to be acted on before the RC pressure and temperature conditions go outside the post trip window. If the plant conditions are not as expected, the operator should take appropriate corrective actions. One such transient which combines both of these situations is the excessive MFW transient. Excessive MFW will cause an overcooling trend. However, this trend is masked by the post-trip RC cooling characteristics which initially seem to be normal. In addition, the excessive MFW can rapidly overfill the SGs requiring operator actions to prevent overfilling the SG or verifying automatic actions have occurred while the RC pressure and temperature relationship is still inside the post-trip window.

An abnormal transient may also be indicated by secondary system steam pressure and steam saturation temperature. Generally, if steam pressure falls below the saturation pressure corresponding to the lower temperature of the post-trip window after trip, a failure has occurred. The SG pressure should stabilize at the TBV setpoint.

3.2 Identifying Upsets in Heat Transfer

The P-T relationship is used to detect the three main symptoms of an upset in the heat transfer process. These symptoms are:

- Loss of Subcooling Margin,

- Lack of Adequate Primary to Secondary Heat Transfer, and

- Excessive Primary to Secondary Heat Transfer.

Loss of subcooling margin determines the status of the heat transfer medium (the RC) which is used to transfer the heat to the SGs and to remove heat from the core.

Lack of adequate primary to secondary heat transfer and excessive primary to secondary heat transfer are mutually exclusive, i.e., the RCS cannot be overcooled and overheated at the same time. However, lack of SCM can occur simultaneously with either of these.

3.2.1 Indications of a Loss of Subcooling Margin

The RCS P-T relationship will clearly indicate when a loss of subcooling margin (SCM) occurs (see Figure II.B-2). The SCM is lost when the RCS P-T relationship becomes less subcooled than the loss of SCM limit.

If a loss of SCM occurs without a concurrent indication of excessive or inadequate primary to secondary heat transfer, the P-T relationship will show a decrease in RC pressure with little or no change in RC temperature and secondary saturation temperature. This symptom would be caused by a loss of RC inventory or pressure control.

A loss of SCM can be concurrent with and caused by inadequate or excessive primary to secondary heat transfer. The secondary steam saturation temperature can be used as supporting information to determine what has caused the lack of SCM. If the cause was excessive heat transfer, then the RCS Tcold will have closely followed the secondary steam saturation temperature as it decreased. In the event of inadequate primary to secondary heat transfer, the SG and RCS will have become uncoupled with the secondary steam saturation temperature slowly decreasing and the RCS re-pressurizing and beginning to heat up.

Loss of SCM is the highest priority symptom and SCM is a major parameter used throughout the guidelines. Therefore, the availability of valid SCM indications is essential, and suitable redundancy in indications should be provided. As discussed in Chapter IV.D, T_{hot} RTD readings may not always be a valid indication of core outlet conditions. Only valid temperature indications should be used to determine SCM status. If, for example, the RCS is in single loop natural circulation then the T_{hot} RTD in the idle loop should not be used to determine SCM status.

3.2.2 Indication of Inadequate Primary to Secondary Heat Transfer

If only inadequate heat transfer occurs, the P-T relationship will show both the RC pressure and temperature increasing. The resulting swell will increase the pressurizer level causing the RC pressure to increase. The pressurizer spray will try to offset the pressure increase. However, the rate at which this equipment can reduce RC pressure is limited. Consequently, the faster the heatup the larger the pressure increase per degree of heatup. When the RC pressure becomes limited by the PORV or code safeties, the SCM will be lost as the RCS continues to heatup. A typical overheating trend is shown in Figure II.B-3.

The P-T relationship will depend on initial conditions. The possible RCS initial conditions during a loss of heat transfer are as follows:

A. RCS Subcooled with RCPs On

When a lack of heat transfer begins, the SG T_{sat} and RC temperature will begin to diverge with the RCS P-T increasing in temperature and pressure and the SG T_{sat} decreasing. The hot and cold leg RTDs along with incore T/C will begin to heatup. Indications of FW flow, SG level, and steam and FW system valve positions may be used to confirm a loss of heat transfer.

B. RCS Subcooled With RCPs Off

If natural circulation has been established before a loss of heat transfer occurs, then the secondary T_{sat} will almost coincide with the primary T_{cold}. T_{hot} is expected to be about 50F higher than T_{cold} within a few minutes after reactor trip. This delta T will decrease on the order of about 10F per each 1% decrease in decay heat. Once the lack of heat transfer occurs the incore T/C temperature indication will begin increasing causing a higher than expected core delta T between incore T/Cs and T_{cold}. Other control room indications of FW flow, SG level, and steam and FW system valve positions may also confirm the reason for a loss of natural circulation.

The best single indication of a loss of natural circulation flow when the RC is subcooled is a divergence developing between the incore T/C and T_{hot}. When the flow is lost, the incore T/C will begin a continual increase toward saturation. The rate will depend on the amount of decay heat. T_{hot} indications may also increase but can actually decrease and begin to converge with T_{cold}. In any case, T_{hot} will not increase as rapidly as the incore T/Cs and the two indications will diverge. Another indication of loss of natural circulation is a "decoupling" between T_{cold} and SG pressure (secondary T_{sat}). If T_{cold} ceases to follow SG pressure, then natural circulation flow has been lost.

C. RCS is Saturated

With the RCS saturated, the best indication of a loss of natural circulation flow or interruption of boiler condenser cooling is a trend of incore T/C temperature vs. RC pressure increasing away from the SG T_{sat} along the saturation curve. The divergence between T_{hot} and the incore T/Cs may not develop significantly. Heat transfer can also be lost due to the RCS P-T decreasing along the saturation curve below the SG P-T due to a LOCA.

3.2.3 Indication of Excessive Primary to Secondary Heat Transfer

If only excessive heat transfer occurs, the P-T relationship will show both the RC pressure and temperature decreasing. The resulting RC contraction will lower the pressurizer level causing the RC pressure to decrease. RC MU and pressurizer heaters will attempt to correct the RC pressure drop. However, the rate at which this equipment recovers RC pressure is limited. Consequently, the higher the cooling rate, the larger the pressure drop per degree of cooling. The RC will remain subcooled unless the overcooling empties the pressurizer. If the pressurizer and surge line empty, saturation will occur at the point in the RCS where the RC is at the highest temperature (see Chapter III.D for full explanation).

The P-T relationship is the quickest and most accurate means of determining that an overcooling is occurring. A typical overcooling trend is shown in Figure II.B-4. Immediately after reactor trip, T_{hot} and T_{cold} will converge and approach SG saturation temperature. This will occur if the RCPs are running. If the RCPs are not running and the RC is subcooled, T_{hot} and T_{cold} will not come together; rather, a temperature difference will develop across the core which is necessary for natural circulation of the RC. The primary T_{hot} and T_{cold} P-T relationship will continue to decrease in both pressure and temperature. The most positive indication that the transient that is occurring is an overcooling rather than a LOCA is the fact that the secondary T_{sat} will be decreasing rapidly. The primary T_{cold} will be following close behind SG temperature indicating that the primary and secondary are closely coupled in the overcooling.

The magnitude of the over-cooling will be determined by a combination of core decay heat level and the failure mechanism causing the overcooling. With an excessive overcooling the pressurizer and surge line may drain. If this occurs, the RC will saturate where it is the hottest. This will normally be in the upper RV head region with RCPs on; however, if the overcooling started during a single loop natural circulation cooldown, saturation could occur first in the idle loop hot leg (see Chapter III.D for full explanation). A bubble may then form where the RC fluid is the hottest, acting like a pressurizer. It is expected that this phenomenon will maintain SCM in the active hot legs and core outlet even if the pressurizer and surge line drain, especially with full HPI flow. The RC P-T relationship will continue to follow T_{sat}.

3.2.4 Symptom Recognition Other Than Post-trip

The post-trip window shown on the P-T diagram is useful for aiding symptom recognition from normal post-trip conditions. However, transients can occur during heatups, cooldowns, etc. when the RCS P-T conditions are not initially within the bounds of the post-trip window. Use of the P-T response, without the use of pre-defined bounds, will enable symptom recognition from all initial pressures and temperatures.

A loss of subcooling margin is easily discernible at any pressure and temperature whether using a digital subcooling readout or a P-T display.

A lack of or excessive heat transfer, however, may not be as obvious if the response on the P-T display is not used. A lack of adequate heat transfer will cause the RCS to reheat and repressurize; an excessive heat transfer will result in cooling and depressurization. These trends are fairly obvious on a P-T display.

There is a natural tendency to base procedure decisions on setpoints. Use of setpoints has advantages in that real-time decision-making is greatly simplified because subjectivity is removed from the process. The principal problem with using setpoints in transient recognition and mitigation is that they depend on the initial conditions. The parameter used, e.g., temperature, must begin above (or below, as appropriate) the setpoint yet be close enough to the setpoint to ensure timely transient recognition. This is not possible for a single setpoint value if the initial parameter reading can vary widely. The initial RCS conditions for transients covered by these guidelines range from full power pressure and temperature to decay heat removal system cut-in conditions.

Even if the initial conditions are defined tightly, e.g. only covering post-trip, such that setpoints could be used as "triggers" in the procedure, the procedure still has to define successful transient mitigation. The successful termination of a transient is essentially identified by termination of the trend. Thus, trend recognition is required anyway; it should also be used for transient recognition in order to address a wide range of initial conditions.

Another potential problem with setpoints is avoided by use of trend information. Process and instrument errors can prevent the parameter from reaching the setpoint even though the transient, which the setpoint was "designed" for, is in progress. A level instrument, for example, can "bottom out" on scale due to instrument and process errors. This problem can be minimized by careful selection of setpoints, considering all possible sources and magnitudes of instrument and process errors.

The guidelines assume that the user is adequately trained to recognize the loss of subcooling margin and the trends associated with a lack of adequate heat transfer or excessive heat transfer. No setpoints, other than a specified SCM value if constant, are used or advocated for symptom recognition. There are a few setpoints used in the mitigation of transients. The general practice of the guidelines is to tie all actions to observed plant conditions and responses to previous actions, regardless of initial conditions. The use of specific parameter values for decision points has been limited to cases where no other method was feasible.

Another aspect of dealing with transients initiating from other than post-trip conditions is the availability of equipment. Automatic system actuations may have been bypassed or otherwise unavailable. Core flood tank isolation valves may be closed. Abnormal system lineups may exist due to maintenance or surveillance. Procedures should not assume that all equipment and automatic actions are available. If, for example, the plant condition calls for HPI, then HPI should be started , not assumed to be on due to ES actuation.

3.2.5 Misdiagnosis

The potential for misdiagnosis leading to a wrong course of mitigating actions is essentially eliminated by use of the P-T symptoms. As stated earlier, a loss of subcooling margin is obvious. The P-T trends for lack of or excessive heat transfer are in opposite directions on a P-T display. The greater the severity of the transient, the more clearly the symptom is displayed.

A loss of subcooling has the highest priority. Even assuming that a heat transfer symptom misdiagnosis did occur, such that the actions taken exacerbated the transient and the transient leads to a loss of subcooling, the loss of subcooling actions will assure core cooling. The emphasis placed on SCM and the obvious nature of the indications do not support a failure to diagnose a loss of SCM.

3.3 Indication of Primary to Secondary Coupling

When primary to secondary coupling exists with either forced or natural circulation, T_{cold} will be about equal to the saturation temperature in the SGs and T_{hot} will be about equal to the incore T/Cs. If the RCPs are lost, T_{hot} will increase as necessary to develop the driving head required for flow (by developing a density difference between T_{hot} and T_{cold}). If the loss of RCPs occurs at a high enough RC pressure and decay heat, this may result in lifting the PORV even though a loss of primary to secondary heat transfer has not occurred. When RCPs are lost, the operator should verify that natural circulation is established.

The best indications that subcooled natural circulation has started are the coupling between T_{cold} and the SG pressure (saturation temperature), the relationship of T_{hot} and the incore T/Cs, and the temperature difference between T_{hot} and T_{cold}. The relationship of T_{cold} vs. steam pressure should remain a few degrees to the right of the saturation curve, the incore T/C temperature indication should track T_{hot} within approximately 10°F, and the DT between T_{hot} and T_{cold} should be stable. The Δ T between T_{hot} and T_{cold} is proportional to decay heat level; it is not expected to exceed 50°F with maximum decay heat. When steam pressure is changed, T_{cold} should follow but a time delay in T_{cold} response (on the order of a few minutes) can be expected due to low loop flow rates.

The best indication that saturated natural circulation has started, is coupling between T_{cold} and the SG pressure (saturated temperature). The relationship between T_{hot} and the incore T/Cs and the temperature difference between T_{hot} and T_{cold} are not good indications of saturated natural circulation flow.

The incore T/C temperature indication will track T_{hot} during saturated natural circulation flow. However, if the RC is saturated, T_{hot} will be similar to the incore T/C temperature indication even if natural circulation flow does not exist.

The temperature difference between T_{hot} and T_{cold} can vary from about 50°F to 0°F depending on how much of the core heat is transferred to the RC as latent heat of vaporization.

Natural circulation flow will regulate itself. That is, as the heat source (decay heat) decreases, the delta T (T_{hot} - T_{cold}) will decrease, and there will be less driving head available; therefore, flow will decrease.

If only one SG is operating during natural circulation, only T_{hot} in the operating loop will indicate core outlet temperature; T_{cold} on the operating SG will be approximately equal to T_{sat} in the operating SG; T_{cold} in the isolated SG may not be equal to T_{sat} in the isolated SG; it will probably be colder due to ambient losses and due to cooler injection water (seal injection, MU, HPI); (T_{hot} - T_{cold}) on the operating SG may be 10°F higher than the 50°F to 60°F Δ T expected with two operating SGs.

Another indication of coupling, whether the RC is saturated or subcooled, is the ability to feed and steam the SG while maintaining SG pressure. Heat transfer must exist to sustain SG pressure during steaming and during feeding through the EFW nozzles.

Figure II.B-1 NORMAL P-T TRACE FOLLOWING A REACTOR TRIP

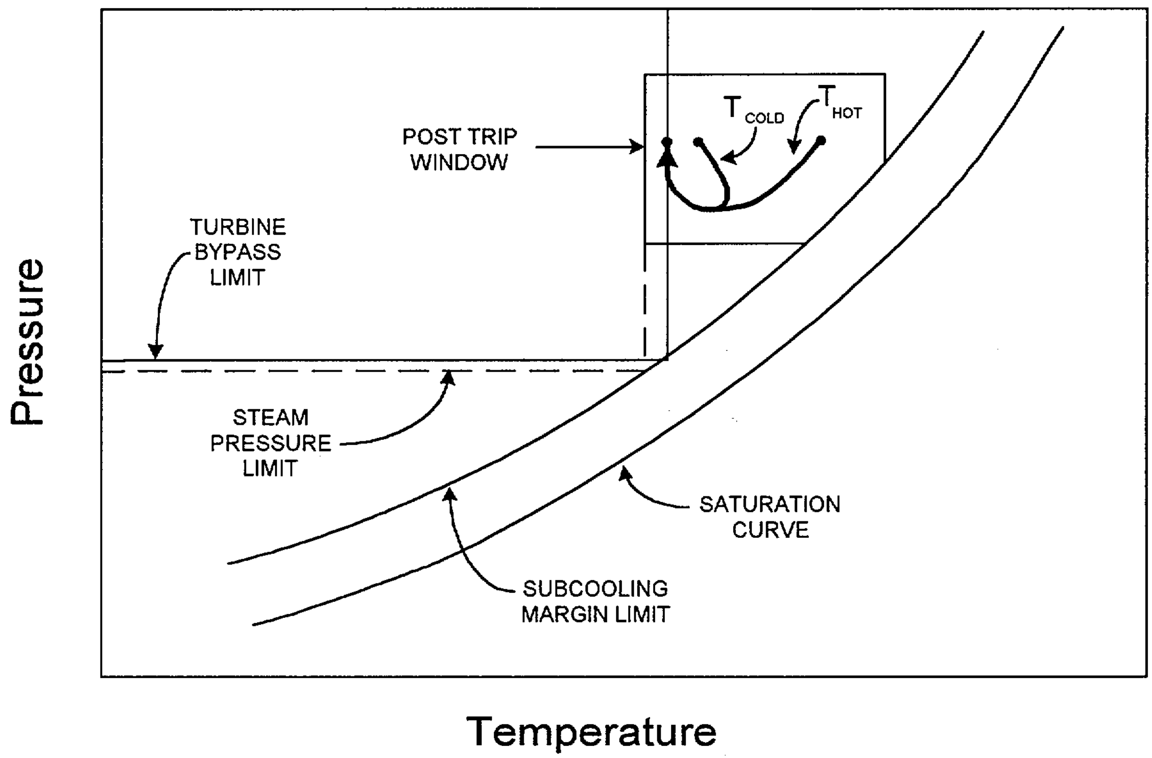


Figure II.B-2 INADEQUATE SUBCOOLING MARGIN

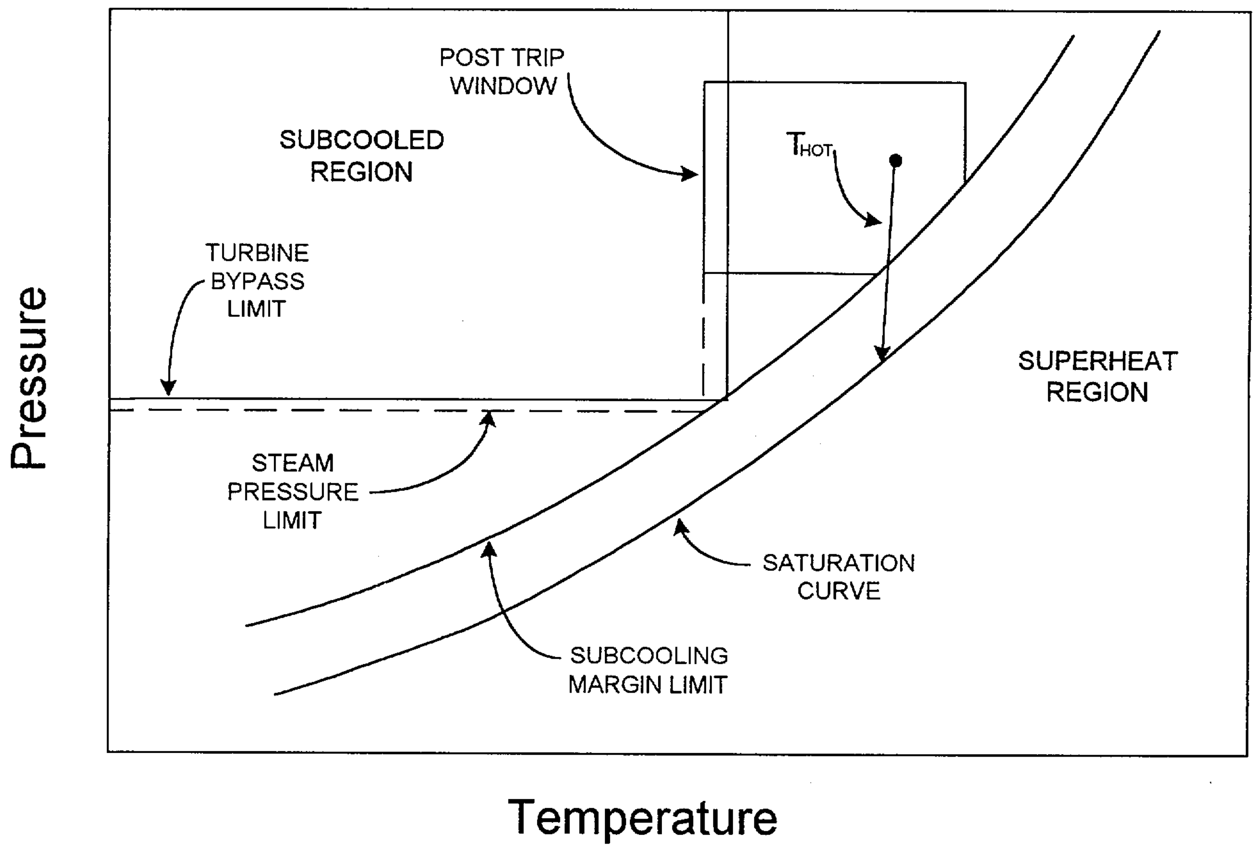


Figure II.B-3 TYPICAL OVERHEATING P-T TRACE

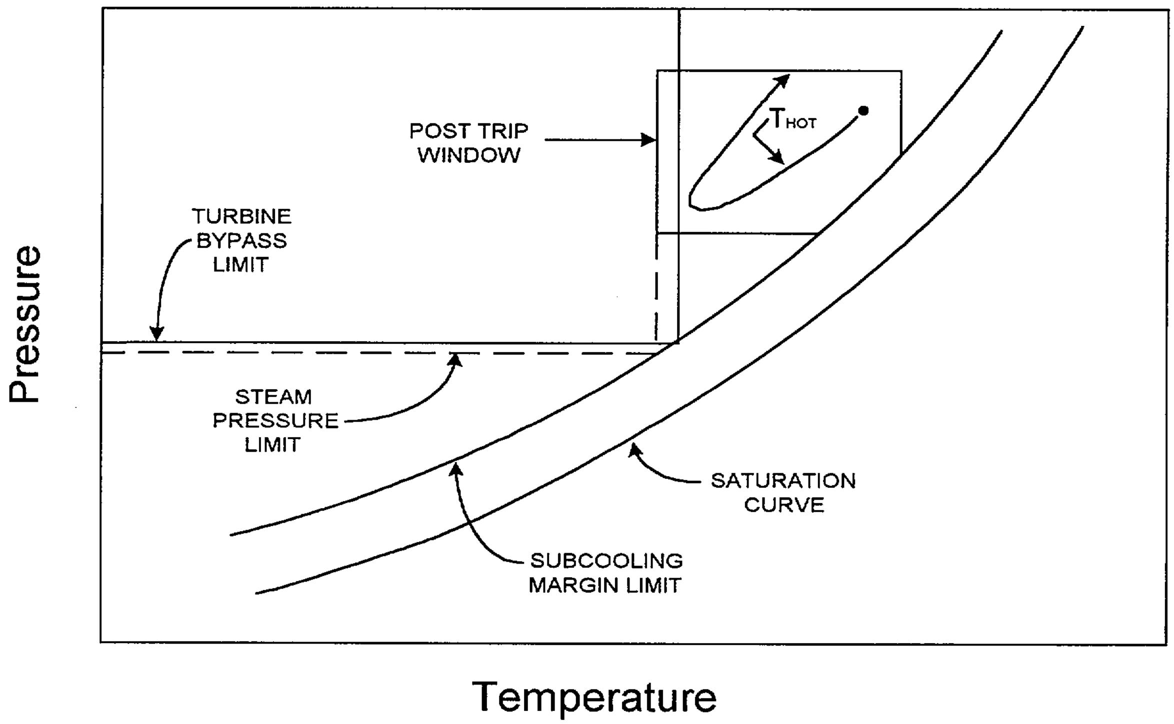
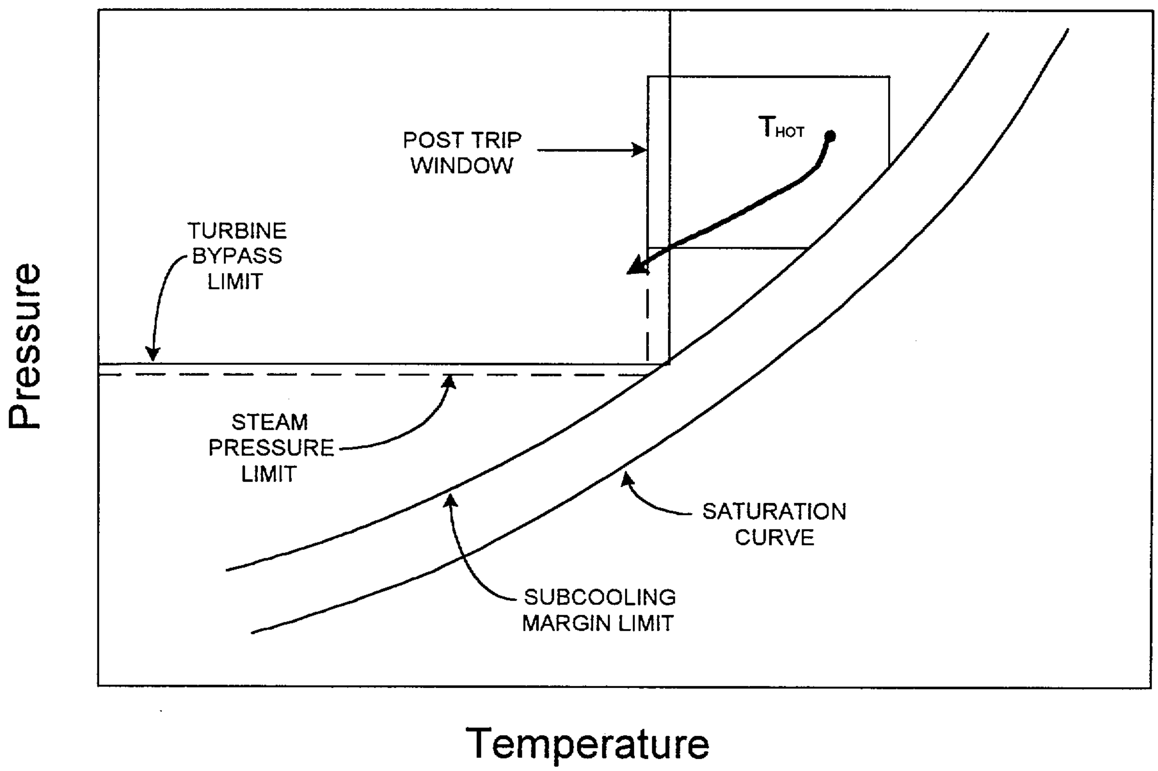


Figure II.B-4 TYPICAL OVERCOOLING P-T TRACE



Chapter II.C

Five Control Functions to Regulate Symptoms

1.0 Introduction

The heat transfer process is controlled by five control functions. This chapter describes the five control functions and how they affect the heat transfer process. The five control functions are:

a) Reactivity Control

b) Reactor Coolant Inventory Control

c) Reactor Coolant Pressure Control

d) Steam Generator Pressure Control

e) Steam Generator Inventory Control

1.1 Upsets in the Heat Transfer Process are Caused and Corrected By Changes in the Five Control Functions

The normal method of removing heat from the core is to transfer the core heat to the RC and then transfer the heat from the RC to the secondary system. Abnormal transients occur when this heat transfer process is upset. This heat transfer process is controlled by the five control functions.

Abnormal transients are caused when one or more of the control functions are out of control. The symptoms of abnormal heat transfer are used to determine which function or functions are out of control. Each of the control functions affect the heat transfer process in a specific way. When a failed control function is identified the operator can attempt to regain control of the function. If he can regain control he will be able to re-stabilize the normal heat transfer process. In the event the failure cannot be corrected, operating the remaining control functions in an off-normal mode may be required in order to compensate for the failed control function.

The failures may result in a loss of the normal method of heat transfer. The normal method relies on heat transfer to the SG for core heat removal. If SG heat transfer cannot be established a backup heat transfer process is available. This process consists of transferring core heat to the RC, then transferring the high enthalpy RC to the RB. The flow path to the RB can be any opening in the RCS but the opening has to be large enough to remove the core energy. Of course, this requires adding low enthalpy water to the RCS. This process is called HPI cooling and is discussed in Chapter IV.B.

A thorough understanding of how each of the five control functions affect the heat transfer process will:

A. Enable operators to manipulate equipment to regain heat transfer control without knowing exactly which equipment has failed. Different equipment may affect the same control function. It is of less importance which equipment is used and of more importance that the control function is being addressed. Consequently, proper heat transfer can be restored more quickly and accurately than if the operator had to identify a specific equipment failure.

B. Allow easier identification of what equipment has failed and, by doing so, isolate, remove from service, or repair the equipment.

C. Provide an understanding of the outcome of an action. The operator actions will have some consequence on the heat transfer process. Consequently, knowledge of heat transfer process will allow judgments to be made about the general effects of operator actions.

2.0 Details of How the Five Control Functions Influence Heat Transfer

The following discussion explains how each of the control functions influence the heat transfer process.

2.1 Reactivity Control

Reactivity control is normally automatic either by ICS rod control or by reactor trip. Reactor trip lowers the core heat output to the decay heat level. The operator must verify rod insertion and decreasing reactor power to ensure the reactivity control systems function properly. After the trip no more heat transfer control can be achieved by use of the rods; unless the rods did not insert. If after manual trip, reactor power is not decreasing (total failure to trip) the operator should perform additional breaker trips to attempt to de-energize the control rod drive mechanisms. If more than one rod remains stuck out or if there is any delay in tripping additional breakers, the operator should begin boration to achieve adequate shutdown margin.

Reactivity control also entails continued surveillance to ensure reactivity excursions and loss of adequate shutdown margin do not occur during transient termination and plant cooldowns. The addition of positive reactivity could occur due to dilution of the coolant or due to cooldown. Thus any activity potentially resulting in dilution or cooling should be suspended until sufficient boron is added to restore adequate shutdown margin.

One exception is the required rapid cooldown for the case of a loss of SCM without HPI. In this case, the cooldown must continue as directed; a significant return to power should not occur, and boron addition with HPI is not available.

An indicated increase in neutron flux can also occur due to voiding in the RV downcomer. This is not a reactivity addition, just an increase in neutron flux reaching the ex-core detectors. Voiding of this magnitude can only occur due to a LOCA or ICC conditions, both of which already require maximizing ECCS injection, which also maximizes boron addition. Thus, if there were any confusion as to whether this was a reactivity concern, the appropriate actions are already being taken.

2.2 Reactor Coolant Inventory Control

RC heat transfer and pressure can be affected by changes in the RC inventory (the volume of subcooled fluid in the reactor coolant system). The volume is affected by changes in mass and density of the RC.

The mass of RC can be varied by: LOCAs, changes in HPI or MU flow, RCP seal injection, seal return, and letdown.

Several ways also exist to vary the density of the reactor coolant. Changes in the rate of heat transfer from the RC to the SG can cause the RC to cooldown when the SGs remove too much heat (low steam pressure, too much FW) causing density to increase and thus RC volume to decrease; or the RC can heat up when the SGs don't remove enough heat (not enough FW) causing density to decrease and thus RC volume to increase.

Regardless of the cause, the changes in inventory in the RCS have two effects:

A. A loss of mass can affect the ability of the RC to transport heat from the core to SGs. If the RCPs are not running, steam can collect in the hot legs and possibly block natural circulation.

   If the volume of liquid RC continues to decrease and the core is covered mostly by steam, then the core will retain the heat and heat up. Fuel failures can result if this situation is not corrected. Conversely, if the core is kept covered it will be adequately cooled.

B. A change of volume of subcooled RC can affect the pressurizer level, limiting the ability of the pressurizer to provide pressure control of the RCS.

The operator has indications to determine if RC inventory is sufficient for core cooling. Pressurizer level is an accurate measure of RC inventory <u>only</u> when the rest of the RC is subcooled (except for a rare condition when free non-condensible gas may exist in the loops; this condition will likely exist only after fuel failures have occurred). This includes subcooling in the volume under the RV head and in the top of the hot leg pipes. These volumes could be saturated even though Thot, Tcold and the incore T/Cs indicate subcooled water temperatures. Another measure is the incore T/Cs; if these read subcooled or saturation temperature, then enough mass exists in the RV to cover and cool the core. The incore T/Cs cannot be used to indicate actual RC inventory. In addition to these indications, hot leg level (HLL) measurements, if available, can be used when no RCPs are running and the HPVs, if installed, are closed. RV head level (RVL) measurement, if available, can be used for checking inventory in the RV head. Restrictions may be imposed on the use of the level measurement instrumentation, e.g., all RCPs off. However, the conditions are plant dependent.

Reactor Coolant Inventory Trending systems (RCITS) have been installed on some plants to monitor the percent void fraction of the RCS when the RCPs are running. RCITS uses RCP current and RCS cold leg temperature (T_{cold}) to derive the percent RCS void fraction. Zero percent void fraction is predicted when the entire RCS, except the pressurizer, is subcooled and 100% void fraction is predicted when all the RC fluid has been converted to steam. RCPs are directed to be tripped on loss of SCM (before the RC reaches saturation where two phase fluid is possible and before void fraction is predicted to be greater than 0%).

Regarding use of RCITS during the mitigation of ICC conditions, a note of caution is prudent. The actual indicated % void fraction can vary depending on RC pressure and temperature. Therefore, RCITS readings should only be used as relative trending information versus absolute % void indications. RCITS could be used along with other indications (RVL, HLL, PZR level, SCM, and various RCS temperatures) to assess the effect of ICC mitigative actions (i.e., a decreasing trend in % void fraction for an improving RC inventory and an increasing trend for a degrading RC inventory) if RCPs are running (i.e., not tripped prior to entry into ICC).

2.3 Reactor Coolant Pressure Control

RC pressure control is required to keep the RC subcooled so that the coolant is in the best state to transfer heat from the core to the SGs. Usually, RCS pressure control is provided by the pressurizer. Use of pressurizer heaters and spray is the normal method of controlling RCS pressure when a steam and water interface exists in the pressurizer. The purpose of the heaters is to maintain the reactor coolant in a subcooled condition by maintaining RCS pressure greater than saturation pressure; the spray retards pressure increases to limit operation of the PORV and safety valves. Neither the heaters nor spray have enough capacity to prevent large abrupt pressure changes, but they can moderate small changes. As a backup to normal spray, auxiliary spray from HPI or LPI may be available. The pressurizer vent or PORV can also be used to reduce pressure.

RCS pressure control by the pressurizer can be lost or hindered in four ways:

A. Draining the Pressurizer

If the pressurizer level drops sufficiently to uncover the heaters, the heaters cannot provide pressure control because no water is available to be boiled by the heaters and the heater power will be terminated by the pressurizer low level heater interlock.

B. Filling the Pressurizer

Spray depressurizes the RC by condensing the steam in the pressurizer. If the pressurizer fills with water, the spray cannot be effective for depressurizing because the steam space is lost.

C. RCS Voids

The RCS pressure can decrease to the saturation pressure of the highest temperature in the system which could be the hot legs or the RV head region. If voids develop in one or more of these locations, they will hinder normal pressure control by the pressurizer.

D. Failure of Spray and/or Heaters

A failure of the spray or heaters in the pressurizer control system can also cause a loss of pressure control. If the spray fails open and cannot be closed, the system will depressurize. Depressurization may also occur if the heaters fail in the "off" mode. Failure of the spray in the "off" mode will limit the ability to depressurize. If the heaters fail "on", pressure increases will not occur because the spray will operate to provide a balance. However, if the spray is inoperable the heaters can cause the system to pressurize and cause coolant (steam) to be lost as long as liquid covers the heaters. When only steam covers the heaters they will no longer raise pressure. If the heaters fail "on" when they are uncovered, no liquid exists to cool them and they will burn out.

2.4 Steam Generator Pressure Control

Heat transfer from the RC to the SG goes to both the steam and water in the SG. After reactor trip, the steam and FW in the SG are saturated and changes of steam pressure will cause a direct change in the saturation temperature of the steam and water. When the

steam pressure is lowered, the heat transfer from the RC to the SG increases because the steam and water in the SG becomes a colder heat sink causing more heat to flow away from the reactor coolant. Two reasons combine to create the colder heat sink: first, the saturation temperature of the steam and water is reduced by lowering the steam pressure. Second, reducing the SG pressure causes the rate of boil-off to increase. The increased boil-off requires more FW flow to be added to maintain level. The FW inlet temperature is colder than the water already in the SG thus its addition contributes to the colder heat sink.

Steam pressure can be lowered in two ways:

A. By releasing steam faster than it is produced (opening condenser dump valves, steam line break, opening ADV, etc.)

B. By spraying cold EFW into the steam space causing more steam to be condensed than is being formed.

Conversely, steam pressure can be increased when below the main steam safety valve setpoint:

A. By releasing steam at a slower rate than it is produced (closing ADV's, condenser dump valves etc.).

B. By reducing the spray of cold EFW into the steam space causing less steam to be condensed than is being formed.

Steam pressure cannot increase above the MSSV setpoint because the safety valves will release steam at the same rate it is produced. Furthermore, several minutes after reactor trip, steam pressure will not increase above ADV or TBV pressure setpoints during automatic pressure control.

2.5 Steam Generator Inventory Control

The SG inventory is controlled to maintain a minimum inventory for a heat sink, to prevent overfilling the SG and for varying the effective elevation of the SG heat sink. Heat transfer from the RC is transmitted to both the steam and the water in the secondary side of the SGs. However, most of the heat transfer occurs just below the water steam interface (in the nucleate boiling region) where the heat is used to change the saturated water to steam.

The AFW enters near the top of the SG. This FW flow will increase heat transfer from the primary to the secondary side as the FW flow is heated and turned to steam. Since the EFW flow enters the top of the SG, the flow will have the effect of raising the SG thermal center higher in the SG. As the flow rate is decreased to zero the thermal center will decrease until it reaches the SG water level.

Consequently, the SG thermal center can be changed by changing the water level and by adding FW through the EFW nozzles. Refer to Chapter IV.C on controlling FW.

FW is cooler than the SG temperature. Therefore, if FW is added to the SG faster than the primary system can heat up the FW, the overall temperature of the SG will decrease. This will result in the RC temperature decreasing if primary to secondary heat transfer exists.

EFW can have a proportionately larger cooling effect on RC for the same flow rate than MFW because of two effects:

a) it is colder (T_{inlet} EFW is less), and

b) it has a steam pressure reduction effect that MFW does not have because it is injected into the steam space at the top of the tube bundle. (This pressure reduction effect will also occur to a lesser extent with MFW if it is added through the EFW nozzles.)

The operator should ensure that the rate of FW addition is controlled properly to maintain the SG inventory. Level measurements in the SG (after trip) give a good indication of the SG inventory for control.

2.6 Defense in Depth

The TBD utilizes the concept of defense in depth in transient mitigation. To restore control of a given function, the best-suited equipment or system is used, regardless of whether or not it is safety grade equipment. If the best equipment or system is not available, for whatever reason, then the best backup is used. If the best backup is also not available, then another backup is used. This continues until control of the function is regained or all backups are found to be unavailable. In most instances, complete loss of control of a function, due to loss of all backups, can still be compensated through control of another function.

Defense in depth (i.e., backup) exists for each control function and between functions as follows (not necessarily in order of priority; priority may differ dependent on plant status):

The defense in depth for reactivity control consists of:

- automatic trip by the RPS
- automatic trip by the DSS
- manual trip from the console
- manual breaker trip (may be several options)
- manual rod insertion

- boration from the BWST
- boration from the chemical addition system

The defense in depth for RC inventory control consists of:

Mass injection:

- HPI
- LPI
- MU
- CFT
- seal injection
- auxiliary spray

Mass relief:

- PSV
- PORV
- Letdown
- HPVs

The defense in depth for RC pressure control consists of:

- pressurizer heaters
- pressurizer spray
- auxiliary spray
- PORV
- PSVs
- HPVs

- MU/HPI combined with PORV or letdown when solid

The defense in depth for SG pressure control consists of:

- TBVs
- ADVs
- MSSVs
- drains when SG is solid or near solid

The defense in depth for SG inventory control consists of:

- MFW
- EFW*
- CBPs
- other plant specific feedwater sources*
- drains

*Note: The TBD uses EFW (emergency feedwater) as the designation for the safety grade feedwater system. Some plants designate the safety grade feedwater system as AFW (auxiliary feedwater) or may have a separate AFW system.

Defense in depth also exists between control functions. For example, HPI cooling (controlling RC inventory and pressure) is a backup to a loss of either SG pressure or inventory control. A loss of control of an RCS relief path (e.g., failed open PSV) is compensated by control of RCS injection. A loss of ability to provide RCS injection is compensated by SG inventory and pressure control.

Chapter II.D

Use of the TBD

1.0 Introduction

The TBD provides generic guidance for the B&WOG plants on abnormal transient recognition and mitigation. The TBD satisfies the vendor guidance portion of the requirements of Item I.C.1 of Supplement 1 to NUREG 0737. Each Utility is required to have a Procedures Generation Package that controls generation, verification and validation of emergency operating procedures. Part of this package is guidance and bases to support the procedures. The TBD represents the NSSS vendor's input to the guidance and bases.

The vendor guidance and bases are contained in Volume 3 of the TBD. Each Utility should have traceable records documenting the disposition of the guidance in the control of their procedure network. The disposition may include not incorporating any part of the guidance as long as appropriate justification is provided. The guidance in the TBD is based in large part on extensive realistic computer analyses, but the generic nature may not optimally suit a given plant. However, some of the TBD guidance, most notably the initial actions for loss of adequate subcooling margin and the guidance on HPI cooling, are derived from an extensive analytical base and are essential in providing adequate core cooling. Justification for deviation from any of the guidance must ensure that all of the relevant bases have been considered. Unless specifically stated otherwise, normal plant limits apply.

Volume 1 of the TBD provides an example of how the guidance in Volume 3 might be structured in a procedural guideline format. Volume 1 is useful in demonstrating how the individual pieces can be meshed to achieve a cohesive transient mitigation tool. However, Volume 1 should not be used as a direct EOP model. In addition, all of the guidance options available in Volume 3 are not included in Volume 1. Volume 1 contains only the "vendor-preferred" path, which is discussed in more detail in Section 3.0 of this chapter.

Volume 2 of the TBD is a bases summary for Volume 1. The purpose of Volume 2 is to allow correlation of Volume 1 steps to the guidance and bases in Volume 3. Volume 2 also provides a quick refresher of the bases for Volume 1 steps.

Volume 4 of the TBD provides guidance for Utility implementation of the TBD in plant EOPs. It includes guidance on implementing the GEOG, including the provision of adequate justification for deviations from the GEOG. It also includes guidance for performing verification and validation of both plant EOPs and of GEOG changes. It also documents some positions on EOP-related issues, such as the assessment of mission doses in accomplishing EOP steps in the plant.

2.0 Basic Mitigation Philosophy

The mitigation philosophy of the TBD is based on true symptom-oriented guidance, with core cooling as the highest priority. This necessarily results in conservative actions for some specific event scenarios, but ensures core cooling for all scenarios. There is some latitude in the prescribed actions based on the severity of the transient. For example, a relatively slow overcooling transient affords time to perform sequential valve control and isolation actions and the sequence can be stopped when the overcooling is terminated. A more rapid overcooling transient may require the more drastic actions of tripping of feed pumps and/or total SG isolation.

2.1 Basic Steps to Transient Mitigation

There are four basic steps to the TBD guidance structure for transient mitigation: symptom recognition, transient termination, stabilization, and restoration of as normal a plant configuration as possible.

2.1.1 Symptom Recognition

The TBD guidance relies on constant surveillance for symptoms anytime the reactor is shutdown except during DHRS operation. This requires that the specific parameters used to define the symptoms must be relevant for any initial plant condition between power operation and DHRS operation. Chapter II.B provides guidance on symptom definition and recognition.

The TBD intent is to implement the appropriate mitigative actions <u>when</u> the symptom arises once the reactor is verified as shutdown. As an example, if a loss of subcooling margin occurs following a reactor trip, it is expected that HPI will be started without waiting to complete the status verification checks. In all probability, power for the HPI pumps will be available and does not need to be verified before attempting to start the pumps. The TBD philosophy does not rely on root cause determination in order to mitigate the transient and this is essentially true for equipment availability as well. The optimum equipment and methods are used first and if not available, regardless of reason, backup equipment and methods are used. It is assumed that means exist to readily identify invalid instrumentation due to a loss of an instrument bus.

There is a definite priority in the treatment of symptoms should more than one exist simultaneously. Assuring subcooling margin is essential to ensuring adequate core cooling and <u>always</u> takes priority over lack of and excessive primary to secondary heat transfer. Excessive or inadequate heat transfer are mutually exclusive (the overall effect on the RCS determines the upset, not overcooling in one SG while drying out the other) and therefore are of equal priority. All three symptoms take priority over tube rupture since a) core cooling takes precedence and b) the existence of a symptom exacerbates the mitigation of a tube rupture.

2.1.2 Termination

The intent of the TBD is to terminate the transient as quickly as possible. Once the transient is terminated, time exists to establish stable, controlled core cooling. Some transients, such as an unisolable LOCA or tube rupture, may not be "terminated" until on decay heat removal system operation. Successful mitigation of these transients involves gaining control of the forced cooldown and depressurization and transition to decay heat removal system operation.

The termination or control of a transient involves varying degrees of actions based on the severity of the transient. A rapid overcooling transient with imminent SG overfill would require tripping of feed pumps while a slower transient allows attempts at manual valve controls. A total loss of heat transfer with no available feedwater source would require a transition to HPI cooling (MU/HPI at Davis Besse) while a source of feedwater allows more time to restore heat transfer since boiler-condenser cooling is ultimately available as a backup.

The TBD utilizes observed plant conditions, to the extent possible, to govern the decision points in transient mitigation. Reliance on time-based decisions is minimized.

The TBD assumes that actions are performed in the control room whenever possible. While local actions are performed when needed, the termination of a transient should not be inordinately delayed to allow localized attempts if an alternative action is available from the control room. For example, repeated attempts at local manual valve manipulation to terminate excessive feedwater flow should not preclude tripping of the feed pumps from the control room.

2.1.3 Stabilization

Stabilization, or establishment of controlled core cooling, should be accomplished as soon as the transient is terminated or brought under control. The degree of stabilization is dependent on the success and method of transient termination. Stabilization can range from essentially normal plant control following successful restoration of feedwater to throttling of HPI to maintain RCS pressure within limits while in HPI cooling. The purpose of stabilization is to verify or establish controlled core heat removal and ensure no other symptoms exist.

2.1.4 Restoration

Restoration of systems, equipment and normal plant configuration can be performed in a controlled, orderly manner following the establishment of stable core cooling. Actions to restore heat transfer to an idle SG, for example, can include precautionary steps to eliminate or account for loop voiding. Ideally, the plant should be returned to a normal forced circulation mode prior to performing a cooldown, but this is not always possible or required.

2.2 GEOG Structure

The Generic Emergency Operating Guidelines (GEOG, Vol. 1 of the TBD) was developed to demonstrate one method of combining the bases of Volume 3 into a cohesive mitigation strategy. Part I of Volume 1 describes some of the characteristics of the GEOG. The basic philosophy on each section of the GEOG is as follows.

2.2.1 EOP Entry/Vital System Status Verification

The basic intent of this section is to verify reactor/main turbine shutdown and proper operation of key systems. There are three basic entry conditions to the GEOG and the use of this section differs slightly based on the entry condition.

The "normal" entry condition occurs following a reactor trip or condition requiring trip. In this use, the intent is to perform the immediate actions to ensure reactor shutdown and turbine trip followed by the verifications. A normal trip would result in successful completion of the verifications and a stable plant. If, however, a symptom were to appear during the performance of the verifications, then the intent is to begin symptom mitigation immediately. The remainder of the verifications can be performed in parallel or following plant stabilization. The only exception is the initial verifications of reactor shutdown. If an ATWS event (failure to trip) occurs, no further mitigation actions are taken until the reactor is successfully shutdown. This includes not applying any of the Rules until the reactor is verified as shutdown. All of the supporting transient analyses are based on a shutdown reactor.

The second possible entry condition is the occurrence of a tube rupture while at power. In this use, entry is directly to the tube rupture mitigation section (III.E) where guidance is provided for shutting down the reactor while preventing lift of the MSSVs. The manual reactor trip and turbine trip and verification of reactor shutdown are performed following the reactor shutdown, with the remainder of the verifications performed in parallel with or following stabilization of the tube rupture transient.

The third possible entry condition is the occurrence of a symptom or tube rupture while the reactor is shutdown in any mode above decay heat removal operation. In this use, entry is still made to III.A, to ensure reactor shutdown. This accounts for conditions where some rods may have been "cocked" for trippable reactivity. Once the reactor is verified shutdown, then the appropriate guideline section for the symptom or tube rupture is entered, with the verifications (starting after the steps for reactor and turbine shutdown) performed in parallel or following symptom mitigation (or tube rupture stabilization).

Except for verification of reactor shutdown and securing steam flow to the turbine, all of the status checks are secondary to transient mitigation. While it may be beneficial to know the status of some systems going into the mitigation actions, it should be unnecessary. Any delay in treating a symptom, even if only a few minutes, could have a significant impact on successful transient mitigation. The mitigation actions must be able to accommodate equipment unavailability, and the equipment may become unavailable after being verified as operable. In some cases, the transient may be directly related to equipment checked in the verifications; however, the symptom approach is based on successful mitigation without knowing the cause. If a user determines that the verifications should be performed as soon as possible, even in the presence of a transient, then provisions should be made to allow parallel performance of the verifications and the appropriate mitigation actions. Appropriate verification checks should also be re-verified if status changes occur following completion of this section, e.g., an automatic protection system actuation occurs.

2.2.2 Loss of Subcooling Margin

A loss of subcooling margin (LSCM) is the highest priority of the symptoms. LSCM signifies a direct threat to core cooling; as long as SCM exists, the core is covered and cooled, even though it may be heating up due to a lack of primary to secondary heat transfer. LSCM can result from several conditions, but it should always be assumed that a LOCA exists until proven otherwise; thus the immediate actions noted below should always be performed on LSCM.

The importance of LSCM is also reflected in that it is the only symptom with a rule governing certain immediate actions. These actions are to 1) trip all RCPs, 2) initiate ES injection systems, and 3) initiate EFW and 4) verify or balance HPI flow rates.

The RCP trip is required for certain size breaks. Since the break size can not be determined, RCP trip is required for all breaks that result in a loss of SCM. The TBD philosophy assumes a break exists anytime SCM is lost, and therefore an RCP trip is required immediately on LSCM. Analyses have been performed to demonstrate that up to ten minutes may be available to accomplish the RCP trip following LSCM. However, ten minutes assumes full flow from at least two HPI pumps; if at least two HPI pumps are not on at full flow, then much less time is available and this time could be spent verifying HPI flows such that the time allowed for RCP trip could expire before the need is recognized. The consequences of failing to perform the RCP trip in time involve mandatory continued pump operation without SCM or adequate NPSH. If RCP operation can not be maintained and RCPs fail while the RCS has a high void fraction, then core uncovery can result. The consequences of tripping the RCPs when the critical size break does not exist are much less severe. In addition, key operator actions should not be time-based but rather plant-condition based. Therefore, the RCP trip should be accomplished as soon as LSCM occurs. The only exception is on RCP restart where SCM could be temporarily lost due to the collapse of a loop void. In this case, the RCP(s) should be tripped if SCM is not regained within two minutes.

The initiation and verification of ES injection system flows (and MU flows at Davis Besse when RC pressure >1650 psig) is necessary to compensate for the reduced primary inventory regardless of the cause. Full injection system flows must be maintained as long as SCM does not exist. However, these flows must also be carefully controlled once SCM is restored. The RCS can be re-pressurized fairly rapidly, especially if the cause of the LSCM is corrected (e.g., isolated break). Verification of full injection system flows while SCM does not exist <u>assures</u> adequate core cooling. ICC conditions will not occur with full injection flows except for a brief period during some LOCAs. Thus the status of injection flows is the single most important indication regarding a "trend" to ICC conditions. Once injection flows are verified, close monitoring of the flows must continue to ensure core cooling and to prevent overpressurization following restoration of SCM.

In addition to the immediate actions covered by the rule, establishing SG levels at the LSCM setpoint, or establishing the minimum EFW flow rate or SG fill rate, is important for certain break sizes and degraded HPI conditions to ensure adequate core heat removal. There is no feasible method to determine break size or location sufficiently to determine that the raised SG levels are not required. Therefore, it <u>must</u> be assumed that the SG levels are required and that the minimum EFW flow rate or SG fill rate is required until the levels are reached. Obtaining the LSCM level can result in cooling of the SGs during periods of no heat transfer, e.g., if the hot legs are sufficiently voided to prevent loop flow. This has been accommodated to an extent by specifying the minimum required flow or fill rates. However, these minimum rates are required even if significant SG cooling results. Mitigation of transients that can lead to the need for the high SG levels is far more important than preventing excessive cooling of the SGs. Excessive SG cooling should only occur if no heat transfer exists thus indicating that the need for the high levels is real, since voiding of the hot legs is a precursor to boiler-condenser cooling.

Another important aspect of LSCM mitigation covers the inability to initiate injection system flows. This could occur, for example, due to a sustained station blackout (SBO) with leakage through the RCP seals. The approach used is to cool the RCS as rapidly as possible using the SGs while sufficient RC remains for core cooling. Boiler-condenser cooling will be established long before core uncovery and the ability to cool and depressurize the RCS in boiler-condenser cooling has been demonstrated by analyses. The objectives are to reduce the leak rate and to obtain core flood tank injection to compensate for the primary system leakage before the core is uncovered. The SGs are then used to continue the cooldown and depressurization to enable LPI flow, if the LPI system is available, and to further reduce the leak rate.

2.2.3 Lack of Heat Transfer

The basic mitigation philosophy for a lack of primary to secondary heat transfer (LHT) is to reduce the heat input to the RCS while taking actions to restore feedwater and heat transfer. If heat transfer cannot be restored before reaching specified plant conditions, then core cooling is provided by HPI cooling.

The plant conditions requiring the initiation of HPI cooling differ depending on feedwater status. HPI cooling can be delayed longer if feedwater is available because the ability to cool using boiler-condenser cooling is available as a backup. HPI cooling is still initiated with feedwater available if SCM is lost because a) full HPI flow is required on loss of SCM and b) if heat transfer could not be restored with feedwater available while adequate SCM existed, then restoration after loss of SCM (other than boiler-condenser cooling) is not likely. If feedwater does not become available, then HPI cooling must be initiated sooner.

If neither feedwater nor HPI are available, then actions must continue to restore one of these capabilities. Unless the RCS is already at low pressures and temperatures where LPI or DHR can be initiated, there are no other cooling mechanisms.

The most important aspect of mitigation of LHT is that HPI cooling must be manually established when required. Delaying the initiation of HPI cooling beyond the specified plant conditions reduces the margin available to accommodate subsequent failures and still provide adequate core cooling. The use of margins is discussed in section 4.0 of this chapter.

2.2.4 Excessive Heat Transfer

The basic philosophy for mitigation of excessive heat transfer (EHT) is to terminate the cooldown (or at least reduce the rate of cooldown) and then restore controlled heat removal. While the actions to terminate the transient are graduated based on severity and success of previous actions, termination may require isolation of both SGs. Isolation of both SGs, if necessary to terminate the excessive heat transfer, is acceptable since the RCS cooldown transient has provided additional margin for responding to a subsequent LHT in the highly unlikely event that neither SG can be restored to operation. In addition, HPI cooling is still available as a backup.

The guidelines are based on mitigation of an uncontrolled cooldown. While any undesired cooldown is technically an EHT, small steam leaks that do not result in exceeding the Technical Specification cooldown rate nor prevent SG level and RC pressure control can be treated as "forced cooldowns" if the leak(s) cannot be isolated and the only other alternative would be SG dryout and establishing HPI cooling. For example, a weeping MSSV on the only available SG, causing a cooldown rate of 30F/hr would not warrant HPI cooling. In addition, a given steam leak size will result in lower cooldown rates as the plant cools down.

Any undesired cooldown should be terminated as soon as possible, within the framework described above. However, the emphasis on gaining control increases as pressurized thermal shock criteria are approached (see Chapter IV.G).

2.2.5 Steam Generator Tube Rupture

The mitigation philosophy for steam generator tube rupture (SGTR) differs considerably from traditional FSAR treatment. Historically, SGTRs were "terminated" by isolation of the affected SG as early as possible. There are several problems, however, with the traditional approach. First, the licensing design basis SGTR scenario essentially ended with the SG isolation. SG isolation does not stop the tube leak flow; the continued leakage can cause problems during the subsequent single loop cooldown. Second, the single loop cooldown, especially if in natural circulation, greatly increases the time required to obtain conditions for decay heat removal system operation and introduces complications such as idle loop voiding and tube-to-shell ΔT concerns. Finally, the TBD must address mitigation of multiple tube ruptures in one or both SGs whereas the FSAR scenario involved the double-ended rupture of a single tube in one SG.

Obviously, early SG isolation is not recommended for SGTRs in both SGs. This would require transition to HPI cooling at relatively high RCS temperature and pressure and decay heat level. An early transition to HPI cooling increases the possibility of lifting MSSVs on a full SG which can result in a failed-open path for release of reactor coolant. Therefore, the guidelines for SGTR mitigation required a new approach.

The approach used in the TBD is to achieve a reasonable balance between optimum plant control over a wide range of possible scenerios and minimizing off-site releases. This entails steaming the affected SG(s) as long as necessary during the cooldown. Steaming both SGs as long as possible, even if only one SG has a tube rupture, would allow a faster cooldown time to DHRS operation and minimize the "window" for other failures to occur. Continued steaming also minimizes the stresses on the SGs and avoids complications due to idle loop conditions, especially when natural circulation is required. A two-loop natural circulation cooldown can be completed in approximately 20 hours, depending on ADV capacity, while a single loop NC cooldown can take as much as five days. In order to establish a reasonable balance with minimizing off-site releases real-time consideration is given to the ability to complete the cooldown on one SG, including the impact on the available BWST inventory.

Extensive off-site dose calculations have been performed to assess the consequences of continued steaming when necessary, and these calculations verified that, for even fairly conservative values of failed fuel, the dose consequences are not significant. The guideline-imposed limit for the peak integrated dose at the site boundary has been established at 1.5R thyroid, roughly equivalent to 10CFR20 limits for unrestricted areas. The SG is isolated if this limit is approached. This limit applies for all SGTR scenarios except one, including scenarios beyond the design basis tube rupture, yet is much less than the traditional FSAR or SRP limit based on a fraction of 10CFR100 (usually 10% or 30R thyroid). The one exception to the 1.5R thyroid limit occurs when the only alternative is to initiate HPI cooling. In this case, continued steaming is allowed to prevent uncontrolled release of reactor coolant through an MSSV. The actual dose consequences are so small that the guideline limit should still allow completion of a natural circulation cooldown, where the steam release is to the atmosphere, with typical failed fuel percentages and not exceed design bases limits.

Two other considerations are imposed by the guidelines for continued steaming of the affected SG(s): prevention of SG overfill and assurance of adequate BWST inventory in the event HPI cooling is required. The SG overfill limit was used in developing the dose limits, by assuming leak rates that would reach the overfill limit first, such that the user need not determine tube leak rates to implement the limits. This greatly simplifies the decision making process in mitigating tube ruptures since accurate leak rate determination is difficult in real time.

2.2.6 Inadequate Core Cooling

Inadequate core cooling (ICC) occurs when the core begins to uncover, resulting in superheated core outlet temperatures. This can only occur briefly during some design basis LOCAs or if mitigating actions for LSCM or LHT are totally unsuccessful in establishing feedwater and/or HPI/LPI flows. Thus the basic strategy for mitigating ICC conditions is to restore one or more feedwater and/or injection systems.

The ICC guidelines are grouped into actions based on the severity of the transient and cover initial core uncovery up to the potential onset of fuel damage. Guidance for actions following the potential onset of core damage are provided in the plant-specific SAGs The intent of the ICC guidelines is to restore core cooling before core damage occurs.

The ICC guideline grouping comprises four regions, with Region 1 being a return to saturated or subcooled conditions. Regions 2and 3 cover increasing severity based on the measured core exit superheat using the incore thermocouples. Region 2 actions are essentially the same actions performed for LSCM for two reasons: a) the LSCM actions, if successful, will restore adequate core cooling and b) inadvertent entry into the ICC guidelines, for example due to instrument error, will not result in inappropriate actions.

Region 3 involves additional actions to vent the RCS high points to remove non-condensibles, depressurize the RCS, and depressurize the SGs to provide stronger heat sinks. The severe accident region involves a transition to the severe accident guidelines.

A very important aspect of the ICC guidelines is that actions performed in one region are not reversed if the core cools to a lesser region. The reason is that the action may have been responsible for restoring core cooling. However, if the core does cool to a less severe region, actions for the more severe region, that had not yet been accomplished, should not be performed.

The only positive indication of ICC is the incore thermocouple temperature. Any time that adequate SCM does not exist, the incore thermocouples must be carefully monitored to ensure timely detection of ICC conditions. In addition, the ICC guidelines must be implemented whenever the incore thermocouples indicate superheat; this superheat indication must not be superceded by indications of any RCS level instrument that might imply the core is adequately covered. Instrument errors can result in a level indication on scale when none exists.

2.2.7 Cooldown Sections

Guidelines for cooling the RCS down to DHRS or long-term LPI operation in various configurations are provided in Part IV of Volume 1. Normally, if conditions permit, the plant would be aligned in as normal a mode as possible before a cooldown is performed. This is not always possible therefore the various cooldown modes are covered. The intended use of the cooldown guidelines is discussed in Part I of Volume 1. Cooldown to DHRS with a SGTR is covered in Section III.E of Volume 1.

2.2.8 Rules

The rules in Volume 1 provide control or mitigation actions that always apply throughout the guidelines. The philosophy behind the use of rules is to emphasize important guideline actions thus providing greater assurance the actions will be performed whenever they are required. Use of rules also eliminates the need to repeatedly state the actions in the guideline wherever they might be appropriate. This allows streamlining of the guidelines and protects against the possible misinterpretation that the actions were not required because they were inadvertently left out of an appropriate location.

Rules should be limited in number and complexity in order to be effective. Exceptions may apply, but are limited. Numerous exceptions increase the complexity and undermine the rule-based response desired. The five rules provided were chosen based on their universal applicability, minimal exceptions, and the importance of the actions.

2.3 Coverage of Specific Issues

The symptom-oriented guidelines of the TBD are designed to facilitate transient mitigation without necessitating identification of the cause of the transient or the specific scenario. The intent is to provide workable guidance for the "unforeseen" event. However, requirements have been imposed on the guidelines to provide coverage of specific scenarios. These requirements stem from generic, industry-wide sources such as NUREG0737 and vendor-specific sources such as the ATOG SER. Where possible, the specific scenario is covered by the symptom treatment but occasionally some event-specific treatment is required.

Coverage of a specific scenario, to satisfy an imposed requirement, by symptom treatment may not be obvious when reading the guidelines. The purpose of this section is to identify specific issues covered by the guidelines that may or may not be obvious. It is expected that, over the life of the guidelines, new issues will emerge requiring guideline coverage.

2.3.1 Multiple Failures

A traditional design requirement for safety-related systems and components involved the ability to accomplish the safety function in spite of a random single active failure. This concept also applied to assumptions used in demonstrating the ability to handle design basis events, and therefore was somewhat implicit in the procedures for those events. One of the more significant realizations from the TMI-2 accident was that multiple, unrelated failures can occur. Thus, NUREG-0737 required that guidelines for emergency procedure development consider multiple failures.

Multiple failures in general are covered by the TBD's use of defense in depth. The TBD utilizes all available equipment, regardless of grade, in order of effectiveness. Another traditional design assumption is that all non-safety grade equipment is unavailable during a transient. While conservative from a design aspect, this assumption is non-conservative from a real-time transient mitigation perspective if the non-safety equipment is, in fact, available. The availability of additional equipment, such as the main feedwater system, provides an extra layer in the defense in depth.

Defense in depth is also utilized in the method of mitigation. As an example, main feedwater provides a system, or equipment, level of backup for the function of feeding the SGs. HPI provides a method backup for the failure of all feedwater systems for the ultimate function of providing core cooling.

A specific multiple failure scenario required by the ATOG SER is treatment of multiple tube ruptures in one or both SGs. Tube ruptures are treated as an event due to their unique identification and control criteria, thus treatment of multiple tube ruptures is obvious in the guidelines. The philosophy of this treatment is discussed in section 2.2.5 of this chapter and in Chapter III.E of Volume 3.

2.3.2 Station Blackout and LOCA Without HPI

Utility coverage for station blackout (SBO) is required by 10CFR50.63 and TBD guidance for SBO is required by the ATOG SER. Equipment operation considerations during an SBO are specifically addressed in Chapter IV.H of Volume 3. The coping strategy for control of the NSSS during an SBO, however, is contained within the symptom guidelines and may not be as obvious.

The major factor affecting the ability (and duration) to cope with an SBO is the possibility of RCS leakage occurring while no means of injection exists to makeup for this leakage. The most likely leak location is the RCP seals since seal cooling and injection may also be lost during an SBO. (NOTE: the N9000 seals have been tested over 8 hours of simulated SBO conditions with seal leakage maintained at less than two gpm). If a plant has an alternate AC source (AAC) or a dedicated AC-independent injection capability (e.g., diesel- driven pump) then the TBD coping strategy may not be applicable. The ATOG SER also required guidance for a LOCA with no HPI available. Both scenarios are essentially the same, differing only in magnitude, thus they are treated together in the symptom-oriented guidance.

If an SBO occurs, the guidelines cover verification of natural circulation (inherent in verification of controlled heat transfer) and references Utility-specific procedures for coverage of such items as battery conservation, restoration of power, etc. Natural circulation is maintained (no intentional cooldown) unless SCM is lost. SCM could eventually be lost if seal leakage occurs and no makeup is available.

A LOCA without HPI can also result in a loss of SCM. If SCM is lost and HPI(MU) is not available, whether due to a LOCA or an extended SBO with seal leakage, then a saturated cooldown is performed. Initially the cooldown may be by saturated NC but may eventually evolve to boiler-condenser cooling (BCC). BCC is very effective at cooling and depressurizing the RCS. The intent is to cool and depressurize the RCS sufficiently to obtain CFT injection. Once CFT injection is obtained, then the cooldown should continue to obtain full CFT injection and LPI flow, if available. LPI flow, if available, should allow restoration of SCM and transition of one LPI train to DHRS operation.

This coping strategy has been verified by SBO analysis to provide adequate core cooling for greater than four hours using the NUMARC 87-00 assumed seal leak rates of 25 gpm/ pump with an additional 11 gpm RCS leakage. No B&WOG plant should have a required coping duration longer than four hours.

2.3.3 Loss of Feedwater Without HPI

The ATOG SER also required guideline coverage for a total loss of feedwater (LOFW) with no HPI available. This scenario was analyzed to determine if any credible actions, such as early RCS depressurization, were available for successful mitigation. The conclusion of this analysis was that, for any appreciable decay heat level at normal RC pressure and temperature, successful mitigation requires the restoration of adequate feedwater or HPI flow. Lower decay heat levels, initial RC temperature and initial RC pressure provide more time for restoration of feedwater or HPI. The guidelines cover continuous attempts to restore either method of core cooling, including after the onset of ICC conditions should the transient progress that far.

2.3.4 Anticipated Transients Without Scram (ATWS)

The ATOG SER required that the guidelines be revised following the completion of ATWS rulemaking. The ATWS rule requires implementation of diverse scram systems (DSS) and a system to automatically trip the turbine and initiate emergency feedwater if an ATWS occurs with a loss of main feedwater. The guidelines acknowledge the existence of these functions and cover verification when necessary. In addition, the guidelines retained possible actions for performing diverse manual scrams.

2.3.5 Pressurized Thermal Shock (PTS)

All of the B&WOG plants' reactor vessels satisfy the screening criteria for RTNDT per 10CFR50.61 such that the risk from PTS events is acceptable within the framework of SECY 82-465 (using B&WOG specific probabilistic evaluations). However, should a rapid vessel cooling occur, it is prudent to limit the pressure stresses. The PTS operational guidance in the TBD is based on evaluations of two basic types of vessel cooling events: injection of cold BWST water (events such as LOCA, HPI cooling, etc.) and rapid RCS cooldown (events such as steam line breaks, SG overfeed, etc.).

The guidelines include actions to terminate overcooling events as soon as possible, but the pressure stresses should be limited both during and following such events. Some events, such as a LOCA, will not be terminated until on long-term cooling; it is still important to limit the pressure stresses for the duration of the event.

3.0 Guideline Options and Deviations

There are several areas of guideline coverage where more than one option is provided for control or transient mitigation. These are not necessarily all conceivable options or acceptable methods that could be used, just all of the methods considered by the guidelines. Wherever options exist in the TBD, there is a so-called "vendor-preferred" path identified. For reasons stated in the appropriate guidance in Volume 3, the guideline writers consider one path preferential to the other options.

The construction of the GEOG (Volume 1) used the vendor-preferred paths and does not use the other options. The use of a single option was done to streamline the GEOG.

The TBD users are not limited to the vendor-preferred paths or to the other options covered by the TBD. However, the TBD users should consider the bases behind the TBD options and only deviate from the TBD guidance with suitable justification. The TBD users also provide input for consideration of revisions to the TBD. It is expected that a user deviating from the TBD guidance would provide input on the alternate method used such that, if appropriate, all TBD users could benefit through a TBD revision to cover the new method.

Use of a TBD-covered option, though not the vendor-preferred path, is not considered a deviation from the guidelines. However, the user-specific reasoning for preferring another option may be cause for reevaluating the vendor choice.

4.0 Application of Analyses Results

The guidance provided by the TBD is based largely on analyses of transients and candidate mitigating actions. Most of the analyses are performed using realistic codes and modeling while some analyses used more conservative licensing codes and models. All of the analytical results are evaluated by systems engineers for application to the guidelines. The application of the results are then reviewed by the analysts who performed the analyses to ensure proper interpretation and use in the guidelines.

Analytical results are often applied directly to the guidelines, for example the specified minimum emergency feedwater flow rates during a loss of SCM. However, there are times when the analyzed margins are modified when applied to the guidelines. This is done primarily to provide additional margin to allow for subsequent failures or complications not specifically covered by the analyses. Basically, the guidelines do not allow intentionally taking the plant to analyzed limits if more conservative or effective mitigation methods are available.

HPI cooling requirements provide some examples of these added margins. Analyses have shown that plants with high head HPI pumps can successfully cool the core using the flow available from only one HPI pump against the code safeties. However, the guidelines require maintaining the PORV open if flow from only one HPI pump is obtained, i.e., the options for PORV cycling are not allowed with only one HPI pump. The reasons behind this further restriction imposed by the guidelines are:

a. The time required to match high decay heat using the flow from one HPI pump is considerably longer than with two pumps. Maintaining the PORV open results in a higher integrated flow from the one pump and higher collapsed liquid levels in the RCS throughout the transient.

b. The collapsed liquid level reached a low of approximately one foot above the core in the analysis. The higher integrated flow with the PORV open results in a higher collapsed liquid level.

c. Maintaining the PORV open prevents repeated challenges to the code safeties and minimizes the possibility of a failed-open code safety.

d. Attempts to restore feedwater and an additional HPI pump will continue. In the interim, the running HPI pump is the sole source of core cooling; maximizing the flowrate from the one pump provides the most margin, and thus time, should the running pump fail.

The MU/HPI cooling criteria for Davis Besse contains similar added margin. Analyses for Davis Besse demonstrated that two high pressure makeup pumps provide adequate core cooling if initiated at a temperature of ~645°F using both makeup lines, suction from the BWST, and discharging against the code safeties. However, the TBD requires that, with two makeup pumps in operation, the PORV be opened no later than 600°F and the HPI pumps be started in piggyback operation. The reasons behind the TBD criteria are:

a. While the analysis demonstrated adequate core cooling, the RC temperature and pressure remained high for an extended period of time. This prevents use of the HPI pumps should one of the makeup pumps fail. One piggybacked makeup pump may provide adequate core cooling if the PORV is maintained open but there is no margin left for additional failures or degradations in equipment performance.

b. The value of 600°F was chosen based on saturation pressure. If the RCS is saturated at 600°F (due to opening the PORV) then the RC pressure is below the piggybacked shutoff head of the HPI pumps. The RC pressure may subsequently increase due to continued heatup, but will not exceed the HPI shutoff head unless the heatup exceeds ~623°F (assuming the RCS reached saturation). It is possible that full flow from two piggybacked MU pumps and two piggybacked HPI pumps will match decay heat and begin to cool the RCS down before reaching 623°F. This would prevent relying on just the makeup pumps and provides additional margin should subsequent failures occur. The use of 600°F also provides some time to restore feedwater before requiring MU/HPI cooling.

The TBD criteria for RCP trip on loss of SCM is another example of added margin as discussed in section 2.2.2 of this chapter. The users of the TBD must realize that engineering application of analyses results can lead to more stringent guideline criteria.

Thus, user knowledge of analyses results should <u>not</u> be used to modify the criteria without first verifying the complete bases for the criteria.

Part III

DIAGNOSIS AND MITIGATION

Chapter III.A

General Approach Overview/Entry Conditions

1.0 INTRODUCTION

1.1 Purpose

This chapter provides a recommended overall approach to diagnosis and mitigation of transients. The entry conditions are identified and a logical flowpath from entry conditions to stable plant conditions is provided for the scope of these technical bases.

The flowpath includes immediate actions, verification that certain vital equipment is available and checking for symptoms of upsets in heat transfer and SGTR (see Chapter II.A section 3.0 & 4.0).

This flowpath should be completed in as expeditious a fashion as possible. During the execution of this flowpath, the plant operators should continuously check for symptoms of upsets in heat transfer and SGTR. If a symptom is identified and the immediate actions have successfully been completed, then the operator should treat the symptom immediately while completing the flowpath as quickly as possible.

1.2 Concerns and Objectives

1.2.1 Concerns

Several concerns exist which must be addressed during the mitigation of abnormal transients and in obtaining stable post-trip conditions. These concerns include the following:

A. Anticipated Transient Without Scram (ATWS)

ATWS could occur due to a failure of the RPS to initiate a reactor trip signal upon one of the reactor trip parameters reaching its trip limit or the control and safety rods failing to insert once the RPS trip signal is given. A Diverse Scram System (DSS) is provided, independent of the RPS, to minimize the potential for an ATWS event. However, the operator must recognize and react to any of the reactor trip parameters that exceeds its limit but does not cause a reactor trip.

B. Steam Generator Tube Rupture (SGTR)

A SGTR is a particular type LOCA which requires special handling to ensure that an unisolable steam leak does not occur which would increase the offsite radiation release. If an SGTR is verified while the reactor is not shutdown, a controlled reactor shutdown should be initiated to prevent lifting of the MSSVs by direct entry into III.E. Any time an MSSV lifts, it has the potential for failing open (or failing to reseat completely) resulting in an uncontrolled radioactive release to the environment. This can be prevented by reducing the reactor power to a low enough level (within the capacity of the TBV) such that the secondary side pressure will not spike to the point of lifting any MSSVs when the reactor is tripped.

C. Automatic Action Failure

Several automatic actions are required to place the plant in a controlled post-trip stable condition. These actions include main turbine stop valve shut, all site loads transferred as necessary to maintain electrical power, MFW flow running back to establish low SG level, and other automatic systems which may have been actuated post-trip.

D. Loss of Offsite Power (LOOP)

During a loss of all offsite power, it is necessary to rely completely upon the emergency power supply which has limited capacity. This results in a loss of RCPs requiring natural circulation of RC to be established as well as the loss of other equipment that is normally used after a reactor trip.

E. Upsets in Heat Transfer Symptoms

It is necessary to check for upsets in heat transfer following a reactor trip since a reactor trip creates a perturbation in heat transfer.

F. Loss of Instrumentation and Control Power

The operator must verify the operability of certain power supplies to assure important plant parameters can be monitored and power is available to important control devices. These devices include pumps, valves, etc., which are needed to safely control the plant and mitigate abnormal transients.

G. Station Blackout

A station blackout involves the loss of all AC power except the AC power provided by battery-backed inverters. A station blackout poses more concerns than just a Loss of Offsite Power due to the potential for additional losses of normal plant equipment and the loss of some emergency equipment. Of particular importance is the loss of RCS makeup and seal injection capability coupled with the potential that some RCS leakage could occur during the event. In addition, all core cooling capability may become vested in the steam driven EFW pump(s), therefore failure of this pump(s) could lead to ICC (some plants have more than one steam driven pump). Some plants may have a qualified alternate AC power source which will alleviate many of the station blackout specific concerns. An alternate AC power source is a power source which is separate from the automatic emergency AC sources and is capable of supplying power to safe shutdown equipment. Some plants may also be equipped with dedicated systems such as a backup seal injection which may help reduce the impact of a station blackout on the plant. Chapter IV.H "Equipment Operation During A SBO" includes additional discussion and bases for actions associated with a SBO.

1.2.2 Objectives

The objective of the diagnosis and mitigation of transients is to address the above concerns in a manner applicable to as broad a number of conditions as practical while minimizing the impact of misdiagnosis.

Treatment of a symptom is the priority action within these guidelines. Entry into the EOPs, from other than a tube rupture while critical, is always to complete the immediate actions to ensure reactor and turbine shutdown, and then to immediately treat the symptom. If, for example, the symptom of lack of adequate primary to secondary heat transfer occurs during a heat up, then entry into the EOP should still occur at the EOP entry. This ensures any rods cocked for trippable reactivity are in fact tripped. Any subsequent EOP instructions, based upon verification guidance of Chapter III.A, should be performed in parallel or after symptom treatment. Sufficient interface needs to be included in plant procedures or training to direct entry into the EOPs at the appropriate point .

References to other plant procedures to perform actions should be minimized and should be done in parallel with the EOP. Once the EOP has been entered, exit from the EOP should not occur until either the transient has been terminated and stable plant conditions have been achieved or the transient is being controlled sufficiently for transfer to a cooldown procedure (e.g., a LOCA cooldown).

Actions that are not appropriate due to plant status may be bypassed if entry into the EOPs is from other than a post reactor trip situation (e.g., during heatup or cooldown). TBD guidance delineates initiation/actuation or operation of necessary equipment/systems rather than just verification that these equipment/systems are operating. For this reason, EOP instructions based upon TBD guidance will perform all necessary appropriate actions (when required) consistent with plant status upon entry into the EOP.

2.0 DIAGNOSIS AND MITIGATION

The flowchart of Figure III.A-1 should be used in conjunction with the following discussion. The numbered subsections of Section 2.0, correspond to the upper numbers in the blocks on Figure III.A-1.

2.1 Entry Conditions

2.1.1 Conditions Exist Requiring a Reactor Trip

The emergency procedures must be used by the operator anytime a condition exists that requires a reactor trip. This includes the case where an automatic reactor trip has occurred or the case where conditions exist for reactor trip but the reactor trip has not occurred.

In the event of an ATWS, the operators should take those actions necessary to de-energize the control rod banks (safety and regulating) or make other rapid negative reactivity insertions to the reactor such as emergency boration.

2.1.2 Reactor Shutdown Required for SGTR

In the event of a SGTR occurring while at power, a forced shutdown will be required. Guidance for performing a forced shutdown for a SGTR is provided in Chapter III.E.

2.1.3 Upsets in Heat Transfer

Anytime a symptom of an upset in heat transfer or tube rupture occurs while the reactor is shutdown above decay heat operation (e.g., during heatup or cooldown operations), the appropriate action for that symptom should be taken once the immediate actions have been successfully completed. If <u>any</u> VSSV steps are appropriate, the VSSV steps should be performed within the symptom treatment (for example, treatment of excessive heat transfer may include verification of a secondary plant protection system actuation) <u>or</u> in parallel with the treatment or following the successful mitigation of the symptom.

2.2 Vital System Status Verification (VSSV)

VSSV pertains to certain systems and components that if aligned properly will enhance expeditious transient mitigation. The systematic check and any subsequent realignment of these systems and components may result in early detection of the transient initiator and/or failure. Checks for adequate shutdown margin, and initial FW response should be made early because of their potential impact on post-trip response if they do not occur properly. Checks on other systems and components are less time dependent, but all VSSV checks can be performed in the order that best suits the Utility.

If during this VSSV phase of transient mitigation, an upset in heat transfer or SGTR symptom occurs, the operator should treat the symptom(s) immediately. That is: TREAT ANY SYMPTOM WHEN IT ARISES; DO NOT WAIT TO COMPLETE VSSV! In general the VSSV phase should be completed as quickly as is reasonable in order to gain the greatest advantage during transient treatment. If, however, a symptom arises during VSSV, treat the symptom, if possible, in parallel with VSSV or treat the symptom and complete VSSV as soon as possible at a later time.

2.2.1 Reactivity Controlled ? (Detailed discussion Section 3.1)

Proper actuation of the RPS or DSS should be verified. If a failure to trip (ATWS) occurs, other available means of de-energizing the CRDMs should be used. If reactor power is still not decreasing to decay heat levels, then the operator should attempt to maintain MFW to the SG while manually shutting down the reactor. If Main Feedwater is not available, then turbine trip and the existence of emergency feedwater flow should be verified. The reactor is shutdown by borating the RCS. Rod insertion should be accomplished by manually tripping the reactor and tripping the breakers to remove power from the control rod drives. Shutdown of the reactor should be achieved before taking additional mitigating actions.
If reactor power is decreasing to decay heat levels but all of the safety or control rods have not fallen into the core, the operator should begin borating as necessary to achieve an acceptable shutdown margin.

2.2.2 Secondary Inventory and Pressure Controlled? (Detailed discussion Section 3.2)

It is necessary for the reactor operator to ensure that both steam flow and FW flow are controlled after reactor shutdown or trip to match reactor decay heat load. Ensuring that turbine stop valves have closed and FW runback has occurred are two of the more important actions which the operator must verify. This includes starting a FW source if necessary. If applicable, the operator should also verify that the appropriate automatic actions have occurred any time the automatic steam line break and EFW control system has been actuated.

2.2.3 Primary Inventory and Pressure Controlled? (Detailed discussion Section 3.3)

The operator should verify that MU and letdown are properly controlled. He should also verify that all automatic actions have occurred if the emergency safeguard system has been actuated (e.g., HPI initiated). If RCS inventory makeup is not available, then the RCS should not be cooled down as long as SCM is maintained.

2.2.4 Plant Electrical Power Controlled?

The operator should verify that plant electrical power is being properly controlled. This includes verifying that a) the output breakers have tripped, b) instrument power is on (in the event that a loss of instrument power, ICS and or NNI has occurred, it is desirable to restore it as soon as possible. However, this is a secondary concern and it should not be necessary for transient mitigation. Until instrument power is restored it will be necessary for the operator to manually stabilize and control the plant using known valid instrumentation and controls while attempting to restore instrument power as quickly as possible), and c) ensure that plant electrical loads are being properly maintained. In the event of a loss of offsite power (LOOP), the operator must ensure that the emergency power supply has been started and that essential power is being supplied. Offsite power should be restored as quickly as possible.

If a station blackout exists, that is, offsite power cannot be restored and emergency power is not available, then actions should be taken in order to adequately cope with the station blackout. The indications of a station blackout, (i.e. loss of normal lighting and all other AC loads except inverter- powered instrumentation), should be easily recognized by operators and readily verifiable by buss voltage indications. The following actions for a station blackout should be carried out even if power is expected to be restored in a short period of time:

a. Start alternate AC power sources, if available.

b. Attempt to restore both emergency AC power and offsite power.

c. Immediately reduce or prevent potential RCS inventory losses. (see section 3.4.B)

d. Verify that the steam driven emergency feedwater pump has started and is supplying both steam generators. Also, proper SG levels and pressures need to be maintained.

e. Perform other plant specific actions which have been predetermined such as shedding of unnecessary DC loads.

2.2.5 Plant Instrument Air Being Controlled?

Plant instrument air supplies should be verified as operable and available. These supplies provide certain plant readouts and control functions. It is necessary to ascertain the status of this equipment and take any necessary action, if required, to assure its availability. Such actions include loading compressors on the emergency power supply, unisolating automatic valves that may have closed due to low pressures, starting engine operated equipment, etc.

2.3 Symptoms of Upsets in Heat Transfer Exist ?

If a lack of subcooling margin exists, the operator must take appropriate actions as detailed in Chapter III.B. If a lack of heat transfer exists, the operator must take appropriate actions as detailed in Chapter III.C. If excessive heat transfer exists, the operator must take appropriate actions as detailed in Chapter III.D.

2.4 SGTR ?

This separate check for SGTR covers cases where the SGTR causes or is the result of a reactor trip or upset in heat transfer. An SGTR can be recognized by steam line radiation monitors, condenser air ejector monitors, SG level increases, mismatches in FW flow, as well as secondary system chemistry. Concurrent LOCA symptoms of decreasing RCS pressure, inventory, pressurizer level, and increased makeup flow. will provide confirmation that a SGTR has occurred. However, the LOCA symptoms of increasing reactor building radiation, pressure and temperature may not be present. Refer to Chapter III.E for details on how to recognize and treat a SGTR.

2.5 Verify Stable Plant Conditions

Verification of stable plant conditions includes checks for any problems which have occurred but may not have shown up as upsets in heat transfer symptoms (e.g., small steam leak or RCS leak). A plant cooldown or preparation to restart is at the discretion of the station management. The operator should begin a continuous monitoring of heat transfer and take appropriate action should any of the symptoms of upsets in heat transfer appear.

3.0 TECHNICAL BASES FOR DIAGNOSIS AND MITIGATION

The flowchart of Figure III.A-1 should be used in conjunction with the following discussion. The numbered subsections of Section 3.0 correspond to the bottom numbers in the blocks on Figure III.A-1.

3.1 Reactivity Controlled ?

The reactor must be immediately shutdown. This step provides an acceptable reactor shutdown margin. It determines whether or not an ATWS or a stuck rod has occurred and then directs the operator to take the appropriate action.

The bases for the action is as follows:

A. Reactor Power Not Decreasing To Decay Heat Levels

In this situation, reactor power has not decreased to expected decay heat levels normally associated with post trip conditions. For this reason, the normal power conversion system of MFW in conjunction with the main turbine should remain in operation. This will maintain the primary to secondary heat balance, thus preventing RCS over-pressurization.

In the event the main turbine trips and reactor power still has not decreased to levels normally associated with decay heat, then attempts should be made to maintain operation of the MFW system. This is because the reactor would be producing more heat than the EFW system can remove. Steam produced during such a situation would be relieved through the steam dump valves and/or the MSSVs. Use of MFW in combination with steam dump valves and MSSVs will provide balanced heat flow from the RCS to the SGs. However, RCS pressure is expected to rise, initially, as SG pressure increases to the MSSV(s) setpoint. Depending upon conditions, this RCS pressure rise may be significant requiring operation of pressurizer spray and/or the PORV to prevent actuation of the pressurizer code safety valves.

If reactor power is not decreasing to decay heat levels, then the reactor has not been shut down. Such a situation requires a failure of all or most of the control and safety rods to insert into the reactor core. If RPS and DSS fail to trip the reactor, then the operator should immediately attempt to shut down the reactor by the alternate methods available including RCS boration. Boric acid addition to the RCS can be initiated quickly from the control room. The method chosen (i.e., boric acid source and flowpath) should be, if possible, the one that provides the maximum boric acid addition rate for the plant and system conditions that exist. However, negative reactivity addition using boron can be a relatively slow process and therefore should only be used if there is a delay in achieving a trip of the rods. The operator should take action to try to trip the rods into the core. This includes actions such as manually tripping the reactor and, if breakers are available in the control room that can interrupt power to the control rod drives tripping these breakers. If the rods have still failed to trip into the reactor, the operator should open other breakers that would remove power from the CRDM, including breakers outside the MCR if necessary. Once the control and safety rods are successfully tripped into the core, or sufficient boric acid has been added to provide an adequate shutdown margin, the reactor will be shut down.

The priority action at this point is the shutdown of the reactor. This should be achieved prior to taking additional mitigating actions because post-trip transient mitigation, from this point forward, is based on the assumption that the reactor is shutdown (subcritical).

B. <u>All Safety and Control Rods are not at the In Limit</u>

Even if the reactor power is decreasing on the intermediate range, it is possible more than one safety or control rod has failed to trip into the core. If this has occurred, it is necessary to begin adding boric acid to the RCS to achieve an adequate shutdown margin. The immediate need to shut down the reactor has been satisfied. The operator is concerned with assuring an adequate shutdown margin is achieved.

3.2 <u>Secondary Inventory and Pressure Controlled ?</u>

After the reactor is shut down, secondary inventory and pressure should be checked to ensure that the secondary system is operating as designed for proper RCS heat removal. These checks include the following:

A. <u>To Ensure that Steam Flow is Controlled</u>

Too much steam removal will cause the RC to overcool.

This includes actions such as:

1. Verify turbine stop valves have shut,

2. Verify the secondary pressure is controlling at the proper setpoint,

3. Verify auxiliary steam flow is controlled properly,

4. Verify minor steam leaks are not indicated such as leaking MSSVs. It may be necessary to check and compare SG pressures and levels. In many cases, MSSVs have been reseated by reducing SG pressure, in which case more drastic measures such as those outlined in Section III.D are not required.

B. To Ensure That FW Flow is Controlled

This includes actions such as:

1. Verify FW has run back. A failure of MFW to run back is one transient that requires quick operator evaluation and action to prevent the possibly severe consequences of water spillover into the steam lines. If the reactor has been operating at full power and then trips without a MFW runback, it is possible that the steam lines can be flooded within one minute. To prevent steam line flooding, it may be necessary for the operator to trip or verify tripped the running MFW pumps. He should then start or verify EFW starts and then control EFW. (Chapter IV.C)

2. FW must be ensured to both SGs after a reactor trip. This includes verifying that the cross-over valve opens on some plant designs and starting of a FW source if necessary.

C. To Verify That Automatic Actions Have Occurred

Large secondary side transients at some plants may result in actuation of the automatic steam line break and FW control systems. If the system has actuated, it is necessary for the operator to verify that all of the automatic actions have occurred and to take any manual actions necessary to control the systems and stabilize the plant.

3.3 Primary Inventory and Pressure Controlled?

After reactor trip, the reactor operator should ensure that the RCS inventory and pressure is being properly controlled. This includes verifying proper MU and letdown flow. Increased MU flow may be necessary to ensure pressurizer level does not decrease abnormally due to the RCS Tave change during normal post-trip cooldown. However, unless a symptom is present (e.g., excessive heat transfer), the HPI system should not be used to control pressurizer level. HPI is not needed for normal post-trip response and can, in fact, complicate achieving stability as well as induce unnecessary thermal cycles on the HPI injection nozzles.

Some RCS leakage, within the capacity of the makeup system, may exist. This could be the result of a small RCS leak of insufficient quantity to warrant entry into the symptom mitigation sections of the EOP or a residual aspect of a transient mitigation that has returned to the VSSV checks. Plant specific treatment of small RCS leaks is typically covered in procedures outside the scope of EOPs; thus the TBD treats such leaks within the status checks of VSSV.

Verification of the status of the ECC systems is required to ensure safe shutdown and core cooling capability along with RB integrity. These systems, including HPI, LPI, RB isolation and RB spray may have been actuated immediately after reactor trip. If these systems are actuated, it is necessary for the operator to verify the automatic actions and to take any manual actions necessary to control the systems.

If MU/HPI is not available, then the RCS should not be cooled down until MU/HPI is restored or if the RCS SCM is lost. This guidance is appropriate even if there is a gradual loss of RCS inventory. A cooldown will cause a contraction of the RCS inventory and decrease the amount of time it will take to lose SCM if there is inventory loss. The objective is to prolong the amount of time available for restoring MU/HPI before SCM is lost. Once SCM is lost however, a cooldown should be started in an attempt to depressurize to obtain the CFTs and LPI initiation. The RCS contraction, due to the cooldown initiated after the loss of SCM, will increase the probability of losing heat transfer due to increased RCS voiding. However, if the transient has progressed to the point where adequate SCM has been lost, then significant RCS losses have occurred and the RCS inventory will need to be augmented by CFT initiation and/or LPI. For further discussion on loss of SCM without MU/HPI see Chapter III.B. The unavailability of MU/HPI may also preclude seal injection. Therefore, the appropriate RCP limits should be observed with regard to seal injection operation and restoration.

3.4 Plant Electrical Power Controlled?

These checks include ensuring proper separation of the main generator from the grid, verification of NNI and ICS power, and proper operation of offsite and/or emergency AC power sources. If the generator output and exciter breakers have not opened, the operator should ensure that the output breaker is opened first before opening the exciter breaker. This is to prevent possibly very high reverse current and potential damage to the main generator. If NNI or ICS power is not available, plant specific procedures for power recovery should be used. Indications in the MCR should be labeled or otherwise noted as unavailable when the respective NNI or ICS channel is out.

Plant electrical power is necessary for the operation of normal and emergency plant equipment post-trip. Therefore, it is important to verify that normal AC power, usually supplied through the station auxiliary transformer(s), is available. If it is not, then actions are necessary to verify or initiate operation of the emergency AC source(s). If both normal and emergency AC power are lost, then a station blackout has occurred. For such events, station blackout procedures provide plant specific actions which are to be taken while efforts are being made to restore AC power.

Some plants have chosen to address the station blackout by using an alternate AC power supply such as additional diesel generators, alternate incoming power lines or gas turbines which are capable of powering shutdown equipment. For these plants, these guidelines assume that a SBO will occur only if alternate AC power supplies fail to start and/or load. SBO specific guidelines should not be implemented if alternate AC supplies are successful in powering shutdown equipment. The following actions for a Station Blackout should be carried out even if power is expected to be restored in a short period of time.

A. Restoration of Offsite or Emergency Power Emphasis must be placed on restoring both emergency AC power and offsite power to the plant. The load dispatcher should be notified of plant loss of power and asked to give high priority to restoring power to the nuclear site as soon as possible. Switchyard and line crews should be dispatched along with Emergency Diesel Generator crews to troubleshoot failures and attempt to restore normal or emergency AC power. If an alternate AC power source is available to the site then actions should be taken to start the source and load it onto the proper electrical bus.

If loss of offsite power is due to damaged incoming transmission lines, priority should be given to efforts to repair at least one line capable of feeding shut-down equipment. Damage to multiple incoming lines for a switchyard may result in efforts being divided to repair each line. Line repair should be organized in a manner which results in the most expedient recovery of shutdown equipment.

Various precautions must be taken upon restoration of AC power whether it is in the form of standby AC power from the diesel generators or preferred offsite power. These precautions include proper breaker sequencing, potential damage to equipment during a SBO, overloading of the restored AC source, and undesired automatic actuations on power restoration. RCP seal damage may have resulted from a sustained loss of RCP seal injection and cooling water flow. RCPs should not be restarted prior to evaluating seal damage unless specifically directed by the EOP.

B. <u>Minimize RCS Inventory Losses</u>

Actions should be taken immediately to reduce or prevent potential RCS inventory losses. Operators should be dispatched as soon as possible to valves requiring manual valve closure. The actions to prevent RC inventory losses include:

1. Isolate all RCS letdown flow.

2. Close RCP seal return isolation valves

3. Attempt to identify and isolate any other leakage paths which may contribute to primary system losses to conserve RCS inventory.

4. Control secondary steam pressure to prevent RCS cooldown and contraction. A predetermined list of potential secondary steam flow paths from the SGs should be used to identify and isolate open steam flow paths. Ensure steam flow path to steam-driven EFW pump is not affected.

C. Maintain Proper SG Levels and Pressures

Operators should verify that the steam driven emergency feedwater pump has started and is supplying feedwater to both steam generators. Operators should be prepared to use alternate supplies of feedwater if and when preferred supplies are depleted. Steam generator pressures should be controlled with ADVs (or TBVs if condenser available) so that an initial RCS cooldown will not occur. Steam generator levels should be raised to the natural circulation setpoints using EFW and natural circulation should be verified. Raising SG levels should be done in a controlled manner which does not result in RCS overcooling.

D. Plant Specific Actions

The following actions should be predetermined on a plant specific basis to help cope with the effects of a station blackout:

1. Battery load shedding to extend battery life for essential loads.

2. Compressed air supplies should be augmented if possible and provisions made for local, manual operation of air-operated components when normal air supplies are depleted.

3. The effects of the loss of ventilation on essential equipment and on habitability in areas where operators may be required to perform actions should be evaluated. Provisions should be made to augment ventilation where required.

4. Some containment isolation valves which are open at the onset of a SBO may require manual closure to ensure containment integrity.

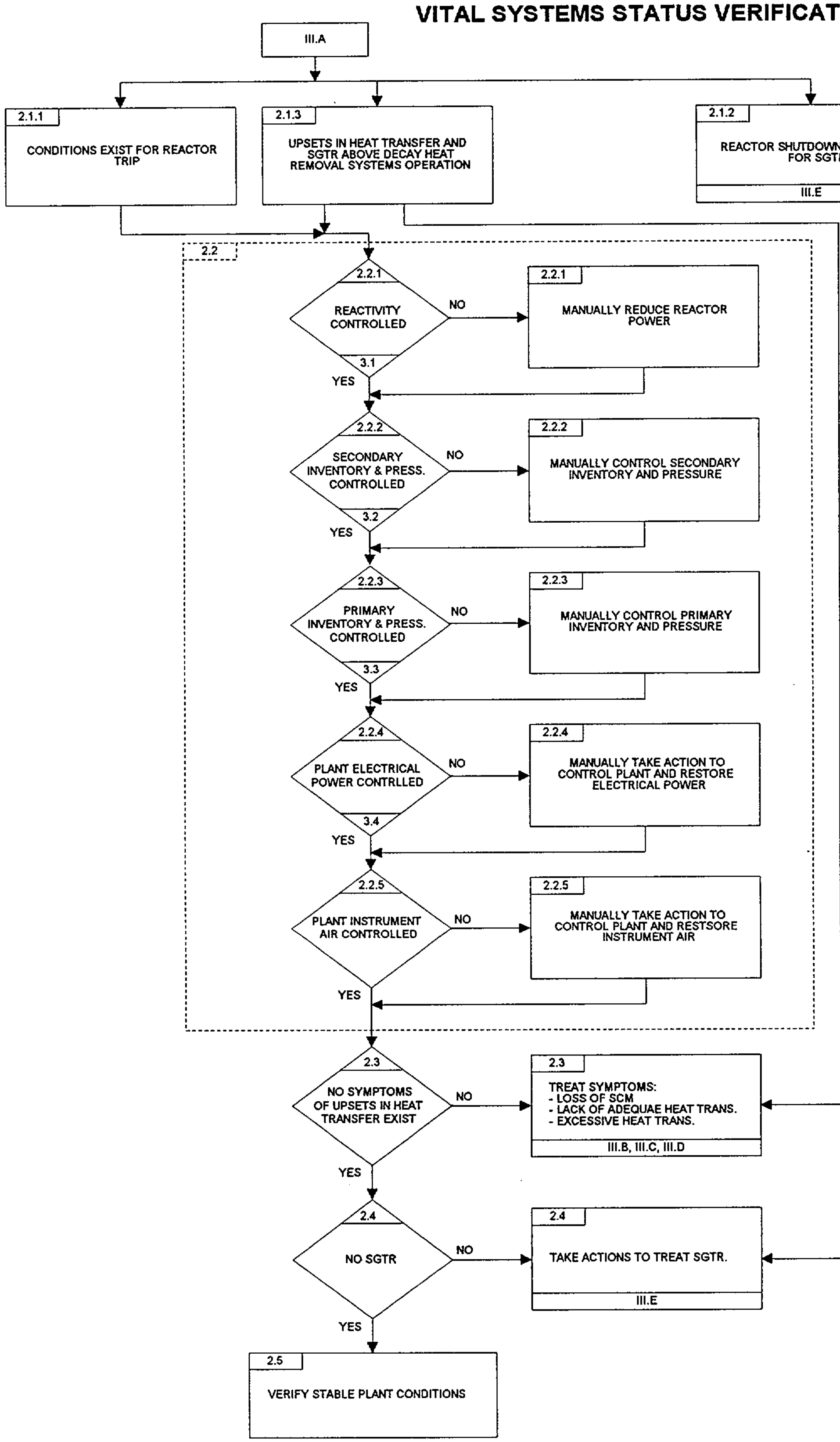
5. The effects of the loss of heat tracing on equipment used to cope with a SBO should be addressed. Problems may also occur upon power restoration as a result of the loss of heat tracing during the SBO.

6. Accessibility to equipment needed to cope with a SBO and to restore AC power should be ensured. In addition, adequate lighting and communications ability should be verified for these locations.

7. Closure of the seal injection isolation valves should be considered to prevent subsequent sudden cold water injection into seals. This action assumes seal injection to be unavailable and may not be applicable if seal injection is being supplied by a dedicated system.

VITAL SYSTEMS STATUS VERIFICATION FLOWCHART

Figure III.A - 1



Chapter III.B

Loss of Subcooling Margin

1.0 INTRODUCTION

The purpose of this chapter is to provide the technical bases for actions taken on loss of subcooling margin (SCM). These bases are applicable whenever a loss of SCM occurs above cold shutdown and have the highest priority of the three symptoms of upsets in heat transfer, i.e., actions for loss of SCM are performed prior to actions for either lack of heat transfer or excessive heat transfer. In addition, this chapter provides guidance and technical bases for a saturated cooldown to LPI/DHR operation with either SG heat removal or cooling by LOCA and HPI flow. All other cooldown methods are discussed in Chapter III.E (tube ruptures) and Chapter III.G (cooldown methods).

1.1 Concerns and Objectives During a Loss of Subcooling Margin

1.1.1 Concerns

As long as the RCS remains subcooled, adequate core cooling is assured. As soon as a loss of SCM occurs actions must be taken to ensure adequate core cooling. For this reason the loss of SCM has top priority requiring treatment ahead of other abnormal heat transfer symptoms or SGTR. The specific concerns during a loss of subcooling margin are as follows:

A. A potential threat to core cooling exists,

B. A saturated RCS can create voids in the hot legs which could impede heat transfer to the secondary side,

C. The potential exists for a LOCA having occurred,

D. Possible entry into ICC conditions.

E. Some special concerns exist if a LOCA exists and HPI (MU/HPI at DB) flow cannot be established.

- Plant cooldown must start immediately upon a loss of subcooling margin in order to avoid severe core damage.

- The addition of boron for core reactivity control may not be possible. This is of concern if the RCS needs to be cooled down since the core reactivity can increase due to the negative moderator temperature coefficient. Although the nuclear designs vary with each core and from plant to plant, in general, sufficient shutdown margin, even with a stuck rod, should be available to permit cooling the RCS down to the Core Flood System injection pressure under saturated RCS conditions, i.e. the Core Flood System would start to inject when the RCS saturation temperature and corresponding saturation pressure decreased to the Core Flood Tank pressure.

- Although severe core damage may not occur, ICC conditions may be unavoidable without HPI to make up for RCS inventory loss. Therefore, it is important to continue efforts to get HPI started to avoid ICC.

- Operator action is required to provide core cooling when the RCS saturates at a pressure below the SG pressure since this causes a loss of primary to secondary heat transfer. Without HPI, the only source of core cooling is with the SGs. The operator will have to reduce the SG pressure in order to establish SG heat removal.

- LPI must be made operational for continued core heat removal after the RCS is depressurized to the LPI operating pressure.

1.1.2 Objectives

The objectives to be considered during the treatment of a lack of subcooling margin are (listed in order of relative priority):

A. Maintain Adequate Core Cooling - Adequate core cooling always has first priority. If assurance of a subcooled RCS has been lost, it is necessary to take actions to ensure that the core remains adequately cooled. These actions include tripping (or verify tripped) RCPs, ensuring adequate HPI/LPI flow, and maintaining primary to secondary heat transfer. If these actions are taken and the equipment operates as designed, ICC conditions will be prevented.

   If HPI is not available, SCM may not be recovered during a LOCA until either HPI is recovered or primary pressure is low enough to allow LPI/DHRS operation.

B. Restore Subcooling Margin - Provided that HPI/LPI is operating, subcooling margin should be restored within about 10 minutes unless a LOCA has occurred. Once subcooling margin is restored, the operator must control RCS pressure within PTS guidelines (refer to Chapter IV.G). PTS guidance would have been invoked by having HPI "on" and the RC pumps "off".

C. Ensure Proper Secondary Control - While the core can be adequately cooled by using HPI or LPI cooling, primary to secondary heat transfer is preferred. During a loss of SCM, the SG level must be raised to the loss of SCM setpoint (defined in Chapter IV.C).

1.2 Causes

A loss of SCM may occur for several reasons. They are:

A. LOCA - Large break LOCAs will result in a sustained loss of SCM. Since RC inventory is being rapidly lost during a large break LOCA, it is especially important that HPI/LPI flow is assured. A loss of SCM can also occur due to a SBLOCA; however, subcooling may be restored by HPI flow. If HPI is not available, SCM may not be recovered during a SBLOCA until either HPI is recovered or primary pressure is low enough to allow LPI/DHRS operation.

B. Prolonged Excessive Overcooling - A large steam line break or an extensive overfeed of a SG is required to create the excessive overcooling which will result in a loss of SCM. For most steam line breaks, the automatic actuation of HPI will maintain SCM; however, if HPI fails or HPI flow is not sufficient, a relatively small steam line break or failed-open steam valve would result in saturated RC once the pressurizer was drained. Chapter III.D discusses overcooling and its mitigation in detail.

C. Prolonged Loss of Heat Transfer - A prolonged loss of primary to secondary heat transfer could result in a loss of SCM. Chapter III.C discusses loss of heat transfer in detail.

D. Failures of the RC Pressure Control System - Failures such as a pressure transmitter failing high could cause the pressurizer spray and PORVs to open and the pressurizer heaters to turn off.

2.0 DIAGNOSIS AND MITIGATION

The flowchart of Figure III.B-1 should be used in conjunction with the following discussion. The numbered subsections of Section 2.0 correspond to the upper numbers in the blocks on Figure III.B-1.

2.1 Identification of a loss of Subcooling Margin (Detailed discussion in Section 3.1)

The RCS P-T relationship will clearly indicate when a loss of SCM occurs. (Refer to Chapter II.B)

2.2 Trip RCPs

All RCPs must be tripped immediately upon a loss of SCM. Refer to Chapter IV.A for details about RCP operation.

2.3 Control RCS Inventory (Detailed discussion Section 3.2)

Control of RCS inventory requires that

A. HPI/LPI flow must be maximized into the RCS,

B. All possible leaks which are isolable should be isolated.

2.4 Maintain Proper SG Levels (Detailed discussion in Section. 3.3)

While a loss of SCM exists, the SG levels must be controlled at the loss of SCM setpoint in each SG that can hold pressure.

2.5 Subcooling Margin Reestablished?

Further actions will depend on whether or not subcooling is regained. Very small LOCAs and termination of excessive overcooling will allow SCM to be regained; large break LOCAs, total loss of FW combined with partial loss of HPI and extended overcoolings may take longer to recover SCM.

If HPI is unavailable, SCM may not be regained until HPI is recovered or until primary system is depressurized to the LPI/DHRS operating pressure.

It is possible for the operator to reach this point in the procedure quickly and SCM may not have been regained but will be restored within a few minutes. If not, the operator should continue to monitor the further steps that are required if SCM is not regained. However, as soon as SCM is regained, the operator should return the plant to as near normal as possible. When the SCM is regained, the actions required by Block 2.6 (Reestablish Normal Plant Control) should be followed. If, however, the RCS remains saturated, then the actions beginning with 2.7 (Superheated?) should be followed.

2.6 Reestablish Normal Plant Control (Detailed discussion in Section 3.4)

As soon as the SCM is restored, the operator should throttle HPI per PTS guidance. PTS guidance is invoked by tripping all RC pumps and having HPI injection. In the event of a lack of primary to secondary heat transfer, the operator should take actions to restore heat transfer. Other symptoms, especially relative to SGTR, which is also a LOCA, should be monitored. In the event that a cooldown is required, refer to Chapter III.G for plant cooldown guidelines. Caution should be taken in reopening the pressurizer spray block valve since this could conceivably reopen the LOCA (if the pressurizer spray block valve had isolated the leak).

2.7 Superheated?

The loss of SCM is a possible prelude to ICC. Should the RCS continue to heat up, becoming superheated, the operator should take actions to mitigate ICC conditions. Refer to Chapter III.F for a detailed discussion of the required actions for ICC conditions.

2.8 Heat Transfer in Both SGs (Detailed discussion in Section 3.5)

Further actions are dependent on whether or not primary to secondary heat transfer exists in either SG. If primary to secondary heat transfer exists in at least one SG, then a saturated cooldown can be performed while attempts are made to restore heat transfer to both SGs, if necessary (Section 2.9 of this Chapter). Whenever the RCS subcooling margin is lost and the HPI (MU/HPI at DB) flow can not be started, then a plant cooldown, at the maximum rate possible, must be started immediately and continued as long as HPI (MU/ HPI at DB) flow is unavailable. If, however, heat transfer does not exist to either SG, then further actions depend on the RCS response (Section 2.10 of this Chapter).

2.9 Saturated Cooldown With SG(s) (Detailed discussion in Section 3.6)

Since the RCS is saturated, HPI flow should be continued at the maximum required flow rate (two HPI pumps if available). Also, secondary side pressure will have to be controlled carefully to continue the cooldown as the RCS cools and depressurizes along the saturation line. Continued saturated natural circulation cooldown will be evident by the incore T/C temperature decreasing as SG saturation temperature decreases due to decreasing secondary side pressure. Some core heat removal may be through latent heat of vaporization of the RC. Consequently, it is possible that little core delta T exists. However, indicated delta T may be larger due to the influence of HPI on the Tcold RTDs. If applicable, efforts should continue to restore heat transfer to an idle SG.

It is highly probable that, with heat transfer to at least one SG and full HPI flow, sustained saturation of the RCS is due to a small break LOCA. However, this is a relatively short- term condition.

If the RCS is in natural circulation and cooling, RC pressure will decrease along the saturation curve. As RC pressure decreases, the break flow will decrease and HPI flow will increase. In this case SCM may eventually be restored without a loss of heat transfer.

If HPI (MU/HPI at DB) flow is not available, then the subcooling margin may not be restored until MU/HPI is recovered, the RCS is cooled and depressurized to the point where LPI flow can be established or if the break can be isolated. If RCS inventory losses continue without recovering MU/HPI, then primary to secondary heat transfer will begin to degrade due to increased RCS voiding. Therefore, a RCS cooldown, at the maximum rate possible, should be started as soon as SCM is lost in an attempt to reach CFT injection and/or LPI. CFTs and/or LPI will aid in core cooling and restoration of RCS inventory which has been lost. Maximizing the cooldown rate minimizes the loss of RCS mass inventory until CFTs and/or LPI can provide make up. The cooldown rate during saturated natural circulation may vary due to the unstable nature of two-phase flow. Periodic primary to secondary heat transfer may be experienced due to excessive voiding of the RCS.

Some RCS repressurization may occur during the period when primary to secondary heat transfer is degraded as a result of increased voiding. If MU/HPI is not available, it is recommended that the PORV not be allowed to cycle automatically if RCS pressure rises to the PORV setpoint. The PORV should be opened when pressure reaches the opening setpoint and left open until RC pressure decreases to about 1600 PSIG. This action should be taken as many times as is necessary to maintain RCS pressure below the PORV setpoint. The prevention of automatic PORV cycling is especially important if the PORV block valve is not available.

If the RCS is in boiler-condenser cooling (BCC) and MU/HPI is being injected, the heat transfer to the SG may be cyclic and heat transfer will probably be lost before SCM is restored. This is because, as the RCS refills, the condensing surface in the SG tube region will be lost. If however, MU/HPI is not available, primary to secondary heat transfer should be more stable since the RCS will not be refilling.

Saturated cooldown with the SG(s) is discussed in detail in Section 3.6. The loop in Figure III.B-1 from 2.12 (conditions not yet established for LPI/DHR cooling) back to 2.5 (check for SCM) covers the possible evolutions discussed above and in Section 3.6. Actions to restore heat transfer to an idle SG are discussed in Chapter III.C.

2.10 <u>RCS Continues to Cool and Depressurize</u> (Detailed discussion in Section 3.5)

Heat transfer will have been lost by one of four situations occurring: a) the LOCA has depressurized the RCS below the secondary side pressure (RC temperature below SG temperature), b) a LOCA has depressurized the RCS below the LPI operational discharge pressure, c) a loss of FW has occurred, d) steam voids have collected in the hot leg terminating natural circulation (this includes cyclic boiler-condenser cooling). For the first case, core cooling is being provided by the break flow and HPI (Section 2.11 of this Chapter).

For the second case, core cooling is being provided by the break flow and HPI/ LPI. Heat transfer to the SGs will not be restored and is not needed to provide adequate core cooling (Sections 2.11 and 3.7 of this chapter).

For the latter two cases, FW flow and/or heat transfer must be restored. Methods of restoring heat transfer with the core outlet subcooled are detailed in Chapter III.C, "Lack of Heat Transfer." If the core outlet temperature is saturated, then no additional actions to restore SG heat transfer are available in III.C. In this case the PORV will be opened to increase depressurization and increase cooling by HPI. A detailed discussion of this decision point is provided in Section 3.5.

2.11 Cooldown on Break/HPI Flow (Detailed discussion in Section 3.7)

If the small break LOCA has resulted in the RCS continually cooling and depressurizing below the SG temperatures and pressures, then the SGs may no longer be required for heat removal. The combination of break flow and HPI is providing adequate core cooling and may continue to do so until the transition to LPI or DHR cooling can be made. The loop on Figure III.B-1 from 2.12 (conditions not yet established for LPI/DHR cooling) back to 2.5 (check for adequate SCM) covers a subsequent change of state, i.e., SCM restored or RC pressure and temperature no longer decreasing. A detailed discussion is provided in Section 3.7

2.12 Conditions Established for Transition to LPI/DHR

This decision point, and the loop back to 2.5 (check for SCM), are provided to address the possibility of a change in plant conditions before LPI or LPI/DHR cooling can be initiated. For example, if the RCS is in boiler-condenser cooling, the progression on the flowchart would be through block 2.9 (saturated cooldown with SG(s)). If the RCS subsequently cycles out of boiler-condenser cooling (Section 3.6), indicating a loss of heat transfer, then the loop back to block 2.5 would provide for a progression through block 2.10 for actions to restore heat transfer or increase cooling from HPI by opening the PORV.

2.13 Initiate LPI/DHR Cooling (Detailed discussion in Section 3.8)

When the RCS cools and depressurizes to within the LPI operating range, the transition should be made to LPI or LPI/DHR cooling, including other long-term cooling actions such as prevention of boron precipitation in the core region. This is discussed in detail in Section 3.8.

3.0 LOSS OF SUBCOOLING MARGIN TECHNICAL BASES

The flowchart of Figure III.B-1 should be used in conjunction with the following discussion. The numbered subsections of Section 3.0, correspond to the bottom numbers in the blocks on Figure III.B-1.

3.1 Identification of a Loss of Subcooling Margin

The P-T relationship provides the fastest and most obvious indication that a loss of SCM has occurred. Refer to Chapter II.B for a discussion of the loss of SCM curve.

3.2 Control RCS Inventory

Immediately upon loss of SCM, HPI/MU must be initiated and maximum flow into the RCS ensured. Refer to Chapter IV.B for a discussion on maximizing HPI flow.

HPI will be started automatically by the emergency safeguards system if RCS pressure decreases below the safeguards system actuation setpoint. If the loss of SCM occurs from lower RCS pressure with ES bypassed, then manual HPI initation will be required. Increasing RB pressure will also actuate emergency safeguards which initiates HPI. Once automatic actions occur, they must be verified and maximum HPI flow into the RCS ensured. It is necessary to ensure maximum HPI flow to ensure adequate core cooling as well as restoring SCM as quickly as possible. If HPI fails to start or is unavailable for any reason, immediate attempts must be made to restore injection capability. Adequate core cooling cannot be ensured unless HPI is available.

The loss of SCM can be caused by the following:

A. Excessive Overcooling Has Occurred

In the event of an overcooling transient, maximum HPI flow only has to make up for RC contraction. Consequently, SCM will be regained rapidly, and HPI flow must then be controlled to prevent excessive repressurization and possibly exceeding RCS pressure-temperature limits.

B. A LOCA Has Occurred

In the event of a LOCA, maximum HPI is required to replace the RC inventory that is being lost out the break. If the LOCA is a large break LOCA (break area approximately equal to or greater than a 10 inch diameter hole), the HPI will be augmented by LPI and CFTs. However, some small LOCAs will require cooling solely by HPI (i.e., will not initially depressurize the RCS below the CFT and LPI actuation pressures). Consequently, HPI must be maximized to replace the RC inventory that is being lost until SCM is restored.

It is also possible to lose SCM due to a small break LOCA or RCS leakage while HPI is unavailable. The SCM in this case may not be restored until HPI is recovered, the break is isolated, or LPI is operating.

All isolable leaks should be isolated, if possible. There are several possible leaks in the RCS which may be isolated by closing certain valves. However, initation of HPI cooling (Chapter IV.B) can result in a loss of SCM. In this case, the PORV and PORV block valve must not be closed.

C. A LOFW Has Occurred

In the event of a LOFW, RC inventory will be lost after the RCS pressurizes to the PORV setpoint. HPI flow is needed to replace this inventory and thereby cool the core.

3.3 Maintain Proper SG Levels

Whenever a loss of SCM occurs, the SG level in the pressurized SG(s) must be controlled at the "loss of SCM" setpoint. Details on SG level requirements are discussed in Chapter IV.C.

The loss of SCM can be caused by the following:

A. Excessive Overcooling Has Occurred

In the event of a steam leak, the SG with the steam leak should not normally be fed until the leak has been terminated. If a steam leak has occurred, attempting to raise the SG water level in the SG with the steam leak would only prolong the excessive heat transfer. However, the level in the SG without the steam leak must be increased to the loss of SCM setpoint as soon as the SCM is lost. If the steam leak can be isolated and heat transfer to the previously leaking SG restored, then its level must also be increased to the loss of SCM setpoint. SG pressure should be controlled to limit RCS reheat and swell for RV pressure-temperature limitations.

B. A LOCA Has Occurred

LOCAs require that SG levels be increased to the loss of SCM setpoint (See IV.C for detailed discussion on achieving the loss of SCM setpoint) at least at the required minimum fill rate when controlled by EFIC or at the required minimum EFW flow rate when manually controlled until the loss of SCM setpoint is reached. Increasing SG levels and maintaining at least the required minimum EFW flow rate (or SG fill rate) help to ensure that saturated natural circulation will continue. In the event that steam voids form in the hot leg and block natural circulation, the establishment of high SG levels will allow boiler condenser cooling to occur.

In addition to raising SG levels, it may be necessary to reduce secondary side pressure to maintain heat transfer. Some breaks can cause the RCS to depressurize and saturate below the secondary system steam pressure. This will result in the SG becoming a heat source because the temperature of the secondary inventory will be higher than that of the RC. If the RCS continues to cool and depressurize, SG heat removal may not be necessary. However, if the RCS pressure stabilizes at a pressure below SG pressure, it may be necessary to also reduce secondary side pressure. Boiler condenser cooling occurs when RC is boiled in the reactor core forming steam (removing core heat) which then flows through the hot leg piping to the SG where it condenses in the SG tubes. The condensed water then returns to the core by the cold leg piping. For the condensed water to flow back into the reactor core, the RC water level in the SG must be above the elevation of the RCP internal lip. This will provide the driving force to allow the water in the cold leg pipe to flow up and over the RCP discharge into the reactor vessel.

It is necessary to increase the SG level to above the RC water level in the steam generator tubes to provide a condensing surface where the RC steam can condense on the surface inside the tubes. This tube surface has to be large enough to remove all of the latent heat of steam at the expected RC steam flow rate. To ensure that the condensing surface above the RC water level in the SG tubes is high enough, the SG water level must be raised to the loss of the SCM setpoint using at least the minimum required EFW flow rate (or SG fill rate) until the setpoint is reached.

If FW is sprayed into the SG through the EFW nozzles at or above the minimum required flowrate (Chapter IV.C) the effective condensing surface of the SG tubes is higher than the loss of SCM level. This is because the EFW nozzle spray will be cooling the tube surface above the loss of SCM level.

Primary to secondary heat transfer is verified by ensuring that the RCS and secondary are coupled. Incore T/C temperature should decrease toward the SG saturation temperature as SG pressure is reduced.

If a larger LOCA occurs, and RCS pressure continually decreases below the SG pressure or decreases below the LPI operational discharge pressure, then secondary side heat transfer may no longer be needed and further core cooling will be supplied through HPI/LPI/CFT. However SG levels should still be raised to the loss of SCM setpoint.

C. Loss of Feedwater Has Occurred

If the loss of SCM was caused by total loss of FW, then the operator may not be able to restore FW and raise SG levels. But after he has established HPI cooling, he should continue his efforts to restore FW. Once FW is restored then the appropriate SG level should be established - loss of SCM if still saturated, natural circulation if now subcooled as indicated by the incore T/Cs. Loop voids may still exist when the core is subcooled but the natural circulation setpoint is adequate because a) a transition to boiler-condenser cooling will not occur with the core subcooled, b) the level is adequate to restore heat transfer when the RCPs are bumped or the HPVs are used to eliminate voids, and c) when heat transfer is restored, the level in the SG will swell.

3.4 Reestablish Normal Plant Control

As soon as SCM is regained, HPI should be throttled per the PTS guidance. Maintaining minimum SCM will also reduce break flow. The PTS guidance is invoked when all RC pumps are "off" and HPI is "on." After starting the RCPs and establishing SG heat transfer, the TBVs and ADVs will have to be adjusted to control RCS cooldown rate. Restrictions on RCP restart are provided in Chapter IV.A.

If primary to secondary heat transfer does not exist after SCM is restored, it is probably due to a lack of FW or steam voids in the hot leg blocking natural circulation. The operator then must take actions to restore heat transfer from the primary to the secondary side (see Chapter III.C for discussion on restoring heat transfer). Failing this, HPI cooling must be continued or started. RCPs must not be operated until the restart criteria of IV.A are fully met.

After this symptom of loss of SCM is treated, attention should be turned to the other symptoms of upsets in heat transfer. If SCM is restored during the treatment for inadequate heat transfer, then the operator can stop the treatment of loss of SCM. For example, if the SG level is being raised to the "loss of SCM" setpoint, the level increase can be stopped. Since a SGTR could have caused depressurization to the point of loss of SCM, this symptom should be closely monitored. A discussion relative to SGTR is detailed in Chapter III.E.

3.5 Heat Transfer in One or Both SGs

Further actions depend on whether or not heat transfer exists in one or both SGs. Previous actions have been made to keep the core covered with water which allows the core to transfer heat to the surrounding coolant. The next step is to remove the heat from the surrounding coolant. If heat transfer exists in one or both SGs and MU/HPI is available, then a saturated cooldown can continue. A cooldown must be initiated if heat transfer exists to at least one SG and MU/HPI is not available (see Section 3.6). If heat transfer does not exist in either SG, then further action depends on the response of the RCS.

If the RCS continues to cool and depressurize below the SG pressures and temperatures, then the break size and HPI flow are sufficient to provide core cooling. The SGs are not required while this condition exists but the SGs should be made available in case they are needed later; e.g., FW restored, if applicable. The cooldown should continue on break/ HPI flow (see Section 3.7).

If, however, the RCS pressure and temperature (incores) stabilize or begin to increase, then SG cooling should be restored. Methods to restore primary to secondary heat transfer or, if necessary, initiate HPI cooling are described in Chapter III.C.

At this point, the RCS is likely still saturated. If heat transfer exists, it is by saturated natural circulation or boiler condenser cooling (see Section 3.3 of this chapter for a discussion of boiler condenser cooling). Since the RCS is saturated, it will be more difficult to determine whether or not natural circulation or boiler condenser cooling mode exists. The best indication of a loss of natural circulation flow when the RCS is saturated or loss of boiler condenser cooling is a trend of incore T/C temperature vs. RCS pressure increasing up the saturation curve.

Natural circulation flow can be lost due to low thermal centers in the SGs or blockage due to voids in the RCS. It is possible that the RCS will be in natural circulation for a while, then natural circulation can be lost if the RCS is losing inventory. With a loss of RCS inventory, steam will form in the hot legs and eventually stop the saturated natural circulation flow.

If natural circulation is lost in a loop, assure that proper SG level and EFW flowrate are being maintained in that loop. However, even with proper SG level and EFW flowrate, heat transfer can be lost. Analyses have shown that for relatively small RCS leaks (leak rates less than the capacity of the makeup system) in conjunction with a loss of MU/HPI, it is possible that the plant will evolve into a saturated single loop natural circulation configuration prior to losing natural circulation flow altogether. As the RCS fluid is lost through the leak site, fluid from the pressurizer, which is hotter than the rest of the system, drains into one loop. An energy imbalance between the two loops can cause the primary fluid in the loop with the pressurizer to void sufficiently to prevent natural circulation flow while flow continues in the other loop. The resulting saturated single-loop natural circulation flow may be sustained for a significant period of time depending on the RCS leak rate.

Eventually, however, the saturated single-loop natural circulation flow will also be lost. If the RCS continues to lose inventory boiler condenser cooling should occur as long as the SG(s) are available, i.e., high enough level and/or minimum required EFW flowrate (Chapter IV.C).

Boiler condenser cooling can be lost due to a loss of adequate condensing surface in the SG tubes. This can occur due to a decrease in effective thermal center on the secondary side due to a low liquid level and insufficient EFW flow or if HPI is being injected, it may be due to an increase in RC level inside the tubes. Boiler condenser cooling may be cyclic in nature because, as the RC steam is condensed, RCS pressure will decrease toward SG pressure causing leak flow to decrease and HPI flow to increase. This may allow the RCS to refill which will reduce the available condensing surface inside the SG tubes. If the heat transfer to the SGs is lost, RC temperature and pressure will begin to increase causing the leak flow to increase and HPI flow to decrease. This will, in turn, cause a net loss in RC inventory which will restore the condensing surface. This self-regulating process may occur with only fluctuations in the amount of heat transfer or it may result in periodic losses of heat transfer. In either case, boiler condenser cooling should continue without further operator action required to restore heat transfer. However, the operator may take the actions discussed in Chapter III.C to aid restoration of heat transfer. Boiler condenser cooling should not be cyclic if HPI is not available. The primary system will not refill and the condensing surface inside the SG tubes will be maintained as long as there is no net addition to RC inventory.

Boiler condenser cooling may also be partially lost due to a continued net loss of RC inventory while boiler condenser cooling exists. Boiler condenser cooling provides or aids core cooling in two ways. First, the condensation of the RC steam in the tube region removes heat from the RCS and, by reducing RC pressure, allows higher HPI flow which also provides cooling. Second, by maintaining a high enough RC liquid level in the SG tubes, coolant is forced over the RCP internal lip where it can flow into the core region. If the RC inventory continues to decrease even with boiler condenser cooling, the level required to force coolant over the RCP internal lip will be lost. How-ever, the condensing surface inside the SG tubes will continue to grow and thus the heat removal obtained by condensing RC steam will continue. This case is essentially a combination of saturated cooldown with the SGs (3.6) and cooldown on break/HPI flow (3.7).

During a saturated cooldown, using either the SGs or break/HPI flow or a combination of both, it is possible for the RC pressure to appear to stabilize when the CFTs begin to discharge. If the net loss of RC inventory is relatively small, the CFTs will "float" on the RCS. The RCS should continue to cool and depressurize but possibly at a slower rate. If the RCS begins to reheat, the operator should attempt to increase heat removal by the SGs. If SG heat removal cannot be increased sufficiently, and HPI flow exists, the PORV can be used to decrease RCS pressure, increase HPI flow, and thus increase cooling due to HPI.

3.6 Saturated Cooldown Using the SG(s)

Cooldown of the RCS, during saturated conditions, is accomplished in essentially the same way as a normal subcooled natural circulation cooldown; however, there are some major differences:

- HPI Flow Required

Full HPI flow from two HPI pumps, if available, must be maintained while the RCS is saturated. This HPI flow can also provide substantial core cooling, thus the operator does not have total control of the RCS cooldown rate with the SGs. If HPI is not available, then the cooldown will be a function of heat transfer to the SGs and the energy that flows out of the break.

- Unstable Cooldown

A saturated cooldown using the SGs is inherently unstable. In order to maintain SG heat removal with saturated natural circulation, a mass and energy balance must exist. If the RCS is initially in saturated natural circulation and core decay heat exceeds the heat removal rate, a mass and energy balance does not exist. In this case steam formation, due to core boiling, can block natural circulation flow with a resultant loss of primary to secondary heat transfer. This may eventually result in boiler condenser cooling and restoration of primary to secondary heat transfer. RCS refill could result if core boiling is suppressed by HPI cooling through the break. If RCS refill does occur, and prevents boiler condenser cooling, then primary to secondary heat transfer will not be restored until single-phase natural circulation develops following RCS refill.

If the RCS is in saturated natural circulation or boiler condenser cooling with a mass and energy balance, a subsequent decrease in core decay heat or increase in SG heat removal will offset the balance. If the RCS is in natural circulation, this will result in RCS cooling and depressurization, which will decrease the break flow while increasing the HPI flow, and should allow eventual restoration of SCM while maintaining primary to secondary heat transfer. If the RCS is in boiler condenser cooling, this will result in refill and a possible interruption in heat transfer. This could then result in either cyclic boiler condenser cooling or continued refill and restoration of natural circulation.

- Normal Cooldown Rates Do Not Apply

When the RCS is saturated normal Technical Specification cooldown rates and the special case RCS cooldown rate for RV head void concerns do not apply.

The reasons that the cooldown rate limits do not apply are that pressure stresses are minimal (the RC pressure is much less than assumed in establishing the cooldown limits) and other considerations become more important. Cooldowns that occur when the RCS is saturated are analyzed as "emergency" events that utilize different criteria from normal cooldown transients.

Cooldown during LOCA-induced saturated RCS conditions should continue expeditiously. Expeditious RCS cooldown (and depressurization) reduces RCS inventory losses and break energy release to the RB during the cooldown period before long term cooling is established. In addition, the RCS depressurization due to the LOCA (including tube ruptures) could result in cooldown rates greater than normal limits; this should not preclude maintaining the SGs available as heat sinks, which could further increase the cooldown rate. However, even when saturated the RCS cooldown rate should only exceed the normal cooldown rate limits as necessary to satisfy the objective of maintaining the SGs as heat sinks. Associated RCS cooldown rates should be large enough to provide for continuous RCS depressurization while maintaining overall plant control and coordination. For example, the SG steaming rates should not exceed available feedwater flow rates, which could lead to inability to maintain the required SG level.

A RCS cooldown must commence when the subcooling margin is lost if HPI (MU/HPI at DB) flow fails to start. RCS inventory losses coupled with the inability to replace these losses with MU/HPI has resulted in the loss of subcooling margin. If the transient continues to progress in this manner, i.e. RCS leakage without HPI, primary to secondary heat transfer will begin to degrade due to increased RCS voiding and the RCS will begin to reheat and repressurize. The re-heating will continue until expansion of RC, primarily in the core and in the RV inlet (due to vent valve flow), causes an increase in the loop mass flow rate over the hot leg candy cane (i.e. spillover) and into the SG causing cooler water to flow from the SG into the RV inlet and core. This will decrease the RC density and pressure causing increased voids in the hot leg candy cane again with a resulting reduction in primary to secondary heat transfer. This reduction in primary to secondary heat transfer will again cause the RC to heat up and repressurize with the resulting increased mass flow rate through the SG. The RC will repressurize to a higher value each time this process is repeated. This process will tend to repeat itself until the RCS leak causes the RC water level in the SG tubes to decrease enough to establish boiler condenser cooling.

Eventually, if RCS inventory losses are not replaced, boiler condenser cooling will decrease and inadequate core cooling will develop with possible core damage resulting. The objective, therefore, is to cool and depressurize the RCS to the point where CFTs and/or LPI may be used to replace RCS inventory. This cooldown should start immediately upon loss of SCM and should occur at as fast a rate as possible even if the normal cooldown rate is exceeded.

If the steaming rate exceeds the available feedwater flowrate, then SG levels will decrease. These level decreases may continue to the point where no measurable SG level exists, however steaming to achieve maximum RCS cooldown rates should continue. This is considered accept-able since continued feeding and steaming is not expected to pose tube to shell ΔT concerns (normally associated with dry SGs) and the primary interest at this point is in depressurizing the RCS to CF/LPI operational pressures. As steam pressure in the SGs decreases, feedwater flow rate will increase and the boiling rate will decrease thus SG level is expected to recover. Also, if HPI is not restored, primary to secondary heat transfer will be lost during transition to BCC; SG levels are also expected to recover during this time. Maximizing the cooldown rate will minimize the loss of RCS mass inventory until CFTs and/or LPI can provide makeup. During the cooldown, attempts to recover HPI should continue and LPI system availability should be verified. After the Core Flood Tanks are emptied, RCS makeup and core cooling will have to be provided by either the HPI or LPI system. The cooldown process may start from a saturated natural circulation state or from a boiler condenser state. If it starts from a saturated natural circulation state, a boiler condenser state will develop at some time afterwards as the primary levels descend into the tube region of the SG.

Analyses have shown that saturated natural circulation flow can be unstable with periods of strong primary to secondary heat transfer followed by periods of little or no SG heat removal. The cooldown rate will most likely not be constant during this period. The transition from saturated natural circulation flow to boiler condenser cooling can cause the RCS to repressurize during the period when virtually no SG heat removal is taking place. Although the RCS cooldown and resulting depressurization may help minimize the peak RCS repressurization during this period, the RCS pressure may increase to the PORV setpoint. The PORV should be manually cycled as discussed in Chapter III.C, Lack of Heat Transfer, in order to minimize repeated automatic lifts and reseats. If, for some reason, the PORV fails to close with no HPI flow available, then the PORV block valve must be closed, if it is available, in order to conserve RCS inventory.

While the RCS is saturated, the CFT isolation valves must remain open until sufficient LPI flow exists (Chapter IV.B). However, once SCM is restored the CFT isolation valves should be closed when conditions permit. HPI/LPI piggyback operation may be required during the cooldown (Chapter IV.B).

3.7 Cooldown on Break/HPI Flow

If the break size is large enough, the RCS will continue to cool and depressurize below the temperature and pressure of the SG(s). This size break, coupled with HPI flow, will provide adequate core cooling and use of the SG(s) may not be necessary. However, the SG(s) should be made available in the event that the RCS does begin to reheat. The only operator actions required for breaks of this size are to ensure full HPI flow and that other injection sources (CFTs and LPI) are available. RCS pressure may tend to stabilize when the CFTs begin to discharge but, as long as the RCS does not begin to reheat, actions to restore SG cooling are not required. If the RCS does not depressurize, via break/HPI flow, then the break is of insufficient size to cause continued RCS cooldown and depressurization. In this situation, the SGs should be used to reduce RCS pressure to CF/LPI operational pressures for the eventual establishment of long term cooling. This situation can exist with subcooled or saturated RCS conditions. If SCM exists with SGs being used to contribute to the cooldown, then TBVs/ADVs should be controlled as necessary to control RCS cooldown rate within limits. During cooldown with a saturated RCS there is no cooldown rate limit and cooldown should continue expeditiously to limit RCS inventory losses and beadk energy release to the RB. However, even when saturated the RCS cooldown rate should only exceed the normal cooldown rate limits as necessary to satisfy the objective of maintaining the SGs as heat sinks. In this situation, cooldown rates should be large enough to provide for continuous RCS depressurization while maintaining overall plant control and coordination. For example, TBVs/ADVs should be controlled such that associated steaming rates do not exceed available feedwater flow rates which would lead to decreased SG level. If control of SGs cannot prevent excessive primary to secondary heat transfer, then the guidance of Chapter III.D should be followed.

HPI/LPI piggyback operation may be required during the cooldown (Chapter IV.B).

3.8 LOCA Considerations for LPI/DHR Cooling

Proper operation of the LPI system should be verified as soon as LPI is actuated whether manually or automatically. This includes verification of proper valve lineup and verification or performance of LPI suction switchover to the sump from the BWST when required and HPI/LPI piggyback lineup if required (Chapter IV.B).

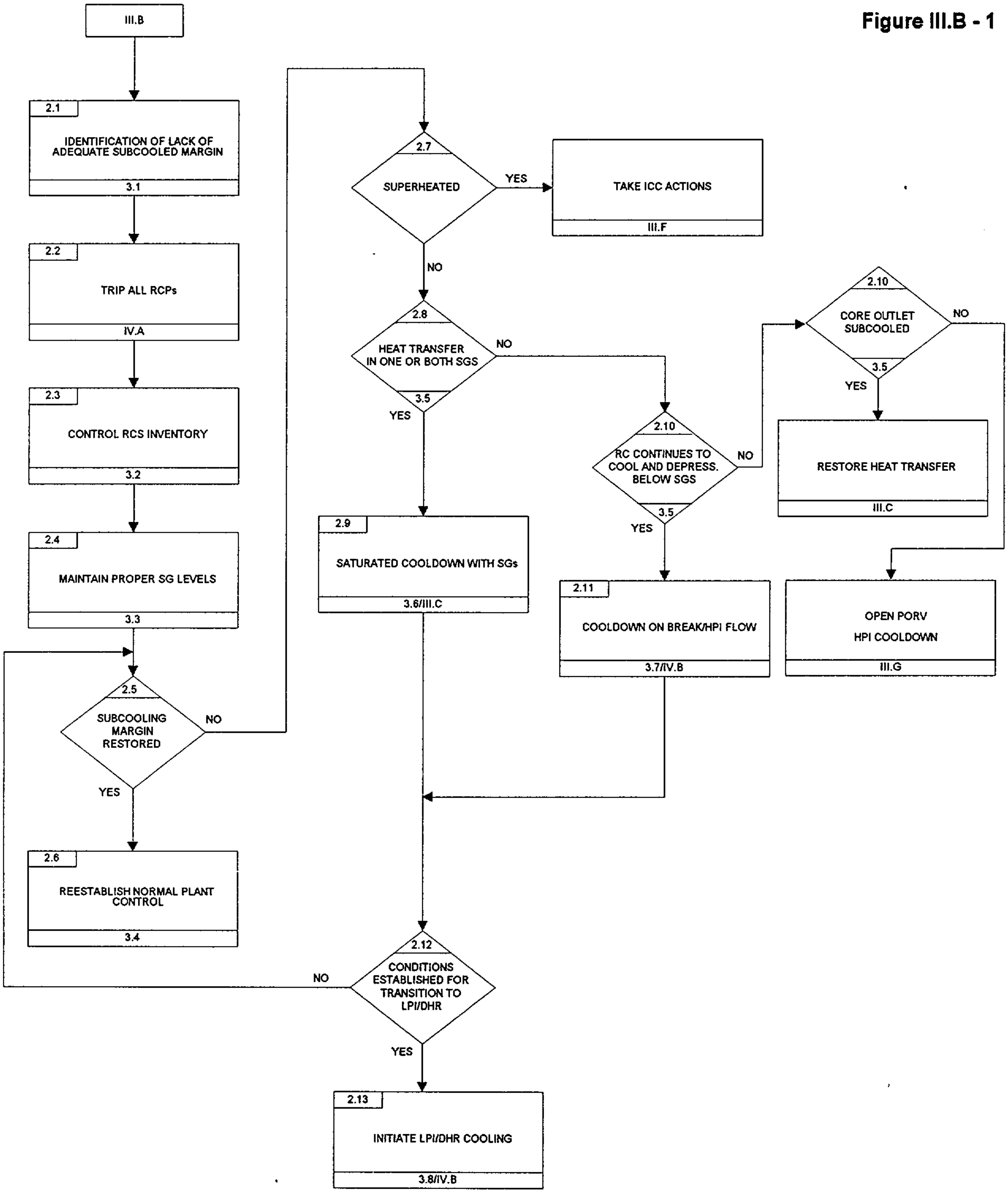
While the RCS is saturated, both LPI trains should remain operating in the injection mode. However, the large capacity of the LPI system may restore SCM. If SCM is restored, then consideration may be given to switching one LPI train to the DHR mode (suction from the drop line) while the other LPI train remains in the injection mode to compensate for the break flow. If SCM is subsequently lost, both LPI trains must be placed back in the injection mode (suction from the BWST or containment sump).

Actions should be taken to prevent boron precipitation in the core region if SCM does not exist within [boron dilution time limit] following a LOCA. This limit is plant specific. These actions involve establishing alternate flowpaths to prevent excessive boron accumulation in the core region. These flowpaths are plant specific thus site procedures should be referenced. More information on boron precipitation prevention is provided in Chapter IV.B.

The LPI coolant should be sampled periodically for boron concentration and pH after suction is transferred to the sump. If necessary, the appropriate chemicals should be added to maintain plant specific boron concentrations and pH levels (refer to plant specific procedures). In addition, if the boron concentration is low, the operator should verify the proper lineup to prevent boron precipitation discussed above and check for possible leaks (e.g., cooling water) in the RB that may be diluting the sump water.

LOSS OF SUBCOOLING MARGIN FLOWCHART

Figure III.B - 1



Chapter III.C

Lack of Adequate Primary to Secondary Heat Transfer

1.0 INTRODUCTION

The purpose of this chapter is to provide technical bases for restoring adequate primary to secondary heat transfer. These bases are applicable whenever a symptom of inadequate primary to secondary heat transfer exists. The RCS may be subcooled or saturated.

1.1 Concerns and Objectives

1.1.1 Concerns

A lack of primary to secondary heat transfer is the second priority symptom (along with its counterpart, excessive primary to secondary heat transfer) which requires treatment as soon as SCM is assured or treated. While a backup source of cooling, HPI cooling, is available, its use will degrade the RB environment. Consequently, heat transfer from the primary to the secondary side should be restored as quickly as possible. However, core cooling has priority and HPI cooling must be used if SG cooling is not available. Concerns during a lack of primary to secondary heat transfer include the following:

A. A Lack of Adequate Core Cooling

The normal method of core cooling does not exist. Maintaining adequate core cooling is most important.

B. Extended Loss of Feedwater with Inadequate HPI.

This can result in ICC.

C. Increasing RC Pressure.

This can minimize HPI flow into the RCS. In addition, a loss of heat transfer while HPI (MU/HPI at DB) is unavailable may result in a RCS repressurization to the PORV setpoint and repeated PORV actuations.

D. Voids in the Hot Leg Loops.

Voids can prevent restoration of natural circulation.

E. PTS Guidance

PTS guidance must be followed if invoked.

F. HPI cooling

HPI cooling results in releasing large quantities of RC to the RB. If the BWST becomes depleted, recirculation from the RB sump will be required.

G. Adding FW to dry SG

Adding FW to a dry SG can cause unanalyzed thermal stresses, although the potential for excessive stresses has been minimized by the use of initial flow limits.

1.1.2 Objectives

The objectives which must be considered during a lack of heat transfer include:

A. Restoring and Maintaining Adequate Core Cooling

Adequate Core Cooling is the primary objective. Core cooling with the SGs is the preferred method. However, HPI must be used for core cooling if it is required and available.

B. Restore and Maintain Primary to Secondary Heat Transfer

Core cooling via primary to secondary heat transfer is the preferred method of core cooling.

C. Maintain Subcooling Margin

SCM may be lost due to an extended LOFW, excessive overcooling, or a LOCA. This chapter covers the impact of a loss of SCM on efforts to restore primary to secondary heat transfer. The details for restoring SCM are provided in Chapter III.B.

D. Follow PTS Guidance

A prolonged loss of primary to secondary heat transfer will require HPI cooling. Due to the possibility of cold HPI water entering the RV and creating thermal shock to the inside of the RV wall, it is important that HPI and RCS pressure be controlled per the PTS guidance. The PTS guidance is provided in Chapter IV.G.

1.2 Causes

A lack of adequate primary to secondary heat transfer can occur due to one or more of the following:

A. Loss of Feedwater

A LOFW can occur for several different reasons. For example, FW pumps can stop, valves can be inadvertently closed, or the source of FW may be depleted. A LOFW would also include the case where, although some FW inventory remains in the SG, it is not sufficient to maintain heat transfer between the primary and secondary sides. This could occur if the SG level was not raised to the setpoint when necessary to establish boiler condenser cooling or failure to raise SG level to the setpoint when required to maintain natural circulation.

B. Loss of Primary Side Loop Flow

A loss of RC flow could occur for several reasons. For example, a LOCA can occur, requiring RCPs to be stopped due to loss of SCM, depleting the RC inventory to the point where steam voids form in the hot legs, thus stopping any natural circulation flow. Prolonged excessive overcooling can also create voids which could impede natural circulation. A prolonged LOFW could result in steam voids blocking the hot legs which could prevent natural circulation from occurring once FW is restored. A loss of heat transfer due to voids in the hot legs would initially be treated through the loss of SCM symptom. Once the loss of SCM actions were taken, this section provides follow-on actions to restore heat transfer.

C. RC Temperature Decreasing Below Secondary Side Temperature

A LOCA can saturate the RCS and cause the RC pressure to go below the SG pressure. This will cause a loss of primary to secondary heat transfer. If the RCS continues to cool and depressurize below the SG temperatures and pressures, then the break flow and HPI are providing adequate core cooling. This case is covered in Chapter III.B.

2.0 DIAGNOSIS AND MITIGATION

The flowchart of Figure III.C-1 should be used in conjunction with the following discussion. The numbered subsections of section 2.0 correspond to the upper numbers in the blocks of Figure III.C-1.

2.1 Identification of Lack of Adequate Primary to Secondary Heat Transfer (Detailed discussion in Section 3.1)

The P-T relationship provides the most obvious indication that a lack of primary to secondary heat transfer has occurred. Refer to Chapter II.B.

2.2 HPI Cooling Required? (Detailed discussion in Section 3.2)

The operator continually monitors RCS and SG conditions to determine if HPI cooling is required. If HPI is not available at this point, efforts to restore HPI should continue and subsequent actions to recover primary to secondary heat transfer should be taken immediately. HPI cooling is required for the following situations:

A. Feedwater Available

With FW available, actions to restore heat transfer can continue, without requiring HPI cooling, until SCM is lost. This is because BCC is available as a backup for core cooling.

If the RCS is saturated, then HPI cooling must be established. If primary to secondary heat transfer is not established after making the SG a heat sink per Section 2.7 (i.e. the SG saturation temperature is about 50°F lower than the incore T/Cs and the SG water level is raised to the loss of SCM setpoint.)

B. Feedwater not Available

With FW not available, HPI cooling will eventually be required. For all plants except Davis-Besse HPI cooling must not be intentionally delayed beyond the point when RC pressure reaches the RV P-T limit or the PORV setpoint or the first PORV automatic lift. For Davis Besse, MU/HPI Cooling must be initiated immediately if only one MU pump is operational or initiated when the core outlet or hot leg temperature reaches 600F if two MU pumps are operational or if RC pressure increases to the RV P-T limit.

It is not necessary to wait for occurrence of RCS and SG conditions that require HPI cooling to initiate HPI cooling. For example if it is known that FW will remain unavailable, then it is acceptable to initiate HPI cooling before RCS conditions require it.

2.3.A Establish HPI Cooling - except Davis-Besse

(Detailed discussion in Section 3.3.A)

In general, HPI cooling involves adding relatively cold water to the RCS with the HPI System while removing relatively hot water through the Pressurizer PORV. HPI cooling is established by first initiating HPI flow to the RCS to assure that water is being added to the RCS before any attempt is made to remove water from the RCS. Two HPI pumps should be started or verified operating with suction from the BWST. The success of adding HPI will determine how the PORV should be operated in removing water from the RCS.

If no HPI pump starts, then the PORV must not be maintained open. In addition, the high point vent valves should be kept closed to conserve RCS inventory until HPI can be initiated. The PORV should be manually cycled to control RCS pressure between the PORV setpoint or RV P-T limit and 1600 PSIG if saturated or minimum SCM). Manually cycling the PORV will limit challenges to the pressurizer safety valves and reduce PORV cycling to reduce the probability of PORV failure. However, if the PORV fails open with no HPI pump operating, then the PORV block valve must be closed in order to conserve RCS inventory. The pressurizer safety valves will then provide pressure relief while attempts to restore HPI and FW continue.

If only one HPI pump starts, then the PORV must be maintained open to maximize the HPI flow into the RCS for sustaining the maximum RCS inventory.

If two HPI pumps start, then there are two choices for operating the PORV. The PORV can be maintained open or cycled (either automatically or manually) for a while, then maintained open. There are pros and cons associated with each choice. Maintaining the PORV open will cause the RCS to depressurize toward saturated conditions but will maximize the HPI cooling capability. Permitting the PORV to cycle before maintaining it open will reduce the HPI cooling capability, cause the RCS to heat up toward saturation and cause the PORV to cycle open and close excessively which may lead to PORV failure. If the PORV is cycled, the RCS pressure will remain high. This will allow the RCS to remain subcooled if the HPI heat removal rate can match the decay heat rate before the loss of subcooling margin is reached. In addition, the RC temperature can increase while PORV cycles so that if the PORV is opened at a later time, the magnitude of the RCS pressure decrease to the saturation pressure will be smaller. In lieu of any extenuating circumstances, the preferred choice is to maintain the PORV open because it will maximize the HPI cooling capability which is consistent with the major objective of HPI cooling, i.e., core cooling. An example of an extenuating circumstance would be the need to avoid certain automatic functions on low RCS pressure such as isolation of service water to ICW coolers resulting in loss of cooling for RCP motors. It may be possible to delay reaching the PORV actuation setpoint by actuating full pressurizer spray. This should result in a smaller RCS pressure decrease when the actuation setpoint is reached, the PORV opens or is opened and then is maintained open. The smaller RCS pressure decrease may prevent the automatic and manual functions on low RCS pressure.

Manual PORV cycling is preferred over automatic cycling because the PORV can be manually cycled over a larger pressure range, (e.g. between its open setpoint and a pressure which is above either the safety system actuation setpoint or the SCM). This will result in fewer cycles and a larger integrated HPI flow. If the PORV fails open while cycling, do not close the PORV block isolation valve until HPI cooling is no longer needed. When the PORV is cycled it should only be cycled long enough to accomplish the intent for the cycling (e.g. the RC temperature has increased enough so that opening the PORV will not cause the RCS to depressurize below the RCS pressure setpoint which initiates Reactor Building isolation), but must be maintained open before or when the RCS SCM is reached in order to establish the preferred method of PORV operation.

If the PORV fails to open or PORV flow cannot be established for any reason after the initiation of HPI cooling, then RC pressure is expected to increase causing cycling of the pressurizer safety valves. If this mode of operation continues long enough (no PORV flow established), RC temperature will begin to decrease while the RC pressure remains high. In this situation, high RC pressure (at the pressurizer safety valve setpoint) and decreasing RC temperature, HPI flow must be throttled to prevent violation of the NDT limit and to comply with the PTS guidance, if invoked.

When establishing HPI cooling, the PTS guidance will become applicable if the RCPs are off. Consequently, the RC pressure will have to be controlled to comply with PTS guidance. Refer to Chapter IV.G for details on PTS guidance.

The number of operating RC pumps should be reduced to one to decrease the heat being added to the RCS. If HPI cooling exists this action will increase the core cooling effectiveness. If HPI is not available, this action will extend the time before uncovering the core which provides more time for establishing feedwater or HPI. One RC pump is kept running to provide fluid mixing until the subcooling margin is lost or the SG tube-to-shell limits are reached.

However, if the PORV is not opened, it is likely that the RCS will continue to heatup for some time before the HPI flow can remove decay heat. In this case, the RCP must be tripped before the SG tubes reach the compressive limit. This will slow further heatup of the SG tubes. The RCPs should not be restarted, even with SCM and the restart criteria of IV.A met until the ΔT between the core outlet temperature and the SG shell temperature is less than the compressive limit.

Pressurizer heaters should be turned off to ensure they will not be automatically energized when the RCS pressure is reduced during HPI cooling. Deenergizing the heaters also reduces the energy input to the RCS to reduce the HPI cooling heat removal demands and to help in reducing RCS pressure. This also protects the heaters should they become uncovered during HPI cooling.

Letdown should be isolated. This prevents loss of inventory outside containment since HPI cooling may require sump recirculation.

Refer to Chapter IV.A for RCP operations, Chapter IV.B for HPI equipment operation and Chapter V.A for HPI Rules. Refer to Chapter IV.G for a discussion regarding PTS guidance and RV P-T limits during HPI cooling. Refer to Chapter III.G for cooldown guidelines during HPI cooling.

2.3.B <u>Establish MU/HPI Cooling for Davis Besse</u> (Detailed discussion in section 3.3.B)

MU/HPI cooling is established in the following manner:

a. Whenever feedwater is unavailable, then immediately attempt to establish RCS makeup flow with both MU pumps. The resultant quantity of MU pumps in operation will determine when MU/HPI cooling must be initiated.

- If only one MU pump is operational, then MU/HPI cooling must be initiated immediately.

- If both MU pumps are operational, then MU/HPI cooling initiation can wait until the core outlet temperature reaches 600°F or the RCS pressure reaches the RV pressure-temperature limit.

b. Align the MU pumps in the MU/LPI piggyback mode (i.e., taking suction from the LPI pump discharge with the LPI pumps taking suction from the BWST).

c. Start both trains of HPI in the HPI/LPI piggyback mode (i.e., taking suction from the LPI pump discharge with the LPI pumps taking suction from the BWST).

d. Start both trains of LPI in the injection mode taking suction from the BWST.

e. If, while waiting to initiate MU/HPI cooling, the RCS pressure reaches the PORV open setpoint, the PORV should be manually cycled to avoid rapid automatic PORV opening and closing cycles. If the PORV fails open, then immediately initiate full MU/HPI cooling flow. The PORV should be manually cycled between the PORV open setpoint and a pressure which is above either the safety system actuation setpoint or the SCM.

f. If neither the MU pumps nor the HPI pumps are available for adding inventory to the RCS, then manually cycle the PORV per item e above while continuing attempts to restore injection flow and feedwater.

g. After aligning water addition to the RCS with the MU, HPI and LPI systems as stated above, then initiate MU/HPI cooling when required (i.e., immediately, when core outlet temperature reaches 600°F or if the RC pressure reaches the RV P-T limit as follows:

- open the PORV and HPVs to remove high energy RC.

- Maximize MU and HPI flow when SCM does not exist. This includes providing MU flow through both the normal and alternate MU lines, closing the makeup pump recirculation lines and opening the makeup control valve bypass valve.

h. With a lack of primary to secondary heat transfer, all RCPs except one should be tripped. If SCM is lost then all RCPs must be tripped. The RCS may heat up for some time before the MU/HPI cooling can match decay heat generation. In this case, all the RCPs must be tripped before the SG tubes reach the compressive limit. The RCPs should not be restarted, even with SCM and the restart criteria of IV.A met, until the ΔT between the core outlet temperature and the SG shell temperature is less than the compressive limit.

i. Presurizer heaters should be turned off to ensure they will not be automatically energized when the RCS pressure is reduced during MU/HPI cooling. Deenergizing the heaters also reduces the energy input to the RCS to reduce the MU/HPI cooling heat removal demands and to help in reducing RCS pressure. This also protects the heaters should they become uncovered during MU/HPI cooling.

j. If the PORV fails to open or PORV flow cannot be established for any reason after the initiation of MU/HPI cooling, then RC pressure is expected to increase causing cycling of the pressurizer safety valves. If this mode of operation continues long enough (no PORV flow established), RC temperature will begin to decrease while the RC pressure remains high. In this situation, high RC pressure (at the pressurizer safety valve setpoint) and decreasing RC temperature, MU flow must be throttled to keep the core outlet temperature between the SCM and NDT limits or within PTS guidance, if invoked.

k. Letdown should be isolated. This prevents loss of inventory outside containment since MU/HPI cooling may require sump recirculation.

Refer to Chapter IV.A for RCP operations, Chapter IV.B for HPI equipment operation, to Chapter V for HPI rules, to Chapter III.G for a discussion regarding PTS guidance during MU/HPI Cooling.

2.4 FW Flow Exists ?

The operator must now determine whether or not FW flow exists before taking further actions. There are three possibilities: heat transfer may have been lost because of a LOFW, primary side steam voids blocking natural circulation (decreasing RCS inventory) or RC pressure is below SG pressure. Control room indications should be monitored closely to determine if adequate FW flow and SG levels exist. Alternate channels of instrumentation should be checked to guard against instrumentation error. One or two RCPs (one in each loop) should be left running to reduce heat input to the RCS yet provide for heat transfer as soon as FW is restored to either SG. The RCP(s) must be tripped if SCM is lost or the SG tube to shell compressive limit is reached.

2.5 Take Actions to Restore FW Flow (Detailed discussion in Section 3.4)

Initiate or verify automatic initiation of EFW. If EFW is initiated, then establish the appropriate SG level while preventing excessive overcooling and depressurization of the primary by controlling EFW flow.

If EFW is not available, then attempt to restore MFW. If neither EFW nor MFW is available, then feed the SG(s) with an alternate source of FW if available.

2.6 FW Flow Restored?

While attempting to restore FW, the operator should continually determine if HPI cooling is required. If FW is restored before HPI cooling is required, then actions should be taken to restore heat transfer.

2.7 Take Actions to Restore Primary to Secondary Heat Transfer (Detailed discussion in Section 3.5)

First, the SG pressure is reduced to create a RC to SG temperature difference of about 50°F and the SG level is increased to the appropriate level as determined by RCS conditions, i.e., saturated or subcooled and RCPs on or off. Refer to Chapter IV.C.

Second, stimulate primary to secondary heat transfer depending on the plant condition as follows:

A. If the RC is subcooled with an operable RCP, start a RCP. (Refer to Chapter IV.A for RCP restart criteria)

B. If the RC is subcooled and no operable RCP

   1. Open the RC hot leg HPVs and maintain or increase RC pressure.

2. Further lower SG pressure to create a RC to SG temperature difference of about 100°F.

3. Increase SG level to the loss of SCM setpoint. EFW is preferred over MFW.

C. If the RC is saturated no additional actions are available other than the initial actions to establish the 50°F primary to secondary delta T and the appropriate SG level.

2.8 Primary to Secondary Heat Transfer Restored?

While attempting to restore primary to secondary heat transfer, the operator should continually determine if HPI cooling is required. If heat transfer is restored before HPI cooling is required, then controlled decay heat removal with the SG(s) should be established.

The P-T relationship provides the easiest method for recognizing when heat transfer is reestablished. Refer to Chapter II.B for a discussion of P-T relationship.

2.9 Establish Controlled Decay Heat Removal With SG(s)

Once heat transfer has been restored, it is necessary to establish controlled decay heat removal. If the RCS is subcooled, it may be possible to return to near normal conditions. This would require recovering from HPI cooling, if initiated, by closing the PORV and HPVs, if open, and controlling HPI (HPI/MU) flow. The primary to secondary heat transfer rate should be controlled by adjusting the TBVs or ADVs to maintain the RC temperature at the present value or to begin a controlled cooldown. If HPI cooling has been initiated, there may or may not be a bubble in the pressurizer. If possible, a bubble may be drawn in the pressurizer.

If the RCS is saturated, it will be necessary to begin a cooldown with a saturated RCS. First, however, it will be necessary to recover from HPI cooling and to carefully control the primary to secondary heat transfer rate. With a saturated RCS, a small break

LOCA or an extended LOFW could have occurred. In this case, a saturated cooldown with the SGs can be performed while HPI maintains the RCS inventory. It is also possible that a loss of HPI coupled with RCS leakage resulted in the current conditions. A saturated cooldown without HPI should be performed in this case while efforts continue to recover HPI.

If heat transfer is occurring in only one SG, then actions should continue to attempt to restore heat transfer to the other SG, if possible. There may be other overriding concerns where it will not be possible to reestablish heat transfer to the other SG (e.g., unisolable steam line break or SGTR having occurred in that SG). These are discussed in Chapters III.D and III.E.

Refer to Chapter III.G for plant cooldown methods.

3.0 LACK OF HEAT TRANSFER TECHNICAL BASES

Note: The numbered subsections of Section 3.0 correspond to the bottom numbers of the appropriate blocks on Figure III.C.

3.1 Identification of a Lack of Heat Transfer

The P-T relationship will indicate a lack of heat transfer. Refer to Chapter II.B for a discussion of the P-T relationship.

3.2 HPI Cooling Required

Primary to secondary heat transfer is the primary method for cooling the core. Should this method fail, core cooling can be provided by HPI cooling. However, HPI cooling must be established in a timely manner depending on RC and SG conditions to assure that adequate core cooling will be provided. With FW available, actions to restore heat transfer can continue, without going to HPI cooling, until SCM is lost since BCC is ultimately available as a backup for core cooling.

If all feedwater flow and HPI (MU/HPI at DB) flow is lost, then core cooling capability is also lost. During such a situation, the operator has only a finite amount of time available to restore one of these core cooling capabilities to avoid uncovering the core and potentially leading to severe core damage. The amount of time available will primarily depend on the amount of core decay heat. Assuming maximum decay heat, core uncovering can start in 20 to 30 minutes. However, the restoration of core cooling, if possible, should be accomplished before the core starts to uncover because there may be some lag time before the core heat removal can match decay heat generation.

If while attempting to restore FW the RC pressure increases to the PORV setpoint or the RV P-T limit, then HPI cooling should be established.

A. Feedwater Available

If heat transfer does not start after establishing the SG as a heat sink (i.e., increasing the SG level to the loss of SCM setpoint and reducing the SG pressure to create an incore T/C to SG temperature difference of about 50°F), then if the RC is saturated HPI cooling must be started because no subsequent actions can be made to stimulate primary to secondary heat transfer.

If HPI is not available at this point, actions must be taken to control RC pressure as discussed in Section 3.5.C of this Chapter.

B. Feedwater not available

For a total LOFW, HPI cooling will be required to keep the core covered and adequately cooled. There are two important aspects of HPI cooling. First, operator initiation is required. There are no automatic systems to initiate HPI cooling. Consequently, the operator needs to continually monitor conditions for when HPI cooling should be started.

Second, the HPI cooling heat removal rate will probably not initially match the decay heat rate. Therefore, it must be started early enough to slow RC inventory depletion enough so that HPI cooling will match decay heat before the core is uncovered. Consequently, for all plants except Davis Besse, the HPI addition must be started as soon as RC inventory starts being lost, i.e., when the PORV open setpoint is reached or the first automatic PORV lift, whichever occurs first.

For Davis Besse, MU/HPI cooling must be considered as soon as feedwater becomes unavailable. If only one MU pump is operable then MU/HPI cooling must be initiated immediately. If two MU pumps are available then MU/HPI cooling initiation can wait until the core outlet temperature reaches 600°F provided the RCS RV PT limit is not exceeded.

3.3.A Establish HPI Cooling - except Davis Besse

Establishment of HPI cooling is accomplished as follows:

1. Two HPI pumps are started and verified to be operating at full flow for the existing RC pressure. HPI flow must be verified before opening the PORV.

2. If HPI flow can not be established, the PORV must not be maintained open. Because the only source of decay heat removal is the inventory that exists in the RCS, that inventory must be preserved as much as possible. The PORV should be closed and manually cycled only as necessary to prevent automatic lifting of the PORV. If the PORV fails open, then the PORV block valve is closed to isolate the PORV. This will minimize the RCS inventory loss as well as maximize its energy removal capability while reducing the number of PORV cycles that would occur if it remained in automatic. Any running RCP(s) should be tripped to eliminate their energy input to the RCS and to reduce the SG tube heatup rate. In this case, HPI and/or FW must be restored to preclude core damage.

3. If flow can be achieved from only one HPI pump, the PORV must be opened and left open. This will reduce RC pressure and maximize the available flow from the degraded HPI system.

<u>NOTE</u>: Analyses have been performed that indicate the core will not uncover, and thus be adequately cooled, with only one HPI pump and without opening the PORV. However, considering the collapsed liquid level can approach the top of the core and that the HPI system is already degraded, the PORV <u>must</u> be opened to retain the maximum RCS inventory for assurance of adequate core cooling.

4. If full flow can be achieved from two HPI pumps, the PORV may be opened or allowed to open automatically when RC pressure increases to the PORV setpoint, or it may be manually cycled. The preferred method is to maintain the PORV open which will reduce RC pressure and allow greater HPI flow thus providing increased core cooling. However, adequate core cooling can be achieved with two HPI pumps if the PORV is allowed to automatically open. In the event the PORV fails open during cycling, DO NOT close the PORV block valve.

   If the preferred method of maintaining the PORV open is used, then it is acceptable to use full pressurizer spray flow, if available, to reduce the rate of RCS pressurization in order to delay reaching the PORV setpoint. At some plants, manual action is required to fully open the pressurizer spray valve. If such actions are taken, then actions to close the spray valve or return control of the valve back to automatic should be ensured. The magnitude of the time delay depends on the decay heat level; the lower the decay heat level, the longer the time delay, including the possibility of preventing the PORV setpoint from being reached with low decay heat levels. Conversely, with high decay levels, use of pressurizer spray may have almost no noticeable effect in delaying reaching the PORV setpoint.

   Delaying reaching the PORV setpoint allows the pressurizer to fill more due to insurges. This may prevent loss of SCM after the PORV is maintained open.

   The reason for this is that the insurge to the pressurizer will decrease the size of the steam bubble so that when the PORV is opened, it will relieve steam for a shorter period of time and begin relieving two-phase liquid sooner. Once two-phase liquid is being relieved, the magnitude and rate of RCS depressurization is greatly reduced compared to single-phase (steam only) being relieved. By relieving two-phase liquid sooner, the magnitude of the RCS depressurization may be small enough to prevent loss of SCM.

5. If the PORV is not maintained open, i.e., cycled automatically or manually, HPI flow must not be throttled until incore T/Cs begin to cooldown and SCM exists. This supercedes the HPI throttling criteria in Chapter IV.B based solely on SCM since, as stated in 3 above, adequate core cooling is assured as long as two HPI pumps are run at full capacity. Once the incore T/Cs indicate decreasing core temperature, the normal HPI throttling criteria (Chapter IV.B) apply.

6. If the PORV fails to open or PORV flow cannot be established for any reason after the initiation of HPI cooling, then RC pressure is expected to increase causing cycling of the pressurizer safety valves. This RC pressure rise and the extent of safety valve cycling will be dependent upon the decay heat level and the amount of flow supplied to the RCS by the HPI pumps.

   If this mode of operation continues long enough (no PORV flow established), RC temperature will begin to decrease while the RC pressure remains high. In this situation, high RC pressure (at the pressurizer safety valve setpoint) and decreasing RC temperature, PTS guidance must be followed, if invoked. Along with continuing attempts to establish PORV flow, HPI flow should be throttled to keep RC temperature from decreasing below the NDT limit or within PTS guidance, if invoked. Throttling of HPI flow can begin after SCM is provided. If HPI is "on" with RCPs "off," then the PTS guidance requires throttling HPI to keep the core outlet subcooling near the SCM limit. In this case HPI flow can be throttled to the point where the RCS begins to reheat in order to establish a temperature band for control.

   As long as PORV flow cannot be established, the plant will remain in this mode until primary to secondary heat transfer is restored, a pressurizer safety valve fails open or decay heat diminishes to less than ambient RCS losses. The HPVs may be opened to aid cooling and, with very low decay heat, pressure reduction.

7. One RCP should be left running as long as SCM and tube to shell compressive limits are maintained to provide thermal mixing. Only one RCP should be used to limit the additional heat input.

8. The remaining RCP must be tripped if SCM is lost or if RC temperature reaches the compressive limit relative to either SG shell temperature. This will slow further heatup of the SG tubes. The RCP should not be restarted, even with SCM and restart criteria of IV.A met, until the ΔT between the core outlet temperature and either SG shell is less than the compressive limit. The use of a deadband will allow some margin for RCP heat input to prevent cycling the RCP unnecessarily.

9. Pressurizer heaters should be turned off to ensure they will not be automatically energized when the RCS pressure is reduced during HPI cooling. Deenergizing the heaters also reduces the energy input to the RCS to reduce the HPI cooling heat removal demands and to help in reducing RCS pressure. This also protects the heaters should they become uncovered during HPI cooling.

10. Letdown should be isolated. This prevents a loss of inventory outside containment since HPI cooling may require sump recirculation.

Refer to Chapter III.G for complete guidance on initiation and control of HPI cooling.

3.3.B Establish MU/HPI Cooling for Davis Besse

If FW cannot be supplied to either SG, then MU/HPI cooling, if started soon enough, can provide adequate decay heat removal. Analyses show that during a complete loss of FW event core uncovering will not occur assuming: 1) two MU flow paths, 2) two MU pumps are started within ten minutes after T_{hot}=600°F and 3) RC flow out through the pressurizer safety valves (i.e., the PORV is not available). The analyses indicate T_{hot}=600°F would be reached in about 1.5 minutes after a reactor trip on high RCS pressure (or 7.5 minutes after a reactor trip on ARTS) following a loss of feed-water with maximum decay heat. Another analysis that assumes only one operating MU flow path and one MU pump started within ten minutes after T_{hot}=600°F with an open PORV and MU/LPI in piggyback operation shows the collapsed core liquid level decreasing to about 6 inches below the top of the core. However, the core should be adequately cooled because a liquid froth would exist at the top of the core rather than a collapsed liquid level. Although adequately cooled, conservatism dictates that the collapsed liquid level should not be allowed to drop below the top of the core. In addition, the TBD philosophy requires selecting the prudent course of action which provides margin for additional failures or errors rather than providing actions which leave no margin for additional failures or errors. Therefore, the guidelines do not wait until T_{hot} reaches 600°F before starting MU/HPI cooling, if only one MU pump starts.

Consequently, the guidelines state that whenever feedwater is unavailable immediately establish makeup flow from the MU pumps. The resultant quantity of MU pumps in operation will determine when the MU/HPI cooling process must be initiated. If only one MU pump is operational then MU/HPI cooling must be initiated immediately. However, if both MU pumps are operational, then MU/HPI cooling initiation can be delayed until the core outlet temperature reaches 600°F or the RV pressure-temperature limit is reached. Initiation of MU/HPI cooling before 600°F should also be considered if HPI piggyback capability is not available. The PORV should not be opened until MU/HPI flow is verified.

If MU/HPI flow can not be established, the PORV must not be maintained open. Because the only source of decay heat removal is the inventory that exists in the RCS, that inventory must be preserved as much as possible. The PORV should be closed and manually cycled only as necessary to prevent automatic lifting of the PORV. If the PORV fails open, then the PORV block valve is closed to isolate the PORV. This will minimize the RCS inventory loss as well as maximize its energy removal capability while reducing the number of PORV cycles that would occur if it remained in automatic. Any running RCP(s) should be tripped to eliminate their energy input to the RCS and to reduce the SG tube heatup rate. In this case, MU/HPI and/or FW must be restored to preclude core damage.

Pressurizer heaters should be turned off to ensure they will not be automatically energized when the RCS pressure is reduced during MU/HPI cooling. Deenergizing the heaters also reduces the energy input to the RCS to reduce the MU/HPI cooling heat removal demands and to help in reducing RCS pressure. This also protects the heaters should they become uncovered during MU/HPI cooling.

Letdown should be isolated. This prevents a loss of inventory outside containment, since MU/HPI cooling may require sump recirculation.

Refer to Chapter III.G for details about MU/HPI cooling initiation.

If the PORV fails to open or PORV flow cannot be established for any reason after the initiation of MU/HPI cooling, then RC pressure is expected to increase causing cycling of the pressurizer safety valves. This RC pressure rise and the extent of safety valve cycling will be dependent upon the decay heat level and the amount of MU supplied to the RCS by the MU pumps (RC pressure will be too great to allow any HPI pump flow).

If this mode of operation continues long enough (no PORV flow established), RC temperature will begin to decrease while the RCS pressure remains high. In this situation, high RC pressure (at the pressurizer safety valve setpoint) and decreasing RC temperature, PTS guidance must be followed. Along with continuing attempts to establish PORV flow, MU flow should be throttled to keep RC temperature from decreasing below the NDT limit or within the PTS guidance, if invoked. Throttling of MU flow can begin after adequate SCM is provided. If MU/HPI is "on" with RCPs "off," then PTS guidance requires throttling MU/HPI to keep the core outlet temperature near the SCM limit. In this case MU flow can be throttled to the point where the RCS begins to reheat in order to establish a temperature band for control.

As long as PORV flow cannot be established, the plant will remain in this mode until primary to secondary heat transfer is restored, a pressurizer safety valve fails open or decay heat diminishes to less than ambient RCS losses. The HPVs may be opened to aid cooling and, with very low decay heat, pressure reduction.

3.4 Take Actions to Restore FW Flow

If FW flow is not available, the operator must take actions to restore FW flow. The operator should first verify automatic initiation of EFW. If necessary, EFW should be manually initiated and throttled as necessary to limit initial flow, establish the appropriate SG level, and prevent an excessive overcooling and depressurization of the primary system. Refer to Chapter IV.C for details of EFW throttling. If EFW is not available, it may be possible to regain MFW (for example, if an ICS failure had occurred closing a MFW valve or tripping a MFW pump, it may be possible to take manual control and restore MFW). The cause of failure should be examined during the attempt to restore MFW or initiate EFW. Possible causes include lack of a source of FW, FW pumps failing, and FW valves failing closed. The determination of the cause of failure of EFW or MFW should continue in parallel with restoring core cooling, even if HPI cooling is required.

If a concurrent loss of both EFW and MFW has occurred, then it may be possible to feed the SGs with alternate sources of FW using alternate pumps. However, specific guidance on this would be determined beforehand.

If steam pressure in dry SG(s) is decaying due to normal losses (as opposed to a steam leak), the automatic isolation of FW on low SG pressure may be bypassed to prevent complications in restoring FW.

In the event that one or both SGs boil dry before EFW or MFW can be restored, FW flow must be initially limited to a dry SG per Rule 4.0. This guidance is provided in Chapter IV.C.

The manual initiation of EFW or MFW to a dry SG should be limited to the initial flowrates specified in Rule 4.0 to limit the stresses imposed on the SG. These initial flow limits are given as one limit for each of three cases to simplify operator actions during transient mitigation. If EFW initiates automatically as designed, the flowrate does not have to be manually limited, since automatic initiation should occur early in the loss of feedwater before tube-shell ΔT becomes a concern. The bases for the initial flow limits are provided in Chapter IV.C.

3.5 Take Actions to Restore Heat Transfer

During the actions to restore primary to secondary heat transfer, RCS pressure and the possible need to initiate HPI cooling must be continually monitored and controlled.

RCS pressure is controlled by manually opening and closing the PORV. This prevents excessive PORV cycling which could occur if the PORV were allowed to operate automatically between normal RCS pressure setpoints.
The PORV is opened when RCS pressure reaches the PORV setpoint and reclosed based upon RC conditions, i.e., saturated or subcooled.

If the RC is saturated, the PORV is reclosed when RCS pressure decreases to about 1600 PSIG. Closing the PORV at 1600 PSIG, eases operator burden by utilizing a single easily identifiable parametric value while maintaining the SGs as heat sinks.

If the RC is subcooled, then PORV is reclosed when RCS pressure decreases to a point above the SCM curve Maintaining margin to the SCM limit prevents having to trip the RCPs and prevents the possibility of void formation which would further hinder the restoration of heat transfer. The point of PORV closure, whether saturated or subcooled RC conditions, also provides the necessary conditions to maintain the SGs as a heat sink.

With FW available the operator can take actions to restore primary to secondary heat transfer.

The first actions are to establish proper SG level and pressure. This will create the necessary heat sink for RCS heat removal. The SG level which must be established depends upon the RCS conditions e.g., if the RCS is saturated, then the SG level must be raised to the loss of SCM setpoint so that boiler-condenser cooling can occur. (Refer to Chapter IV.C for a discussion of the proper SG levels). Verification of the proper SG level being established and maintained is vital. SG level instrumentation should be monitored to confirm the proper SG level. Alternate channels may be checked along with the different ranges. Caution must be taken in comparing SG levels among the different ranges. Some instrumentation may require temperature compensation before they can be used as a valid check of the SG level. If the RC is saturated, EFW is preferred over MFW for raising the SG level because EFW instantaneously raises the SG thermal center above that required for boiler condenser cooling. Also in lieu of building a SG level when level cannot be increased e.g., after a steamline break, EFW flow can be continuously added. The SG pressure which must be established depends on the RCS temperature. The SG pressure must be reduced as necessary to create about a 50°F temperature difference between the incore T/C and SG. The SG temperature will be determined by the saturation temperature for the existing SG pressure. If primary to secondary heat transfer was lost because of RC pressure continually decreasing below the secondary pressure, then cooling can be provided by LOCA/HPI flow (see chapter III.B). If, however, RC pressure stabilizes below SG pressure, then decreasing the secondary pressure is necessary to enable heat transfer to be restored. While lowering secondary pressure, it is important to monitor SG levels very closely. FW flow must be increased once heat transfer is established to maintain the appropriate SG level. Provided the RCS hot leg loops are water solid, heat transfer should be restored once secondary pressure is sufficiently reduced. During these actions it may be necessary, if not already done, to bypass the secondary plant protection system to prevent unwanted isolation of steam and feed lines. SG pressure should not be reduced below the minimum pressure required by the turbine-driven EFW pump unless other steam sources or motor driven EFW pump(s) are used. After establishing the SG as a heat sink the operator will perform actions which stimulate heat transfer. The actions will be different depending on whether the RC is subcooled and whether any RCPs are operable. These actions are as follows:

A. RC Subcooled With No Loop Voids

If heat transfer could not be restored with a SG available and the RCS is subcooled, the likely causes are a loop void or thermal stratification (e.g., due to extended HPI cooling). If there are no loop voids, then a RCP should be started per restart criteria of IV.A, to establish primary to secondary heat transfer. If only one SG is available as a heat sink (i.e., sufficient FW flow or level exists and SG Tsat is below the RC temperature), then the first RCP started should be in that loop if possible in order to establish RC flow through the available SG for forced flow heat transfer. This will also establish reverse flow through the other loop, i.e. with the unavailable SG.

RCP restart could result in a loss of SCM depending on initial RCS conditions. If a loss of SCM does occur, full HPI flow must be initiated. If SCM is not restored within two minutes, then the RCP must be tripped. To limit the chance of losing SCM when the RCP is started, it is desirable to have pressurizer level at ~75% full scale and SCM at the minimum value plus ~20^{0}F at the core outlet. This will help compensate for the expected pressurizer level and RC pressure decrease due to RCS contraction and should prevent a loss of SCM.

However, the start of the RCP should not be delayed by attempts to increase pressurizer level or SCM. At this point, no primary-to-secondary heat transfer exists and therefore it is more important to start an operable RCP. Heat transfer may be restored by the RCP start even if the RCP must be tripped due to loss of SCM. If heat transfer is not restored and SCM is lost, the RCP start still should be beneficial by lowering RCS pressure due to contraction from the heat transfer occurring while the RCP was operating. The reduced pressure will aid refill by HPI. If SCM cannot be restored, then refer to actions for saturated RC conditions. If heat transfer is restored, a second RCP should be started to establish a normal plant configuration.

B. RC Subcooled with Loop Voids

The operator should vent the hot leg by opening the hot leg HPVs to remove any steam or gas which may be blocking natural circulation flow of the RC. While the HPVs are open, RCS pressure must be maintained constant or slightly increasing to prevent additional flashing in the loop. If all of the steam voids can be relieved through the HPVs before the RCS becomes saturated, then it may be possible to restore heat transfer. Analyses have been performed that demonstrate venting through the HPVs to be effective. These analyses show that, with the voids extending approximately fourteen feet into the hot leg from the top of the U-bend, loop void elimination could occur within ten minutes (depending on vent size) after the start of venting. This degree of effectiveness requires that the core outlet be subcooled during the venting operation. Therefore, if heat transfer is not restored before SCM is lost, the actions for RCS saturation conditions should be taken.

The hot leg level measurement indication, if available, might be used to confirm that the steam void is being eliminated. However, the level measurement may not be correct while the HPVs are open and for a while after closing them. Once the hot leg voids have been eliminated, the operator should be able to restore natural circulation.

The SG thermal center should be raised by simultaneously using two approaches: increasing the SG level to the loss of SCM setpoint and adding water to the SG using EFW (EFW enters the SG at a high elevation). If the RC is subcooled and no RCPs are operable, raising the SG level to the loss of SCM level using EFW may be desirable to get the SG thermal center as high as possible to stimulate RC flow. A steam void in the loop may penetrate below the loss of SCM setpoint but not the natural circulation setpoint. Increasing the SG water level and using EFW will condense some of the steam void. Also the water in the cold leg may have cooled considerably (due to seal injection, etc.) requiring a higher SG thermal center to move the cold slug of water over the RCP lip and into the RV. This action, in conjunction with lowering SG pressure, may cause hot leg spillover and aid in initiating NC flow. It may be possible to subsequently start RCPs to aid cooldown; see Chapter IV.A for restart criteria.

C. RC Saturated

While trying to stimulate primary to secondary heat transfer, the RC pressure should be reduced by opening the PORV whenever the RC pressure increases to the PORV setpoint. This will allow increased HPI flow, if it is available, for core cooling, to prevent challenges to the pressurizer safety valves, and to prevent excessive PORV cycling (especially important if PORV block valve is failed open). However, the PORV should be closed when the RC pressure decreases to about 1600 PSIG. This is to maintain the SG as a heat sink.

Analyses were performed that examined the effects of operator actions to restore natural circulation when the RCS is saturated.

The operator actions examined were:

- opening the HPVs,
- depressurizing the SGs in conjunction with raising SG level to the loss of SCM setpont level by EFW injection.

These analyses showed that opening the HPVs did not contribute to the reestablishment of natural circulation. This action may result in earlier boiler condenser cooling due to the increased loss of RC inventory, but had a negligible effect overall on reducing the probability of cyclic boiler condenser cooling. However, the HPVs may help and opening the HPVs should not hinder restoration of SG coolng and therefore should still be used.

The effect of SG depressurization (in excess of that needed to establish a 50°F delta T between incore T/Cs and SG Tsat) was also evaluated. The analyses showed that operator action to further reduce SG pressure had a negligible effect on the reestablishment of natural circulation. Therefore, HPI cooling should be established if primary to secondary heat transfer does not occur after the SG has been established as a heat sink. Because the RC is saturated, HPI should be in operation; hence, it is only necessary to open the PORV (and PORV block valve if necessary) to ensure an HPI cooling path.

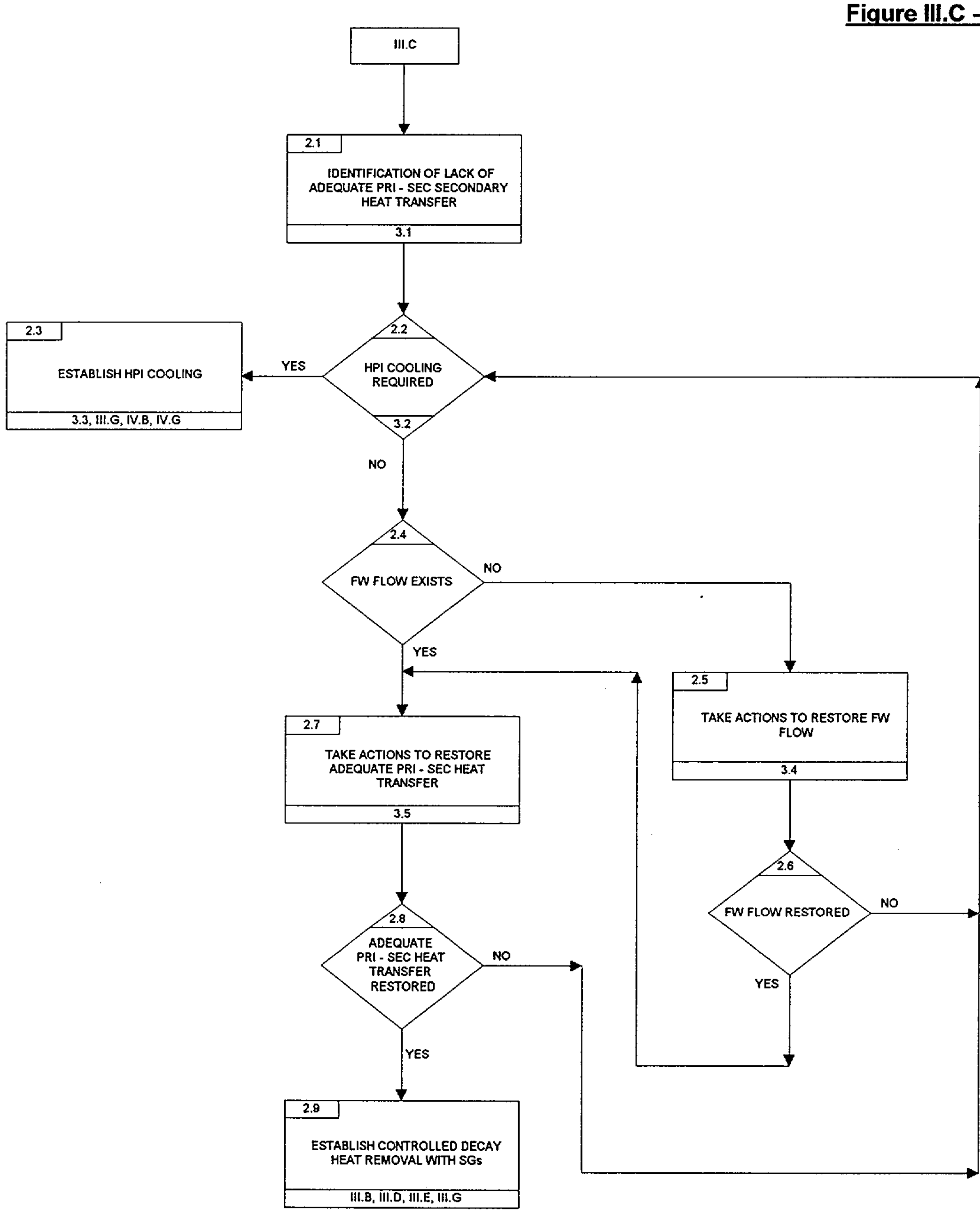
If HPI (MU/HPI at DB) flow is not available, then HPI cooling cannot be established and the RCS pressure may begin to increase since little decay heat is being removed from the core. The magnitude and duration of the repressurization will depend heavily on the RCS leak rate or break size (if any) and on the decay heat level. If the leak rate is large enough, the period of time between losing natural circulation flow and establishing boiler condenser heat transfer may be relatively short allowing little or no RC repressurization to occur. However, if the leak rate is small it may take a longer time for primary levels to decrease below the elevation of the EFW nozzles or SG pool level at which point boiler condenser cooling will begin.

During this time periodic primary to secondary heat transfer may develop. The RCS leakage can cause the primary to secondary heat transfer to degrade due to increased RCS voiding causing the RCS to reheat and repressurize. The reheating will continue until expansion of RC, primarily in the core and in the RV inlet (due to vent valve flow), causes an increase in the loop mass flow rate over the hot leg candy cane (i.e. spillover) and into the SG causing cooler water to flow from the SG into the RV inlet and core. This will decrease the RC density and pressure causing increased voids in the hot leg candy cane again with a resulting reduction in primary to secondary heat transfer. This reduction in primary to secondary heat transfer will again cause the RC to heat up and repressurize with the resulting increased mass flow rate through the SG. The RC will repressurize to a higher value each time this process is repeated. This process will tend to repeat itself until the RCS leak causes the RC water level in the SG tubes to decrease enough to establish boiler condenser cooling.

As before, if the RCS repressurizes to the PORV setpoint, the PORV should be opened to reduce RCS pressure and reclosed when RCS pressure is about 1600 PSIG. It is worth noting that during PORV cycling inventory will be passed out the PORV which will result in a faster transition to boiler condenser cooling. Attempts to establish HPI cooling should continue.

LACK OF ADEQUATE PRIMARY TO SECONDARY HEAT TRANSFER FLOWCHART

Figure III.C - 1



Chapter III.D

Excessive Primary to Secondary Heat Transfer

1.0 INTRODUCTION

The purpose of this chapter is to provide technical bases for operator actions to terminate excessive primary to secondary heat transfer from the RC to the SG(s). These bases are applicable whenever a symptom of excessive primary to secondary heat transfer exists. The RC can be either saturated or subcooled.

1.1 Concerns and Objectives

1.1.1 Concerns

Excessive primary to secondary heat transfer is always caused by a failure in the control of secondary side parameters. This failure manifests itself as a loss of steam pressure or excessive steam or FW flow or perhaps a combination of both. While a momentary overcooling is only troublesome, an extended overcooling is a severe shock to the plant and requires quick and effective action by the operator to mitigate the transient. There are several concerns as follows:

A. Loss of Pressurizer Level

An extended overcooling can result in a loss of pressurizer level. This, in turn, causes a loss of RC pressure control. An extended overcooling can empty the surge line which results in the RCS becoming saturated at the hottest location (see Section 3.2 for further explanation).

B. Saturated RCS With Extended Overcooling

A large steam line break or extended overcooling (i.e., continued FW with small steam line break) can result in a saturated RCS. This requires treatment of the top priority symptom which is a loss of SCM. After treating the loss of SCM (e.g., tripping RCPs and initiating HPI), the excessive overcooling should be treated.

C. Possible SG Damage

A rapid overcooling could result in SG damage from tube vibration due to high steam/feed flow as well as thermal shock to the SG and from excessive SG tube tensile loads due to exceeding tube-to-shell delta T limits. The SG tube- to-shell delta T limits may be exceeded because the tube temperature will decrease corresponding to the SG saturation temperature while the SG shell will cool relatively slowly due to its large mass. The potential exists for an SGTR to occur from the overcooling. If the steam leak is unisolable it may be necessary to boil the SG dry. Reintroducing FW to a dry SG must be performed in accordance with Rule 4.0. Refer to Chapter IV.C for a discussion of feeding a dry SG.

D. Pressurized Thermal Shock (If applicable)

With an extended overcooling, thermal shock becomes a concern. PTS guidance must be invoked if the criteria specified in Chapter IV.G are exceeded. The RCS must be controlled to ensure that PTS guidance is not violated. This requires action on the part of the operator to control RC pressure and temperature.

Refer to Chapter IV.G for a discussion of PTS guidance.

1.1.2 Objectives

The main objective for the operator is to terminate the overcooling transient as quickly as possible. This will minimize the contraction of the RCS and minimize the potential for invoking PTS guidance as well as minimizing possible SG damage.

If the PTS guidance is invoked, it will be necessary to follow PTS guidance. The operator must control HPI to prevent RCS repressurization.

Once the overcooling is terminated, it is necessary to restore control of decay heat removal.

1.2 Causes

In general, an overcooling is caused by either excessive steam flow (failure of SG pressure control low) or excessive FW (failure of FW inventory control high).

Overcooling can result from failed open TBVs, ADVs, MSSVs, or steam line breaks. Overcooling can also occur from excessive MFW or EFW.

2.0 DIAGNOSIS AND MITIGATION

The flowchart of Figure III.D-1 should be used in conjunction with the following discussion. The numbered subsections of Section 2.0 correspond to the upper numbers in the blocks of Figure III.D-1.

2.1 Identification of Excessive Heat Transfer (Detailed discussion in Section 3.1)

An overcooling transient is best identified by the P-T relationship (Refer to Chapter II.B).

2.2 Control Pressurizer Level (Detailed discussion in Section 3.2)

Pressurizer level control may be difficult during an overcooling transient. Increased MU flow and even HPI flow should be utilized to try and prevent pressurizer level from going off scale low. However, the pressurizer may still empty. If the pressurizer surge line is emptied, a bubble could form at the hottest RC region, most likely under the RV head (see Section 3.2 for full explanation). While this in itself is not a detriment to core cooling, it is best prevented if possible to enhance RC pressure control. Early termination of the overcooling transient and/or initiation of additional makeup/HPI will help to prevent draining of the surge line. However, with an overcooling transient in progress, control of HPI or MU flow is required to avoid violating RV P-T limits. In addition, the HPI should be controlled to prevent excessive RC pressure and subcooling with the pressurizer level gradually restored to normal.

2.3 Overcooling SG Apparent? (Detailed discussion in Section 3.3)

SG and RC loop parameters should be compared between SGs to determine which SG is causing the overcooling. If the overcooling is small, it may be difficult to determine which SG is causing the overcooling. It is possible that both SGs could be causing the overcooling. If the overcooling is large, the SG causing the overcooling should be more easily identified. However, it may mask the fact that the other SG is also contributing to the overcooling. But this will become apparent after the first SG is isolated.

If the cause of the overcooling is identified as a MSSV, then SG isolation may not be required. If SG level can be controlled and the cooldown rate is within TS limits, then continued feeding and steaming of the SG is preferable to SG isolation and dryout. In this case, a forced cooldown can be performed until such time that the leak can be terminated.

2.4 Isolate Both SGs

If the overcooling SG is not apparent or if both SGs are causing the overcooling, then it may be necessary to isolate both SGs. Isolating a SG means to stop all FW flow (MFW and EFW) and steam flow (close TBVs, ADVs, steam supply to FW pumps, etc.). If excessive MFW exists, such that steam line flooding is imminent, then it is necessary to trip the running MFW pumps. If the MFW overfeed is not as severe then it should be adequate to close the appropriate FW valves. Steam line break control systems may close all or some of the FW and steam valves. In this case, it is only necessary for the operator to verify that these automatic actions have terminated the overcooling transient and, if necessary, close additional valves.

2.5 Isolation or control of the Overcooling SG

If the overcooling SG has been identified then, with the exception of the specific MSSV case discussed in section 2.3, that SG should be controlled or isolated. Isolating a SG means to stop all FW flow (MFW and EFW) and steam flow (e.g., close TBVs, ADVs, steam supply to FW pumps, MSIVs etc.) If the steam lines are in danger of being flooded, then it may be necessary to trip the running MFW pumps. FW flow should be maintained to the unaffected SG and cooling stabilized using the unaffected SG.

Isolation or control of a SG or both SGs should always follow a logical progression of increasingly more drastic attempts to isolate the SG. For example, if the overcooling is not severe it may be possible to close or control both the TBVs and ADVs as well as the auxiliary steam valves in an attempt to isolate or control the SG. If this does not work then, for those plants which have main steam isolation valves, the main steam isolation valve should then be closed. However, in a more serious overcooling it may be necessary to close the main steam isolation valve first, in an attempt to isolate the steam leak. Provisions must also be made for frequent occurrence of MSSVs leaking immediately after trip. In most cases a leaking MSSV can be reseated by simply lowering SG pressure until the leaking valve reseats, then normal SG pressure can be restored.

2.6 SG Pressures & Levels Have Stabilized (Detailed discussion in Section 3.4)

The required actions from this point depend upon determining whether or not SG levels and pressures have been stabilized. If both SG pressures and levels have stabilized (or SG pressures begin increasing) then the overcooling transient has been terminated. The cause of the overcooling was either an isolable steam leak (failed open TBV, ADV or steam line break downstream of the isolated valves) or excessive feedwater which has now been terminated. On the other hand, if SG pressures and levels are not stabilized then one or both SGs have an unisolable steam line leak.

2.7 Reestablish Heat Transfer to One or Both SG(s) (Detailed discussion in Section 3.5)

The following operator actions will be required:

A. If FW was isolated, FW must be reintroduced to the available SG(s).

B. TBVs or ADVs must be utilized to stabilize primary to secondary heat transfer.

C. Reheat and swell of the RCS should be prevented to maintain the RCS within pressure limits and prevent filling the pressurizer.

D. Maintaining pressure limits may also require throttling HPI and even opening the pressurizer vent/PORV to limit repressurization.

2.8 Trickle Feed One or Both SG(s) or HPI Cooling (Detailed discussion in Section 3.6)

If pressure and level cannot be restored to either SG, it may be possible to trickle feed one or both SGs. Careful control of EFW flow rates is necessary to maintain RCS cooldown limits. EFW should be used for feeding a dry SG. However, a SG with a steam line break inside the RB should not be trickle fed if the steam release to the RB is determined to be inappropriate. HPI cooling must be used if trickle feeding is not possible or controllable.

2.9 Verify Stable Plant Conditions

As soon as the overcooling is terminated and heat transfer has been reestablished, it is necessary to verify stable plant conditions. The operator should continue to monitor for all the symptoms of upsets in heat transfer. For example, immediately after an overcooling has occurred, the operator should check for a loss of SCM. A prolonged overcooling can result in a loss of SCM, in which case the operator would have to take actions. See Chapter III.B for details of treatment for a loss of SCM. It is also prudent to check for a SGTR. Excessive overcooling could result in damage to the SG tubes, thereby causing a tube leak. Verification that a SGTR has not occurred may require steam line radiation monitoring in the case of an unisolable steam line break.

If the break is upstream of the steam line monitors, the steam line monitors may not give an indication that a SGTR had occurred.

3.0 TECHNICAL BASIS

The flowchart of Figure III.D-1 should be used in conjunction with the following discussion. The numbered subsections of section 3.0 correspond to the bottom numbers of the appropriate blocks on Figure III.D-1.

3.1 Identification of Excessive Heat Transfer

The P-T relationship is the quickest and most accurate means of determining that an overcooling is occurring. The characteristics of an "overcooling" type transient are discussed in Chapter II.B.

3.2 Control Pressurizer Level

The consequence of loss of pressurizer level such that the surge line empties, during an overcooling, is saturated RC somewhere in the RC system. However, this will normally not result in a loss of core exit subcooling margin nor should it interfere with mitigation of the transient and restoration of controlled core cooling.

The place where saturation first occurs will be where the RC temperature is the highest. During an overcooling transient the core exit temperature or Thot (hot leg) will be decreasing at a rate faster than the temperature of the RC in the upper head region even with RCPs on. Data from overcooling events indicates that some mixing does occur in the upper head region but at a much slower rate than the rest of the system. Therefore, the highest temperature RC following initiation of an overcooling transient with RCPs on will be in the upper head region.

In the event a single loop natural circulation cooldown is in progress at the time an overcooling occurs, the hottest RC may be in the hot leg of the idle SG.

Bubble formation could occur in the hottest region of the RCS when the pressurizer and surge line empty. If bubble formation occurs, the RC pressure decrease will slow markedly; in effect the upper head region or idle loop is now acting as a second pressurizer. RC pressure will now decrease more slowly as a function of the overcooling, HPI flow and bubble growth until the overcooling is stopped and/or HPI begins refilling the RCS. Since the RC temperature at the region of the bubble is greater than the core outlet and any circulating hot legs and is saturated (same effect as the normal pressurizer), the core outlet and circulating hot leg(s) should remain subcooled. The subcooling will be equivalent to the difference between the RC temperature in the bubble region and the temperature at the point of subcooling measurement (core outlet and hot legs).

For overcooling events that empty the pressurizer and surge line, with full HPI flow, the RC in the active hot legs and at the core outlet (where subcooling is measured) is expected to remain subcooled. Data from rapid overcooling occurrences shows that subcooling during these periods can increase to greater than 100F. For this reason it is very important that the HPI flow be throttled to prevent exceeding the RV P-T limits and PTS guidance, if invoked; DO NOT wait for pressurizer level to return to throttle the HPI flow.

Depending on conditions, such as rapid overcooling for extended period of time or loss of HPI during rapid overcooling, the bubble could become large enough to partially mix with the RC exiting the core. As this mixing occurs, the cooldown rate of the RC exiting the core will decrease (due to the gain in energy from the condensing vapor of the bubble) and RCS pressure will fall (due to condensation of bubble vapor) leading to a reduction of subcooling. If subcooling drops to less than the subcooling margin, RCPs must be tripped.

Generally, during an overcooling transient (especially with HPI on) it is not expected that emptying the pressurizer and surge line will lead to loss of core exit SCM.

3.3 Overcooling SG Apparent?

Identification of the overcooling SG will allow early isolation of the overcooling SG while not disturbing FW flow to the non-overcooling SG. This is the preferred method for mitigating this type of transient. Since it is possible for both SGs to be contributing to the overcooling, the following discussion should aid in identifying a single overcooling SG.

To identify the overcooling SG, first compare SG and RC loop parameters. The SG associated with the lowest and fastest decreasing Tcold is the overcooling SG. For an overcooling event, especially a rapid overcooling caused by a steam system upset or failure, for example, the overcooling SG can also be identified because its steam pressure will be lower than and decreasing at a rate faster than the non-overcooling SG. Since steam pressure in the non-overcooling SG will also be decreasing, it is important to understand why this occurs in order to avoid confusion.

RCS temperature will determine the pressure in the non-overcooling SG. Since RCS temperature is decreasing due to excessive heat transfer in the overcooling SG, saturation pressure for the non-overcooling SG is decreasing, causing the actual pressure in the non- overcooling SG to decrease. This process causes a lag time between the overcooling and non-overcooling SG; i.e., the non-overcooling SG pressure decrease will always be behind the overcooling SG.

For these reasons, feedwater valve positions, feedwater flow rates, and SG levels should also be checked to verify identification of the overcooling SG. They should also be checked to ensure that excessive feedwater addition is not occurring and contributing to the overcooling. Excessive feedwater addition could be occurring due to a failure in the feedwater system itself, or it could be occurring due to the steam leak. For example, if the SGs are on level control, feedwater flow will increase to one or both of the SGs in an attempt to maintain the level setpoint. Since boil-off in the overcooling SG is greater than in the other SG, a difference in feedwater flows to the two SGs should exist.

For some plants, if a large overcooling occurred, the automatic systems for steam line break or overfill may be actuated. If an automatic system is actuated the operator must verify that all of the actions have occurred as designed. The most important verification after actuation of an automatic system is to ensure that the right SG has been isolated and that the overcooling has been terminated.

If the cause of overcooling is determined to be a leaking MSSV, then SG isolation may not be necessary. If the resulting cooldown rate is within TS limits, and if the SG level can be maintained, then it is usually preferable to continue plant cooldown rather than isolate the SG. SG isolation would result in SG dryout and, if in natural circulation, loss of control of the SG tube-shell ΔT. Continuing the plant cooldown using both SGs will allow control of SG parameters.

Leakage through the MSSV is specified because the leak location is not detrimental to personnel or key equipment and because the leak is unisolable until the MSSV reseats or can be gagged shut. Thus the only alternative would be SG dryout. The same concept could be applied to any steam leak location that is both small enough and not in a location that could be detrimental to personnel or key equipment. TS cooldown rate limits and the ability to control SG level are specified because these conditions ensure equipment operation within limits. Barring any increase in MSSV leak rate, the cooldown rate would normally decrease with decreasing SG pressure. However, if the cooldown rate does subsequently exceed the TS limits, then SG isolation should be performed. Similarly, if the SG level control can not be maintained, then the SG should be isolated.

3.4 SG Pressures and Levels Have Stabilized

Whether or not SG pressures and levels have stabilized will indicate if the overcooling was due to an isolable or non-isolable steam leak or excessive FW (MFW and AFW). If SG pressures and levels have stabilized, then the overcooling was isolable or controllable and the overcooling has now been terminated by stopping or controlling FW flow and closing steam valves. If SG pressures and levels continue to decrease then the leak is non-isolable. The overcooling SG(s) must then be allowed to boil dry.

3.5 Reestablish Heat Transfer to One or Both SGs

If the overcooling has been terminated and pressure and level has stabilized in at least one SG, heat transfer can be reestablished to the good SG(s). At this point it is possible that only one SG was isolated. In this case, heat transfer has been maintained in the unaffected SG. FW can then be carefully reintroduced to the isolated SG if stable and its steam valves manually controlled. The RCS should be depressurized to and maintained as low as possible but above the SCM limit and RCP NPSH requirements. This minimizes SG tube tensile stress caused by primary to secondary differential pressure. If both SGs have been isolated then heat transfer must be carefully restored to the good SG(s).

At this point, the cause for the overcooling may not have yet been determined. Consequently, attempting to reestablish heat transfer in the isolated SG(s) may reinitiate the overcooling transient. For example, if the cause of overcooling was a failed ICS controller to the TBVs, then when the operator attempts to restore automatic control of the TBVs the overcooling would be reinitiated. In this case the operator should restore manual control of the TBVs and maintain manual control until the problem with the automatic control could be determined and fixed.

Immediately after termination of a severe overcooling transient, it is necessary to reestablish controlled heat transfer. If PTS guidance is invoked then follow PTS guidance. Observing RV P-T limits is necessary, even if momentary opening of the pressurizer vent/ PORV is required to maintain the RCS pressure. The SG pressure should be controlled to prevent reheat and swell of the RC. HPI must also be carefully throttled to control RCS inventory and to prevent repressurization of the RCS. Considerable inventory could have been added during the overcooling to compensate for contraction, thus failing to control inventory through makeup or temperature changes after termination of the event could lead to large RCS pressure increases. Refer to Chapter IV.G for discussion of pressure limits.

3.6 Trickle Feed SG(s) or HPI Cooling

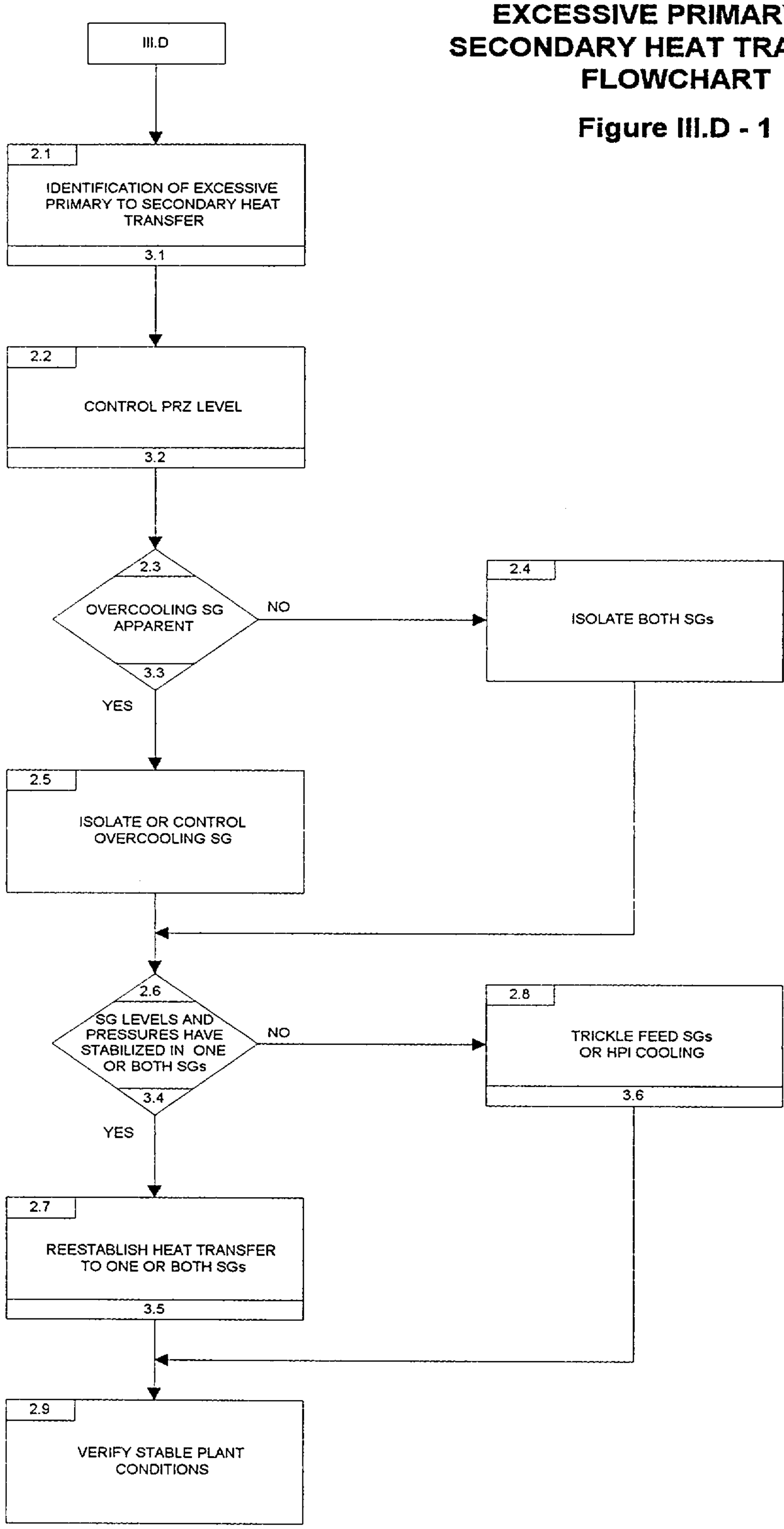
If restoration of pressure and level is not possible in either SG, then it may be possible to trickle feed one or both SGs to perform the cooldown. This could be necessary, for example, in the case of an unisolable steam leak on both SGs.

If it is decided to perform the cooldown by using trickle feeding, it will be necessary to control the rate of FW addition to the SGs to maintain RCS cooldown limits. The FW flow rate should be adjusted to get the desired cooldown rate. Once the proper flow rate is attained, this flow rate will have to be gradually decreased in order to match the exponentially decreasing decay heat. Refer to Chapter IV.C for control of feedwater to steam generators that cannot hold pressure.

If trickle feeding is not possible or controllable, then HPI cooling may be required (refer to Chapter III.C). The quantity of available FW should also be considered before deciding on trickle feeding. Since the FW is being irretrievably lost through the unisolable leak, it may be necessary, at some point in the cooldown, to switch to a lower quality FW or to HPI cooling. If an RCS leak exists such that adequate core cooling exists with break/HPI flow, then HPI cooling may not be required.

EXCESSIVE PRIMARY TO SECONDARY HEAT TRANSFER FLOWCHART

Figure III.D - 1



Chapter III.E

Steam Generator Tube Rupture

1.0 INTRODUCTION

This chapter provides the technical bases for mitigation of steam generator tube ruptures (SGTR). The purpose of these technical bases is to provide sufficient information regarding the expected NSSS response during SGTR transients such that, when coupled with the related technical bases in other chapters referenced herein, the user can develop plant specific procedures for diagnosis and mitigation of SGTRs.

SGTR events impose a unique problem on guideline and procedure writers as well as the plant staff. The ultimate goal of a SGTR procedure is to achieve cold shutdown with controlled cooling by the decay heat removal system and termination of the tube leak flow. The most expedient and controllable method to achieve this state is by cooldown using both steam generators. However, this must be balanced against the goal to minimize the release of radiation. One method to minimize the release of radiation is to isolate the SG as soon as conditions permit. This action (isolation of the SG), at best, places the plant in an abnormal condition and lengthens the time required to complete the cooldown. More importantly, these bases are designed to cover SGTRs in both SGs. Isolation of both SGs requires a transition to HPI cooling which is a less desirable mode of core cooling and presents special concerns with SGs full of reactor coolant.

The philosophy of this guideline, in light of this apparent conflict, is to attempt to strike a reasonable balance between controlled cooldown of the plant and what can be considered acceptable levels of activity release. Previous guidance on acceptable activity release for SGTRs has been limited to FSAR requirements for the design basis event. At present, these limits are interpreted to be 10% of 10CFR100 doses during the first two hours at the exclusion area boundary (EAB) and for 30 days at the low population zone (LPZ).

However, the design basis SGTR is a double-ended rupture of a single tube while these bases cover multiple ruptures in both SGs. In addition, plant cooldown cannot be accomplished in the two hour assumed duration of the design basis case. Thus the question becomes what are reasonable dose limits for events ranging from small leaks to multiple tube rupture flow rates greater than the design basis case.

To answer this question, integrated dose calculations were performed for a spectrum of tube leak flows and RC activity levels. These calculations were performed using both conservative assumptions as in the FSAR and more realistic assumptions. The conclusions reached from this effort form the foundation for these bases.

1.1 Concerns and Objectives Relative to SGTRs

1.1.1 Concerns

A SGTR is a break of the RCS pressure boundary which is the second of the three barriers to fission product release. This provides a path through the third barrier (reactor building) via the steam lines. Specifically, the concerns associated with SGTRs are:

A. The loss of RC (a SGTR is essentially a SBLOCA) with the potential threat for interruption of core cooling.

B. The potential for activity release outside the containment.

C. Management of contaminated secondary water.

D. Depletion of BWST inventory with no borated water accumulation in the RB sump, i.e., sump recirculation, if needed, may not be available.

1.1.2 Objectives

The objectives to be considered during the mitigation of SGTRs are (listed in order of relative priority):

A. Maintain core cooling - Core cooling is always a top priority; however, with one, and possibly two, barriers to the release of fission products already breached, clad integrity becomes even more important.

B. Minimize activity release to the atmosphere - The intent is to steam the affected SG(s) as much as necessary to aid the RCS cooldown, but limit the releases to less than pre-determined limits. An important aspect of this objective is to prevent, if at all possible, the need for HPI cooling. HPI cooling may result in uncontrolled release of reactor coolant if RC pressure cannot be maintained below the MSSV setpoint on a full, isolated SG.

C. Minimize the integrated tube leakage - This objective consists of two basic parts; minimize the leak flow rate and minimize the duration of the transient before the leak flow is terminated. The purpose of this objective is also two- fold; a lower integrated leakage minimizes storage problems associated with the contaminated secondary water and minimizes the potential for BWST depletion. In addition, the accomplishment of this objective directly aids the objective of minimizing activity release in 1.1.2.B above.

NOTE: Reference is made throughout this chapter to "affected SG," "most affected SG," and "least affected SG." These terms are used to denote, respectively, the SG with a SGTR when only one SG has a SGTR, the SG with the largest leak rate when both SGs have SGTRs, and the SG with the smallest leak rate when both SGs have SGTRs.

Reference is also made throughout this chapter to "fill" and "filling" of SG(s). The meaning of these terms is that the SG(s) levels are increasing or being increased to the point where water will enter the steam lines. The suggested fill limit for steaming (section 3.6.1.a.ii) is concerned with water entering the steam lines through the penetration in the steam annulus shroud for the operate range upper level sensing tap, while the fill of an isolated SG involves water spill over the top of the steam annulus shroud.

2.0 DIAGNOSIS AND MITIGATION OF SGTR

This section provides a brief description of the recommended logic to be used in dealing with SGTRs from the initial diagnosis through plant cooldown and depressurization to decay heat removal system (DHRS) operation when the leak flow can be terminated.

Figure III.E-1, "SGTR Functional Flow Diagram," provides a basic action/decision logic chart for mitigating SGTRs. This chart is intended to provide major decision points and major function level actions. In addition, the chart is organized to present a recommended logic and priority in dealing with the different aspects and complications that can occur during a SGTR. However, the order that items appear in the flow chart is not intended to represent the only logical sequence. The primary purpose of the flow chart is to identify the major aspects of SGTRs in some logical order. The user should address these aspects in plant specific procedures in the order which best fits the specific plant capabilities.

The flowchart depicts the basic mitigation strategy for SGTR events. In all cases, both SGs are used to complete the initial RCS cooldown and depressurization to less than 500°F and 1000 PSIG. The intent is to not isolate any SG until RCS and SG pressure can be maintained less than the lowest MSSV setpoint.

Control of the SGs below 500°F and 1000 PSIG depends on several factors, some of which are plant specific. The preferred approach depends on the number of SGs available and the number of SGs with tube leaks. If both SGs are available and only one has a tube leak, then the preferred course is to isolate the affected SG and complete the cooldown to DHRS operation using the unaffected SG. If, however, both SGs have tube leaks or the only available SG has a tube leak, then the preferred course is to continue the cooldown with all available SGs. There are other factors that may alter the basic strategy, including available BWST inventory, steaming capacity and availability of the condenser, etc.

The numbered subsections in the remainder of Section 2.0 correspond to the upper numbers in the blocks on Figure III.E-1.

2.1 Identification of SGTR and Plant Shutdown

2.1.1 Identification

The most rapid means of identifying that a SGTR has occurred while at power is by secondary plant radiation monitors (e.g. the condenser air ejector, vacuum pump exhausts or main steam line radiation monitors). Main steam line monitors may also identify the affected, or most affected, SG.

Backup methods include primary leak rate calculations, LOCA symptoms (except changes in RB environment), SG samples, and anomalies in FW flows and/or SG levels after reactor shutdown. Once the affected SG is identified, non-essential steam loads (including the MFW pump turbine) should be isolated from the affected SG as soon as possible. Methods for identifying a SGTR and the affected SG are discussed in 3.1.

2.1.2 Power Reduction and Reactor Shutdown

If possible, reduce power as quickly as possible, but in a controlled manner, to well within the turbine bypass system capacity before tripping the reactor to prevent lifting of the MSSVs. This includes cases where maximum MU or HPI flow and letdown isolation are required to keep up with the tube leak. Power reduction is intended to minimize atmospheric releases and avoid the possibility of a stuck open MSSV. However, if pressurizer level cannot be stabilized and a reactor trip is unavoidable, then the operator should trip the reactor and monitor MSSV response. Power reduction is discussed in 3.2 and 3.4.1.1.

2.2 Subcooling Margin and Primary to Secondary Heat Transfer

2.2.1 Subcooling Margin

Verification of SCM is the first major decision point in the flow chart for several reasons:

a. If the tube leakage is large enough to cause a loss of SCM (which requires complete failure of several tubes), the loss of SCM will occur early in the transient.

b. On any loss of SCM, it must be assumed that a LOCA exists which requires certain prompt actions, discussed in 2.2.2.

c. Maintaining SCM is very important in maintaining optimum control of a SGTR transient and performing an expeditious cooldown.

The flow chart continuously loops back to this decision point for the duration of the cooldown until the DHRS is in operation. This signifies a constant surveillance of SCM and other key plant conditions during the performance of any subsequent portion of the flow chart.

The content and definition of SCM is discussed in Chapter II.B. During the cooldown it is highly desirable to maintain RCS pressure and temperature close to, but above, the minimum SCM. This minimizes the differential pressure between the RCS and the affected SG(s), thus minimizing the tube leak flow rate.

2.2.2 Loss of Subcooling Margin

On loss of SCM, the operator must assume a LOCA exists and perform the following actions:

a. Trip all RCPs.

b. Initiate full HPI (MU) flow with two HPI (MU) pumps from the BWST.

c. Begin (or verify) raising SG level(s) to the loss of SCM setpoint. (SG level setpoints are defined in Chapter IV.C.)

These actions, and their bases, are discussed in detail in Section III.B. Actions a and b above must always be performed on loss of SCM. However, control of SG levels differs slightly for SGTRs. Normally, a loss of SCM requires raising the level in both SGs to the loss of SCM setpoint; however, this may cause subsequent inventory control problems in the affected (leaking) SG. Therefore, if full HPI flow from at least one HPI pump exists and filling of the affected SG is not desired at this time, then only raise the level in the unaffected SG (or least affected SG, if both SGs have tube leaks) to the loss of SCM setpoint. Do not intentionally raise the level in the affected, or most affected, SG. Instead, only inject FW as necessary to maintain heat transfer. This allows continued use of both SGs for cooldown. Allow the level to increase to the loss of SCM setpoint due to the tube leak flow. One SG, with feedwater properly controlled per section 4.4.3 of Chapter IV.C, will provide sufficient heat removal and RC pressure reduction to allow the flow from one HPI pump to keep the core covered.

If, however, full HPI flow from at least one HPI pump cannot be achieved or maintained or the affected SG will be allowed to fill, then raise the level in both SGs to the loss of SCM setpoint. If only one SG is available, then raise the level in that SG to the loss of SCM setpoint, regardless of HPI status, even if the SG has a tube rupture.

If SCM is restored at any time during the subsequent cooldown, restart RCPs (when all other conditions for RCP restart exist) and allow the unaffected SG level to boil down to the normal forced flow setpoint, or normal natural circulation setpoint if the RCPs were not restarted. In addition, throttle HPI flow as necessary to maintain pressurizer level and maintain RCS pressure close to, but above the SCM and, if applicable, within PTS guidance (Chapter IV.G).

2.2.3 Primary to Secondary Heat Transfer

The second major decision point in the flow chart is verification of controlled primary to secondary heat transfer. A major goal in mitigating SGTRs is to achieve an orderly but expeditious cooldown to cold shutdown conditions. This goal is best achieved with forced flow and controlled primary to secondary heat transfer to both SGs.

Methods of verifying heat transfer and recognizing a loss of primary to secondary heat transfer are discussed in Chapter III.C. Methods of recognizing and mitigating excessive primary to secondary heat transfer are discussed in Chapter III.D.

2.2.4 Loss of Controlled Heat Transfer

If primary to secondary heat transfer does not exist to either SG, restore primary to secondary heat transfer to at least one SG as soon as possible, even if it is the affected or most affected SG.

Possible causes for loss of SG primary to secondary heat transfer and methods of restoring heat transfer are discussed in Chapter III.C. Possible causes for excessive primary to secondary heat transfer and methods of restoring controlled heat transfer are discussed in Chapter III.D. In addition, special considerations for steam leaks concurrent with SGTRs are discussed in Section 3.8 of this chapter.

2.2.5 Restoration of Heat Transfer

As soon as controlled primary to secondary heat transfer is restored to one SG, begin cooldown while attempting to restore controlled primary to secondary heat transfer to the other SG.

If heat transfer is lost and cannot be restored to either SG before conditions requiring HPI cooling occur (Chapter III.C), then initiate HPI cooling (2.4.6). Recognition of heat transfer restoration is also discussed in Chapter III.C. Chapter III.D provides methods for terminating excessive heat transfer transients and restoring controlled cooling including control methods for unisolable steam leaks. Unisolable steam leaks impact SGTR transients as discussed in Section 3.8 of this chapter.

2.3 Initial Cooldown and SG Isolation

2.3.1 Cooldown and Depressurization to Below MSSV Setpoint

The intent of the initial cooldown is to prevent/minimize lifting of the MSSVs by reducing primary hot leg temperature below the saturation temperature corresponding to the lowest MSSV setpoint (requires cooldown to approximately 540°F.

Reduce RC pressure below the lowest MSSV setpoint to preclude lifting of the MSSVs in the event the affected SG(s) filled solid. In order to maintain SCM, this requires further cooldown below 540°F.

The pressurizer cooldown rate required to reduce RC pressure below the lowest MSSV setpoint should be kept, if possible, within the plant specific maximum allowable cooldown rate provided in the RCS functional specification for rapid depressurization transients, discussed in Section 3.3.1.

Use the normal cooldown rate limit or the emergency cooldown rate limit depending upon conditions and limits provided in Section 3.3 of this chapter.

The normal cooldown rate limit is 100°F/hr. The emergency cooldown rate limit is 240°F/hr .

2.3.2 SG Isolation

The preferred path is to isolate the affected SG and continue the cooldown on the unaffected SG. However, if both SGs have tube leaks or the only available SG has a tube leak, then the preferred course is to continue the cooldown with all available SGs. If both SGs have tube leaks, but the leak rate is substantially smaller in one SG, it may still be preferable to isolate the most affected SG. The decision on whether to isolate the SG also depends on other factors, which are explained in Section 3.3.2.

2.3.3 Isolation and Control of the Affected SG

The primary intent of isolating a SG is to minimize the releases from the SG, thus it is normally expected that the SG will be left isolated and allowed to fill. However, there are several factors that go into determining whether to isolate a SG. Some of these factors may indicate a preference to maintain the SG available, i.e., not allow it to overfill, in the event it is needed later in the cooldown.

Section 3.3.3 discusses the bases for the preferred path and the considerations for filling the isolated SG.

2.4 Limits on SG Cooldown

2.4.1 SGTR Steaming Limits

At this point in the flow chart, cooldown is being accomplished with either both SGs or on one SG with periodic cooling provided by the most affected SG. There are, however, limitations on continued steaming, even periodically, of SG(s) with tube leaks.

Two criteria are recommended for use in determining when an alternate cooldown method should be used. These criteria are based on the following considerations:

a. Activity (Iodine) releases approaching predetermined limits.

b. SG filling due to tube leakage despite steaming to achieve the maximum allowable cooldown rate.

These criteria and their bases are explained in detail in section 3.4.

2.4.2 Decision on Use of SG Drains

If a SG overfill limit is reached, then SG drains, if available, could be used to prolong the availability of the SG for steaming. However, there are limitations on the use of drains that should be considered before their use. The limitations on the use of drains are discussed in section 3.5. If the drains are not used then the most affected SG is isolated and allowed to fill (2.4.3).

2.4.3 Filling of the Isolated SG

If the decision was made not to provide for further steaming of the affected SG (or most affected SG if both have tube leaks) in 2.3.3 or 2.4.2, or if use of the drains will not prevent reaching the overfill limit (2.4.9) then the SG is isolated here and allowed to fill.

As the SG approaches a solid condition, it is important to maintain RC pressure below the MSSV lift pressure since the solid SG will pressurize to RC pressure. Section 3.6 discusses special considerations for isolation and filling of the SG.

2.4.4 Cooldown on One SG

If only one SG had a tube leak and was isolated (2.4.3), cooldown on the remaining SG (if available) should be possible without reaching a steaming limit.

If both SGs had tube leaks, isolation of the most affected SG (2.4.3) may allow continued cooldown on one SG without reaching a limit. Therefore, closely monitor the parameters listed in 2.4.1.

If one SG has been isolated but has been maintained available (2.3.3), then if problems arise with the remaining SG that prevent its further use, attempt to restore the previously isolated SG to service before resorting to HPI cooling.

2.4.5 Isolation of the Remaining SG

If cooling down on one SG does not prevent reaching the SG overfill limit (because both SGs have tube leaks), then isolate the remaining SG, allowing it to fill, and initiate HPI cooling (2.4.6).

2.4.6 Initiation of HPI Cooling

If neither SG can provide heat transfer, initiate HPI cooling. Requirements for when to initiate HPI cooling on loss of heat transfer are provided in Chapter III.C.

If HPI cooling is required due to a lack of adequate primary to secondary heat transfer (e.g., total loss of feedwater) from 2.2.5, then continue attempts to restore heat transfer to at least one SG (covered by eventual loop back through 2.2.3).

If HPI cooling is required due to intentional isolation of both SGs (2.4.5) then HPI cooling will probably be required until DHRS transition unless there is reason to believe that resumed SG operation will subsequently become available (e.g., pressure and temperature subsequently decreasing to within SG drain capability). This is covered by eventual loop back through 2.4.1.

Methods of initiating and controlling HPI cooling are discussed in Chapter III.G.

2.4.7 Actions to Prevent Lifting MSSVs

If HPI cooling is required, maintain RC pressure below the MSSV setpoint since the SG(s) may fill solid.

If HPI cannot be throttled (SCM does not exist) and RC pressure is above the MSSV setpoint or HPI throttling (SCM exists) will not keep RC pressure below the MSSV setpoint, perform one or more of the following as necessary:

a. Open letdown line.

b. Open RCS HPVs.

c. Open SG drains on isolated SG(s).

d. Open turbine bypass valves.

e. Open atmosphere dump valves.

These actions and their bases are discussed in Section 3.7 of this chapter.

2.4.8 SG Drain Operation

The intent of using the SG drains is either to prolong use of the SGs for the cooldown or to prevent filling of an isolated SG. Use of the drains to allow continued steaming may be especially effective if the limiting condition is continued SG fill at the maximum allowable cooldown rate. Using the drains may also be effective for the radiation limit depending on the methodology used, as discussed in Section 3.5.

2.4.9 Continued Cooldown/Draining

Once SG draining has been established, reevaluate the approach to overfill to confirm effectiveness of the drains and take the appropriate path as shown. Refer to Section 3.4 of this chapter for a discussion of tube rupture steaming limits and their bases.

2.4.10 Activity release Limits

If the activity release limit is being approached, then isolation of the most affected SG depends on both the event and the type of limit used. If isolation of the SG would require HPI cooling, then the SG should only be isolated if the overfill limit will be exceeded. If both SGs have tube leaks, then isolation of one SG may not prevent exceeding the release limit, and could possibly result in higher releases. If both SGs are available, and only one SG has a tube leak, then the affected SG should be isolated before exceeding the release limit.

2.5 Continued Cooldown Using SG(s)

2.5.1 Reactor Coolant Pump Status

Forced circulation cooldown is preferable to natural circulation, especially during SGTRs where an expeditious cooldown is desired.

Forced circulation eliminates stagnant hot spots that can occur during natural circulation, and thus avoids the complications and cooldown delays that result from void formation in the RCS. In addition, forced circulation provides pressurizer spray flow, which in turn optimizes RCS pressure control. RCP operation also results in a lower RCS differential temperature which allows a lower primary to secondary differential pressure, thus minimizing the tube leak flow rate.

Finally, forced circulation allows for a faster overall cooldown to DHRS operation, thus minimizing the integrated tube leak flow and activity releases.

2.5.2 Criteria for RCP Restart

If the RCPs are not operating, attempt to satisfy the criteria for restarting the RCPs as soon as possible while continuing to cooldown with natural circulation. The criteria for RCP restart are provided in Chapter IV.A.

Observe RCP NPSH requirements, which may require RC pressure somewhat higher than minimum SCM, during the cooldown when RCPs are operating or restarted.

2.5.3 RCP Restart

As soon as the criteria for RCP operation (Chapter IV.A) are satisfied, restart RCPs. The number and selection of the RCPs to be restarted depends on plant conditions. Running one RCP in each loop balances heat transfer, but other RCP combinations may be desired for higher spray flow capability or lower NPSH requirements. (Refer to Chapter IV.A for precautions and recommendations to be considered before RCP restart).

2.5.4 Natural Circulation Cooldown

If tube leak conditions are relatively stable (i.e., small leak flow, overfill not imminent), it may be preferable to maintain existing temperatures and pressures and just remove decay heat with natural circulation until RCPs become available. If, however, continued cooldown is warranted, or RCPs will not be available for an extended period of time, then proceed with a natural circulation cooldown (Chapter III.G).

2.5.5 Forced Circulation Cooldown

Continue forced circulation cooldown to DHRS cut-in conditions (refer to Chapter III.G for discussion and limits).

2.5.6 Pressurizer Bubble Status

The existence or absence of a pressurizer steam bubble dictates RCS pressure control methods during the cooldown (Chapter III.G).

2.5.7 Restoration of Pressurizer Bubble

RCS pressure control with a steam bubble is preferred. If conditions permit, draw a steam bubble in the pressurizer.

2.5.8 Solid Plant Pressure Control

Control of RCS pressure by MU/HPI flow and letdown/leak flow is discussed in Chapter III.G. Draw a pressurizer steam bubble, however, should conditions subsequently permit (covered by loop back through 2.5.7).

2.5.9 Enhanced Idle Loop and RV Head Cooling

Actions to enhance RV head cooling are only applicable during natural circulation when the RV head region is relatively stagnant. Similarly, actions to enhance idle RC loop cooling are only applicable during single loop natural circulation.

The objectives in performing these actions are to reduce thermal stresses on the RV head and to prevent void formation in the RV head or idle RC loop. Void formation will hinder RCS depressurization in that the void acts like a pressurizer. In addition, the existence of a void in the RV head requires that the cooldown be limited to $\leq$ 50°F/hr below 500°F. These factors will result in a prolonged cooldown and may result in higher integrated tube leakage.

Methods to enhance RV head and idle RC loop cooling are discussed in Chapter III.G.

2.5.10 Void Mitigation

Actions to mitigate voids are also only applicable during natural circulation cooldown. Recognition and mitigation of voids is discussed in Chapter III.G.

2.6 Transition to Decay Heat Removal System Operation

2.6.1 Plant Conditions

Continue the cooldown with either the SG(s) or HPI until RCS conditions allow DHRS operation. A loop is provided back to 2.2.1 when DHRS conditions have not yet been attained. The purpose of this loop is to signify continued attempts to establish the most "normal" cooldown mode possible. The required plant conditions for DHRS operation are provided in Chapter III.G. Additional considerations for transition to DHRS operation from HPI cooling are provided in Chapter IV.B.

2.6.2 Initiation of DHRS Operation

Place the DHRS into operation when RCS conditions permit and cooldown and depressurize to cold shutdown. At cold shutdown drain the RCS to an elevation that will terminate or limit the tube leak flow (below the elevation of the SG steam nozzles).

If the RCS is saturated, both LPI trains should be operated in the injection mode. However, the large capacity of the LPI system may restore SCM. If SCM is restored, then one LPI train may be switched to the DHR mode (suction from the drop line) while the other train remains in the injection mode to make up for the tube leak. If SCM is subsequently lost, both LPI trains must be placed back in the injection mode.

Specifics on DHRS operation are provided in Chapters III.G and IV.B.

3.0 SGTR TECHNICAL BASES

This section provides a more detailed discussion of the items unique to SGTRs. Items that are not unique to SGTRs are covered elsewhere in the referenced technical bases, and augmented as necessary with aspects to be considered for the case of SGTRs in Section 2.0. It should be noted that the discussions in 3.1 through 3.7 assume that unisolable steam leaks do not exist. The impact of unisolable steam leaks on SGTR mitigation is discussed in 3.8. The subsections in section 3.0 correspond to the bottom numbers in the related blocks on Figure III.E-1.

3.1 Identification of SGTR and the Affected SG

When a SGTR occurs, it is important to diagnose the event and identify the affected SG(s) since subsequent actions depend on this information. The initial indications of a SGTR will usually be either radiation readings/alarms on the steam lines and/or condenser or an unidentified RCS inventory loss.

Radiation alarms on the steam lines or condenser are positive indications of a SGTR but may only occur while at power. If radiation monitors are unavailable or ineffective due to plant conditions, then the first indication may be anomalies in RCS inventory control indicating an unidentified loss of reactor coolant (e.g., makeup flow greater than letdown and seal return flows while maintaining a constant pressurizer level). Depending on the amount of tube leakage, indications of a LOCA may exist without an accompanying change in RB parameters.

If the reactor is shutdown and FW is on automatic SG level control, anomalies may also exist in FW flow rates and/or SG levels (e.g., both SGs maintained at the correct level but one with a significantly lower FW flow rate or an SG level increasing above the level setpoint without FW flow). These indications will not exist while at power since the SGs are not on level control and differences in FW flow rates would be insignificant.

In any case, if a SGTR is suspected, draw SG samples as soon as possible to verify a SGTR exists and to identify the affected SG(s). Coolant activity introduced into one SG through a SGTR can quickly contaminate both SGs through the FW system. Therefore, sample the SGs for boron since boron will normally be contained in the affected SG(s).

3.2 Power Reduction and Reactor Shutdown

If a SGTR occurs while at power, it is highly desirable to reduce power, at least to well within turbine bypass system capacity, before tripping the reactor. The intent is to prevent lifting of the MSSVs on the affected SG(s) for two reasons: 1) any lifting of the MSSVs provides a path for activity release directly to the atmosphere and, 2) less likely, an MSSV may fail to reseat, thus prolonging the release to atmosphere and complicating control of the plant cooldown.

Attempt a controlled power reduction even if HPI (MU) flow from the BWST and letdown isolation are required to keep up with the tube leakage and the RC contraction that will occur below 15% power. The added boron from the BWST will reduce reactor power and may result in some RCS contraction due to cooling if a power mismatch develops.

When reactor power is within turbine bypass capacity, such that SG pressure can be controlled below the MSSV setpoint, and below the anticipatory trip setpoint for turbine trip, unload and trip the turbine; then trip the reactor.

All non-essential steam loads should be isolated from the affected SG as soon as possible. This includes the associated MFW pump turbine when power has been sufficiently reduced.

If a reactor trip is unavoidable or occurs while treating the symptoms for a SGTR, then continue to treat the SGTR while performing the reactivity control verification of Chapter III.A (2.2.1). Perform the remaining portions of the VSSV in parallel with SGTR or after the SGTR actions are complete.

3.3 Cooldown and SG Isolation

3.3.1 Initial Cooldown/Limits

Once the reactor is shutdown, commence cooldown with both SGs to reduce RC hot leg temperature below 540°F. At this temperature, pressure in an isolated SG should be below the lowest MSSV setpoint, thus preventing a MSSV from lifting on an isolated SG. Above this temperature, steaming both SGs with turbine bypass valves (or atmospheric dump valves, if necessary) should maintain steam pressure below the MSSV setpoint.

If the SG is to be isolated, this isolation may be performed anytime after the initial cooldown to 540°F T_{hot} unless an SG is filling. Continue the RCS cooldown in accordance with the rate limits given below and depressurize the RCS (while maintaining SCM) to below the lowest MSSV setpoint. This prevents lifting the MSSV should the isolated SG fill and pressurize to RCS pressure.

If the SG will not be isolated unless necessary due to steaming limits (2.4.1) and HPI (MU) flow from the BWST is required, then makeup to the BWST should be initiated if possible.

The cooldown should be performed within normal cooldown limits provided SCM exists at the core outlet (3.3.1.3). The pressurizer cooldown rate required to depressurize the RCS below the lowest MSSV setpoint will be greater than the normal cooldown rate limit. However, the cooldown rate should be kept within the plant specific maximum allowable cooldown rate, if possible. The maximum allowable cooldown rate for the pressurizer is provided in the RCS functional specification for rapid depressurization transients and covers depressurization from normal post-trip RCS pressure to 800 PSIA in 15 minutes. Normal pressurizer cooldown rate limits are assumed below 800 PSIA.

In addition, except when RCP NPSH limits are applicable and are more restrictive, RCS pressure should be maintained close to, but above, the minimum SCM to minimize RCS-SG differential pressure. The reason for minimizing RCS-SG differential pressure is to reduce the leak flowrate from primary to secondary to as low as possible. Therefore, this procedure (minimizing SCM) is desirable whenever possible. It should be noted, however, that loss of the RCPs will cause T_{hot} and RC pressure to increase during the transition to natural circulation, which could lead to a loss of SCM. Therefore, it may be desirable to maintain additional subcooling, especially during periods of potential grid instability (e.g., lightning storms). If SCM is maintained during the cooldown, isolate the CFTs when conditions permit. Do not, however, isolate the CFTs if SCM cannot be maintained.

These limits may vary depending on the plant conditions. Each one is discussed separately in sections 3.3.1.1, 3.3.1.2, 3.3.1.3, and 3.3.1.4.

3.3.1.1 Emergency Cooldown Rate

The cooldown rate may be increased to a maximum of 240°F/hr down to 500°F T_{hot} if :

a. the affected SG level(s) will reach the SG level limit (3.6.1.a.ii) before the SG can be isolated using the normal cooldown rate, including the use of SG drains if available, or

b. activity release rates are projected to reach the integrated limit (3.4.1.3) before 500°F T_{hot} at the normal cooldown rate.

NOTE: Several large tube leaks would probably have to occur before either of these criteria would require an emergency cooldown rate.

The typical plant design allows for 40 cycles of an emergency cooldown to 500°F T_{hot} at 240°F/hr. This rate is allowed for any SGTR event. However, it is recommended that the use of this emergency cooldown rate be limited to the two cases noted above because the faster rate may increase the potential for voiding in the RV head region during natural circulation. The faster cooldown rate is not expected to adversely affect SG tube-to-shell differential temperatures. Even if the SG shell does not cool at all during the cooldown to 500°F (regardless of the cooldown rate), the tube-to-shell differential temperature is not expected to exceed about -60°F (tubes colder) when the cooldown to 500°F is completed. The tube to shell differential temperature is limited to a maximum allowable as discussed in 3.3.1.2.

The emergency cooldown rate is recommended for the two cases noted because several large SGTRs and/or a relatively high percentage of failed fuel already exist. In these cases, it is more important to prevent liquid discharge through the MSSVs and limit the duration of high activity release rates. For the case of impending carryover (water entrained in flowing steam), the affected SG (or most affected SG if both have SGTRs) should be steamed as much as possible to achieve the cooldown rate in order to limit the rate of level increase. If the cooldown is being performed in natural circulation, then the unaffected or least affected SG should be steamed sufficiently to maintain NC flow and prevent possible stagnation and voiding of the associated hot leg U-bend. This is important since the use of the emergency cooldown rate indicates the affected or most affected SG will have to be isolated. The limit to be used to determine if carry-over is imminent is plant specific, but a suggested basis for the limit is provided in 3.6.1.a.ii.

Usually a SG can be isolated after Thot has been reduced to 540°F. However, if a SG is filling, Thot should be further reduced before isolation. The additional cooldown must be sufficient to allow the RC pressure to be reduced below the MSSV setpoint (plus adequate pressure margin of ~100 PSI) while maintaining SCM. This will allow the isolated SG to fill and pressurize to the RC pressure without lifting a MSSV.

For the case of high activity release rates, the unaffected SG (or least affected SG if both have SGTRs) should be steamed as much as possible to achieve the cooldown rate in order to limit the integrated release before the SG(s) can be isolated. If both cases apply, then prevention of carry-over takes precedence. It is especially important to prevent liquid discharge through the MSSVs with high RC activity. As long as the affected SG level continues to increase above the desired control point, then level control is not assured and the correct course of action in this case is to increase the steaming of that SG to achieve control.

3.3.1.2 Tube-to-Shell ΔT

The normal tube-to-shell ΔT limit for cooldowns is 100°F (tubes colder) and, during an emergency cooldown (3.3.1.1) this limit may be increased to 150°F. Methods to control tube-to-shell ΔT are discussed in Chapter III.G.

This relaxation is allowed to facilitate an emergency cooldown should it be required. However, two important points should be considered:

a. Whenever tube-to-shell ΔT exceeds 100°F a post-transient stress evaluation will be required.

b. Higher tube-to-shell ΔTs will increase the tensile stresses on the tubes and may lead to higher leak flows. Indications of this occurring have been observed during actual tube leak transients.

Therefore, some judgement is required before a decision is made to increase tube-to-shell ΔT. Normally, it is recommended that tube-to-shell ΔT be kept much lower than the normal cooldown ΔT limit if at all possible. However, there may be cases where an increase in ΔT is necessary to accommodate an expeditious cooldown which may be accomplished with little or no risk (e.g., decision has already been made to isolate the affected SG and allow it to fill, thus increases in leak flow rate may not significantly impact the transient). As noted in section 3.3.1.1, the use of the emergency cooldown rate to 500°F should not result in excessive tube-to-shell ΔTs.

3.3.1.3 Cooldown Limits

The normal cooldown limit is the Technical Specification limit. With the exception of section 3.3.1.1, this limit should not be exceeded during a plant cooldown when the RCS is subcooled. If the RCS is not subcooled, then this limit does not apply as discussed in Chapter III.B.

3.3.1.4 Summary of Limits During Cooldown

The following limits should be observed, if at all possible:

a. If section 3.3.1.1 applies, then above 500°F the cooldown rate limit is 240°F/hr

b. Otherwise, the cooldown rate limit is the [Technical Specification Limit]. The cooldown rate is limited to 50°F/hr if a RV head void exists. These limits are applicable when subcooled conditions exist at the core outlet.

c. MSSVs should not be allowed to lift, especially if the affected SG is full (requires RCS pressure below MSSV set pressure).

d. PTS guidance, if applicable.

e. Site emergency radiation limits should not be exceeded.

f. Tube-to-shell ΔT should not exceed 150°F with the requirement that any increase above 100°F will require a post-transient evaluation.

3.3.2 Control of the Affected SG Following Initial Cooldown

The more probable tube rupture scenario is a tube leak in one SG with both SGs available. The preferred mitigation strategy is therefore isolation of the affected SG following the initial cooldown to 500°F. This limits the radiological consequences of the event, but does require cooldown to DHRS operation using one SG. Single loop cooldowns and less probable tube rupture scenarios, including leaks in both SGs, pose other complications that may lead to continued steaming of all available SGs as the preferred approach. The decision between isolation and continued steaming is also influenced by plant design differences, such as installed steam relief capacity, and by situational-dependent factors such as the availability of offsite power and depletion rate of the BWST.

The guidance provided covers tube rupture scenarios from a small tube leak in one SG to multiple tube ruptures, including a tube rupture in both SGs while limiting the off-site radiological consequences to orders of magnitude less than the 10CFR100 limits. One simple mitigation strategy will not work for such a broad range of events. Therefore, there are several decision points in developing the strategy. Some decisions can be made in advance and built into the EOP based on design features of the plant. Some decisions will necessarily be based on the specific event, but can be couched in terms of readily observed plant response to facilitate the selection of the appropriate path.

This section provides considerations for steaming and isolation of the affected SG(s), other plant and event specific considerations, and the bases for the preferred path and the relevant factors affecting the decisions. The potential benefits of continued steaming and of SG isolation are discussed, as are plant-specific and event-specific factors, and the logic used to select the preferred path is explained. Ultimately, the path used by a given plant in the EOP should be based on these considerations coupled with plant-specific design capabilities and limitations.

3.3.2.1 Considerations for Continued Steaming

The historical approach to tube rupture mitigation has been to isolate the affected SG as soon as possible to limit the off-site release of radiation. The design basis for this approach considered the double-ended rupture of a single tube. The TBD guidance for tube rupture mitigation is designed to cover multiple tube ruptures in one or both SGs as well as small leaks from a single tube. The historical approach does not work when both SGs have tube leaks since isolating both SGs requires a transition to HPI cooling at high pressures, temperatures, and decay heat levels. This leads to lifting MSSVs on the isolated SGs which, if full, leads to a high probability of a stuck-open MSSV and release of reactor coolant outside the RB.

Therefore, the consequences of continued steaming during multiple tube ruptures were evaluated to at least allow delay of SG isolation until RC pressure could be maintained below the MSSV lift pressure even while in HPI cooling. This evaluation used realistic bounding assumptions as opposed to the highly conservative FSAR assumptions. The results of the evaluation indicated that the off-site dose consequences of continued steaming were not as high as previously expected. Thus the preferred path for tube ruptures in both SGs is to continue to steam, within limits discussed later.

Isolation of a single SG, even for relatively small tube leaks, has always posed potential problems in guidelines and EOPs that address multiple failures. Many of these problems are eliminated or at least abated by continued steaming. The isolation of the SG does not terminate the tube leak nor the transient. Rather, the isolation of the SG complicates the subsequent cooldown and significantly lengthens the time at higher pressures and temperatures where other failures can have a detrimental impact.

There are only two viable methods to terminate the tube leak flow: 1) drain the RCS to the leak elevation once on DHRS operation or 2) isolate the SG and allow it to fill. Cooling down using both SGs is the fastest and most controllable method to get on DHRS operation. Filling an isolated SG may not terminate the tube leak flow if the SG and steam line valves do not have leak-tight integrity. In addition, the isolated SG becomes a heat source, further delaying the cooldown, and the potential for backflow and dilution of the RCS requires frequent sampling to ensure adequate boron concentration is maintained. These considerations, coupled with the calculated low off-site dose consequences, led to extending the steaming option to all tube rupture scenarios as opposed to just multiple SG scenarios. The additional benefits for using the steaming option, even when only one SG is affected, are as follows:

a. Once the affected SG is isolated, it may not be possible to restore steaming, if needed (e.g., SG full with water in the steam lines), thus reducing the margin to requiring HPI cooling. The decision to steam the SG is reversible should conditions change and is reversed if any of the steaming limits are reached. The decision to isolate the SG may not be reversible.

b. Steaming both SGs minimizes the duration of the cooldown and thus the susceptibility to further complications such as additional failures. Two-loop cooldowns represent the fastest method to reach DHRS operation. If the condenser is available, the off-site dose consequences are minimized by condenser partitioning. If the condenser is not available, then two-loop cooldowns considerably reduce the cooldown time and the condensate required.

c. Steaming minimizes the stresses on the SG.

d. Steaming in two loops is the normal plant configuration and prevents idle loop voids when in natural circulation.

e. If the SG is isolated and then subsequently steamed, there is no significant reduction in dose consequences over those resulting from the SG being steamed all along:

   i. Noble gas and iodine concentrations in the SG increase during periods of non-steaming.

   ii. The higher concentrations due to accumulated tube leakage, coupled with lower steam velocities (when steaming to the atmosphere, due to delaying release until lower SG pressures exist) results in higher instantaneous dose rates and similar integrated doses.

f. For the relatively "benign" tube leak where leak rates are small and there are no other complications, steaming the SG for the duration of the cooldown results in a very small differential in integrated doses (tenths of a millirem) since a significant portion of the release occurs in the initial steaming required to reach the earliest isolation point and since the release rates are small. If the condenser is available, the condenser's 104 partitioning factor for iodine removal reduces off-site dose consequences to the point that the radiation limit cannot be reached regardless of the number and size of the tube leaks or fuel pin leaks.

g. When the tube leak transient is not as "benign," other factors begin to weigh heavily:

   i. If in natural circulation, going from two loops to one loop significantly extends the cooldown time (e.g., from ~20 hrs to ~120 hrs for 6.4% ADV capacity on each SG).

   ii. If the only available SG is the one with the leak, or both SGs have leaks, then isolation requires HPI cooling. Initiation of HPI cooling for a certain range of RCS pressures, temperatures, and decay heat levels will result in RC pressures greater than MSSV setpoint pressures for some period of time. When the SG is full or near full it will follow RC pressure and a lift of a safety valve could result in a failure to reseat due to entrained water.

h. Off-site releases, the major concern with tube rupture, are still limited to values similar to 10CFR20 limits for unrestricted areas by use of the radiation limits.

In summary, the benefits and controllability of maintaining a two-loop cooldown, the low dose consequences of continued steaming, and the undesirability of forcing HPI cooling with a full SG led to a decision to provide an option for continued steaming vs. early isolation for all tube rupture scenarios.

3.3.2.2 Considerations for SG Isolation

SG isolation involves termination of feeding and steaming of the affected or most affected SG as soon as plant conditions permit. The SG may then be left isolated or fed and/or steamed periodically as discussed in section 3.3.3.

The main benefit in selecting this path is that, if subsequent complications do not arise, activity releases off-site are reduced. However, if both SGs have tube leaks, isolation of the most affected SG could actually result in higher integrated doses due to the significant increase in time required to reach DHRS operation. Most of the additional time required occurs at low SG pressures where the atmospheric dispersion is not as effective.

If only one SG has a tube leak, early isolation will minimize secondary plant contamination and can significantly reduce site monitoring requirements. Successful isolation can also allow slowing or stopping the cooldown if necessary, for example, to wait for RC pump and condenser availability. RCP and condenser operation will minimize the time required to reach DHRS operation and potential problems with idle loop and SG cooling. However, the cooldown should not be stopped until RC pressure can be maintained below the lowest MSSV setpoint.

If the cooldown will continue in single-loop natural circulation, tube-to-shell ΔT in the isolated SG can be minimized by allowing the SG to fill, including aiding the fill with feedwater if necessary. While a single-loop natural circulation cooldown considerably lengthens the time required to reach DHRS operation, and thus the condensate inventory required, the idle loop will saturate and equalize in pressure with the isolated SG. Thus, even if the isolated SG does not fill completely, the tube leak rate may be reduced.

It is recommended that this option not be used for scenarios involving tube leaks in both SGs since additional complications already exist (reduced margin to requiring HPI cooling) and, as noted, isolation could actually result in higher integrated doses. Use of this option for other scenarios should consider the following; as well as the items discussed in 3.3.2.3.

a. If the condenser is available, isolation of the affected SG will minimize SG cross-contamination and off-site releases. However, off-site releases will be much less than the radiation limit if the SG is not isolated due to partitioning of iodine in the condenser.

b. If the condenser is not available, isolation of the affected SG will minimize off-site releases. Cooldown times and condensate requirements are increased by nearly an order of magnitude if the SG is isolated (see Figure III.G-14).

3.3.2.3 Additional Consideratoins

There are several plant-specific design considerations as well as event-specific considerations that should be factors in determining the preferred EOP strategy. Design considerations can be factored directly into the basic strategy. The goal in factoring in event-specific considerations is to provide decision points or other methods that are based on readily observed conditions, thus minimizing the decision making burden on the plant staff. In some instances, it may be preferable to "bound" an event-specific consideration with a pre-selected path that covers all eventualities.

Design Considerations

There may be many plant-specific design considerations, and this section does not attempt to enumerate them all. There are four significant factors that are addressed: steaming capacity, available BWST volume, condenser availability, and SG isolation capability.

The installed steaming capacity, both to the condenser and to the atmosphere, can be a major factor in determining the preferred mitigation strategy. Relatively large steaming capacities provide the capability to temporarily isolate the most affected SG while retaining the ability to resume steaming as necessary to control the level in the most affected SG. Smaller steaming capacities may require continuous steaming to control levels, and may require SG isolation and fill earlier in an event. Larger steaming capacities also provide for faster cooldowns while in single SG operation.

The available BWST volume, for the purposes of SGTR mitigation, must consider the possibility of the event transitioning into HPI cooling. The RC lost through the SGTR to a steaming SG is not recoverable for re-injection to the RCS. This fact will not normally present a problem during single tube rupture with an expeditious cooldown to DHRS conditions, since the integrated leakage is much less than the available BWST inventory. However, larger leaks or more complicated events could lead to a need for HPI cooling. This will require sufficient remaining BWST inventory to ensure adequate RB sump level for recirculation as well as filling both SGs to the first isolation valve. The design consideration for the BWST involves two aspects, the initial available volume considering HPI cooling and the ability to makeup to the BWST during the cooldown.

Assuming a backup source to replenish the BWST is not available, then BWST depletion must be terminated at some pre-determined low level. It is suggested that the low-level limit be based on sufficient remaining BWST inventory to:

a. Fill both SGs out to the first steam line isolation valve,

b. Fill the RB sump (via HPI cooling through the PORV) to the minimum level required for sump recirculation, and

c. Account for all applicable instrument errors.

The necessity to isolate and fill both SGs is unlikely, but it is possible and therefore should be taken into account. In addition, plant procedures may call for filling, or aiding the fill, of a SG by the use of FW (section 3.6.2) but the BWST low-level limit should be based on the assumption that FW is not available and the entire fill must be accomplished using BWST inventory. As an option, a second BWST limit can be used for fill of one SG such that, once the first SG is filled, the second limit can be used to govern continued steaming of the second SG when both SGs have tube leaks. This will account for additional BWST inventory that may be available due to partially filling the first isolated SG with feedwater.

If possible, makeup to the BWST should be established early in the transient to prolong the BWST availability. The installed capacity to replenish the BWST is another design aspect that may affect the strategy. The ability to replenish the BWST in real-time during the event effectively increases the available BWST volume.

The availability of the condenser affects SGTR mitigation significantly. First, the off-site consequences of continued steaming of the most affected SG are greatly reduced. Second, steaming capacities to the condenser are generally higher which allow for more expeditious cooldowns with one or both SGs. Finally, steaming to the condenser allows FW recycling whereas steaming to the atmosphere may be limited by condensate inventories. While the EOP must cover the possibility of the condenser not being available, plant design features that increase the probability of condenser availability may affect the basic strategy.

SG isolation capability refers to two aspects: the ability to isolate the steam lines as close to the SG as possible and the expected leak integrity of the steam isolation valves. The decision to isolate and fill a SG for plant designs that do not include main steam isolation valves will require greater fill volume and may expose a larger number of isolation valves to RC pressure. In addition, leak integrity of the isolation valves may impact the decision to transition to HPI cooling on low BWST level. If a continued net loss of BWST inventory through steam isolation valves can not be prevented, then it may be preferable to continue steaming the affected SG to DHRS conditions. This is also dependent on design capability to replenish the BWST and event-specific BWST depletion rates. Even if the SG isolation valves are not leak-tight, the expected leakage may be substantially less than the tube leakage and within BWST replenishing capability, thus allowing transition to HPI cooling if necessary.

Event Considerations

There also may be many event-specific considerations that affect mitigation strategy. This section addresses four significant factors: RCP availability, condenser availability, BWST depletion rate, and number of affected SGs.

RCP availability affects tube rupture mitigation in several ways. RCPs usually provide for a faster, more controlled plant cooldown, lower integrated tube leakage and thus lower BWST depletion rates, and possibly less impact on RB environment. The cooldown rate is primarily faster because the condenser is usually available when RCPs are available. If the condenser were not available, RCP operation could actually delay the cooldown at lower temperatures due to the added pump heat coupled with the lower steam relief capability to the atmosphere. The cooldown is more controllable with the RCPs for several reasons: the availability of pressurizer spray to better control RC pressure, the prevention of idle loop voids that could hinder RC pressure reduction, and the lower integrated tube leakage due to the ability to maintain less RC-SG differential pressure than required for natural circulation. This is offset somewhat at lower temperatures by the required additional subcooling for pump NPSH, but overall is a significant benefit. The ability to reduce RC pressure with RCPs and pressurizer spray could preclude the necessity to reduce RC pressure using the PORV, thus reducing the impact on the RB environment.

Condenser availability also affects tube rupture mitigation in several ways. First and foremost, steaming the affected SG to the condenser significantly reduces the off-site releases compared to steaming the affected SG to the atmosphere. Second, the condenser allows recycling the FW inventory. Third, the condenser allows faster cooldown times due to higher steaming capacities, both due to valve capacities and to lower pressure.

The BWST depletion rate is an important real-time decision factor in tube rupture mitigation as long as affected SGs are steamed. Regardless of installed capacities and makeup capability, the event-specific BWST depletion rate may dictate the mitigation path. If steaming the affected SGs and providing available BWST makeup results in a net BWST inventory loss, then the ability to achieve DHRS operation with continued steaming must be evaluated against the possibility of the event requiring HPI cooling. The number of affected SGs, expected leak integrity of steam isolation valves, etc., will also affect this evaluation. HPI cooling is the least desirable path during tube rupture mitigation, but the possibility must be accounted for in providing coverage for multiple tube ruptures and multiple failures.

3.3.2.4 Preferred Path

The preferred path for mitigation of SGTR has two basic elements: control of the SGs following the initial cooldown to 500°F and control of an isolated SG. The overall strategy is aimed at striking a reasonable balance between minimizing the off-site releases and minimizing the risk of a potentially more severe transient, such as HPI cooling with a full SG.

Both SGs are always used in the initial cooldown to 500°F. Prevention of MSSV lift on the affected SG(s) is integral to the goal of minimizing off-site release, and assurance requires RCS temperatures at or below 500°F. Once this initial cooldown and RCS depressurization to < 1000 PSIG is completed, then SG isolation can be considered.

If both SGs are available and only one has a tube leak, then normally the preferred path would be to isolate the affected SG. If the SG can be left isolated while the unaffected SG is used to cool the RCS to DHRS conditions, then the offsite release can be minimized.

If, however, both SGs have tube leaks or the only available SG has a tube leak, then the preferred path is to continue the cooldown using all available SGs. In these cases, the only way to terminate steaming of affected SGs prior to DHRS operation is to transition to HPI cooling. HPI cooling is the least desirable cooldown method during tube rupture mitigation due to the threat of lifting a MSSV on a full SG. This could lead to an unisolable RC leak outside containment with much worse radiological consequences than continued steaming. If both SGs have tube leaks then both should be steamed as long as possible. Isolating one SG will not appreciably reduce off-site releases and, in most cases, can result in greater off-site releases due to the longer cooldown times on one SG.

There are limits imposed on steaming affected SGs beyond the initial cooldown to 500°F. These are limits based on preventing SG overfill and on off-site releases, and are discussed in Section 3.4. Section 3.4 also discusses the impact of these limits on the preferred mitigation strategy.

3.3.3 Control of the Isolated SG

The preferred path for events involving one tube rupture with both SGs available is to isolate the affected SG following the initial cooldown to 500°F. Other factors may lead to SG isolation for other scenarios as well. In the preferred path, the affected SG is isolated to terminate activity releases, therefore the SG is expected to remain isolated and be allowed to fill if necessary. However, other factors may lead to a decision to maintain the SG available for subsequent use if necessary. The preferred path for a tube rupture in all available SGs is to continue steaming all available SGs until SG isolation is required due to a steaming limit (Section 3.4) or allowed due establishing DHRS operation. However, as previously discussed, the preferred strategy at a given plant may differ due to design and event differences, and a path to isolate a SG prior to reaching a steaming limit may exist, which may also result in actions to maintain the isolated SG available. The decision on which method to use should consider the bases for the preferred path and the relative merits of each method.

3.3.3.1 Considerations for Maintaining the Isolated SG Available

This path involves temporary unisolation of the SG to feed, drain, and/or steam as required to accomplish a given objective. The SG is then isolated again until further needed.

The primary reason for maintaining the SG available is to provide added margin to prevent or at least delay the transition to HPI cooling should subsequent problems arise with the active SG. If the SG was isolated as an option rather than being forced due to a steaming limit, it should be possible to maintain the isolated SG available should the active SG become unavailable.

Maintaining the SG available by periodic steaming may also result in shorter single loop cooldown times by a) reducing the time the isolated SG acts as a heat source and b) preventing idle loop void formation (if in natural circulation) thus aiding RCS depressurization.

Maintaining the SG available requires that the SG level be maintained below a plant specific value that prevents water entering the steam line and that the associated hot leg be maintained subcooled. The actions required depend on RC pump status. If forced flow exists, then no specific actions are required to maintain idle loop subcooling. Idle loop temperatures will follow the active loop temperatures though some heat may be added by the isolated SG. SG level can be maintained by either periodic draining or steaming.

If the cooldown is by natural circulation, then actions will be required to periodically promote idle loop flow to maintain idle loop subcooling. SG level can still be maintained by draining, but will probably be maintained by periodic steaming since steaming will be required to promote loop flow. The actions provided for prevention of idle loop voids in Chapter III.G, section 3.8.1 are primarily intended for isolated dry SGs; however, the conditions noted for initiating FW flow should also be used for promoting idle loop flow during a tube rupture. The existence of the tube leak will increase level in the SG while it is isolated, but feeding may still be required for small tube leaks while the SG is being steamed. Feeding and steaming may also be required to maintain the tube-to-shell temperature difference below the compressive limit.

The actions performed to maintain the SG available will also prevent termination of the tube leak flow and may result in higher instantaneous dose rates if steaming to the atmosphere. The leak flow cannot be terminated since RC pressure is maintained higher than the SG pressure and the SG is not allowed to fill. The instantaneous dose rates may be higher due to accumulation of noble gasses and iodine in the SG during non-steaming periods. Since the SG was not approaching a steaming limit and actions to maintain SG level are successful, neither the continued leak flow nor the higher release rates during steaming should present a problem.

3.3.3.2 Considerations for Filling of the Isolated SG

This path involves allowing the affected SG to fill due to the tube leakage after isolation. The timing of this path should be such that the SG will not fill solid before RC pressure is being maintained below the MSSV setpoint. The SG will fill at approximately one inch per minute for every 40 gpm of leak flow with no steaming or feeding. This option should also not be used until RC pressure and temperature are within boundaries established by the user in the plant specific evaluations performed to assure steam line integrity.

The main benefit in selecting this option is that the tube leak flow may be terminated while RC pressure and temperature are above the range for decay heat removal operation. Tube leak flow can be terminated if the SG fills, the secondary side maintains leak integrity, and RC pressure is maintained below the MSSV setpoint. Tube leak flow can also be essentially terminated if in natural circulation and the idle loop saturates and voids, eliminating the driving force for the leak. In either case, reverse leakage may occur during the subsequent RCS depressurization. This requires frequent RC samples for boron concentration, although representative samples may not be possible if in natural circulation. If the SG is allowed to fill solely due to tube leakage this should not be a problem. If, however, filling of the SG is aided by feedwater then the potential for some dilution exists.

Successful isolation and termination of the leak flow will limit the demand on the BWST and reduce further radiological releases to releases due to the residual cross-contamination in the feedwater system if only one SG has a tube leak. The high water level in the isolated SG should aid control of tube-to-shell differential temperatures although forced circulation cooldowns may still need to be slowed to maintain tensile limits. Natural circulation cooldowns will be hindered somewhat by the stagnation and voiding of the idle loop, but this is less of a time delay factor than the greatly increased cooldown time due to steaming one SG to the atmosphere.

Although the flow chart allows for subsequent return of an isolated SG to service by the loop back through 2.3.2, any decision to fill the isolated SG should consider the following:

a. Once the SG has been filled to the point where water has entered the steam lines, the SG should not be returned to service until draining of the steam lines is assured. This is because water can be entrained in the steam flow and damage steam valves; if this occurs subsequent isolation of the steam valves may not be possible.

b. If it cannot be assured that the steam lines can be drained, then once the SG has been filled per a. above it should be considered unavailable for the remainder of the cooldown. Thus subsequent steam or feedwater control problems on the remaining SG may require transition to HPI cooling that may not have been necessary had the isolated SG been kept available for heat removal. HPI cooling with a full SG poses special problems as discussed in section 3.7.

3.3.4 Control of Unaffected SG Following Initial Cooldown

If at all possible during RCS cooldown, the unaffected or least affected SG should be mantained as a heat sink. This is more important when RCPs are not running and especially if SCM does not exist. If the unaffected SG is not maintained as a heat sink, then core heat removal will stop if the affected SG is isolated. If voids have formed in the hot leg of the unaffected SG (possible condition if SCM does not exist), then natural circulation may not initiate when the unaffected SG's secondary side pressure is reduced.

Such a situation will cause the RCS to reheat and the affected SG to repressurize. This can lead to challenges of the MSSVs on the affected SG. It should be noted that, even if SCM is adequate, it might take a period of time to develop natural circulation following unaffected SG depressurization. During this time the affected SG's MSSVs may be challenged.

If the affected SG is being steamed at a high rate to prevent its filling due to the TR, then the unaffected SG can become a heat source. Reducing and maintaining the unaffected SG's secondary side T_{sat} below RCS temperature can prevent the SG from becoming a heat source. Normal cooldown rates apply during subcooled natural circulation. However, if the RCS is saturated, then normal cooldown rates do not apply and may be exceeded as necessary. An expeditious cooldown limits RC inventory losses to the SG. Steaming the affected SG as much as possible to prevent overfill should not preclude steaming the unaffected SG as necessary to maintain the SG as a heat sink.

3.4 Bases for Steaming Limits

These guidelines have been structured to promote steaming of the SG(s) with a SGTR as far into the cooldown as possible to provide better overall plant control if all available SGs have a tube leak. The basic philosophy of these guidelines is to maintain as normal a plant configuration for as long as possible in order to expedite the cooldown to DHRS operation and minimize potential for development of complications. In addition, HPI cooling is the least desirable cooldown method with a tube rupture. However, there are limitations on continued steaming of a SG with a SGTR. These limitations consider the overriding concerns of SGTR transients that dictate the isolation of the SG and initiation of HPI cooling if necessary.

These limits are as follows:

a. Radiation integrated dose approaching predetermined limits.

b. SG filling due to tube leakage despite steaming to achieve the maximum allowable cooldown rate.

The bases for each of these criteria are discussed separately in 3.4.1 and 3.4.2. In addition, consideration of BWST depletion (section 3.3.2.3) may also lead to SG isolation.

3.4.1 Activity release

As stated in 1.1.2, one of the major objectives in mitigating SGTRs is to minimize the amount of activity released to the environment. This guideline achieves this objective as follows:

a. Performing a power reduction rather than tripping the reactor.

b. Performing actions as necessary to minimize the potential for uncontrolled releases.

c. Providing an overall limit on integrated doses at the site exclusion area boundary (EAB).

These facets of radiation control are discussed in the following sections.

3.4.1.1 Power Reduction

This guideline strongly recommends performing a controlled power reduction as opposed to a reactor trip for two radiological considerations:

a. A reactor trip will result in steam release directly to the atmosphere through the MSSVs and ADVs. A power reduction will direct the radioactive steam to the condenser. Although all of the noble gases will still be released, virtually all of the iodine that leaked into the SG will be contained in the secondary system. Since studies show that the thyroid doses, which are due to iodine, are limiting for SGTRs, this will greatly reduce the radiological consequences of the event. In addition, the noble gases will be released through the stack which will provide better dispersion.

Even though the power reduction will take longer to reach the same post-trip conditions, calculations show that the integrated thyroid dose during the reduction will be on the order of 200 times less than if the plant were tripped from full power. Whole body doses will increase slightly due to the additional time, but even for .05% failed fuel the integrated whole body dose should still be less than 3mR. In addition, these calculations show that allowing the steam safeties to lift for only 30 seconds due to a trip from full power will contribute approximately 75% of the integrated thyroid dose for the entire transient assuming a subsequent 10 hour cooldown using the condenser and the SG with the SGTR (66% for a lift duration of only 20 seconds). Thus a power reduction will significantly reduce the radiological consequences.

b There is a small but real possibility that a MSSV can fail to reseat after lifting. A failure to reseat on a SG with a SGTR will result in uncontrolled releases since no practical method exists to terminate the leak flow or steam flow. Therefore, the prudent approach is to prevent challenges to the MSSVs during a SGTR event. As can be seen from the calculations described in item a., a failure of a MSSV to reseat for even a short duration will significantly increase the integrated thyroid dose.

There may be instances when a reactor trip is unavoidable, but following the actions outlined in section 3.2 should prevent MSSV lifts for most SGTR transients.

3.4.1.2 Uncontrolled Releases

In addition to the power reduction before reactor shutdown, there are two other specific conditions when the guideline recommends actions to minimize the potential for uncontrolled releases through the MSSVs on the affected SG. Again, the intent is to prevent the initial lift of the MSSVs even if use of the ADVs is required, since the ADVs can be isolated should they fail. The two conditions are:

a. The SG should not be allowed to fill into the steam lines while RC pressure is greater than the lowest MSSV set pressure. This condition would cause the MSSV to open as the steam line fills with water and the secondary and primary pressures equalize. The subsequent liquid relief through the MSSV would increase the probability of a failure to reseat.

b. If a transition to HPI cooling is required, it may not be possible to maintain RC pressure below the lowest set MSSV lift pressure following normal HPI cooling procedures. If the affected SG is also full or filling, then additional actions are necessary to prevent lifting the MSSVs. This is discussed in more detail in section 3.7.

3.4.1.3 Integrated Dose Limits

The overall integrated dose limit for all tube leak rates and cooldown times should be no more than doses similar to 10CFR20 limits for unrestricted areas (10CFR20 limits are yearly limits while this criterion is an event limit). In other words, the dose limits, regardless of the number of ruptured tubes, should be no more than 1.5R to the thyroid and 0.5R to the whole body at the EAB for the duration of the cooldown. There is one exception to these limits which is discussed in section 3.4.4.1. Section 3.4.4.2 provides guidance for one method of implementing this limit.

The whole body integrated dose limit of 0.5R is derived directly from 10CFR20.105 paragraph (a). There is no directly equivalent integrated thyroid dose limit in 10CFR20; however, 10CFR20.106 and Table II in Appendix B do provide limits on radioactive effluents. The three iodine isotopes that comprise most of the dose-equivalent I^{131} are I^{131}, I^{133} and I^{135}. The integrated thyroid dose limit of 1.5R is less than half the yearly dose that would result from yearly exposure to these three major iodine isotopes at the concentration limits specified in Appendix B, Table II.

This limit is conservative with respect to design basis requirements for SGTRs that approximate the design basis case and is very conservative for SGTRs beyond the design basis. For tube leaks equal to and smaller than the design basis case, realistic calculations indicate that expected doses will be much lower than these limits even when the entire cooldown is performed steaming directly to the atmosphere. This limit is a guideline established well below licensing limits and has no relationship to licensing requirements.

3.4.2 SG Carry-Over Level Limit

This criterion is intended to prevent carry-over from a steaming SG. Carry-over (water entrained in flowing steam) could damage the open steam valves (TBVs or ADVs) and result in steam leaks. In addition, as discussed in Section 3.3.3, it may be preferable to prevent filling a SG, even if not steaming, since once the SG is filled it may no longer be available should it subsequently be needed. As the cooldown progresses, it may be necessary to reduce or terminate FW flow to, and increase steaming from, the affected SG to limit the SG level increase. Reduce steaming and feeding of the good SG as necessary to maintain the cooldown rate within limits.

However, for relatively large SGTRs or SGTRs in both SGs, these actions may not prevent filling of one or both SGs. Therefore, a high SG carry-over level limit (3.6.1.a.ii) should be determined that will terminate steaming before carry-over into the steam lines occurs, accounting for instrument errors.

3.4.4 Application of Steaming Limits

3.4.4.1 General Guidance

Note that both steaming limits are somewhat rate dependent. The radiation limit can be implemented such that absolute measurable parameters are used rather than rate of change (section 3.4.4.2). Plant procedures should make allowances for the rate at which the limit for overfill is being approached and the estimated time required to implement an alternate control method e.g., use of drains. The method of implementing these limits is plant specific and therefore the determination of "approach" to a given limit is plant specific.

Note too that, in actual practice, none of these limits may be reached (for a relatively small SGTR and expeditious cooldown) or both may be reached (for a relatively large SGTR and/ or significant delays in the cooldown). The least limiting is the radiation limit; it is highly likely that the overfill limit will be reached first.

However, either one may be limiting, depending on the actual plant conditions, therefore both (or their equivalent) should be included in the procedures.

When a limit is being approached, an alternate course of action may be to use SG drains if available (section 3.5). This allows for reduction of the level increase rate and/or the steaming rate of the affected SG(s) so that the use of the SGs for cooldown may continue without violating a limit. Carefully monitor the approach to the limits during and after the transition to SG draining to assess the effectiveness of the drains.

If the drains are unavailable, are not used, or are otherwise ineffective, isolate the affected SG and allow it to fill (section 3.6). If SGTRs exist in both SGs, isolate the SG with the larger leak rate and monitor the approach to overfill during continued steaming of the other SG. If overfill is still expected to be violated due to continued steaming of the remaining SG (both have tube leaks), isolate the remaining SG and initiate HPI cooling (section 3.7).

If the only limit reached is the radiation limit and the isolation of the SG will require HPI cooling, then do not isolate the SG unless and until the overfill limit or BWST depletion considerations become limiting.

The reason for this is that HPI cooling can result in much higher off-site doses if an MSSV lifts and fails open due to entrained water in the steam flow. The radiation limit is very conservative and a tube rupture scenario that leads to HPI cooling is considerably beyond the design basis tube rupture. Continued steaming of the SG beyond the radiation limit should still result in off-site doses less than the design bases limits. This exception does not apply to the limit for SG overfill and considerations for BWST depletion. Continued steaming beyond the SG overfill point can also lead to failed open steam release paths and either adequate BWST inventory for successful HPI cooling or the ability to attain DHRS operation must be assured.

3.4.4.2 Specific Guidance for Implementing the Radiation Limit

The guidance provided in this section covers one method of implementing the radiation limit. Basically, the guidance allows steaming to the atmosphere for the SG(s) with the tube rupture(s) based on measurable parameters (steaming to the condenser is not limited). Other plant-specific methods may be used, but the method used here is recommended for the following reasons:

a. The iodine concentration values provided are based on numerous calculations performed to allow implementation in a streamlined manner while ensuring the limit is not exceeded for a broad range of tube ruptures from small leaks to the double-ended rupture of many tubes in both SGs.

b. The values provided are valid for all of the plants due to use of bounding site characteristics and weather patterns. Use of plant-specific site characteristics may allow steaming within larger values, but the values allowed by this generic guidance should not be too restrictive.

c. Use of the generic method does not require determination of the tube leak rate. Determination of the leak rate with any degree of accuracy can be difficult during the transient.

Integrated whole body dose consequences from a tube rupture transient are very small such that the integrated thyroid dose limit should always be the most limiting factor, i.e., the thyroid limit should always be reached before the whole body limit. The tube rupture cases analyzed to develop this implementation guidance all resulted in whole body doses much less than the 0.5R limit. Therefore, the implementation guidance concentrates on controlling to the thyroid integrated dose limit. Controlling the transient to within the 1.5R thyroid limit should ensure control to within the whole body limit as well. It is still prudent, during a tube rupture transient, to also monitor whole body dose rates calculated from measured airborne activity.

Two values of iodine concentration are used: the pre- existing concentration from the last available RC sample prior to the transient and the peak concentration values observed from samples drawn during the transient. When a tube rupture occurs with the condenser unavailable, the initial steaming limit is based on the last available sample data (pre-existing concentration value). The RC should be sampled frequently for iodine. The results from these follow-up samples are then used to ensure the transient iodine limit is not exceeded. The pre-existing concentration from the last available RC sample prior to the transient is compared to the limit on initial reactor coolant activity for continued steaming to the atmosphere. The limit on initial reactor coolant activity is 0.7μCi/g (0.5μCi/cc). The transient reactor coolant activity limit for continued steaming to the atmosphere during SGTR is 5.15 μCi/g (3.62 μCi/cc). These values make the SGTR EOP guidance and UFSAR assumptions compatible. The SGTR EOP guidance values were reduced to less than the NUREG 0800 and utility UFSAR values to make the UFSAR assumptions always valid. Concentrations less than these values will not result in thyroid doses greater than 1.5R even with all of the iodine in the reactor coolant released to the atmosphere.

The iodine concentration limits limits are based on the following assumptions:

- An iodine spiking factor of 100; i.e., the steady-state release rate of iodine from the failed fuel rod gaps increases by a factor of 100. This factor bounds most observed iodine spikes.

- A spiking factor of 100 would result in all of the iodine in the fuel rod gaps being released in 2.75 hours, but the release was sustained in the calculations for 3.0 hours for added margin.

- No credit was taken for operation of the purification system.

Thus, the probable result is that the steaming allowed by the pre-existing concentration will not be further curtailed due to periodic samples since the observed iodine peak should remain below the calculated peak. If, however, an iodine sample results in exceeding the transient iodine limit then steaming of the affected SG should be terminated unless it would require HPI cooling. Use of observed transient iodine concentrations accounts for the possibility of actual spiking factors greater than 100, actual tube leak rates lower than assumed (resulting in higher coolant concentrations for the same spiking factor), and for the less likely case that additional fuel rod cladding failures have occurred. Sampling frequency should be increased whenever iodine concentrations are observed to be increasing. If RC sampling cannot be performed, then allowed steaming based on the pre-existing iodine concentration should be used in conjunction with site monitoring. This is acceptable since the analyses used somewhat conservative assumptions such that the probable result is that transient iodine concentrations will remain less than the transient iodine limit.

The tube leak flow rates do not need to be determined when these iodine limits are used to govern allowed steaming. The dose consequences resulting from these iodine concentrations were arrived at assuming leak flow rates that would result in filling the SG(s) before the radiation limit could be reached. Thus, if the SG does not reach the overfill limit, then the actual leak rates are less than the leak rates used in the analyses. If the SG does reach the overfill limit, then the resulting integrated off-site doses will be less than the doses calculated in the analyses and thus less than the radiation limit.

The iodine limit values are applicable for steaming one or both SGs to the atmosphere with tube leaks in one or both SGs.

Site monitoring will be performed during a tube rupture in accordance with plant-specific emergency plans. Results of the site monitoring should be used as a cross-check of the allowed steaming values. One method of accomplishing this would be to calculate thyroid dose rates at the EAB from air samples and comparing these dose rates to the integrated dose limit. For example, assume the reactor coolant samples result in no steaming restrictions and that the highest EAB air sample results in a calculated thyroid dose rate 12mR/hr. In this case, the allowed steaming duration should be limited to 125 hours to remain within the 1.5R limit. This is somewhat conservative since actual dose rates during a tube rupture will not be a linear average.

In summary, three methods are described for determining the allowable steaming durations to the atmosphere (steaming to the condenser is not limited):

a. The pre-existing reactor coolant iodine concentration, from the last available sample prior to the tube rupture, is less than 0.7μ Ci/g (0.5μCi/cc).

b. Reactor coolant sample results obtained during the transient are less than 5.15μCi/cc (3.62μCi/cc). If samples cannot be drawn, then the ability to steam is based on the pre-existing iodine concentration limit.

c. EAB air samples are converted to thyroid dose rates.

The results of each of these sample methods should be used to govern steaming to the atmosphere. The one exception to limiting steaming due to iodine concentration is noted in 3.4.4.1.

3.5 Considerations for Use of SG Drains

The intent in using SG drains is either to prevent or delay the necessity of isolating the affected SG(s) by reducing the required steaming rate or to prevent filling of an isolated SG. It is desirable to delay fill of the SG until RCS pressure is below the MSSV setpoint.

This discussion assumes that a readily accessible high energy SG drain system is available during a SGTR. When developing procedures, consider the plant specific SG drain system design limitations, which will not be discussed here.

There are, however, generic considerations for limiting the use of SG drains depending on the limiting concern. If depletion of BWST level is the concern, for example, use of the drains will not alleviate the concern. But, if the drain flow path is such that the drained coolant is available for re-injection by HPI (e.g., drains to the reactor building sump), then use of the drains may negate the low BWST level concern. This method is considered acceptable since it involves a large tube leak flow rate and feedwater should be isolated before the drains are used; therefore virtually all of the fluid drained from the SG(s) will be RC. However, provisions should exist to sample the drained fluid and add boron as necessary.

If activity release rate is the limiting concern use of the SG drains reduces the steaming rate required on the affected SG(s) and thus may reduce the activity release rate, depending on drain location. However, in this case the drains should not be used if the site boundary dose rates would increase due to the storage location for the contaminated fluid, e.g., an open storage tank near the site boundary. If the recommended iodine limits described in Section 3.4.4.2 are used, use of the drains will not allow steaming beyond the limits as these limits are leak rate and steaming rate independent.

If the limiting concern is high SG level, use of the drains may permit continued steaming of the SG(s) until another concern becomes limiting.

3.6 SG Isolation

If the SG drains are unavailable, are not used, or are otherwise incapable of preventing SG overfill, isolate the affected, or most affected, SG (or second SG, in block 2.4.5) by closing all steam, feed, and drain lines to that SG. Depending on plant conditions and whether the SG was isolated for reasons other than overfill, there may be situations where it is desirable to temporarily unisolate a steam, feed, or drain line as follows:

3.6.1 Steam Lines

a. Chapter III.G describes periodic feeding and steaming of an otherwise isolated SG to enhance idle loop cooling during natural circulation. These methods may also be used for SGTRs provided:

   i. Additional steaming, at least periodically, will not result in unacceptable activity releases.

   ii. The level in the isolated SG is low enough to allow steaming without inducing carry-over. A suggested level limit is that equivalent to the elevation of the bottom of the steam line, accounting for full range level instrument errors. Water will enter the steam annulus via the penetration for the operate range upper level sensing tap, but should not induce carry-over at low steam flow rates if the level does not reach the steam line.

   These two restrictions should apply if the sole motivation for steaming is to enhance idle RC loop cooling during natural circulation.

b. It may be desirable to open TBVs or ADVs to prevent lifting of MSSVs, even if activity releases and/or liquid release will occur. This is especially true if the MSSVs would pass liquid, since failure to reseat becomes more probable. A TBV or ADV could also fail to reseat under this condition, but should be used if necessary and block valves are available to isolate the stuck open valve.

3.6.2 Feed Lines

a. Unisolation of the feed lines may be desirable to enhance idle RC loop cooling as discussed in item a of 3.6.1 and in Chapter III.G.

b. If the isolated SG is expected to fill due to the tube leakage, it may be desirable to augment the filling with FW. Use of FW for filling will:

i. provide additional RCS cooling during the fill

ii. reduce the depletion of the BWST inventory

iii. dilute the RC in the steam lines to reduce radiation levels.

However, if filling of the SG is to be accomplished using feedwater, the following precautions should be adhered to:

- When filling the SG with feedwater, maintain the SG pressure below both the MSSV setpoint and RC pressure. This will prevent lifting MSSVs and dilution of RC by feedwater.

- During cooldown, pressure in the SG may become greater than RC pressure. Therefore, during the cooldown increase sampling frequency of the RC and borate as required.

3.6.3 SG Drains

a. Unisolation of SG drains may be desired to prevent filling an isolated SG if:

i. RCS pressure is at or above the low MSSV set pressure or

ii. subsequent steaming of the isolated SG is anticipated.

b. Use of the SG drains may be desired to aid depressurization of the isolated SG and the RCS during HPI cooling (section 3.7).

If the SG is isolated because of approach to a limit, any subsequent actions to unisolate a steam, feed, or drain line should consider the potential impact on the limit. There may be instances where violation of a limit, at least temporarily, is warranted to prevent potentially worse situations. For example, as stated in item b under 3.6.1, it may be preferable to open an ADV on a full, isolated SG even though radiation and/or liquid release could occur to prevent the potential of uncontrolled release through a stuck-open MSSV (assuming block valves are available to isolate a stuck-open atmospheric dump valve).

3.7 SGTR Considerations During HPI Cooling

Methods to initiate and control HPI cooling are provided in Chapter III.G. However, HPI cooling concurrent with a SGTR may pose special problems which are discussed here.

Criteria for control of HPI (MU) (Chapter IV.B) dictate full HPI flow from two HPI (MU) pumps when SCM does not exist. When SCM is established, then HPI (MU) flow can be throttled to limit RCS pressure and cooldown rate while maintaining SCM.

However, following the HPI (MU) criteria may result in RCS pressure greater than an MSSV setpoint. If a SG has been isolated and allowed to fill, its pressure will follow RCS pressure, thus presenting the risk of lifting an MSSV and passing liquid.

If SCM does not exist, the criteria for full HPI (MU) flow from two HPI (MU) pumps takes precedence; therefore, throttling of HPI (MU) flow to limit or reduce RCS pressure cannot be performed until SCM exists. However, if this requirement could result in lifting of an MSSV on a solid SG, the following actions may be taken in an attempt to limit RCS pressure increase:

a. If available, reestablish letdown flow.

b. If available, open HPVs on the hot legs, pressurizer, and RV head. This will augment the relief through the PORV and may provide enough additional flow to limit or reduce RCS pressure below the MSSV setpoint.

c. If available, open the drains on the isolated SG. This action essentially performs the same function as use of the HPVs.

d If neither of the above are available or sufficiently effective, open the TBVs and/ or ADVs on the isolated SG. Again, this essentially performs the same function of increasing relief capacity from the RCS. Block valves should be available if needed to isolate a stuck-open TBV or ADV.

3.8 Impact of Unisolable Steam Leaks

Unisolable steam leaks concurrent with SGTRs limit the flexibility the operator otherwise has in controlling cooldown rates, SG inventories, and activity release rates. The extent of the impact is dependent on the number, size, and location of the steam leaks. Chapter III.D discusses methods to control cooldown rates and SG inventories (without SGTRs) with unisolable steam leaks. This section discusses the impact of concurrent SGTRs on control of SG inventories and activity release rates.

The basic philosophy presented in Chapter III.D for mitigation of unisolable steam leaks is to attempt continued cooling on both SGs and to isolate a SG only if the cooldown cannot be controlled or if the steam leak is inside the RB and continued steaming is determined to be inappropriate. In addition, the SG should be isolated if the steam leak is in a location hazardous to personnel or key equipment. The same basic philosophy should be followed in mitigating unisolable steam leaks concurrent with SGTRs, which may impact the decision to isolate a SG. However, there is a major difference. In Chapter III.D, a steam leak can be terminated, if necessary, by isolating FW to the SG and allowing it to boil dry. If the SG also has a SGTR, however, the steam leak will continue due to boil-off of the tube leakage. Since continued steaming through the leak is unavoidable in this case, continue to intentionally steam the SG unless restricted by other limits.

If the unisolable steam leak is on a SG without a tube rupture, the SG should only be isolated and allowed to boil dry if the cooldown cannot be controlled or the steam leak is in a location hazardous to personnel or key equipment

As an option, SG drains may be used, if available, to reduce the steaming rate through the unisolable steam leak. This will not prevent steam release, but may decrease the rate of release if accumulated tube leakage can be drained before it boils off. This will only be effective for small steam leaks and/or large SGTRs; for example, a steam leak size the equivalent of a stuck open MSSV with a single SGTR will result in virtually no accumulated leakage; therefore, the drains would be ineffective.

SGTR FUNCTIONAL FLOW DIAGRAM

Figure III.E - 1

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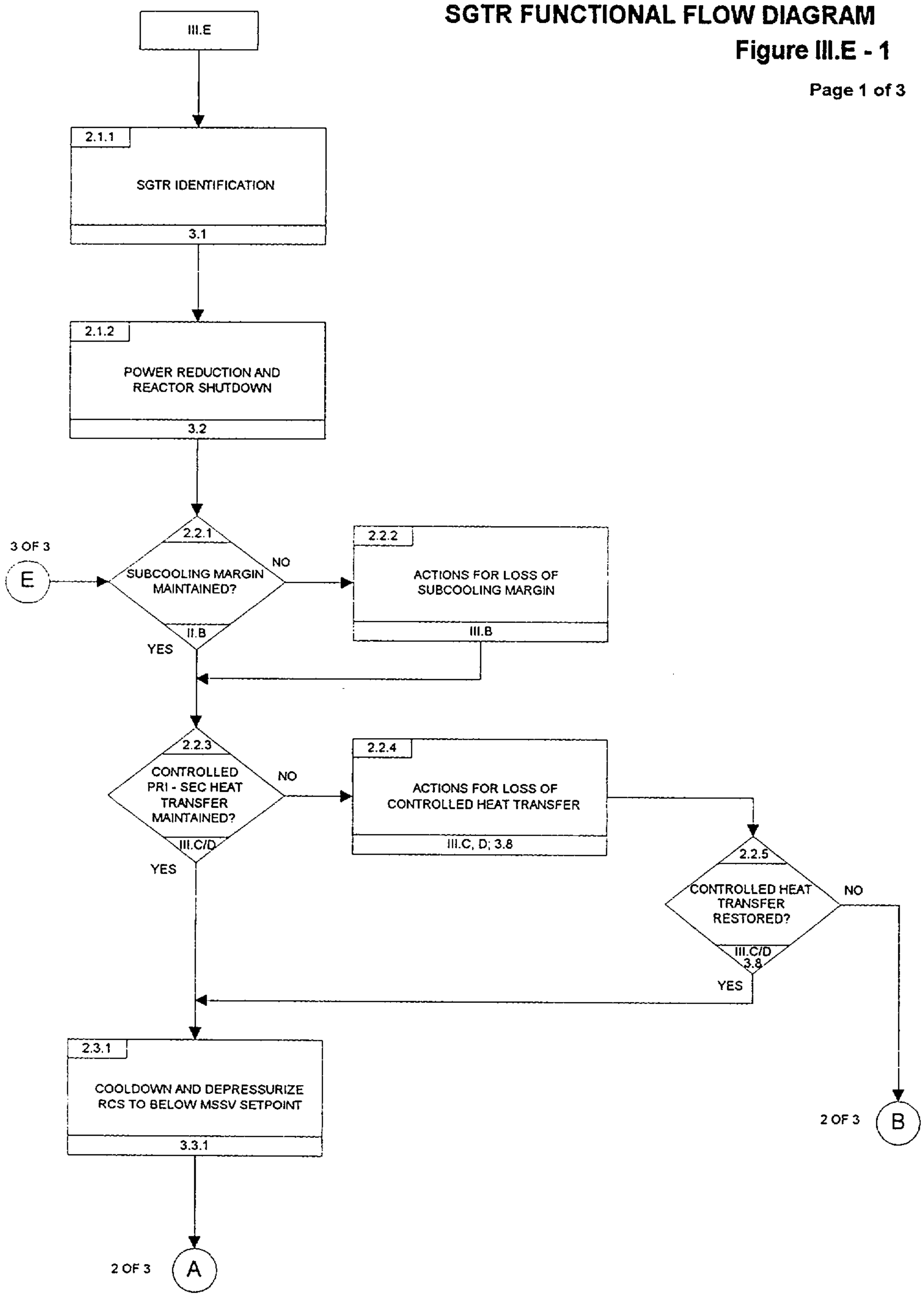

SGTR FUNCTIONAL FLOW DIAGRAM

Figure III.E - 1

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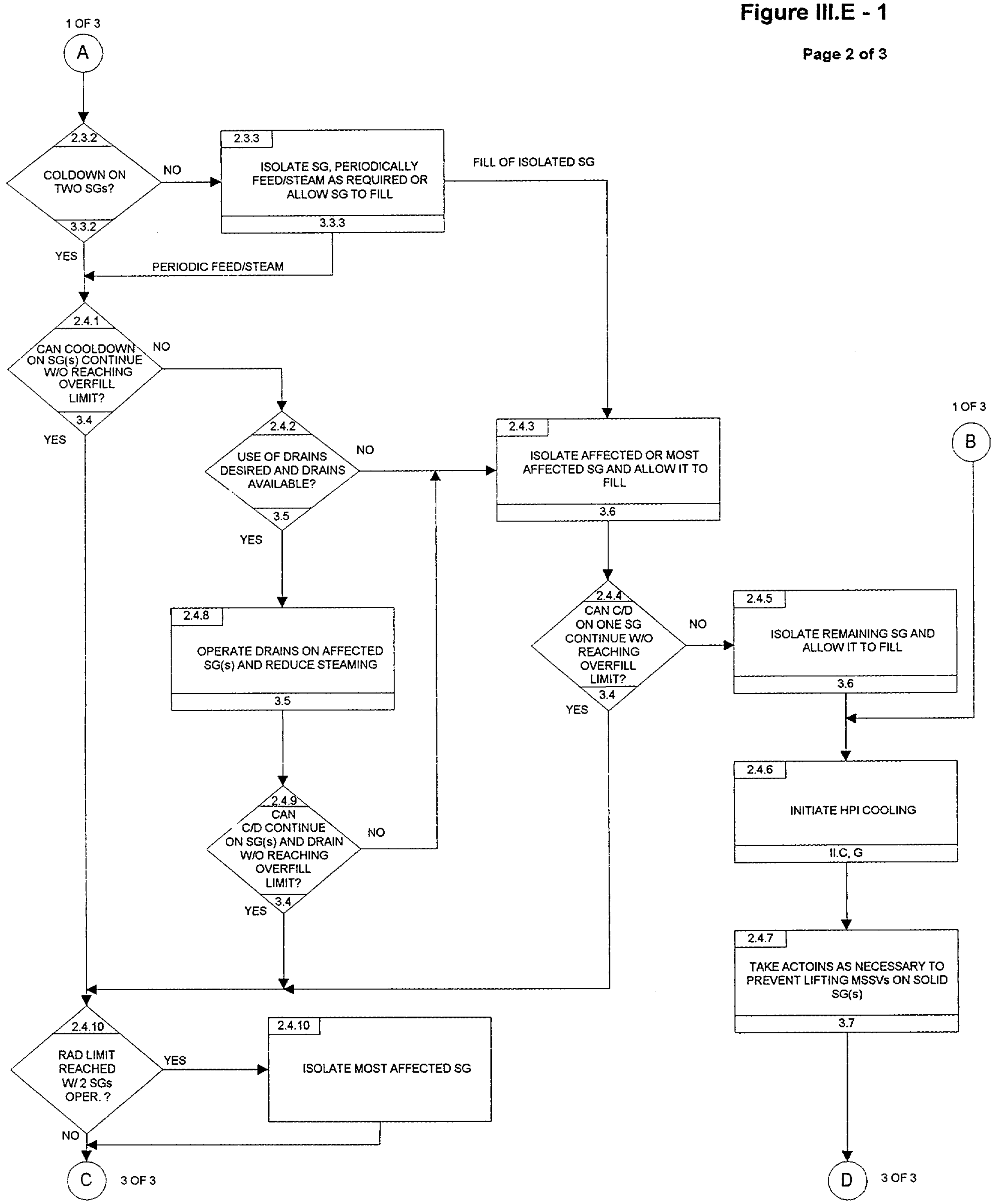

SGTR FUNCTIONAL FLOW DIAGRAM

Figure III.E - 1

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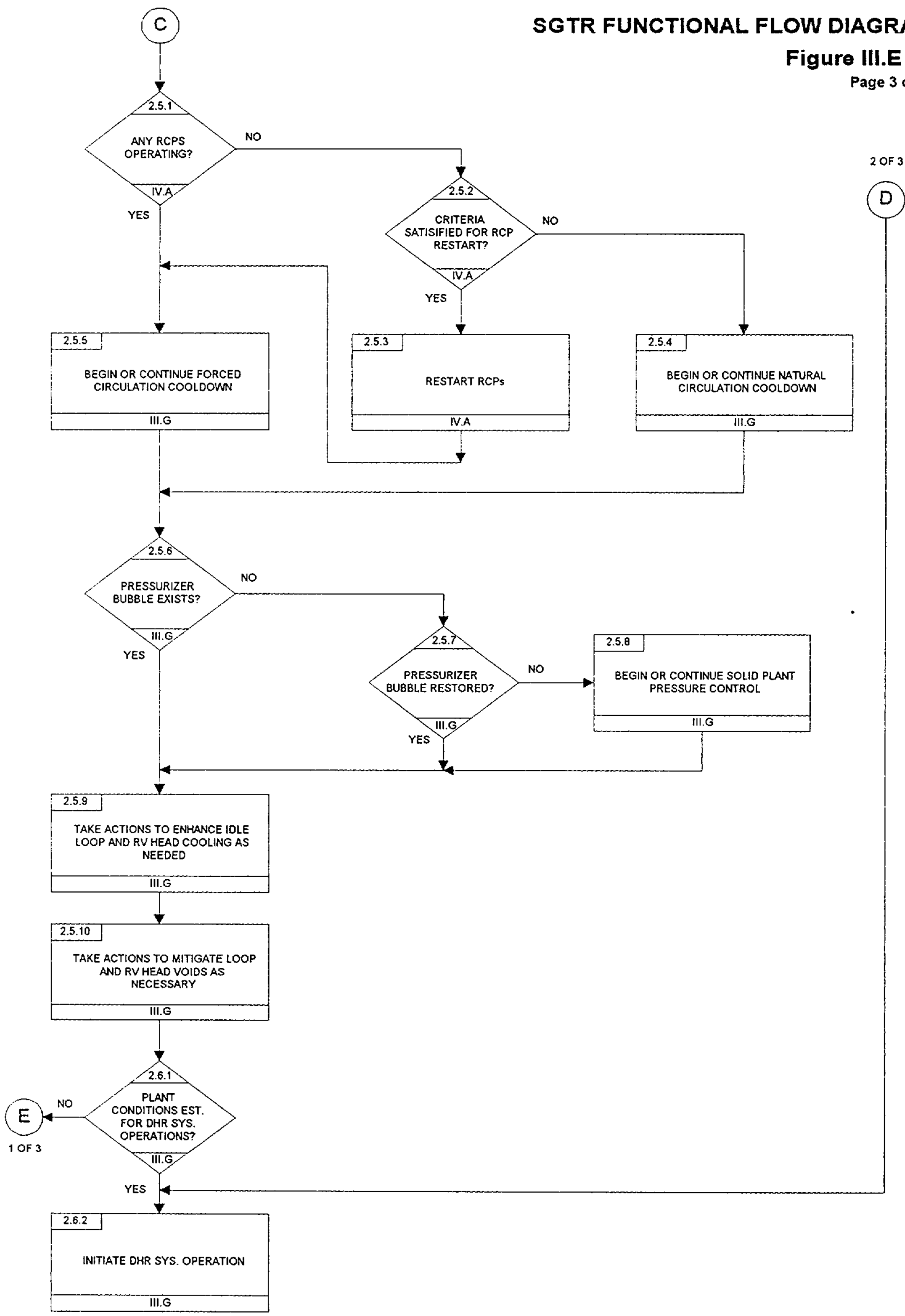


Chapter III.F

Inadequate Core Cooling

1.0 INTRODUCTION

This chapter provides the Technical Bases for the guidelines to mitigate an inadequate core cooling condition. An inadequate core cooling condition exists whenever the incore thermocouples indicate a superheated-temperature.

1.1 Concerns and Objectives During ICC Conditions

1.1.1 Concerns

Inadequate core cooling is not expected, as long as the guidelines are followed and equipment failures do not occur.. However, some LOCAs can temporarily exhibit ICC conditions and any transient can progress into ICC conditions, provided enough equipment failures occur. As soon as the RCS is superheated, adequate core cooling can no longer be assured. Consequently, actions must be taken to restore the RCS to at least saturated conditions as quickly as possible. The specific concerns during ICC are as follows:

A. Possible fuel damage.

B. Production of non-condensable gases.

C. Degraded RB environment.

D. Possible radiation releases to the atmosphere.

E. Equipment damage.

F. RB Integrity.

G. Clad-water reaction becoming a dominant heat source.

1.1.2 Objectives

The objectives to be considered during the treatment of ICC conditions are as follows:

A. Restore adequate core cooling - The primary concern is to restore the RCS to at least saturated conditions. The core is adequately cooled while the RCS is saturated.

B. Estimate the severity of the ICC condition - The actions taken to mitigate ICC depend upon the severity of the ICC condition. The more severe the ICC is, the more drastic the actions. If fuel damage is imminent, then actions to restore heat transfer are more drastic. However, whether the ICC conditions are severe or not as severe, the actions that should be taken are aimed at preserving the future integrity of the RCS and its associated equipment as well as the integrity of the SGs as a fission product barrier.

C. Eliminate non-condensable gas in the RCS - If the ICC condition is severe enough, then non-condensable gases will be produced. If primary to secondary heat transfer is to be restored, it is necessary to eliminate the non-condensable gases from the RCS to allow for RC natural circulation or boiler condenser flow.

1.2 Causes

The events which will cause ICC have a low probability of occurrence. Some examples of where ICC conditions could develop, provided the event lasts for a long enough time are:

A. LOCA with a total failure of the HPI system.

B. Total loss of feedwater (both MFW and EFW) with a concurrent total failure of the HPI system.

C. A total loss of power including all diesel generators with a failure of the steam-driven EFW pump to run (even if the steam driven EFW pump runs, an extended total loss of power may eventually lead to degraded RCP seal performance. Also, without power to the HPI pumps, ICC conditions would eventually occur).

D. During a specific size LOCA tripping the RCPs at a time when the RC void fraction is 70% or greater. This could only occur if the RCPs had not been tripped upon loss of SCM.

2.0 DIAGNOSIS AND MITIGATION

The flowchart of Figure III.F-2 should be used in conjunction with the following discussion. The numbered subsections of Section 2.0 correspond to the upper numbers in the blocks of Figure III.F-2.

2.1 Identification of ICC (Detailed discussion in Section 3.1)

The RCS P-T relationship will indicate when ICC conditions occur (see Figure III.F-1). As soon as the combination of RCS pressure and incore T/C temperature exceed the saturation curve then superheated conditions exist. It is recommended that the level instruments (RVL, HLL or PZR LVL) not be used for the following purposes:

- determining the onset of ICC.
- developing a trend toward ICC.
- as a cross check to incore thermocouples.

The incore thermocouples plotted on a P-T plot versus RCS pressure are the only valid indication of ICC conditions. If level instruments are used for these purposes then indications of superheat using the incore thermocouples must override level indications and result in transfer to the ICC guidance.

Instrument and process errors can lead to indications of superheated conditions when the core exit is at saturation conditions. The actions taken in the first region of superheat (i.e., Region 2) are appropriate for saturation conditions as well. Thus, inadvertent entry into ICC actions due to instrument errors is not detrimental from a core cooling perspective. Inadvertent entry, due to instrument and process errors, could prevent transferring to appropriate cooldown guidance if erroneous ICC indications persist. The use of an error band to establish an ICC curve, similar to the band used for the SCM curve, or other alternatives, such as the trend relative to the saturation curve, should alleviate procedural problems.

Instrument errors can also result in saturated RC indications when the core exit is actually superheated. This also should not be a problem in that a) the actions taken for a loss of SCM are also appropriate for ICC and b) if ICC conditions persist, the actual core exit conditions will trend deeper into the ICC region, making ICC recognizable even with instrument errors.

The types of errors involved usually will result in false indication of ICC rather than false indication of saturated conditions. In any case, when in doubt ICC should be assumed and actions taken accordingly.

2.2 Initiate HPI/LPI/CFT

The first action which should be taken during the onset of ICC conditions is to ensure full HPI and LPI flow into the RCS. Also, the CFT block valves should be verified open at this time. Decreasing CFT levels should be verified as soon as the RCS pressure decreases below the CFT actuation point. Ensuring full HPI and LPI flow is especially important because most postulated scenarios for the occurrence of ICC involve a failure of HPI/LPI. Restoration of HPI/LPI at the onset of ICC will likely restore saturated or subcooled conditions. If full flow from at least one HPI pump can be established, then the PORV and PORV block valves should be opened, and left open, to aid core cooling. If HPI flow is not established and RCS pressure increases to the PORV setpoint, open the PORV and reduce RC pressure to about 100 PSI above SG pressure or the next higher ICC curve, then reclose the PORV.

Refer to Chapter IV.B for a discussion on full HPI/LPI flow.

2.3 Take Actions to Increase Primary to Secondary Heat Transfer (detailed discussion in Section 3.2)

SG levels should be increased to the loss of SCM setpoint. FW flow must be assured and SG pressure lowered to achieve a secondary T_{sat} of about 100°F lower than T_{sat} for existing RCS pressure. This temperature differential must be maintained as the RCS depressurizes until primary to secondary heat transfer is established. During these actions it may be necessary, if not already done, to bypass the secondary plant protection system to prevent unwanted isolation of steam and feedwater lines.

2.4 RCS is in Which Region of ICC Figure III.F-1? (Detailed discussion in Section 3.3)

If the RCS P-T point has returned to Region 1, then the previous actions were successful and a normal cooldown can begin.

If the RCS P-T point is still in Region 2, then the operator should continue to ensure maximum HPI/LPI/CFT flow and continue to induce primary to secondary heat transfer.

If ICC conditions worsen into Region 3, then more drastic actions are needed to restore adequate core cooling. Refer to Section 2.5.

If the RCS P-T point reaches the Severe Accident Region, then serious ICC conditions exist. Drastic actions are required to minimize major core damage. Refer to Section 2.7.

2.5 Take Region 3 Actions to Increase Heat Transfer From Reactor Core to Reactor Coolant (Detailed discussion in Section 3.4)

The RCS P-T relationship is in Region 3. The secondary plant protection system should be bypassed as necessary and available SG(s) depressurized to 400 PSIG or less to achieve approximately 100°F decrease in secondary T_{sat}. SG pressure should not be reduced below the pressure requirements for the turbine driven EFW pump unless another steam source or another feedwater source is available.

All HPVs should be opened to relieve non-condensable gases from the RCS. HPVs should remain open at least until the RCS becomes subcooled or LPI cooling is established. Further instructions on the use of HPVs are detailed in Chapter IV.E.

2.6 Primary to Secondary Heat Transfer Established?

After the previous actions of 2.5 have been taken, primary to secondary heat transfer should be checked. If heat transfer has not been reestablished, then open the PORV and leave it open in an attempt to achieve CF and LPI cooling if CFTs and/or LPI are available. If primary to secondary heat transfer has been established, then it will be possible to cool the RCS with SGs, using HPI/ MU to replace RCS inventory.

If ICC conditions worsen, such that the RCS P-T point enters the Severe Accident Region, then transition is made to plant specific SAGs Refer to Section 2.7.

2.7 Severe Accident Region Entered (Detailed discussion in Section 3.5)

ICC conditions have worsened such that the RCS P-T relationship has crossed into the Severe Accident Region of Figure III.F-1. Plant conditions are now beyond the scope of the EOPs. A severe accident could not be prevented; all RCPs should be tripped to preserve SG tube integrity.

Further guidance will be in accordance with the plant specific SAGs.

3.0 TECHNICAL BASES

The flowchart of Figure III.F-2 should be used in conjunction with the following discussion. The numbered subsections of section 3.0 correspond to the bottom numbers of the appropriate blocks on Figure III.F-2.

3.1 Identification of ICC Conditions

The RCS P-T relationship will clearly indicate when ICC conditions occur. As soon as the RCS P-T point reaches the adequate SCM curve the incore T/C readings should be used to better determine the actual conditions of the reactor core. As soon as the RC pressure and incore T/C temperature combination exceeds the saturation curve, then superheated conditions are possible in the RCS. The operator must now take action as though the RCS were superheated in an attempt to restore the RCS to saturated conditions. However, due to instrumentation and process errors, it is possible that the RCS P/T combination indicates superheat when the RCS is indeed only saturated. This is not a problem with the recommended actions, since most of the recommended actions are to continue the same actions that are taken in the event of a loss of SCM. In addition, the other actions required have been reviewed to assure that these actions do not cause further problems if the RCS is only saturated. The fact that the RCS is saturated rather than superheated can be verified by noting that the incore T/Cs temperature moves parallel to the saturation curve. If ICC conditions actually exist, the RC P-T would continue to trend into the ICC region away from the saturation curve. See Figure III.F-1.

False indications of ICC due to instrument errors can cause a problem in procedure routing. Usually, ICC procedures are not exited until the RCS regains saturated or subcooled conditions. If the RCS is actually saturated but ICC indications persist due to instrument errors, this may prevent transfer to a more appropriate procedure for saturated cooldown. One method of preventing this problem is to develop an error band for ICC similar to the error band developed in support of the SCM limit. The error band would consider expected instrument errors and process errors such as elevated RB pressure conditions. An ICC curve can be based on this error band such that ICC procedures are not entered until the ICC curve is exceeded. A similar approach could be used based on trending relative to the saturation curve.

As long as this error band is reasonably small, it should not have a detrimental impact on the response to actual ICC conditions. The actions required for loss of SCM, if successful, will restore adequate core cooling. Until adequate core cooling is restored, the actual RC conditions will continue to trend away from the saturation curve, exceeding the error band and ICC curve. Significant actions beyond those taken for loss of SCM are not performed until Region 3 of ICC and any error band/ICC curve used or decisions based on trending relative to the saturation curve should be well short of the Region 3 curve. The error band should be on the same order of magnitude as the error band used for the SCM limit, although the combined ICC errors may be somewhat larger due to some of the process errors involved, most notably the RB pressure impact on the RC pressure indication discussed below.

The response time and location of the RC loop temperature detectors are reasons they are not used in determining if the RC has become superheated. For a rapid decrease in RC temperature, the hot and cold leg temperature detectors will indicate a higher temperature than actually exists, due to the response time of the detectors. For example, a LOCA will cause the RC pressure to rapidly decrease to the saturation pressure. The RC hot leg temperature will also decrease, however, the indicated hot leg temperature will change slower than the actual temperature causing a superheat temperature indication while actually the RCS is only saturated. This is one of the reasons that incore T/C temperature is recommended, rather than using the hot or cold leg RTD indications. The primary reasons for using the T/Cs are because they respond quicker than the hot and cold leg temperature detectors and will indicate actual RCS conditions more accurately. Another cause for a false ICC indication is the increased RB pressure following a LOCA. When the absolute pressure of the RC is determined from the RC gauge pressure, the effect of the increased RB pressure is generally not accounted for. Increasing RB pressure usually results in decreasing the indicated RC pressure. The hot and cold leg temperature detectors can become disassociated with core outlet temperature when the temperature becomes superheated because of a lack of RC loop flow. If there is any doubt of the actual RCS conditions, ICC conditions should be assumed and appropriate actions taken. As stated before in the discussion on instrumentation errors, the required ICC actions in Region 2 are still appropriate if used during a lack of adequate subcooling margin. It is only after the

RCS has proceeded into Region 3 that more drastic actions must be taken (instrument errors are not great enough to indicate Region 3 when the RC is saturated).

Level instruments should not be used to determine entry into ICC because a non-ICC transient can cause RV level to decrease below the design range of the instruments before recovering from the transient without uncovering the core. Additionally, due to normal instrument errors, a level instrument could show some level when none exists in the measured range, leading operators to believe that the core is adequately covered when it is not. These reasons also preclude the use of level instruments as a cross-check to the incore thermocouples. The incore thermocouples are the only reliable indication of ICC.

It is also recommended that level instruments not be used as diagnostic trends relative to ICC predictions. This is because a continuing decrease in level after initiation of injection systems does not mean that an ICC condition is imminent. Some larger size SBLOCAs, for example, will result in a period of continual inventory decrease even after initiation of full HPI flow. However, the existence of HPI flow will prevent these LOCAs from uncovering the core. The real "trend" indication relative to ICC conditions is the success or failure of the mitigating actions. For example, if HPI cannot be started and the leak cannot be terminated, then ICC may occur (most SBLOCAs can be mitigated without HPI by cooling and depressurizing to the CFTs/DHR system using the SGs). If HPI is successfully initiated, then ICC conditions will not occur.

Large break LOCAs can result in actual ICC conditions even when all of the ES systems are performing as designed. This is due to the blowdown where the core is initially uncovered and the time required for the subsequent reflood and refill. If this occurs, proper operation of the ES systems, especially LPI, should be verified. If the LPI system is performing properly, then a transition to the ICC actions for Region 2 is not required. The Region 2 actions are either satisfied by the existence of LPI flow or are not applicable (e.g., PORV operation) since the RC pressure is below the LPI shutoff head. However, if proper LPI operation is not verified, or if ICC conditions continue to trend into Region 3, then ICC actions should be performed.

3.2 Take Actions to Increase Primary to Secondary Heat Transfer

At the onset of ICC conditions the operator must attempt to restore primary to secondary heat transfer, if at all possible. Actions to restore primary to secondary heat transfer include raising SG levels to the maximum limit allowed. To accomplish this it is necessary to ensure adequate FW flow. Also, SG pressures should be lowered in an attempt to induce heat transfer. The pressure should be lowered until primary to secondary heat transfer is restored or secondary T_{sat} is about 100°F lower than T_{sat} for the existing RC pressure. In this situation, RCS superheated, large RC (incore thermocouples) to SG T_{sat} ΔTs will exist as a consequence of RCS conditions (RC to SG ΔT in this situation has little meaning). For this reason primary to secondary ΔT is established based upon T_{sat} for the existing RC pressure and SG T_{sat}. This ensures that the SG(s) remain heat sinks when heat transfer is restored and the RCS returns to saturation. This differential must be maintained as the RCS depressurizes until heat transfer is restored. Once heat transfer is restored, there is no cooldown rate limit as long as the RC remains superheated. However, once the RC returns to saturation, then SG pressure will be controlled to maintain the desired cooldown rate. The minimum steam pressure should not be decreased below that necessary to power the steam driven EFW pump, unless auxiliary steam is being used to power the pump or motor driven EFW pumps are being used. If RC pressure increases to the PORV setpoint, open the PORV and reduce RC pressure to about 100 PSI above SG pressure or about 100 PSI above the next ICC region curve, whichever occurs first, then reclose the PORV. This action minimizes PORV cycling, prevents lifting pressurizer safety valves and maximizes HPI/CFT/LPI flow to help cool the core and refill the RCS (which will help lead to faster restoration of primary to secondary heat transfer) while maintaining adequate positive primary to secondary ΔT (maintains SG(s) as a heat sink). Closing the PORV 100 PSI above the next higher ICC region curve ensures that operator action, to control RC pressure, does not cause the RCS to degrade into a more severe region. These actions are similar to those for a loss of SCM in case the ICC guidelines are inadvertently implemented. If full flow from at least one HPI pump is established, then the PORV and PORV block valve should be left open. This essentially establishes HPI cooling and should allow for increased HPI flow and better core cooling.

3.3 RCS is in Which Region of ICC Figure III.F-1?

After taking initial actions to mitigate ICC conditions, the operator must now determine how severe the ICC conditions are before taking further actions. This enables the operator to take actions which may damage plant equipment depending on the severity of the ICC conditions. If the RCS P-T point (as determined by RCS pressure and the incore T/C readings) is in Region 1 then the RCS has returned to a saturated or even subcooled condition because of the previous actions. At this point a cooldown can proceed with the RCS in a saturated or subcooled condition. It may be necessary, at first, to perform a saturated cooldown with the SGs. On the other hand, it may be necessary to cooldown with HPI/LPI/CFTs alone, depending upon the condition of the RCS. Refer to Chapter III.G for details of cooldown and Chapter III.B for details of cooldown with a small LOCA.

If the RCS is still superheated and in Region 2 of ICC Figure III.F-1, then ICC conditions still exist, but it is not serious enough to cause immediate core damage. In this case, the operator should maintain HPI/LPI flow and continue to control primary to secondary heat transfer until the RCS returns to a saturated condition. As soon as the RCS does return to a saturated condition then cooldown may proceed.

If the RCS P-T point reaches Region 3, then cladding temperature in the high power regions of the core may be 1400°F or higher. Above this temperature there is a chance for rupture of the fuel rod cladding material. The clad-water reaction begins to produce hydrogen which will collect in the reactor coolant loops and may escape to the reactor building. Region 3, then, is the onset of very serious ICC conditions. Conditions are serious enough to warrant abnormal use of plant equipment. However, precautions in operating plant equipment should still be taken in an attempt to maintain future integrity of the equipment. Necessary actions to mitigate ICC conditions in Region 3are detailed beginning with Section 2.5 and the corresponding bases in Section 3.4.

If the RCS never exceeds Region 3 (before returning to Region 1), then there has been no appreciable clad oxidation and cooldown can be accomplished by normal procedures. However, if the RCS exceeds Region 3, entering the Severe Accident Region, then further direction for accident mitigation will be provided by Station Management based on the plant specific SAGs.

If the RCS P-T point enters the Severe Accident Region, i.e., clad temperature > 1800°F, then initiation of a severe accident is indicated. This situation can lead to significant clad oxidation, attendant H_2 production and heat release. A badly damaged core may be unavoidable. Additional operator actions, related to this condition, are discussed in Section 3.5.

The following principles apply to actions in all regions:

1. In checking each system (e.g., HPI, LPI, EFW) the operator confirms that the system is operating correctly and at full capacity. He attempts to correct any malfunctions in the system, if practical and possible.

2. If while taking actions in one region, the RCS conditions enter a more severe ICC region, the operator should transfer to guidelines for the more severe ICC region.

3. If any time the RCS conditions enter a less severe ICC region, the operator should not revert to the actions for the less severe ICC region. The reason being that the action which caused the conditions to improve may be cancelled causing the ICC conditions to worsen again.

   If the intent of a group of actions for a given ICC region has been satisfied then further actions may not be necessary. The operator should watch the system response to each action being made so that he can judge whether not the intent has been satisfied; e.g., the incore T/C temperature is returning to saturated conditions.

4. During ICC full flow from both HPI and LPI should be maintained. If core exit thermocouples are still indicating superheated conditions (even with the required LPI flow rate that normally allows HPI termination), then HPI pumps should be aligned in the piggyback mode, during transfer to the RB sump, in order to maintain full injection.

3.4 Take Region 3 Actions to Increase Heat Transfer From Reactor Core to Reactor Coolant

The RCS P-T has reached Region 3. More drastic actions are now justified to restore adequate core cooling. The secondary plant protection system should be bypassed as necessary and available SG(s) depressurized to 400 PSIG or less to achieve approximately 100°F decrease in secondary T_{sat}. SG pressure should not be reduced below the pressure requirements for the turbine driven EFW pump unless another steam source or another feedwater source is available.

When the RCS P-T enters Region 3, i.e., clad temperature $\geq$ 1400°F, then H_2 and other non-condensable gases can form in the RCS. To prevent these non-condensable gases from collecting in the high points of the RCS, all HPV valves should be opened as long as primary to secondary heat transfer has not been restored. Refer to Chapter IV.E for further instructions on HPV valve operation.

In this situation, superheated RCS in Region 3 and no primary to secondary heat transfer, the PORV and PORV block valve should be opened in an attempt to depressurize the RCS in order to achieve CF and/or LPI cooling. However, if CF and LPI is not available then the PORV should be opened when RC pressure reaches the PORV setpoint and reclosed when RC pressure is ~100 PSI > SG P_{sat} or ~100 PSI > 1800°F T_{clad} curve, whichever occurs first. This will minimize PORV cycling.

When the RCS P-T point is in Region 3, clad temperature in some regions of the core may be 1400°F or higher. Hydrogen gas, along with other non-condensable gases are being produced. To prevent these non-condensable gases from collecting in the high points of the RCS, all HPV valves should be opened. Refer to Chapter IV.E for further instruction on HPV operation.

When heat transfer is restored and the RCS is superheated, the RCS should be cooled at the maximum rate attainable until saturated RCS conditions are reached. Once saturated RCS conditions are reached, the cooldown rate should be reduced as necessary to maintain overall plant control. Cooldown rate may exceed the Technical Specification limit as long as SCM is not restored.. Also, the PORV, if open, may be closed when the RCS returns to saturation since heat transfer has been restored.

3.5 Severe Accident Region Entered – Transition to Severe Accident Guidelines

The RCS P-T point has now entered the Severe Accident Region of Figure III.F-1, i.e., clad temperature $\geq$ 1800°F. Significant clad oxidation is occurring with attendant H_2 production and heat release. A severe accident has initiated and a badly damaged core may be unavoidable. Plant conditions are now beyond the scope of the TBD.

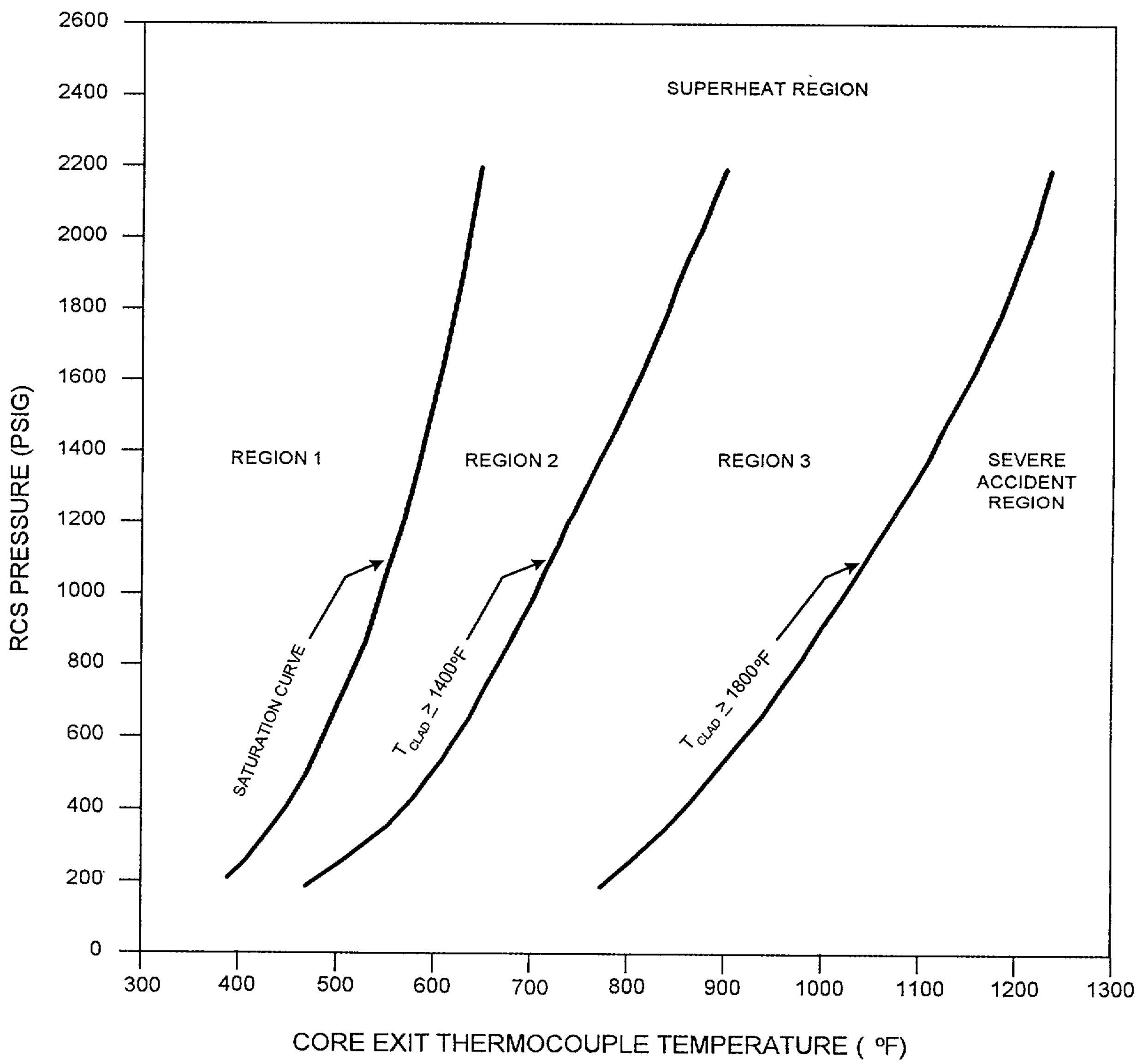
In the unlikely event RCPs are still running because they were not tripped within 2 minutes of loss of SCM, then the RCPs should be tripped at this time. Worsening RCS conditions are evidence of the RCPs' inability to provide primary to secondary heat transfer. Tripping them ensures they will not contribute to circulation of high temperature steam and gas through the SG tubes. Forced circulation of high temperature steam and gas through the SG tubes was determined, during the development of the generic SAG, to increase the likelihood of tube failure due to creep rupture.

The PORV may have been opened in Region 3 in an attempt to achieve injection from the CF and/or LPI systems. If either of these injection sources are available and the PORV is open, then the PORV should be left open. It may subsequently be closed at the discretion of Station Management.

If the HPVs are open, it is for the purpose of removing non-condensable gases from the RCS. In the present condition, these gases are continuing to be formed; therefore, leaving the HPVs open will result in continued removal of non-condensable gases from the RCS. The HPVs may be subsequently closed at the discretion of Station Management.

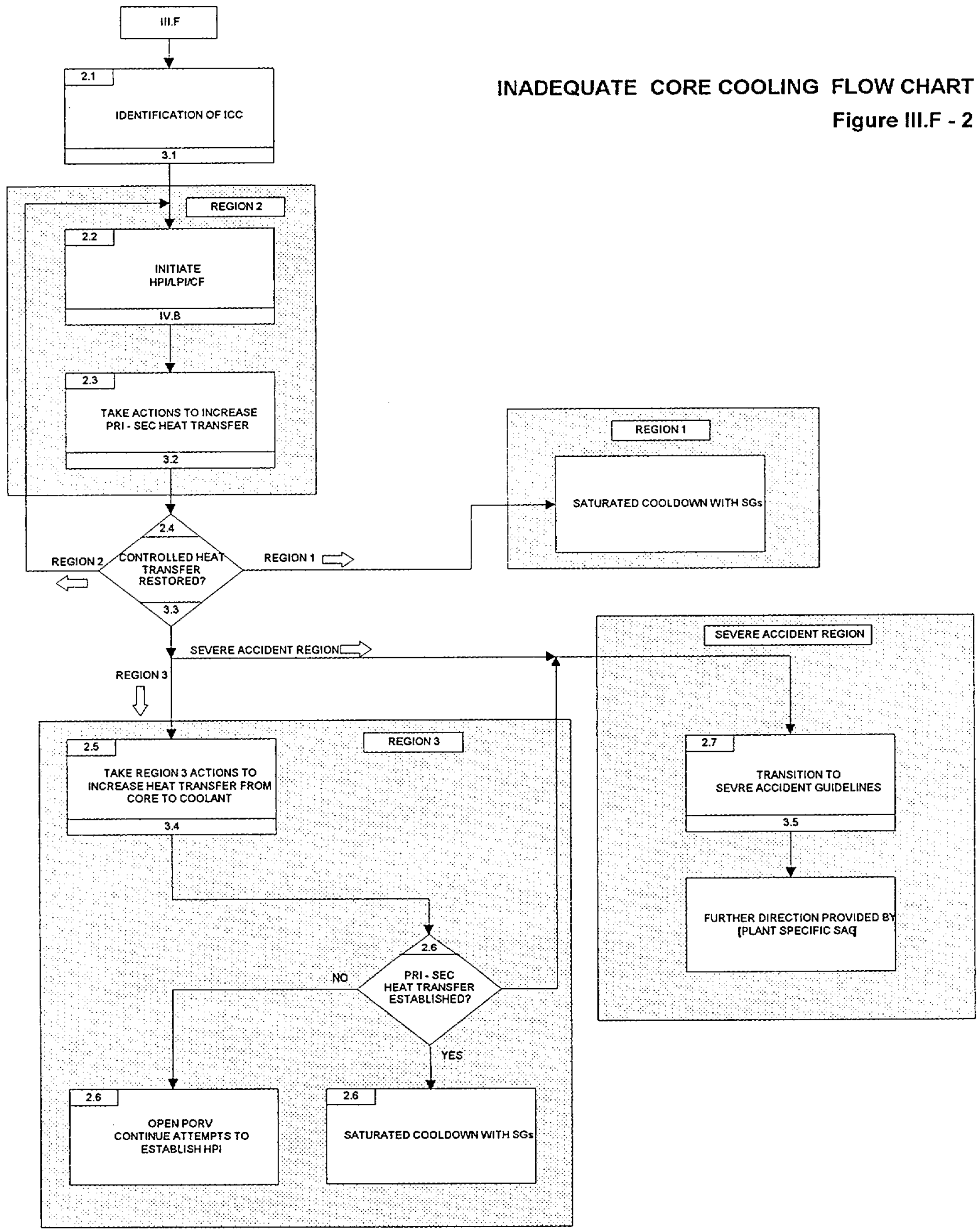
Because plant conditions are now beyond the scope of the TBD, transition is made to plant specific SAG. Following the use of the plant specific SAG, DO NOT return to the TBD for additional guidance. The TBD guidance is not designed to account for the effects of possible core damage.

Figure III.F-1 CORE EXIT FLUID TEMPERATURE FOR INADEQUATE CORE COOLING



INADEQUATE CORE COOLING FLOW CHART

Figure III.F - 2



Chapter III.G
Cooldown Methods

1.0 INTRODUCTION

This chapter provides technical bases for plant cooldown. The purpose of these technical bases is to provide sufficient information regarding the expected NSSS performance during cooldown transients and provide guidance for the operation of key systems and equipment such that the user can develop plant specific procedures for cooldown. Although normal and near normal conditions are considered, the main purpose is to provide technical bases for cooldown under abnormal conditions. Guidance for cooldown with a SBLOCA or with a tube rupture is provided in Chapters III.B and III.E, respectively.

1.1 Concerns and Objectives

1.1.1 Concerns

Several concerns are created because of various equipment failures which are assumed in this chapter. The major concerns are as follows:

A. Cooling the liquid volume under the RV head during natural circulation cooldown.

B. Cooling the RC in an idle RCS loop during a natural circulation cooldown with only one operable SG.

C. SG tube-to-shell compressive and tensile stress limits when cooling down with only one operable SG.

D. Controlling RC pressure when cooling down with a liquid water filled pressurizer.

E. Reducing the RC pressure and temperature low enough to initiate DHRS operation before depleting existing cooling water inventories.

1.1.2 Objective

The objective is to cooldown and depressurize the RCS as quickly as possible to the RCS conditions which allow DHRS operation. This is done without violating equipment design limits and with any combination of the following
equipment availability:

A. with or without an operable RCP

B. with or without a pressurizer steam bubble
C. with two, one or no operable SGs.

Furthermore, the objective assumes the cooldown follows any upset in heat transfer. However, cooldown following a LOCA and SGTR are discussed in Chapters III.B and III.E respectively.

2.0 GENERAL OPERATOR ACTIONS

This section provides a brief description of the recommended logic to be used during a plant cooldown from the initial decision to cooldown to decay heat removal system operation. Figure III.G-1, "Cooldown Logic Diagram," provides a basic action/decision logic chart for determining the appropriate cooldown method.

A loop is provided in the logic diagram from 2.7 (when plant conditions are not yet established for DHRS operation) back to 2.2.1 (subcooling margin (SCM) status). The purpose of this loop is to signify continuous surveillance of key plant conditions during the cooldown that may a) require changing cooldown methods (e.g., loss of reactor coolant pumps (RCPs)) or b) permit changing to a preferred cooldown method (e.g., heat transfer restored to both steam generators (SGs)).

The logic diagram is structured such that positive responses to normal cooldown criteria lead down the far left vertical path. Any abnormal conditions that affect the cooldown method result in branches to the right.

2.1 Determination of Cooldown Requirement

The decision to cool down the plant should be based on an evaluation of specific plant conditions weighing both present and future plant safety and control at hot standby against cooling down with abnormal plant conditions. In some cases, the cooldown may be forced due to a small steam leak or the need to control tube-shell ΔT in an idle SG. The recommended procedure is to restore the plant to as near normal conditions as possible prior to cooldown unless compelling reasons exist to continue the cooldown. The reactor must be shut down within applicable reactivity limits prior to starting cooldown operations. Care must be taken to maintain the shutdown margin during cooldown.

This chapter of the technical bases assumes the decision to cooldown has been made and neither a SG tube leak nor a LOCA exists. Cooldown with a LOCA or SGTR is described in Chapter III.B or III.E, respectively. However, this chapter does describe the impact of a simultaneous SGTR.

2.2 Subcooling Margin and Primary to Secondary Heat Transfer

2.2.1 Subcooling Margin

Verification of subcooling margin (SCM) is the first major decision point because it determines available equipment and heat transfer characteristics:

A. Heat removal from the core and transport to the steam generator is most easily accomplished when the fluid is subcooled.

B. Loss of SCM requires prompt actions as defined in Chapter III.B

C. Maintaining SCM is very important in maintaining optimum plant control and performing an expeditious cooldown.

The logic diagram continuously loops back to this decision point for the duration of the cooldown until the DHRS is in operation. This signifies a constant surveillance of SCM and other key plant conditions during the performance of the remaining cooldown. The concept and definition of SCM is discussed in Chapter II.B.

2.2.2 Loss of Subcooling Margin

On loss of SCM, the operator must perform or verify the following actions:

A. Trip all RCPs.

B. Initiate full HPI (MU) flow with two HPI (MU) pumps from the BWST.

C. Begin raising SG levels to the loss of SCM setpoint. (Chapter IV.C discusses raising the SG level.)

Further discussion of actions (and their bases) required upon loss of SCM is provided in Chapter III.B. Since this chapter does not assume a SGTR or LOCA, the loss of SCM is assumed to be a temporary condition (e.g., overcooling) that can be corrected and SCM restored. Chapter III.B covers cooldown with a sustained loss of SCM.

When SCM is restored, restart RCPs (if all other conditions for RCP restart exist, i.e., Chapter IV.A and plant specific procedures for RCP restart) and shift SG level control to the appropriate setpoint. In addition, throttle HPI (MU) flow as necessary (Chapter IV.B) to maintain pressurizer level and minimum SCM and, if applicable, pressurized thermal shock (PTS) guidance (Chapter IV.G).

2.2.3 Primary to Secondary Heat Transfer

The second major decision point in the logic diagram is verification of controlled heat transfer in both SGs. The preferred cooldown method is a normal cooldown with forced flow and controlled heat transfer to both SGs. Methods of verifying heat transfer and recognizing inadequate or excessive primary to secondary heat transfer are discussed in Chapter II.B. Methods of mitigating inadequate or excessive primary to secondary heat transfer are discussed in Chapters III.C and III.D respectively. If controlled heat transfer exists in both SGs, then proceed down the left vertical path of the logic diagram (toward a normal cooldown).

2.2.4 Loss of Controlled Primary to Secondary Heat Transfer

If controlled primary to secondary heat transfer does not exist in either SG, restore controlled heat transfer in at least one SG (and preferably in both SGs) as soon as possible. Possible causes for inadequate primary to secondary heat transfer and methods of restoring primary to secondary heat transfer are discussed in Chapter III.C. Possible causes for excessive primary to secondary heat transfer and methods of restoring controlled primary to secondary heat transfer are discussed in Chapter III.D.

2.2.5 Restoration of Primary to Secondary Heat Transfer to at Least One SG

If controlled primary to secondary heat transfer is restored to at least one SG, return to the far left vertical path. Subsequently, a decision point is used to separate cooldowns with one SG and cooldowns with two SGs. If primary to secondary heat transfer was lost and cannot be restored to either SG following the guidance provided in Chapter III.C, then HPI/MU cooling will be required (2.2.7).

2.2.6 Number of Steam Generators Operating (Detailed discussion in Section 3.5)

If the operator is controlling the feeding and steaming of both SGs, the cooldown can continue in a normal mode (depending on RCP and pressurizer status). If the operator can control heat removal in only one SG, continue attempts to restore primary to secondary heat transfer in the other SG. Care must be taken to prevent loss of heat transfer in the operating SG while these attempts are being made. Section 3.5 of this chapter discusses the special considerations of single SG cooldowns.

2.2.7 HPI Cooling (Detailed discussion in Section 3.9)

If neither SG can provide primary to secondary heat transfer, initiate HPI cooling. HPI cooling will be required until DHRS initiation unless SG operation can be restored. The operator should continue efforts to restore primary to secondary heat transfer in the SG. Restoration of controlled primary to secondary heat transfer to either SG is covered by the eventual loop back through 2.2.1. Methods of initiating and controlling HPI cooling are described in section 3.9 of this chapter.

2.3 Reactor Coolant System Flow

2.3.1 Reactor Coolant Pump Status (Detailed discussion in Section 3.2)

RCP operation is preferred since it may provide pressurizer spray, eliminates RV head and idle loop cooling concerns, alleviates thermal shock concerns (if HPI cooling is being used), mixes the RCS (providing better use of RC temperature measurements), and allows for faster cooldown. Section 3.2 discusses alternate depressurization methods for RCP combinations which do not provide sufficient pressurizer spray flow.

2.3.2 Criteria for RCP Restart

If the RCPs are not operating, attempt to satisfy the criteria for restarting the RCPs as soon as possible. The criteria for RCP restart are provided in Chapter IV.A.

2.3.3 Reactor Coolant Pump Restart Restart

RCPs when the criteria for RCP operation are satisfied. The number and selection of the RCPs to be restarted depends on plant conditions. Running one RCP in each loop balances heat transfer, but other pump combinations may produce higher spray flow. Section 3.9.1 discusses RCP operation considerations applicable for HPI cooling. Refer to Chapter IV.A for precautions and recommendations to be considered before RCP restart and for expected system response to RCP restart.

2.4 Reactor Coolant System Pressure Control

2.4.1 Pressurizer Status (Detailed discussion in Section 3.4)

Normal RCS pressure control is achieved with a pressurizer steam bubble, spray and heater operation, and with the rest of the RCS solid and subcooled. If a pressurizer steam bubble does not exist and cannot be drawn, then solid plant pressure control will be required. If a steam bubble does exist but heaters and/or spray capability is lost, solid plant pressure control may be required (if the pressurizer cannot be maintained as the hottest region in the RCS). Operation with solid plant pressure control is discussed in section 3.4.

If normal pressure control is hindered due to voids in the hot legs or RV head, actions should be taken to eliminate the voids (see Sections 3.7 and 3.8).

2.4.2 Solid Plant Pressure Control (Detailed discussion in Section 3.4)

During solid plant operation, primary pressure is controlled by primary inventory controls (e.g. MU/HPI and letdown/ seal bleed off/leakage flow). Solid plant pressure control is not

the preferred path and therefore attempts should be made to restore pressurizer steam bubble control whenever possible. Solid plant pressure control is discussed in section 3.4.

2.5 Cooldown and Depressurization

2.5.1 Normal Cooldown (Detailed discussion in Sections 3.1 and 3.2)

A normal plant cooldown is defined as one where SCM is maintained while utilizing forced flow, two steam generators, and normal RC pressure control with a pressurizer steam bubble. This chapter provides guidance for plant cooldown when one or more of these do not exist, except for sustained saturation which is covered in Chapter III.B. The purpose of the dashed box on the logic diagram (Figure III.G-1) is to signify coverage of normal plant cooldown by site specific procedures (i.e., not covered by this chapter). In addition, the inclusion of this box in the logic diagram signifies that the site specific procedures should have decision points to return to cooldown procedures for abnormal plant conditions should the plant status change during the cooldown (e.g., loss of RCPs).

During normal cooldowns, it is appropriate to bypass safety actuations (e.g., low RCS pressure ES actuation) and isolate safety equipment (e.g., CFTs) where these actions are normally performed. ES equipment actuation should not be bypassed if adequate SCM does not exist since a LOCA may be in progress. In addition, even with adequate SCM, if ES equipment is already operating (e.g., HPI cooling) this should be considered in deciding to bypass. Specific requirements on bypass limitations are provided in Chapter III of Volume 4.

2.5.2 Abnormal Forced Circulation Cooldown (Detailed discussion in Sections 3.1 and 3.2)

An abnormal forced circulation cooldown is defined as one with forced flow combined with one inoperable SG or SG with a small unisolable steam leak and/or solid plant pressure control.

For forced circulation with one SG inoperable, SG shell cooling must be considered by the operator in maintaining tube-to-shell ΔT limits (see Section 3.6). Solid plant pressure control is discussed in Section 3.4. The operator should attempt to restore equipment such that a normal cooldown can be initiated.

2.5.3 Natural Circulation Cooldown (Detailed discussion in Sections 3.1, 3.2 and 3.3)

A natural circulation cooldown may be required following a loss of RCPs. It is normally preferable to maintain existing RCS conditions and just remove decay heat with natural circulation until the RCPs become available. This is because of special considerations applicable during natural circulation cooldowns: lack of normal pressurizer spray, RV head cooling (2.6.2), idle loop cooling (2.6.3), and SG shell cooling (2.6.1). Should it be necessary to perform a natural circulation cooldown, these considerations must be addressed.

2.6 Special Considerations for Abnormal Cooldowns

2.6.1 SG Shell Cooling (Detailed discussion in Section 3.6)

Actions to increase SG shell cooling are performed to allow single loop cooldowns to proceed at an appreciable rate without violating tube-to-shell temperature differential limits. Methods of enhancing SG shell cooling are discussed in Section 3.6.

2.6.2 Reactor Vessel Head Cooling (Detailed discussion in Section 3.7)

Actions to increase RV head cooling are performed to allow natural circulation cooldowns to proceed at an appreciable rate without causing head void formation. Cooldowns with a void in the upper head can proceed at 50°F/hr without causing excessive head stresses. Methods for enhancing RV head cooling, and recognizing and eliminating head voids, are discussed in Section 3.7.

2.6.3 Idle Loop Cooling (Detailed discussion in Section 3.8)

Actions to increase idle loop cooling are performed to allow single loop natural circulation cooldowns to proceed at an appreciable rate without causing idle loop void formation. Methods for enhancing idle loop cooling, and recognizing and eliminating loop voids, are discussed in Section 3.8.

2.6.4 Trickle Feed (Detailed discussion in Section 3.10)

Trickle feed refers to the method used for providing FW to the SG when neither SG can hold pressure. Such a situation would occur if there were unisolable steam leaks on both SGs. In this case, following mitigation of excessive heat transfer, core cooling would be by HPI cooling. It may be desirable to attempt plant cooldown using trickle feed, which if successful would allow termination of HPI cooling. When trickle feed is used, either EFW or MFW is fed to one or both SGs at the rate required to remove decay heat and provide the desired RCS cooldown rate.

2.7 Continue Cooldown to DHRS Operation

Continue plant cooldown with either SG(s) or HPI cooling until conditions allow DHRS operation. A loop is provided back to 2.2.1 when DHRS conditions have not yet been attained. The purpose of this loop is described in Section 2.0.

Station management will provide further direction once plant conditions for DHRS operation have been met.

3.0 ABNORMAL COOLDOWN TECHNICAL BASES

This section provides a detailed discussion of abnormal cooldowns and the technical bases for operator actions described in Figure III.G-1

3.1 Cooldown Limits and Considerations

Normal and abnormal cooldowns must observe the following constraints. (Shown in parentheses are the plant parameters that must be monitored continuously to ensure these criteria are not violated).

- Cooldown rate limit.
  (Average primary temperature vs. time)
- Subcooling margin.
  (Primary pressure and hot leg or incore temperature)
- Reactor vessel P-T limits and pressurized thermal shock (PTS) guidance.
  (Primary pressure and cold leg or incore temperature)
- Pump NPSH limits. (when applicable)
  (Primary pressure and temperature)
- Tube-to-shell ΔT limits.
  (Primary hot leg and cold leg and SG shell temperatures)
- Shutdown margin.
  (Boron concentration measured periodically)

Normal cooldowns are preferred because they can be better controlled and because faster cooldown rates can be achieved. When the normal cooldown criteria are not satisfied, additional cooldown concerns arise. Figure III.G-2 is a matrix of plant status vs. cooldown concerns. These cooldown concerns, along with others, are listed below along with the technical bases section in which they are addressed.

- Solid Plant Pressure Control (3.4).
- SG Shell Cooling (3.6).
- Reactor Vessel Head Cooling (3.7).
- Idle RC Loop Cooling (3.8).
- HPI Cooling (3.9).

It should be emphasized that attempts should be made to return plant status to the normal cooldown path whenever possible.

3.1.1 Impact of Tube Rupture on Plant Cooldown

Steam generator tube ruptures (SGTR) complicate plant cooldowns and will usually result in abnormal cooldowns. To minimize offsite releases, expeditious cooldowns may be required. Therefore, the operator may not be able to prevent RV head or loop voiding. However, void formation will hinder RCS depressurization because the void acts like a pressurizer. This will result in a prolonged cooldown and may result in higher integrated tube leakage. SGTRs may also result in single loop natural circulation cooldowns or HPI cooldowns because of loss of SCM and SG isolation. Chapter III.E contains a discussion of SGTR concerns.

3.2 Alternate RCS Pressure Control Methods

RCS pressure is normally controlled via the pressurizer by the pressurizer heaters and spray valve. The pressurizer heaters provide RCS energy input to increase pressure and pressurizer spray provides RCS energy dissipation to decrease pressure. In general, if an increase in RCS pressure is desired, spray flow is decreased and heater output (KW) is increased. Conversely, if a decrease in RCS pressure is desired heater output is decreased and spray flow is increased. The coordinated control of pressurizer heaters and spray, either by automatic or manual means, maintains RCS pressure as appropriate during normal operations. Alternate RCS pressure control actions are available and may be used to control pressure during abnormal cooldowns.

Adjusting pressurizer level alters the steam space volume which in turn alters RCS pressure. This is accomplished by manipulating control of the makeup (and perhaps HPI) and letdown valves. If letdown flow is altered with no attendant change in makeup flow, RCS pressure will increase or decrease depending upon the resultant change in pressurizer level. If pressurizer level increases, RCS pressure will increase and if pressurizer level decreases, RCS pressure will decrease. This relationship would generally be expected to occur unless there is a leak in the pressurizer steam space, e.g., PORV open. Also, RCS pressure may be difficult to increase, even with all the heaters available, if pressurizer penetrations are open or leaking. Should this situation occur, then it should be ensured that the pressurizer vents and the PORV and PORV block valves are closed.

If the pressurizer steam bubble is lost, i.e., the RCS becomes water solid, then control of RCS pressure must consider the large (and possibly rapid) pressure changes that occur due to small temperature changes in a fluid solid system (see 3.4 for detailed discussion). If a steam bubble exists, but spray is not available (e.g., loss of RCPs) or ineffective (RCP combinations may result in little or no spray flow), then the following methods may be used to augment primary depressurization.

3.2.1 High Pressure Auxiliary Spray (if available)

High pressure auxiliary spray is a backup to normal pressurizer spray. Plant pressure control methods for high pressure auxiliary spray should be the same as normal spray though depressurization rates may be lower than those of normal spray. Should voids form in the RV head or an idle loop, achievable depressurization rates will decrease. Actions may be taken to eliminate any voids that form. (see Sections 3.7, 3.8).

High pressure auxiliary spray may be used if the temperature differential between the auxiliary spray nozzle and the spray water is not greater than the limit (see Plant Limits and Precautions). Once initiated, a continuous minimum flow should be maintained to limit thermal cycles. Also, adequate HPI pump recirculation flow should be maintained to provide the minimum required HPI pump flow. The letdown flow rate should be adjusted if necessary to control pressurizer level.

3.2.2 Venting

Depressurization rates with the PORV will be larger than with the high pressure auxiliary spray. At operating pressures, PORV depressurization rates with a pressurizer steam bubble are 180 to 240 PSI/min, while pressurizer vent depressurization rates are expected to be much less. Using the PORV or pressurizer vent has the characteristic of removing coolant from the system, which must be made up (in addition to the contraction experienced during normal cooldowns). The operator should monitor quench tank instrumentation to prevent unintentionally blowing the rupture disk on the tank. Sufficient discharge of fluid will degrade the environment of the RB.

During venting, SCM and pressurizer level should be monitored. Primary inventory and pressure controls (makeup/HPI and letdown) should be adjusted to prevent loss of SCM and to maintain pressurizer level on scale. Allowing the RCS to become saturated will lead to void formation in the RV head or hot legs which will tend to slow the depressurization. If voids form, pressurizer venting should be stopped if the voids are to be eliminated. (see Sections 3.7 and 3.8).

3.2.3 Ambient Losses

If other depressurization methods are not used, the primary pressure will decrease slowly due to ambient losses. Depressurization rates depend on pressurizer inventory and pressurizer insulation (as-built); a nominal value is 0.5 PSI/min at normal operating temperatures and pressures. Ambient loss rates will decrease as temperature decreases. Depressurization due to ambient losses is not normally used for cooldowns but may become important in maintaining pressure at hot standby if heaters are unavailable. To minimize the pressure reduction due to ambient losses the pressurizer level should be maintained as low as practical since the heat transfer rate in the steam region is considerably lower then the heat transfer rate in the liquid region.

3.2.4 Lowering the Pressurizer Level and Refilling It with Subcooled Water

The temperature inside the pressurizer determines the pressurizer pressure. If the temperature is reduced the pressurizer pressure will also be reduced. The temperature can be reduced by draining the pressurizer then refilling the pressurizer with colder water. The pressurizer temperature will decrease to a new, lower equilibrium temperature. Overall, the pressurizer pressure will decrease from an initial saturation pressure to a new saturation pressure. However, the decrease in pressure will not be steady and continuous. The pressure will decrease as the pressurizer is drained, then increase as the pressurizer is refilled, then decrease as the pressurizer cools.

3.2.5 Impact of Steam Generator Tube Rupture

Steam generator tube ruptures remove primary inventory and therefore tend to depressurize the RCS. The tube rupture(s) will cause pressurizer level to decrease. MU or HPI flow should be increased to maintain pressurizer level.
This will help stabilize RC pressure.

3.3 Natural Circulation Cooldown

3.3.1 Natural Circulation Cooldown Concerns

Natural circulation occurs in the RCS if the RCPs are not operating and certain conditions are satisfied (e.g., heat source at a lower elevation than heat sink, solid loop). It is preferable to remove decay heat with natural circulation and maintain existing primary conditions until the RCPs become available. The difficulties in performing a natural circulation cooldown are:

- Control of natural circulation with low decay heat
- RV head cooling
- Idle RC loop and SG shell cooling
- Primary pressure control
- Longer cooldown time (FW requirements)
- Possible thermal shock (if HPI on)

Typically, the EFW initiation and control systems are designed to provide sufficient EFW flow to remove maximum decay heat assuming a single failure of the system. When less than full decay heat exists, and especially when little or no decay heat exists, the EFW system can initially provide excess EFW flow to the SGs and may rapidly depressurize them. Proper initiation and control of the EFW system during a natural circulation event should be verified, and manual control taken, as necessary, to properly throttle and control EFW flow to prevent excessive overcooling and depressurization of the SGs.

When little or no decay heat exists, little or no heat transfer by the SGs will be required. Thus, while it is desirable to provide a continuous EFW flow to the SGs to reduce the thermal cycles on the EFW nozzles, it may not be possible to continuously feed the SGs without overcooling the SGs. Intermittent RCS flow stagnation may occur in one or both of the RCS loops when these conditions exist. However, if EFW flow has been stopped or throttled, the incore T/Cs will provide indication that heat transfer is necessary (temperature increasing), and that EFW flow needs to be increased. The resumption or increase in EFW flow will result in reinitiating natural circulation flow in the RCS. The requirements for establishing natural circulation levels in the SGs are discussed in Section IV.C.3.2, and the requirements for initiating and throttling EFW are discussed in Sections IV.C.4.2 and IV.C.4.3.

During natural circulation, the RV head fluid remains stagnant and cools very slowly (unless the plant has a passive vent system). To prevent head void formation, head cooling must be enhanced or the cooldown rate must be limited (see Section 3.7 for a more detailed discussion of RV head cooling). A similar situation occurs in the hot leg during single loop natural circulation cooldowns. The idle loop of the RCS stagnates and cools slowly, unless action is taken to enhance idle loop cooling (see Section 3.8 for more detailed discussion of idle loop cooling). Also, SG shell cooling difficulties may occur during single loop natural circulation cooldowns (see Section 3.6 for a more detailed discussion of SG shell cooling). Normal pressurizer spray is unavailable following a loss of RCPs. Therefore, alternate primary depressurization methods are needed during natural circulation (see section 3.2).

Because of lower achievable cooldown rates and the previously mentioned difficulties, longer cooldown times may result before reaching DHRS initiation for natural circulation cooldowns. Longer cooldown times result in larger condensate requirements if steam is being vented to the atmosphere.

These cooldown times will vary depending on number of ADVs available, DHR cut in temperature, and decay heat level. Figure III.G-14 shows cooldown times and condensate requirements assuming maximum decay heat load.

In general, the more steaming capacity and the higher the DHR cut in point, the faster the cooldown can be accomplished. There are, however, times when head bubble considerations may force longer cooldown times regardless of other conditions.

3.3.2 Natural Circulation Cooldown Initiation and Verification

To initiate a natural circulation cooldown when SCM exists, the water level in each SG should be raised to the natural circulation level setpoint. If the RCS is saturated, raise the level to the loss of SCM setpoint. The TBVs (condenser dump valves or ADVs) should be opened and controlled to limit the cooldown rate. Enough boron should be in the reactor coolant system to ensure preservation of shutdown margin should fluid in regions such as the pressurizer, idle loop or RV head mix with the remainder of the RCS and subsequently enter the core. Adequate shutdown margin can be complied with by RCS boron concentration or by boron injection as allowed by Technical Specifications.

Once natural circulation has been initiated and verified, RV head cooling considerations should be addressed (see Section 3.7). For the case of single loop natural circulation cooldowns, idle loop cooling and shell cooling difficulties should be addressed (see Section 3.8 and 3.6). Verification of natural circulation and recognition of a loss of natural circulation are discussed in Chapter II.B.

3.3.3 Impact of Steam Generator Tube Rupture

Natural circulation cooldowns with SGTRs may result in an idle loop because of SG isolation or a loop with intermittent flow because of periodic steaming. In either case, one loop may be cooling much more slowly than the other and voids will result if saturated conditions occur in the loop that is cooling much more slowly. Discussions of the prevention and elimination of loop voiding are contained in Section 3.8.

3.4 Solid Pressurizer Operation

Plant operation with a pressurizer steam bubble is preferable to solid pressurizer operation. With a pressurizer steam bubble, primary pressure can be increased using the pressurizer heaters and decreased with pressurizer spray (if RCPs are operating) or with one of the alternate depressurization methods described in section 3.2. With a solid pressurizer, primary pressure can be increased or decreased using primary inventory controls (makeup/HPI and letdown). However, because of water's low compressibility, small changes in inventory or temperature result in large pressure responses. Primary pressure control is thus more sensitive with a solid plant than with a pressurizer steam bubble. One of the operator's objectives is to prevent pressurizer safety valve challenge. During solid plant operation this objective has added importance because of an increase potential of failing the safety valve due to passing water.

Under some conditions, it may be difficult to control primary pressure with a steam bubble in the pressurizer. For instance, ambient heat losses from the pressurizer may prevent maintenance of a steam bubble if heaters are not available. It may then be easier to control pressure with a solid pressurizer than with a pressurizer steam bubble. The pressurizer should be filled slowly to avoid an excessive pressure increase when the steam bubble completely collapses. It is preferable to use the pressurizer vent instead of the PORV to eliminate the steam bubble since the vent has a smaller relief rate. To fill the pressurizer solid, MU/HPI flow must exceed pressurizer vent and letdown flow. A full pressurizer is indicated by a sudden change in rate of pressure increase. As the vent is closed, MU should be throttled to stop the pressure increase. MU and letdown can then be used to control RCS pressure during the cooldown. If the pressurizer is being filled for reasons other than heaters being not available, then the heaters should be deenergized.

During solid plant operation sudden large pressure increases or decreases may occur when tripping or restarting reactor coolant pumps (see chapter IV.A for RCS response to RCP trip/restart during solid plant operation).

3.4.1 Impact of Steam Generator Tube Rupture

For solid pressurizer operation, SGTRs represent another outflow path that must be considered along with the other inventory controls: MU, letdown, HPI, PORV, vents. Also, rapid pressure changes that can occur during operation with a solid pressurizer can affect the leak rate of the SGTR and the pressure in the SG if the SG is also filled.

3.5 Number of Steam Generators Operating

It is preferable to cooldown with both SGs controlling primary to secondary heat transfer. Two cooldown concerns exist when only one SG is available: SG shell cooling (forced and natural circulation) and idle RC loop cooling (natural circulation). SG shell cooling concerns are discussed in 3.6 and idle loop cooling concerns are discussed in 3.8.

From a heat removal standpoint proper SG operation with a subcooled primary system has the following characteristics:

- T_{cold} approximately equal to SG $T_{sat.}$

- Automatic or operator controlled FW maintains constant level at the appropriate setpoint.

- Steam pressure is controllable.

Single SG operation implies that one SG has been isolated because of a lack of heat transfer (III.C), excessive heat transfer (III.B) (e.g., unisolable steam leak), or Steam Generator Tube Rupture (III.E). The isolated SG will not possess all of the above characteristics.

During the cooldown, controlled heat transfer should be restored to an idle SG whenever possible to help alleviate the shell cooling and idle loop concerns. However, care must be exercised to prevent loss of heat transfer to the operating SG when attempting to restore heat transfer to the idle SG. For example, steam pressure in the idle SG should only be decreased such that secondary T_{sat} is ~20°F below core exit temperature vs. the ~50°F ΔT used in Chapter III.C. This smaller ΔT will decrease the probability that heat transfer to the operating SG will be lost when the heat transfer to the idle SG is restored. If heat transfer is lost to the previously operating SG, then actions to restore heat transfer can be taken.

3.5.1 Impact of Steam Generator Tube Ruptures

SGTRs may result in SG isolation or limited steaming in one or both SGs.

3.6 SG Shell Temperature Concerns

SG shell cooling concerns arise when one SG is isolated, for both forced and natural circulation cooldowns. In dry idle SGs, the shell is no longer cooled by steam and FW flow but rather by ambient losses. Limits pertinent to cooldowns and shell cooling are:

- Normal Tensile Tube-To-Shell ΔT limit:

  ΔT (tube colder) < 100°F

- Compressive Tube-To-Shell ΔT limit:

  ΔT (shell colder) < 50°F when RCS pressure < 1800 PSIG
  and tube temperature > 500°F

  < 60°F all other conditions

- Emergency Tensile Tube-to-Shell ΔT limit:

  ΔT (tube colder) < 150°F

These limits are based on SG tubes that have experienced wall thinning but do not yet require tube plugging. Methods to estimate the tube-to-shell ΔT are provided in Chapter IV.K. During forced circulation cooldowns with one dry, isolated SG the associated RC loop is cooled via the unisolated SG. During natural circulation cooldowns with one dry, isolated SG, the loop is cooled using idle loop cooling methods (see Section 3.8). In both cases, the shell cools due to ambient losses unless other shell cooling actions are performed.

If the tubes are cooling faster than the shell in an idle SG, then the cooldown rate will have to be decreased or shell cooling increased to prevent violation of the tensile tube-to-shell ΔT limit. If the shell of the idle SG is cooling faster than the tubes, increasing the cooldown rate using the operable SG, if in forced circulation, may prevent violation of the compressive tube-to-shell ΔT limit.

The SG shell will cool slowly via ambient losses. If it is cooling too slowly the operator can supplement the ambient losses by providing a source of water to produce steam for heat transfer between the shell and the tubes. To accomplish this, some source of FW must be available. Introduction of EFW is preferred. Some of this EFW will be flashed into steam in a hot SG but some will also tend to run down the tubes and cool them. Introducing EFW at a sufficiently small rate may provide an adequate supply of water to produce steam for shell cooling while a minimum number of tubes are impacted over a minimum length. The key aspect is that the establishment of steaming provides a thermal coupling between the tubes and the shell. If the operator observes that small rates of EFW injection to that idle SG are causing the tensile tube-to-shell temperature difference on the SG to approach the limits without cooling the SG shell, he should stop EFW injection to the idle SG. Alternate actions for maintaining the idle tube-to-shell ΔT within limits are discussed in Chapter IV.K.

Steam may also be produced to cool the SG shell by introducing MFW. Flow through the MFW nozzles helps cool the lower portion of the shell. If MFW is used (i.e., EFW is not available) a small but continuous flow is desirable to minimize thermal cycling in the MFW nozzles and lower tubesheet region. Additional SG shell cooling will be provided if a level can be established in the idle SG. The decision to feed a dry SG should consider the location of the unisolable steam leak. The SG should not be fed if the steam leak can endanger personnel or key equipment. Guidance on feeding a dry SG is provided in Chapter IV.C.

During single loop forced flow cooldown the idle SG tube temperature will follow the temperature in the active loop. If the shell temperature cools too slowly and the tensile limits in the idle SG are approached, the cooldown rate can be slowed or stopped while the shell cools. Another option in single loop operation with forced flow is to try to establish heat removal with the idle SG before continuing with the plant cooldown. However, while attempting this, the idle SG shell will cool due to ambient losses while the tubes remain hot and there is a potential for approaching the compressive shell/tube temperature limits. In that case the operator must cool the primary fluid by steaming the active SG.

In single loop natural circulation the idle loop SG is not directly influenced by steaming the active SG. The idle loop shell will cool by ambient losses while the active loop temperature drops in accordance with the cooldown. During this period the idle loop temperature remains high. The operator may have to cool the idle loop to prevent the occurrence of saturated conditions as well as to maintain the tube-to-shell temperature difference below the compressive limits (shell cooler). To do this the operator induces natural circulation in the idle loop by injecting EFW and steaming the idle SG. In addition to the cooling provided by the SG, some of the cooler active loop fluid is circulated into the idle loop. As a result, if the active loop has been cooled too far below the idle loop shell temperature, excessively cold water will be introduced into the idle loop. Actions to cool an idle loop should be performed before the active loop temperature decreases below the idle SG shell temperature by an amount that otherwise could result in excessive tensile stress in the idle SG. Further discussion of cooling an idle loop is provided in Section 3.8. Guidance on feeding a dry SG is provided in Chapter IV.C.

3.6.1 Impact of Steam Generator Tube Ruptures

SG tube-to-shell limits are less of a plant control problem when a level exists in the SG. SGTRs may result in SG isolation. In this case, if the loop is idle, the SG may have a substantial inventory and the shell will cool more slowly than a dry depressurized SG. However, the shell below the water level should cool at about the same rate as the tubes. Opening the drains (if available) may also cause the shell and tubes to cool. If conditions allow, as discussed in Chapter III.E, steaming the isolated SG will induce shell cooling.

3.7 Reactor Vessel Head Cooling Concerns

During natural circulation, the RV head fluid remains stagnant and does not communicate with the rest of the RCS (unless the plant is equipped with a passive vent system). Thus, the RV head fluid cools slowly (4°F/hr to 5°F/hr). The impact on the cooldown is as follows:

- The cooldown rate may have to be slowed if RV head void formation is to be prevented without venting the RV head.

- Head void formation will slow the depressurization and thus the cooldown.

- With an RV head void and the core outlet subcooled, the maximum permissible RCS cooldown rate below 500°F is 50°F/hr based on stresses produced in the RV closure head and upper shell region. These stresses are due to the relatively slow cooldown of the RV upper head region. If the core outlet is saturated, this limit is not applicable.

3.7.1 Head Void Prevention

RV head void formation can be precluded by controlling the RCS cooldown and depressurization such that the RV head fluid temperature remains less than the saturation temperature. RV head fluid temperature may be obtained directly from a temperature measurement (if available) or inferred from predicted plant specific head fluid cooldown rates.

For plants without RV head vents, RV head ambient cooldown rates are about 4°F/hr to 5°F/ hr. (NOTE: GPUN has performed independent analyses, not verified by FTI, that indicate these cooldown rates can be as high as 8°F/hr to 30°F/hr depending on RC cooldown rates.) To avoid steam formation, slow cooldowns are required. Bumping of the RCPs will not appreciably lower the temperature in the RV head region because the pump bumps do not produce significant flow into the RV head region.

Higher cooldown rates can be achieved with passive vent systems (flow path between RV head and the hot leg or steam generator plenum). Flow through these lines occurs due to density differences between the RV head fluid and the discharge (hot leg or SG plenum) fluid. Therefore, faster cooldowns can be performed without void formation. In situations where flow through the passive vent system cannot occur (e.g., voids or stagnant conditions in discharge hot leg), the RC loop HPV must be opened to initiate flow through the passive head vent line.

Some plants are equipped with active vent systems in which operator action is required to provide a flow path from the RV head to a suitable discharge (e.g. quench tank). Head fluid temperature response during venting is dependent on primary pressure, temperature, RV head temperature, and venting configuration (minimum vent flow area).

A sample outline of a method for cooling the RV head using an active vent is provided below.

- Determine head fluid temperature either from direct measurement or estimate from previously calculated value. If venting has not been performed, estimate RV head fluid temperature as the highest incore T/C reading since the RCPs were last operating adjusted for RV head ambient heat losses as described above.

- Cool the primary until a 50°F temperature differential exists between the head fluid temperature and incore T/C. Maintain at least 20°F SCM in the RV head. It is preferable to maintain maximum SCM since the venting rate increases with primary pressure and the head fluid cooldown rate increases with venting rates.

- When a 50°F head fluid-incore T/C ΔT is achieved, halt the primary cooldown and maintain constant primary temperature with natural circulation continuing. Open the RV head vent. Maintain RC pressure and pressurizer level by increasing MU. Vent for 15 to 30 minutes (if possible) and use Figures III.G-3 - III.G-6 to estimate the RV head fluid temperature response. The fastest RV head fluid cooldown rates occur in the first 20 to 30 minutes.

- Close the RV head vent and throttle MU to maintain primary pressure and pressurizer level.

- This venting process is repeated during the cooldown.

3.7.2 RV Head Void Recognition

RV head void formation may be detectable using RV head level measurements, if available. In addition, formation of head voids can usually be associated with:

- Opposite trending between RC pressure and pressurizer and/or MU tank level (pressurizer and/or MU tank level increases with RC pressure decrease). Note: This is also an indication of RC loop void formation. Therefore, hot leg level measurements may be useful in helping to determine RV head void formation.

- Difficulty in reducing pressure after void formation.

- RV head fluid temperature (if available or from previous estimates) or passive RV head vent line temperature equal to primary saturation temperature. If natural circulation flow can be verified in both loops, it may be assumed that any void forming is a RV head void. Note that, unless vented, the RV head will be the hottest region in the primary loop and thus more likely to void first.

3.7.3 Head Void Elimination

Elimination of the RV head void should facilitate the depressurization during cooldown after RV head void formation occurs. As previously mentioned, head voids tend to slow the depressurization, and thus the cooldown, since it acts as a second pressurizer. RV head voids can be eliminated or reduced by:

- Venting.

- Ambient Heat Loss Induced Condensation.

- RCP Restart

Increasing the void size due to depressurization should be prevented after the vent is opened. To accomplish this, MU flow should be increased to compensate for venting. The RC pressure is to be maintained or slightly increased. Successful venting has occurred when primary pressure and pressurizer level increase suddenly. This level increase will occur even if a void exists in a hot leg.

RV head level measurements should only be used to indicate trends and may not suffice to determine if the void has been completely eliminated. RV head level measurements (if available) may not be accurate while venting is in progress.

RV head void elimination due to ambient heat loss induced condensation is a slow process and may require extremely long cooldown times. RCP restart with a RV head void is addressed in Chapter IV.A.

3.7.4 Cooldown With Voided Head

The RCS can be cooled and depressurized with a RV head bubble. The depressurization rates achievable using the PORV will depend on the volume of steam in the system. Depressurization will only be possible with the PORV while a steam bubble exists in the pressurizer. The exact reduction of the depressurization rate will depend on the sizes of the RV head bubble and the pressurizer bubble. As the cooldown progresses the RV head bubble will slowly expand. When the PORV is opened the bubble will expand rapidly and if large enough will expand into the hot leg. For natural circulation flowrates as slow as 3 percent, and temperatures in the hot leg within 10°F of saturation, a steam void escaping into the hot leg will be condensed long before it reaches the highest portion of the hot leg. A 50°F/hr cooldown with a 600°F steam void in the RV upper head is acceptable from an operations as well as a stress analysis standpoint. The flow regime expected at the RV outlet is one of bubbly flow as opposed to slug flow. This indicates that the condensation will not be violent. During this mode of expansion of the RV head void (steam escaping into the hot leg), the RV head void will not hinder depressurization.

The existence of a head void would normally require that the cooldown rate be limited to < 50°F/HR. However, if the cooldown rate cannot be limited to this value, then continued SG cooling is preferable to HPI cooling. HPI cooling would induce greater thermal stress on the RV than continued SG cooling at > 50°F/HR with a head void.

3.7.5 Impact of Steam Generator Tube Ruptures

If a fast depressurization and natural circulation cooldown is performed for SGTRs, RV head void formation is likely. Actions consistent with SGTR management may be taken to eliminate the RV head void and prevent subsequent RV head void formation whenever possible. (See Chapter III.E).

3.8 Idle Loop Cooling

During single loop natural circulation cooldowns, fluid in the idle loop remains stagnant and does not thermally communicate with the rest of the RCS. It thus cools very slowly due to ambient losses. This has the following potential impact on the plant cooldown:

- To avoid idle loop void formation the plant cooldown rates may have to be reduced.
- The formation of loop voids will slow the depressurization and cooldown of the plant.
- Unacceptable compressive tube-to-shell temperature differences in the idle SG could result if the idle loop is not cooled while the SG shell is cooling to ambient.

3.8.1 Idle RC Loop Void Prevention

The temperature of the fluid in the idle RC loop may be kept below saturation temperature through either periodic injection of EFW to the SG in the idle RC loop or the bumping of a RCP in the active RC loop, provided the RCP restart criteria of IV.A are met. The hot fluid in the idle RC loop is replaced with fluid closer to the active RC loop temperature by the bumping of a RCP. Injection of EFW should not be used if an unisolable steam leak exists in a location that could be hazardous to personnel or key equipment.

Using EFW to induce idle RC loop cooling involves periodically injecting EFW to the SG in the idle RC loop and then observing the primary temperature response. Since natural circulation will start slowly, several minutes may elapse before the hot leg RTD begins to change.

The SG in the idle loop may be bottled up or dry. EFW (or MFW diverted through the EFW header) should be fed at less than 700 GPM to an idle SG (or within the limits of Rule 4.0 if the SG is dry) whenever the following conditions exist:

- Idle RC loop tube-to-shell temperature differential (shell hotter than the SG tubes) is increasing to within 10°F of the tensile tube-to-shell temperature differential limit. It is expected that this action will momentarily increase the temperature differential before the proper thermal coupling is established between the shell and the tubes. A more complete discussion of shell/tube temperature differences is contained in Section 3.6.
- The saturation temperature during the cooldown is reduced to within 10°F of the idle loop hot leg temperature.

- The active loop temperature is reduced more than 50°F below the idle loop temperature.

The initial injection of EFW should be two to three minutes in duration. The maximum flowrate of 700 GPM is based on engineering judgement. A sufficient flow to induce natural circulation is desired while preventing excessive cooling of the tubes. The minimum flow required to induce natural circulation flow is plant and situation dependent and has not been determined by analysis. 700 GPM should be sufficient based on engineering evaluations of available data. The initial flowrate limit to a dry SG (Rule 4.0) is based on analyses and is intended to prevent excessive cooling of the SG tubes (Chapter IV.C).

This process promotes natural circulation in a void free loop. Idle RC loop hot leg and cold leg temperatures and tube-to-shell temperature differential should be observed for the next several minutes. Subsequent injections of EFW may be necessary to continue the cooling of the idle RC loop if the active loop cooling continues. The operator should be able to maintain a sufficient inventory of water for steaming the idle RC loop SG with small injections of EFW once natural circulation is started. The small flowrates will minimize tube impingement and direct contact cooling of the SG tubes although some tubes will always be cooled by EFW flow. The goal is to establish thermal coupling between the tubes and the SG shell through use of EFW. If cyclic idle RC loop cooling operations are performed, a very small rate of EFW should be continuously fed to the SG between cooling cycles to avoid repeatedly thermally shocking the EFW nozzles. If this process does not result in natural circulation in the idle loop, available loop instrumentation should be checked for the presence of loop voids. If voids are present they should be eliminated before trying to induce natural circulation in the idle loop.

3.8.2 Idle Loop Void Recognition and Elimination

The formation of idle loop voids can be detected by some of the same means used to determine if a RV head void exists. These are discussed in Section 3.7.2 and include opposite trending of RCS pressure and pressurizer level and difficulty in reducing RCS pressure with the PORV or pressurizer vent. A loss of primary-to-secondary coupling indicates a loss of natural circulation and may be a result of loop voiding. A loss of loop SCM may also be a precursor to idle loop voiding; however, due to the elevation of hot leg RTDs, this indication may not detect hot leg voids. This is because the saturated level in a RC loop may be above the elevation of the RTDs. Also, the existence and approximate size of a RC loop void may be determined from the trend of loop level measurements, however, this indication should be used when the plant conditions do not interfere with valid instrument readings (e.g., no forced or natural circulation flow).

Two means of void elimination when SCM exists are:

- venting through the HPVs,
- allowing the void to condense through ambient heat losses.

Venting through the HPVs should be the first choice as condensation through ambient heat loss is not very effective.

The use of HPVs may not be desirable if no release to the containment has occurred prior to venting. If vents are used in this case and the vents are routed to the quench tank, it may be desirable to avoid exceeding the quench tank capacity. Additionally, if the core outlet is saturated, the HPVs cannot remove a sufficient amount of steam to offset steam production in the core region and allow refilling of the hot legs. However, if a SBLOCA has occurred, venting will not drastically alter conditions in the containment. This section will address the situation where the plant is subcooled in single loop natural circulation. A void is assumed to exist in the idle loop hot leg and a RV head void may or may not be present. With the exception of the RCS voids, the plant is assumed to be stable with adequate core decay heat removal being provided by natural circulation in the active loop. Under these assumed conditions, void elimination and idle loop recovery becomes a controlled evolution with no sense of urgency present. However, if a loss of SCM condition existed or subsequently occurred during idle loop recovery, more immediate action is necessary to ensure or restore adequate core cooling. Therefore, if SCM is lost, the operator should immediately proceed to the loss of SCM section (Chapter III.B) for required or recommended action. Similarly, if an inadequate heat transfer condition subsequently occurred during idle loop recovery or if excessive heat transfer occurred following idle loop recovery, the operator should immediately proceed to the appropriate section (Chapter III.B or III.C) for required and recommended action.

This section further assumes that EFW flow has been used to establish SG levels at the NC level and is being properly controlled per section IV.C. The effects of EFW flow upon loop void elimination have been investigated. These effects are summarized as follows:

- Based on analyses performed, EFW flow, by itself, had no significant impact on eliminating idle loop voids. Increasing EFW flow to the active loop merely increased the heat transfer rate in that SG without causing any significant perturbations to the idle loop. This was true even before voiding of the idle loop occurred.
- Providing EFW to the idle SG only resulted in minor oscillations in idle loop primary flow for the analyses performed. These oscillations were insufficient to cause a steady, positive primary flow in the idle loop. This result is similar for saturated RCS conditions. However, this result may be dependent on void size and may be successful

for cases where a minimal amount of loop voiding has occurred. Larger loop voids may result in some boiler-condenser cooling when EFW is injected into the idle SG, but this process will not refill the loop or restore natural circulation.

- Even though EFW is not very effective at eliminating idle loop voids, EFW should be controlled as discussed in Chapter IV.C. During the time when there is no heat transfer to the idle SG, EFW flow will continue to depressurize the SG until idle SG level is stabilized at the natural circulation level setpoint. At this point little additional depressurization is expected since EFW will have been throttled to maintain this level.

It should also be noted that natural circulation can be restored, in an idle voided loop, by eliminating only the idle loop voids. The RV head void does not have to be eliminated for natural circulation to be restarted. This is also true for plants with passive RV head vents; once the loop void is eliminated and natural circulation restored in the loop connected to the passive RV head vent, the RV head void venting and steam collapse in the now active loop will resume.

3.8.2.1 Venting Through the HPVs

Venting the idle loop hot leg through the HPVs is an effective method of void elimination. The venting process for eliminating loop voids is similar to the RV head void elimination. After the vent is opened, MU or HPI should be increased to balance letdown and vent flow and maintain pressurizer level and RCS pressure (to prevent flashing in the idle loop hot leg). Analyses showed that venting was successful at eliminating a large hot leg void (~333 FT^3) and reestablishing natural circulation within approximately 10 minutes. Using HPI flow to refill the void with RCPs "off" would invoke PTS guidance.

Venting allows natural circulation to continue during void elimination and avoids sudden changes in RCS pressure and pressurizer level. However, venting requires a discharge to the quench tank or directly to the RB. For plants with passive RV head vents, the existence of an RV head void should not impact the ability to vent a void in the connected loop. The RV head void will not vent a significant amount of steam to the loop while it is idle. Once the loop void is sufficiently reduced to allow restoration of loop flow, RV head venting to the loop and void collapse will resume due to the presence of subcooled liquid.

This method of void elimination should be used during post-ICC recovery to vent the RCS of non-condensible gases.

Expected Plant Response

In the active loop, there will be little change in loop temperatures upon opening the idle loop HPVs. Active loop ΔT will stay approximately constant. Once idle loop natural circulation is restarted, core decay heat removal should be split between the two SGs. This split of the core decay heat removal will cause the active loop ΔT to decrease.

RCS pressure and pressurizer level should be maintained constant or slightly increasing. The operator should adjust makeup or HPI flow and letdown flow as necessary to accomplish this objective. If RCS pressure is allowed to fall, additional hot leg liquid (in the voided loop) will flash. This will extend the time required to refill the idle loop hot leg. Depending on the design, hot leg level indications may not be accurate, even for trending information, while the vents are open. In this case progress can be checked by periodically closing the vents. When the loop fills and the vent begins to pass liquid, RC pressure and pressurizer level should show an increase (if RC pressure and pressurizer level were being held constant) or a slightly faster and
steady rate of increase.

Limitations and Considerations

1. This method can result in RB contamination depending on where the HPV discharge is routed.

2. This method is relatively slow (approximately 10 minutes for the 333 FT^3 void case).

3. The rate of idle loop recovery is also dependent on hot leg vent size, HPV discharge backpressure, and how much hot leg flashing is allowed to occur.

4. This method can only be used when the core outlet temperature is subcooled.

Summary of HPV Option

This method of void elimination is effective when the core is subcooled;it is very controllable and does not result in rapid changes in RCS parameters. Additionally, this method is available during post-ICC recovery for both venting of non-condensible gases and refilling the hot leg (provided the core is subcooled). See Chapter III.F for ICC uses of the HPVs.

3.8.2.2 Idle Loop Void Condensation

The idle loop void may also be condensed over a long period of time due to ambient heat losses. This method is slow and may not be feasible due to compressive SG tube-to-shell ΔT limits (i.e., shell cooldown rate > idle loop cooldown rate to ambient).

3.8.2.3 Indications of Void Elimination and Plant Stabilization

The most reliable indication of loop void elimination is the reestablishment of primary-to secondary heat transfer either by forced or natural circulation flow (see Chapter II.B). Loop level indications may be used (if available), under certain situations, to determine if the void is becoming smaller. These situations require that the loop in question be in a static condition and that there be no pressure influence upon the loop level instrument except the static head of the loop fluid. For example, if the instrument shares a common tap with the HPV and the HPV is open then the level indication will not be accurate and must not be relied upon.

Hot leg temperature indications (indications of SCM) are not an accurate means of determining void elimination because the saturated level in a stagnant RC loop may be above the elevation of the hot leg RTD (i.e., void exists while hot leg RTD indicates subcooling). For this reason hot leg temperature indications should not be used to infer void elimination.

Once idle loop natural circulation heat transfer has been restored, the initially idle loop SG may assume the majority of the total core decay heat removal because of its lower T_{sat}. This shift in heat removal may result in primary flow stagnation in the previously active loop. Therefore, it is desirable to control the depressurization of the idle loop SG by throttling EFW as discussed in Chapter IV.C. When heat transfer has been restored to the idle loop, symmetric SG heat removal should be established. If heat transfer is lost to the initially operating SG, then actions to restore heat transfer should be taken.

3.8.3 Impact of Steam Generator Tube Rupture

SGTRs may result in isolation of a SG. Opening the condenser dump valves (if available) will result in idle loop cooling. Periodic steaming of the isolated SG will promote natural circulation in this loop but also results in offsite releases. SGTR management criteria (Chapter III.E) may preclude the use of the methods mentioned to eliminate voids.

3.9 HPI Cooling

HPI cooling is the least preferred cooldown method discussed in this chapter. Even with RCPs running, HPI cooling has the following problems:

- RB contamination.
- Potential for recirculation from RB sump if long term HPI cooling is required.
- Primary cooldown rate and pressure control difficulty.

In addition, HPI cooling without RCPs operating poses RV head and idle loop cooling problems, as well as PTS problems. Because of these concerns, HPI cooling should be used to cooldown the plant only if no other means exist. When it is determined that HPI cooling is the only means currently available to cool the core, HPI cooling may be initiated. That is, there is no need to wait for "HPI cooling required" criteria, such as automatic PORV operation to initiate HPI cooling. It should be noted that waiting for this criteria (reference III.C.2.2) poses no problem relative to adequate core cooling as long as HPI cooling is initiated when any of the criteria are met.

To minimize heat addition to the primary system, operate only one RCP during HPI cooling. One RCP should be operated if possible during HPI cooling to provide thermal mixing of the RC. However, more RCPs can be operated if heat needs to be added to the RC to reduce the cooldown rate. Once HPI cooling is initiated, pressurizer heaters should be deenergized. Pressurizer heaters should be turned off to ensure they will not be automatically energized when the RCS pressure is reduced during HPI cooling. Deenergizing the heaters also reduces the energy input to the RCS to reduce the HPI cooling heat removal demands and to help in reducing RCS pressure. This also protects the heaters should they become uncovered during HPI cooling.

HPI cooling requires one or more HPI pumps to inject coolant into the RCS, a source of borated water (BWST), and a flow path to the RB or quench tank.

The flow paths to the reactor building are one or more of the following:

- PORV
- Pressurizer Vent
- HPVs

Normal RCS letdown should be isolated to prevent loss of inventory outside containment, since HPI cooling may require sump recirculation. The vent paths alone will not be of sufficient size for HPI heat removal except for very low decay heat rates. However, they can be used to augment RCS pressure reduction. For example, during HPI cooling, opening all the HPVs would reduce RCS pressure, thereby allowing more HPI flow into the RCS. This may be especially advantageous where low head HPI pumps are used. RCS pressure reduction is also vital during HPI cooling with a solid SG which has a tube rupture. In this situation, it is important to maintain RCS pressure below MSSV setpoints to prevent uncontrolled releases.

3.9.1 Initiating HPI Cooling (for all plants except Davis Besse)

With feedwater (Main and Auxiliary) not available, HPI cooling must be initiated when the RC pressure reaches the PORV open setpoint. When feedwater cannot be supplied to either SG, then if HPI cooling is started soon enough, it can provide adequate decay heat removal. This has been determined by an analysis using 10CFR50 Appendix K input assumptions. The analysis shows that during a complete loss of feedwater event, the core can be cooled meeting the criteria of 10CFR50.46 if two HPI pumps are started within twenty minutes and with mass and energy removal by the pressurizer safety valves (i.e. the pressurizer PORV remains closed and the RC pressure remains near the pressurizer safety valve setpoint). An additional analysis using 1.0 ANS(1971) decay heat and the remaining 10CFR50 Appendix K input assumptions demonstrated that one HPI pump is sufficient to cool the core.

Consequently, HPI cooling must be started if feedwater is not available. However, this action must be made soon enough (i.e. before too much RCS inventory is lost).

The 20 minutes in the above analysis occurs some time after the RCS starts losing inventory out the pressurizer safety valves. Therefore, HPI cooling should be started when or before the RCS pressure reaches the PORV open setpoint, i.e. the first automatic PORV lift, since that is when RCS inventory will start being lost. Keying the action to RC pressure also avoids the use of time as an action criteria.

Whenever HPI cooling is initiated the HPI flow must be maximized until specific criteria are met. HPI cooling is initiated by first starting both HPI pumps taking suction from the BWST to provide injection water to the RCS and then operating the PORV in a manner which is dependent on how many HPI pumps are operating. Opening the PORV results in mass loss from the RCS, therefore, the amount of mass addition to the RCS must be assessed first before the PORV is operated.

No HPI Pumps Operable

Whenever HPI cooling is attempted and no HPI pump is operable then the PORV must not be maintained open. It should be manually cycled between the PORV setpoint or RV P-T limit and the most limiting low pressure (ES actuation or adequate SCM). If HPI flow cannot be started, the only source of decay heat removal is the water inventory which exists in the RCS. The PORV is not left open in order to maximize the energy removal capability of the existing RCS inventory, i.e. the RCS should be allowed to absorb as much energy as possible before it has to be released from the RCS. If the PORV fails open then its block valve must be closed for the same reason. If the PORV block valve is closed, the RCS inventory will then heat up to the saturation temperature corresponding to the pressurizer safety valve setpoint and RC will be relieved through the safety valves. In addition to preserving RCS inventory, the RC pumps should be stopped and pressurizer heaters deenergized to eliminate their energy input to the RC. The inventory loss will continue until the core is uncovered unless HPI flow or steam generator cooling is regained. HPI cooling must be regained before too much inventory is lost in order to prevent core uncovery because the net inventory loss from the RCS will continue after HPI flow is regained, although at a slower rate, until the HPI heat removal rate exceeds the decay heat rate.

One HPI Pump Operable

Whenever HPI cooling is initiated and only one HPI pump is operable then the PORV must be maintained open. When only one HPI pump is available, the effect of promptly opening the PORV is to reduce the rate at which the net RCS inventory decreases and consequently, the minimum RCS inventory reached will not be as low as would be reached if the PORV were not opened or if the PORV opening was delayed. Delaying initiation of HPI will have a similar effect as not opening the PORV. Keeping the core covered is the highest priority objective because doing so will assure adequate core cooling. Therefore, the PORV must be maintained opened if only one HPI pump is operable during HPI cooling.

Two HPI Pumps Operable

Whenever HPI cooling is initiated and two HPI pumps are operable then two choices exist for the operation of the PORV. The PORV can be maintained open or cycled (either automatically or manually) for a while then maintained open. During manual cycling the RCS pressure should not be permitted to exceed the PORV open setpoint. This is to prevent opening the pressurizer safety valves and to prevent the HPI flow rate from decreasing below that which would be provided with the RCS pressure at the PORV setpoint. In general, the preferred option is to maintain the PORV open. However, other considerations as discussed below may make the other option more desirable.

Promptly opening the PORV causes the HPI heat removal rate to equal the decay heat rate earlier than if the PORV was not opened or if the PORV opening was delayed. RCS inventory depletion in either case is not significant. While opening the PORV after its setpoint is reached should not be delayed, it is acceptable to attempt to delay reaching the PORV setpoint by using full pressurizer spray flow if it is available. Delaying reaching the PORV setpoint may prevent loss of SCM when the PORV is opened and maintained open once its setpoint if finally reached. This is expected to occur because the time the PORV is passing single phase fluid (steam only) has been decreased. A representative analysis was made of a loss of feedwater event. The analysis showed the HPI heat removal rate would match the decay heat rate in 21 minutes if the PORV is maintained open with HPI cooling initiated 10 minutes after the loss of feedwater (see Figure III.G-8) and in 77 minutes if the PORV is allowed to cycle with HPI cooling initiated 6 minutes after the loss of feedwater (see Figure III.G-9). Delaying initiation of HPI will have a similar effect as not opening the PORV.

If the PORV is not maintained open during HPI cooling, the RC will continue to heat up as the PORV is opened and closed either automatically or manually to control pressure. This heatup will continue until the RCS becomes saturated or the HPI mass flow starts removing more energy than is being added to the RC. The HPI flow must always be maximized when the SCM does not exist. In addition, while the PORV is being cycled either manually or automatically, the HPI flow must be maximized until the core outlet temperature is decreasing. The additional criteria was added because PORV cycling is permitted only if the HPI flow is maximized; therefore, throttling the HPI flow cannot be permitted until the HPI flow is sufficient to remove decay heat. Two HPI pumps must be operated at full flow to assure adequate core cooling if the RCS pressure is maintained near the pressurizer safety valve setpoint. Therefore, HPI should be maximized until the HPI heat removal rate exceeds the decay heat rate, i.e. the core outlet temperature starts to decrease. A net energy removal from the RCS can occur because the decay heat rate decreases with time, the RC pumps and pressurizer heaters are off and HPI can remove more energy per pound mass at the higher temperature. An analysis of HPI cooling 6 minutes after a LOFW with automatic PORV cycling, shows the HPI heat removal rate matching the decay heat rate about 71 minutes after initiation and the RC did not become saturated. The minimum subcooling reached was 9.3°F (see Figure III.G-10). Therefore, if both HPI pumps are operating during HPI cooling, then opening the PORV is preferred because the HPI heat removal rate will match the decay heat rate sooner than if the PORV is cycled first. Opening and closing the PORV to keep the RCS pressure high may be desirable for specific plant design features such as to prevent low RCS pressure ES actuation.

If the PORV is cycled, then manually cycling the PORV is preferred over automatic cycling because the PORV can be closed at a lower RCS pressure during manual cycling. This will result in fewer PORV cycles (i.e. less challenges to the PORV which could lead to valve failure) and produce a larger integrated HPI flow rate (i.e. more core heat removal). If the PORV fails open during cycling the PORV block valve should not be closed to isolate the flow until HPI cooling is no longer needed.

When the PORV is allowed to cycle, it should only be cycled long enough to accomplish the objective for the cycling (i.e. permitting the RC temperature to increase so that when the PORV is opened the resulting depressurization will not cause a Reactor Building isolation) and be maintained open when the RCS subcooling margin has been lost. The PORV should be maintained open after cycling to establish the preferred method of PORV operation.

If the PORV fails to open or PORV flow cannot be established for any reason after the initiation of HPI cooling, then RC pressure is expected to increase causing cycling of the pressurizer safety valves. This RC pressure rise and the extent of safety valve cycling will be dependent upon the decay heat level and the amount of flow supplied to the RCS by the HPI pumps.

If this mode of operation continues long enough (no PORV flow established), RC temperature will begin to decrease while the RC pressure remains high. In this situation, high RC pressure (at the pressurizer safety valve setpoint) and decreasing RC temperature, action must be taken to follow the PTS guidance, if invoked. Along with continuing attempts to establish PORV flow, HPI flow should be throttled to keep RC temperature from decreasing below the NDT limit or maintained within the PTS guidance, if invoked. Throttling of HPI flow can begin after adequate SCM is provided but must be accomplished soon enough to prevent violating the PTS guidance.

As long as PORV flow cannot be established, the plant will remain in this mode until primary to secondary heat transfer is restored, a pressurizer safety valve fails open or decay heat diminishes to less than ambient RCS losses. In this case HPI flow can be throttled to the point where the RCS begins to reheat in order to establish a temperature band for control. The HPVs may be opened to aid cooling and, with very low decay heat, pressure reduction.

Initiation of HPI Cooling From Lower RCS Pressures and Temperatures

The previous guidance on initiation of HPI cooling assumes the loss of primary to secondary heat transfer occurs at or near normal post-trip conditions. If a loss of heat transfer occurs at lower pressures and temperatures (e.g., during a cooldown or heatup), other considerations may apply to operation of the PORV. The RV P-T limit is always applicable. The RC pressure must not exceed the RV P-T limit. Therefore, if the RC pressure increases to the RV P-T limit following a loss of primary to secondary heat transfer, the PORV should be opened and HPI cooling started to limit the pressure increase. After the pressurizer fills with RC, the HPI flow should be throttled as necessary to try and keep the RC pressure below the RV P-T limit or within the PTS guidance, if invoked. Refer to Chapter IV. G for information on the PTS guidance.

The PTS guidance must not be violated while it is in effect. If the PTS guidance is in effect or will be in effect due to HPI initiation, then RC pressure must be controlled per the PTS guidance.

Refer to Chapter IV.G for information on the PTS guidance.

3.9.2 Initiating MU/HPI Cooling (Applicable to Davis Besse)

If FW cannot be supplied to either SG, then MU/HPI cooling, if started soon enough, can provide adequate decay heat removal.

In general, MU/HPI cooling is a core cooling method which involves adding relatively cold water to the RCS using the Makeup, HPI and LPI systems while removing relatively hot water through the Pressurizer PORV. Whenever feedwater is unavailable, immediately establish makeup flow from the MU pumps to determine when the MU/HPI cooling process must be initiated. If only one MU pump is operational then MU/HPI cooling must be initiated immediately. However, if both MU pumps are operational, then, with one exception, MU/HPI cooling initiation can wait until the core outlet temperature reaches 600°F. This delay allows time to try and restore feedwater flow and primary to secondary heat transfer before initiating MU/HPI cooling.

The one exception is when the PORV must be opened to try to avoid violating the RV pressure-temperature limit. Because the PORV will need to be opened for pressure reduction with the resultant loss of RCS inventory, MU/HPI cooling should be initiated.

Calculations were performed which determine that the core will not uncover if the following conditions exist:

a. full MU flow to the RCS via the two operating MU flow paths,

b. two MU pumps are operating,

c. MU flow to RCS is started within ten minutes after T_{hot}=600°F,

d. the MU pumps are taking suction from the BWST and

e. the flow out of the RCS is via the pressurizer safety valves.

Based on this information, the EOP bases permit waiting until the core outlet temperature reaches 600°F before initiating MU/HPI cooling if there are two operating MU pumps.

Another calculation was performed which assumed:

a. flow to the RCS is via only one MU flow path,

b. one MU pump operating,

c. MU/LPI piggyback operation,

d. MU/HPI Cooling is started within ten minutes after T_{hot}=600°F and

e. flow from the RCS is via an open PORV.

This calculation determined that the collapsed core liquid level decreases to about 6 inches below the top of the core. However, the core should still be adequately cooled because a liquid froth would exist at the top of the core rather than a collapsed liquid level. Although the core is adequately cooled, the margin to onset of ICC conditions is significantly reduced. One objective of these guidelines is to provide a margin from inadequate core cooling, therefore having the collapsed liquid level drop below the top of the core is not desired. In addition, the TBD philosophy requires selecting the prudent course of actions which provide margin for additional failures or errors rather than providing actions which leave no margin for such failures or errors. This is the bases for not waiting until Thot reaches 600°F before starting MU/HPI cooling when only one MU pump starts. Instead MU/HPI cooling is immediately initiated to minimize the decrease in RCS water level and to reduce RCS pressure as low as possible to maximize HPI flow.

These bases state to operate the MU pumps in the MU/LPI piggyback mode with two operating MU pumps even though the analysis determined that the core could be adequately cooled without doing so (i.e., piggyback operation of the MU pump is only necessary for adequate core cooling when only one MU pump is operational). The piggyback mode is stipulated for conservatism since the additional flow to the RCS will increase the MU/HPI cooling capability. The piggyback mode is also stipulated in order to provide simplicity of operator actions, (i.e. the operator will perform the same actions whether one or two MU pumps are operational).

The MU/HPI cooling analyses assumed that actions were taken to initiate MU/HPI cooling ten minutes after T_{hot} reached 600°F. The guidelines require the actions to be taken at 600°F. The guideline requirement is based on engineering judgement, using the results of both the Davis Besse specific analyses and related generic analyses, and is intended to provide margin beyond the analyzed margins as discussed in Chapter II.D, Section 4.0. The Davis Besse specific analyses demonstrated that two MU pumps could provide adequate core cooling as can one MU pump if piggybacked with the PORV open. However, the analyses also demonstrated that the RC pressure would remain above the HPI pump shutoff head for periods of an hour or greater thus placing core cooling reliance solely on the continued operation the MU pump(s) during that time unless feedwater is recovered. The intent of the guideline is to increase the availability of the HPI pumps for core cooling, thus providing additional margin in the event of additional subsequent failures.

The guideline does not allow waiting until 600°F to initiate MU/HPI cooling if only one MU pump is available for reasons previously stated. The guideline use of 600°F for cases where two MU pumps are available is based on the following logic:

1. Additional margin is available for equipment failures (i.e., with two MU pumps operating, the availability of the PORV and piggyback could be lost or one MU pump could be lost and the core will still be adequately cooled).

2. The Davis Besse PORV is large enough that opening the PORV should result in RCS saturation even if the pressurizer has filled prior to reaching 600°F.

3. Piggybacked HPI pumps can provide additional flow for core cooling as long as RCS pressure is less than ~1830 PSIG. This corresponds to a saturation

temperature of ~623°F, thus the HPI pumps will remain available as long as the RCS does not heat up to 623°F.

4. At this time after trip from full power operation, the RCS heatup rate, with no cooling available, should be no more than about 4°F/minute (assuming an ARTS trip occurred vs. a trip on high RC pressure). Since flow from two MU pumps plus flow from one or two HPI pumps exists, the heatup rate will be considerably less than 4°F/minute.

5. Generic analyses performed for the LL plants, which have a higher decay heat to HPI flow ratio than Davis Besse, showed that flow from two HPI pumps would match decay heat and begin to cool and depressurize the RCS within ~6 to 8 minutes. Therefore, the greater HPI flow capacity at Davis Besse, plus the additional flow from two MU pumps, has a good probability of cooling and depressurizing the RCS before reaching 623°F. This would allow continued MU/HPI cooling and prevent long periods of cooling using only the MU pumps.

If HPI piggyback capability (i.e., regardless of MU piggybacking capability) is not available, then initiation of MU/HPI cooling should be considered before 600°F, even with two MU pumps available. This is because the intent of 600°F, which relies on the HPI pumps being piggybacked as stated above, is no longer met. Without the ability to piggyback the HPI pumps, the HPI pump shutoff head would be reached at a saturation pressure corresponding to ~608°F. This may not allow sufficient time to match decay heat before reheating and repressurizing above the HPI pump shutoff head. If this occurs, the core should still be adequately cooled by the MU pumps but RCS pressure will remain above the HPI pump shutoff head for periods of an hour or longer as demonstrated by the analyses. This could also occur, for example, if the loss of feedwater resulted in a reactor trip on high pressure instead of an ARTS trip. In this case, 600°F could be exceeded within a few minutes after trip and it may not be possible to fully initiate MU/HPI cooling within this time. The added margin between the guideline and the analyses accounts for these cases, i.e., the core should still be adequately cooled if RC pressure can not be maintained below the HPI pump shutoff head if at least one MU pump is operated in piggyback with the PORV open.

Prior to initiating MU/HPI cooling, the PORV should be cycled for pressure relief to limit challenges to the pressurizer safety valves. Automatic PORV cycling should be avoided by manually cycling the PORV over a larger RC pressure range, (e.g. between the PORV open pressure setpoint and a pressure which is above either the safety system actuation setpoint or the SCM) which will result in fewer PORV open/close cycles (to reduce the likelihood of PORV failure) and a larger integrated MU and HPI flow to the RCS. If the PORV fails open, then MU/HPI cooling is started rather then closing the PORV block valve. If the PORV block valve were to be closed then it may not open when MU/HPI cooling is started. However, if neither the MU or HPI pumps are operational (i.e., there is no inventory addition to makeup for inventory loss out the PORV), then manually control RC pressure between the PORV setpoint or PTS limit and ES actuation setpoint or adequate SCM limit. This is to prevent excessive cycling which could cause the PORV to fail open. If the PORV does fail open then close the PORV block valve and allow the pressurizer safety valves to provide pressure relief while attempts to initiate MU/HPI Cooling and feedwater flow continue.

Before MU/HPI cooling is initiated, inventory addition to the RCS is established as follows:

a. Run the operational MU pumps and provide MU flow in the MU/LPI piggyback mode (i.e., taking suction from the LPI pump discharge with the LPI pumps taking suction from the BWST).

b. Operate both trains of HPI in the HPI/LPI piggyback mode (i.e., taking suction from the LPI pump discharge with the LPI pumps taking suction from the BWST). If both trains of HPI are not operational still continue MU/HPI initiation while continuing efforts to get both trains operational.

c. Operate both trains of LPI in the injection mode taking suction from the BWST. If both trains of LPI are not operational still continue MU/HPI cooling initiation while attempting to get both trains operational.

The above operations are performed during a lack of heat transfer event immediately after determining that feedwater is unavailable. This is so the full inventory addition rate can be promptly attained when HPI cooling is initiated, i.e., when the PORV is opened. In addition to opening the PORV, the high point vents can be opened to increase the MU/HPI cooling capability. However, because of their small flow rate, opening the high point vents will have little effect on the MU/HPI cooling capability.

This sequencing also verifies that a source of makeup water is available before creating a flow path out of the RCS. Consequently, the PORV and HPVs should not be left open if there are no HPI or MU pumps capable of adding water to the RCS. In this case, efforts to restore feedwater and MU flow must be expedited while the PORV is cycled manually as previously described.

After opening the PORV assure maximum MU and HPI flow if adequate SCM is lost, i.e., provide MU flow through both the normal and alternate MU lines, close the makeup pump recirculation lines, open the makeup valve bypass valve, and maintain piggyback operation of two HPI pumps.

The PORV is required to be open during MU/HPI cooling with both MU pumps operational even though the core can be kept covered and adequately cooled with two MU pumps operating with the PORV closed (i.e., RCS fluid being released via the pressurizer safety valves). If the PORV was not opened, then the core may not be adequately cooled if one MU pump should subsequently fail and the PORV could not be opened. In addition, opening the PORV permits matching decay heat sooner and depressurizing the RCS.

When the core temperature is increasing, RC heat input should be minimized by reducing the number of running RCPs to one because of the limited heat removal capability of MU/ HPI cooling. At least one RCP should be run to promote thermal mixing of HPI and MU injection water in the RCS. The last RCP must be tripped if the SCM is lost. Pressurizer heaters should also be de-energized to stop their energy input into the RC.

The RCS may heat up for some time before the MU/HPI cooling can remove decay heat. In this case, all the RCPs must be tripped before the SG tubes reach the compressive limit. This will slow further heatup of the SG tubes. The RCPs should not be restarted, even with SCM and restart criteria of IV.A met until the ΔT between the core outlet temperature and the SG shell temperature is less than the compressive limit. The intent is to prevent pumping core exit water to the SG tubes which could cause the SG shell to tube compression limit to be exceeded.

If the PORV fails to open or PORV flow cannot be established for any reason after the initiation of MU/HPI cooling, then RC pressure is expected to increase causing cycling of the pressurizer safety valves. This RC pressure rise and the extent of safety valve cycling will be dependent upon the decay heat level and the amount of MU supplied to the RCS by the MU pumps (RC pressure will be too great to allow any HPI pump flow).

If this mode of operation continues long enough (no PORV flow established), RC temperature will begin to decrease while the RC pressure remains high. In this situation, high RC pressure (at the pressurizer safety valve setpoint) and decreasing RC temperature, action <u>must</u> be taken to follow the PTS guidance if invoked. Along with continuing attempts to establish PORV flow, MU flow should be throttled to keep RC temperature from decreasing below the NDT limit and within the PTS guidance, if invoked. Throttling of MU flow can begin after adequate SCM is provided. If HPI is "on" with RCPs "off," then the PTS guidance requires throttling HPI to keep the core outlet temperature near the SCM limit. In this case MU flow can be throttled to the point where the RCS begins to reheat in order to establish a temperature band for control. As long as PORV flow cannot be established, the plant will remain in this mode until primary to secondary heat transfer is restored, a pressurizer safety valve fails open or decay heat diminishes to less than ambient RCS losses. The HPVs may be opened to aid cooling and, with very low decay heat, pressure reduction.

<u>Initiation of HPI Cooling From Lower RCS Pressures and Temperatures</u>

The previous guidance on initiation of HPI cooling assumes the loss of primary to secondary heat transfer occurs at or near normal post-trip conditions. If a loss of heat transfer occurs at lower RCS pressures and temperatures (e.g., during a cooldown or heatup), other considerations may apply to operation of the PORV. The RV P-T limit is always applicable. The RC pressure must not exceed the RV P-T limit. Therefore, if the RC pressure increases to the RV P-T limit following a loss of primary to secondary heat transfer, the PORV should be opened and HPI cooling started to limit the pressure increase. After the pressurizer fills with RC, the HPI flow should be throttled as necessary to try and keep the RC pressure below the RV P-T limit or within the PTS guidance, if invoked. Refer to Chapter IV.G for information on PTS guidance.

3.9.3 Control of HPI Cooling

The decay heat removal rate is primarily a function of the mass addition rate to the core and the core outlet temperature and quality. Consequently, for an existing core outlet temperature and quality, the energy removal rate can be increased by increasing the mass addition rate. This is done by opening the PORV to reduce the RCS pressure by venting the pressurizer steam. If this is done from near normal operating conditions, the RCS pressure will decrease because the steam volume flow rate through the PORV will far exceed the volume flow rate into the RCS from the HPI and the effective volume increase due to RC expansion. The RCS pressure will decrease until either RC saturated pressure conditions are reached causing the RC to expand due to steam formation or until the pressurizer fills with water causing the PORV discharge fluid to change from one phase steam to a two phase mixture. The saturation pressure reached is a function of the RC temperature when the PORV is opened, i.e., the lower the RC temperature is when the PORV is opened then the lower the RC pressure will go and the higher the HPI flow rate which will be obtained. If this causes a loss of subcooling margin, the RC pumps will need to be tripped; however, transition to the loss of SCM guidance of Chapter III.B is not necessary. This is because the loss of SCM is most likely a consequence of the action taken (i.e., opening the PORV). Even in the extremely unlikely event of a concurrent LOCA, transfer to III.B in this instance is not necessary. Before opening the PORV, HPI flow was verified; therefore, the loss of SCM guidance to initiate HPI has already been taken. The RCPs are tripped per Rule 1.0, and attempts to restore FW and heat transfer have already been made. No other Chapter III.B guidance is appropriate for this situation.

After decreasing to a new RC pressure and HPI flow rate, the RC will either continue to heat up or begin to cooldown depending on the heat removal capability of the increased HPI flow rate. If the HPI heat removal rate is less than the decay heat rate then the RC will continue to heat up (see Figure III.G-10). If the RC is saturated, its temperature and pressure will increase along the saturation curve. The resulting higher temperature will allow more energy to be removed per pound of water added by the HPI. However, the increased pressure will also decrease the HPI flow rate. The overall effect will be a decreasing rate of energy removal as the RC heats up. Consequently, if the RC starts to heat up it may continue to heat up and pressurize to the pressurizer safety valve setpoint and the HPI cooling rate may not match the decay heat rate until the RCS water level, i.e. hot leg level, has decreased below the pressurizer surge line. The safety valve has more capacity then the RC volume expansion rate due to decay heat and therefore will stop further pressure increases.

If the RCS heats up to the safety valve setpoint, the RC will probably remain saturated at the safety valve setpoint while the RCS inventory decreases to the pressurizer surge line elevation. When the surge line nozzle entrance is uncovered, the two phase mixture from the core outlet can flow directly through the surge line to the PORV. The mass flow rate through the PORV is a function of the PORV inlet conditions. Consequently, the increasing fluid quality at the PORV inlet will cause the PORV volumetric flow rate to go up which will cause the RC pressure to start decreasing and the HPI flowrate to increase. The increased quality will also cause the mass flow rate out the PORV to decrease. When this happens the net inventory loss rate from the RCS will decrease leading to RCS refill and the heat removal rate will increase leading to RC cooldown (see Figures III.G-7 and III.G-11).

If the HPI heat removal rate is larger than the decay heat rate then the RC will start to cooldown. If the RC starts to cooldown, both its temperature and pressure will decrease. The lower temperature will decrease the amount of energy removed per pound of water added. However, the decreased pressure will also increase the rate of mass addition. The overall effect will be an increasing rate of energy removal. Consequently, if the RC temperature starts decreasing the RC will probably continue to cool and depressurize at an increasing rate until the operator reduces the HPI flow rate or starts a RC pump <u>after</u> the subcooling margin is re-established.

When the PORV is not maintained open all RC pumps except one should be tripped even though the SCM exists. Tripping all RC pumps except one will reduce the heat input to the RC from the RC pumps while maintaining thermal mixing of the RC.

When the PORV is not maintained open, the last RC pump should be tripped when its NPSH limit, the SCM or the steam generator tube to shell temperature compression limit is reached. The NPSH limit and SCM will be reached as the RC temperature approaches saturation. The tube to shell limit can be approached because the tube temperature will increase as the RC temperature increases while the steam generator shell temperature remains the same or decreases because no water is available to the SG for boiling and transferring heat to the SG shell.

When the RC pumps are tripped, the RC loop flow will decrease to natural convection flow. This natural convection will continue as long as the core outlet temperature increases or substantial voids do not accumulate in the reactor outlet pipes. Consequently, tripping the RC pumps can not prevent exceeding the tube to shell temperature limit but it will limit the magnitude by which the limit is exceeded. This is due to the long loop flow transit time and reduced SG tube heat transfer during natural convection.

When the RCS inventory is decreasing (i.e. steam voids expanding in the hot legs), the steam generator primary side inventory will flow to the reactor vessel. Consequently, all HPI flow will flow to the reactor vessel and none of the HPI flow will circumvent the reactor vessel by flowing backwards through the loops to the pressurizer. This will prevent localized SG tube cooling due to HPI flow.

After the SCM is regained a RC pump should be started to provide thermal mixing of the RC and the HPI flow should be throttled. The HPI flow is controlled to obtain the desired subcooling value. The resulting HPI flow will dictate the cooldown rate. If the cooldown rate is excessive then an additional RC pump can be started to add heat to the RC to slow the cooldown without affecting the subcooling value. A representative analysis of HPI cooling showed that with low decay heat, two HPI pumps started and the PORV maintained open, the SCM was lost (but the RC did not go saturated) and a 180°F/hr cooldown began almost immediately. When the subcooling reached 50°F, the HPI was throttled to maintain the 50°F subcooling causing the cooldown rate to decrease to about 65°F/hr (see Figures III.G-12 and III.G-13).

Another representative analysis with high decay heat showed the cooldown rate changing from 80°F/hr to 65°F/hr after starting a RC pump when the SCM reached 25°F. Operator actions must be prioritized to first establish SCM then throttle HPI flow to maintain SCM and start RC pumps to affect the cooldown rate. The RC pump should also be started as soon as possible to provide thermal mixing of the RC and before the RC temperature is reached which would cause the SG tube-to-shell tensile limit to be exceeded when the RC pump is started. During HPI cooling, the core outlet temperature could significantly increase above the SG shell temperature. If this occurs, the RC pumps should not be started until the ΔT between the core outlet temperature and the SG shell temperature has been reduced to less than the compressive limit.

3.9.4 Restoration of Steam Generator Cooling

If SG heat transfer can be restored, the transition from HPI to SG cooling should be made. SG inventories should be restored to their appropriate levels (low level limit or NC). If a RCP is running, then following restoration of SG level, SG heat transfer should be restored and reducing SG pressure should establish an RCS cooldown. If no RCPs are running, then following restoration of SG level, a positive primary-to-secondary ΔT of about 50°F should be established to ensure the SGs are a heat sink. If NC does not occur the HPVs may be opened to help eliminate hot leg voids. The HPVs may not help if the RC is saturated, but their use under saturation conditions should not hinder restoration of heat transfer; hence, they are used regardless of SCM. Due to the temperature profiles that can occur during HPI cooling, a SG ΔT of about 100°F should be established if NC does not initiate after taking the previous actions. In this situation, starting or bumping a RCP, provided restart criteria of IV.A are met, may help.

The preferred method of transferring from HPI to SG cooling is to first establish primary to secondary heat transfer and then close the PORV and/or HPVs. However, depending upon conditions, it may be necessary to close the PORV and/or HPVs before primary to secondary heat transfer is verified.

During HPI cooling, decay heat is transported to the RB via the PORV. If decay heat levels are low (started low or time has passed since heat transfer was lost), it may be difficult or impossible to transfer the decay heat load to the SG(s) with the PORV open. This may be true even with all necessary primary to secondary heat transfer conditions restored (e.g., appropriate levels and primary to secondary ΔTs). For this reason the PORV may be closed once all primary to secondary heat transfer conditions are met (such an action should take into account the expected decay heat levels). This should transfer the entire decay heat load to the SG(s) thus aiding establishment of primary to secondary heat transfer. In the event RCS P-T increases (if PTS is invoked) or primary to secondary heat transfer is not established, then the PORV must be reopened and HPI cooling restored.

Once SG steaming commences, cooldown rate and SCM should increase. HPI should be throttled and letdown opened as the PORV and/or HPVs are closed to control SCM and prevent exceeding RCS pressure/temperature limits. When the HPI valves are fully closed, then HPI may be stopped. Re-establish a pressurizer bubble if possible. If a bubble cannot be established use alternate primary pressure control as described in 3.2. Continue the cooldown to DHRS conditions using SG cooling. Once heat transfer is restored and restart criteria of IV.A are met, two RCPs should be started to establish a normal plant configuration for plant cooldown.

3.9.5 Impact of Steam Generator Tube Rupture

SGTRs result in a depletion of primary inventory until the leak flow is stopped. Therefore, it is desirable to restore heat transfer to the SG to enable an expeditious cooldown or reduce RC pressure by throttling HPI to minimize loss of coolant. Inventory may also be preserved if the SG drain discharge is recoverable for reinjection to the RCS. In addition, HPI cooling with a SGTR may impose RC pressure control problems. Refer to Chapter III.E for a detailed discussion.

If a SGTR results in an isolated solid SG, RC pressure must be kept below the low MSSV setpoint if at all possible. With HPI cooling this is normally accomplished by throttling HPI flow while maintaining adequate SCM. If, however, the RCS is saturated, HPI must not be throttled. In this case, additional relief paths must be opened. These include HPVs, letdown, and drains on the isolated SG if available. Refer to Chapter III.E for more details on HPI cooling with a SGTR.

3.10 Trickle Feed

If it is decided to perform the cooldown by using trickle feeding, it will be necessary to control the rate of FW addition to the SGs to maintain RCS cooldown limits. The FW flow rate should be adjusted to get the desired cooldown rate. Once the proper flow rate is attained, this flow rate will have to be gradually decreased in order to match the decreasing decay heat.

If possible EFW should be used to limit SG thermal stresses. If MFW is used with the MFW nozzles, it will only be effective with forced flow. This is because SG levels cannot be raised to the NC setpoint (it may not be possible to maintain any level) and the MFW nozzles do not introduce FW at a high enough elevation to initiate NC.

When trickle feeding, FW will be irretrievably lost through the steam leak. For this reason, the amount of available FW should be considered before initiating trickle feed. Depending upon the amount of FW available, at some point in the cooldown it may become necessary to switch to a lower quality FW source or re-initiate HPI cooling.

A SG with a steam line break inside the RB should not be trickle fed if the steam release to the RB is determined to be inappropriate. Also, trickle feed should not be attempted if it would be detrimental to personnel or key equipment.

Refer to Chapter IV.C for control of feedwater to steam generators that cannot hold pressure.

3.10.1 Impact of Steam Generator Tube Ruptures

SGTRs would normally result in SG isolation or limited steaming in one or both SGs. However, if the SG also has an unisolable steam leak, it will continue due to the boil-off of the tube leakage, i.e., isolation is not possible. In this case, the tube ruptured SG should continue to be fed unless restricted by other limits (see III.E.3.8).

3.11 Continue Cooldown to DHRS Operation

While continuing cooldown toward DHRS operations, low RCS temperature overpressure protection (LTOP) is required. LTOP precludes inadvertently exceeding the P-T limit. The conditions requiring LTOP and the actions to implement LTOP are plant specific.

Continue cooldown until conditions allow DHRS operations. DHRS operations are addressed in Chapter IV.B. When DHRS operational conditions are achieved, further direction will be provided by station management.

COOLDOWN LOGIC FLOW DIAGRAM

Figure III.G - 1

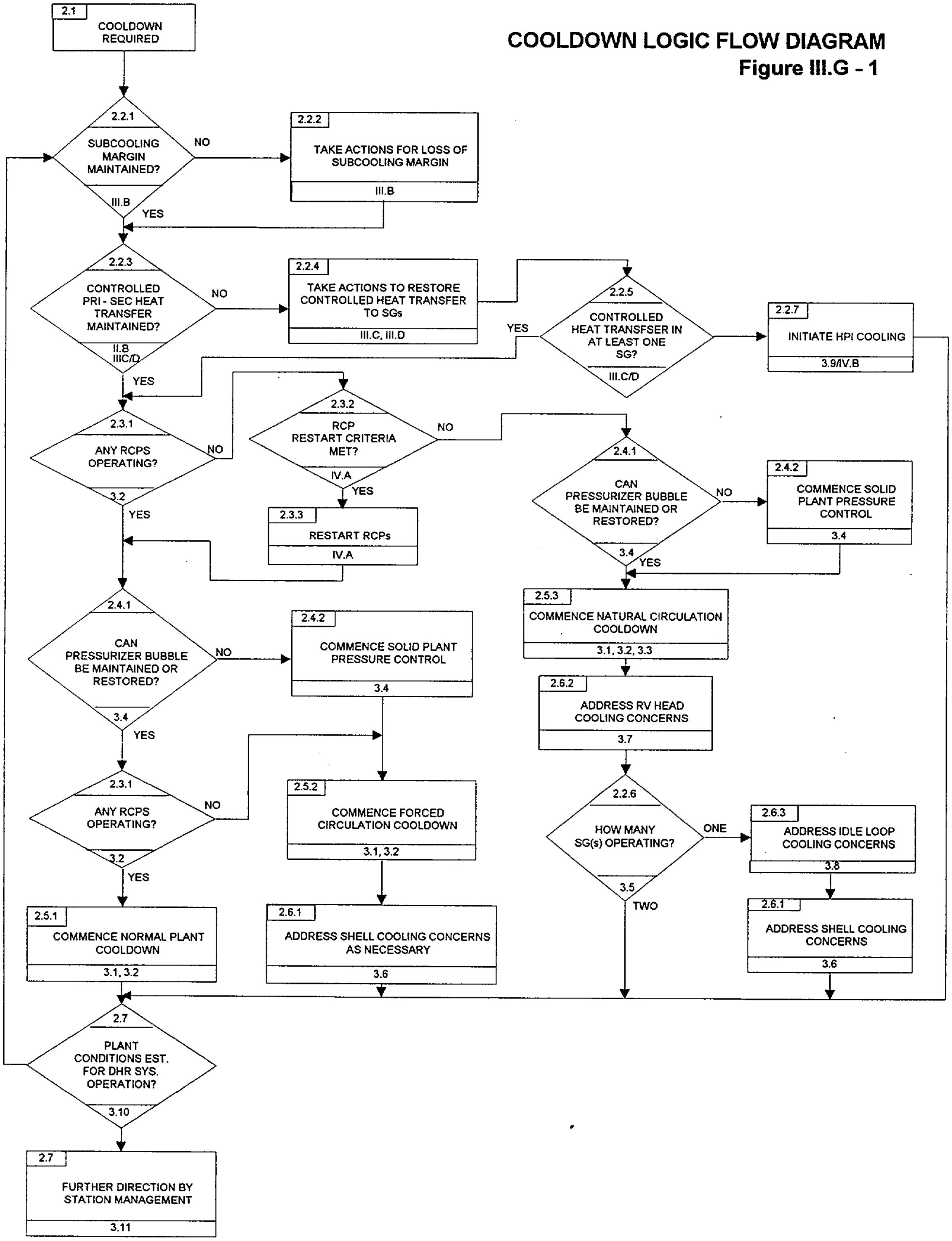


Figure III.G-2 Plant Status vs Cooldown Concerns

PUMP STATUS	STEAM GENERATOR STATUS	PRESSURIZER STATUS	COOLDOWN MODE RCS LOOP FLOW	COOLDOWN CONCERNS				
				PLANT LIMITS	SHELL COOLING	SOLID PLANT PRESSURE CONTROL	RV HEAD COOLING	IDLE LOOP COOLING
PUMPS ON	TWO SGs	BUBBLE	FORCED	X				
		NO BUBBLE	FORCED	X		X		
	ONE SG	BUBBLE	FORCED	X	X			
		NO BUBBLE	FORCED	X	X	X		
PUMPS OFF	TWO SGs	BUBBLE	2 LOOP NATURAL	X			X	
		NO BUBBLE	2 LOOP NATURAL	X		X	X	
	ONE SG	BUBBLE	1 LOOP NATURAL	X	X		X	X
		NO BUBBLE	1 LOOP NATURAL	X	X	X	X	X
PUMPS ON	NO SG (HPI COOLING)	NO BUBBLE	FORCED	X	X	X		
PUMPS OFF			NONE	X		X	X	X

Figure III.G-3 Head Fluid Temperature Response While Active Vent Is Open (Primary Pressure – 2200 PSIA)

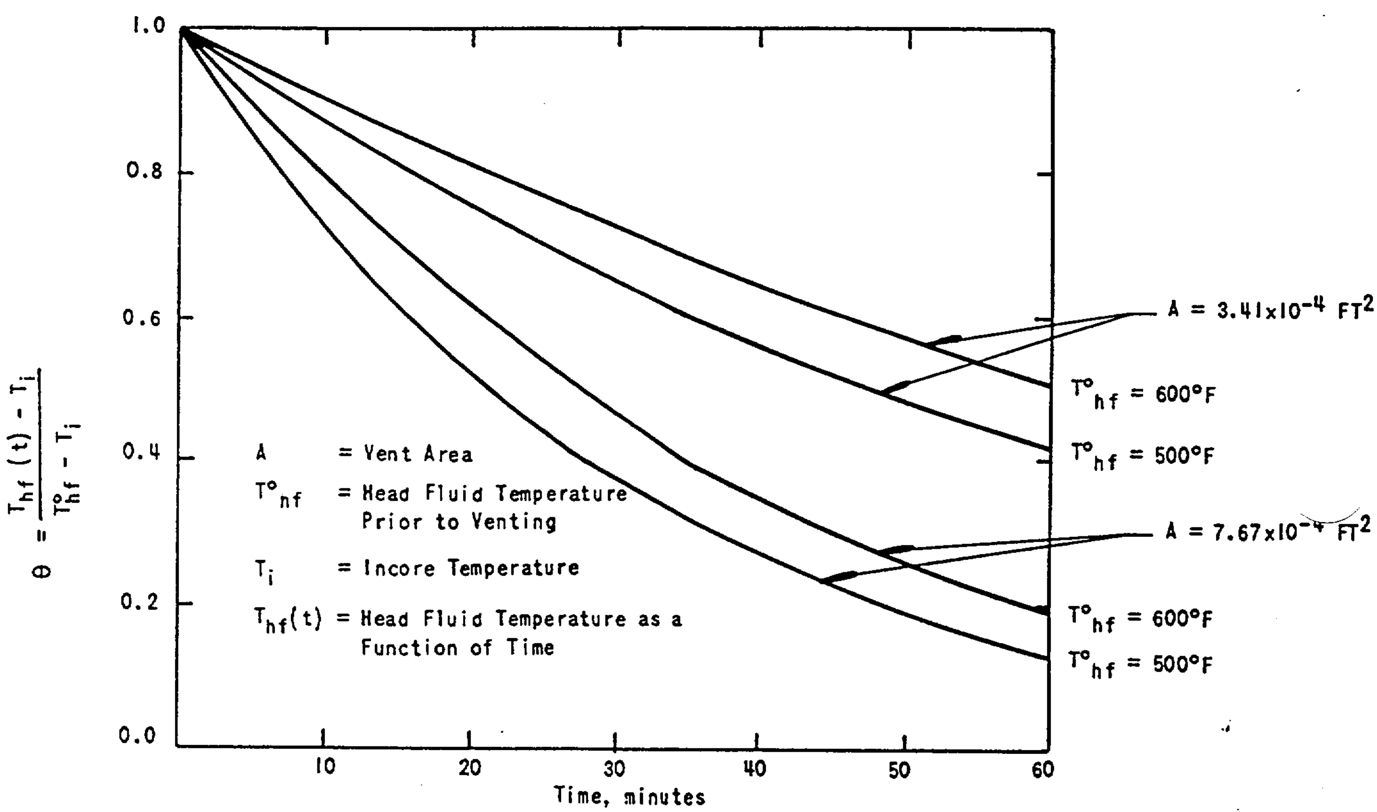


Figure III.G-4 Head Fluid Temperature Response While Active Vent Is Open (Primary Pressure – 1600 PSIA)

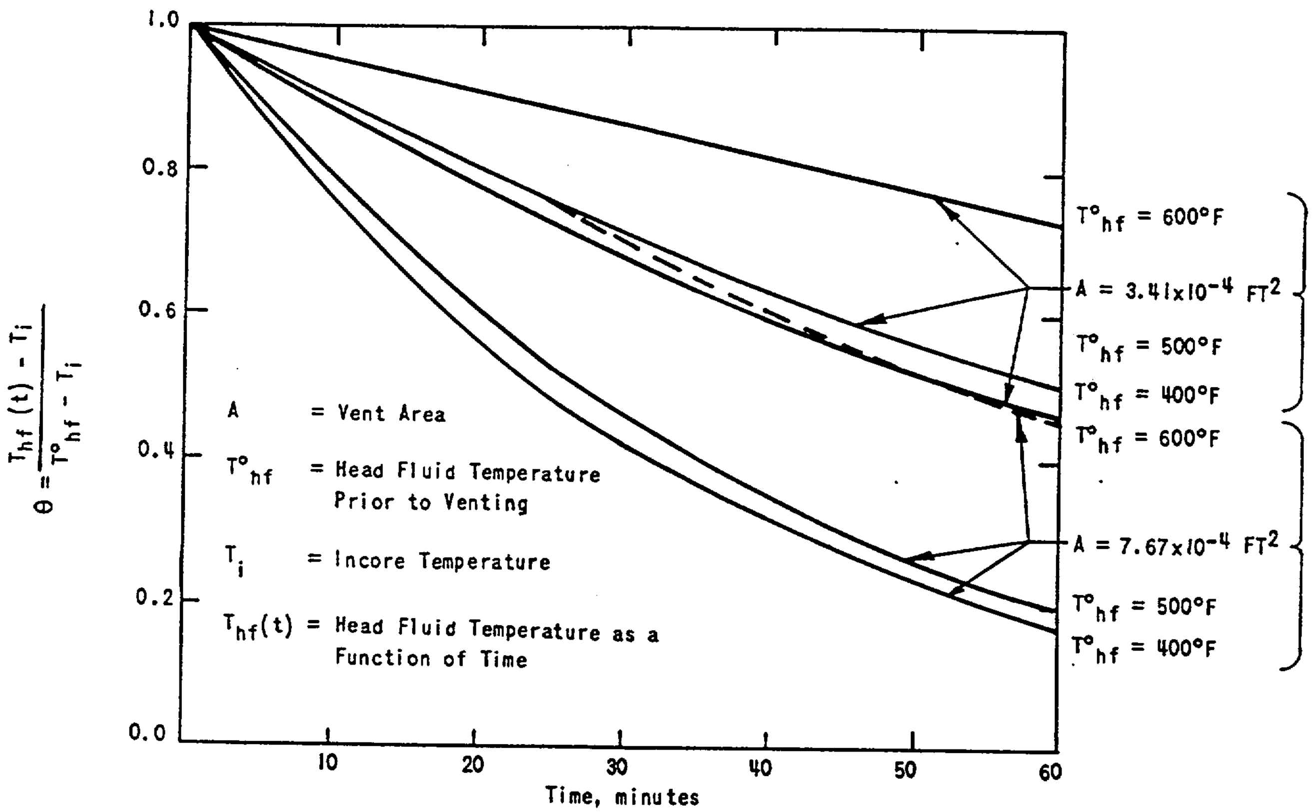


Figure III.G-5 Head Fluid Temperature Response While Active Vent Is Open (Primary Pressure – 1000 PSIA)

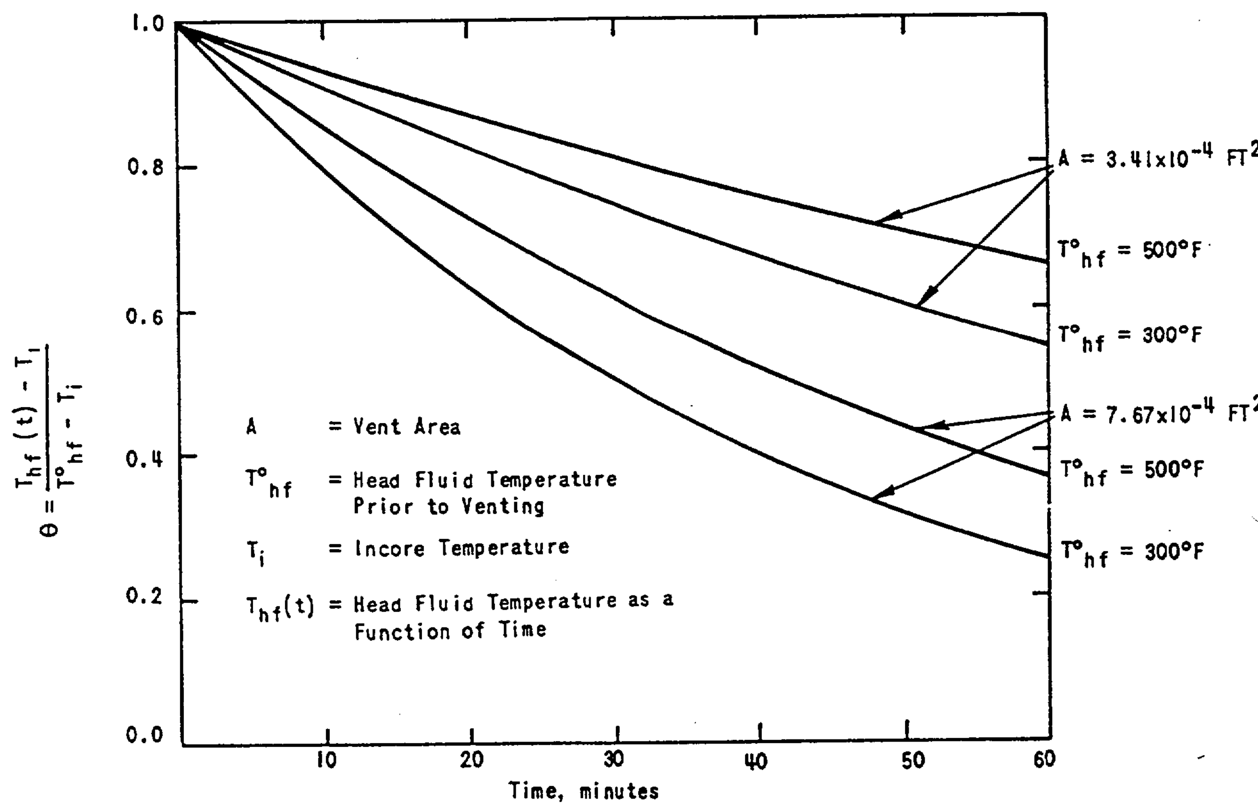


Figure III.G-6 Head Fluid Temperature Response While Active Vent Is Open (Primary Pressure – 400 PSIA)

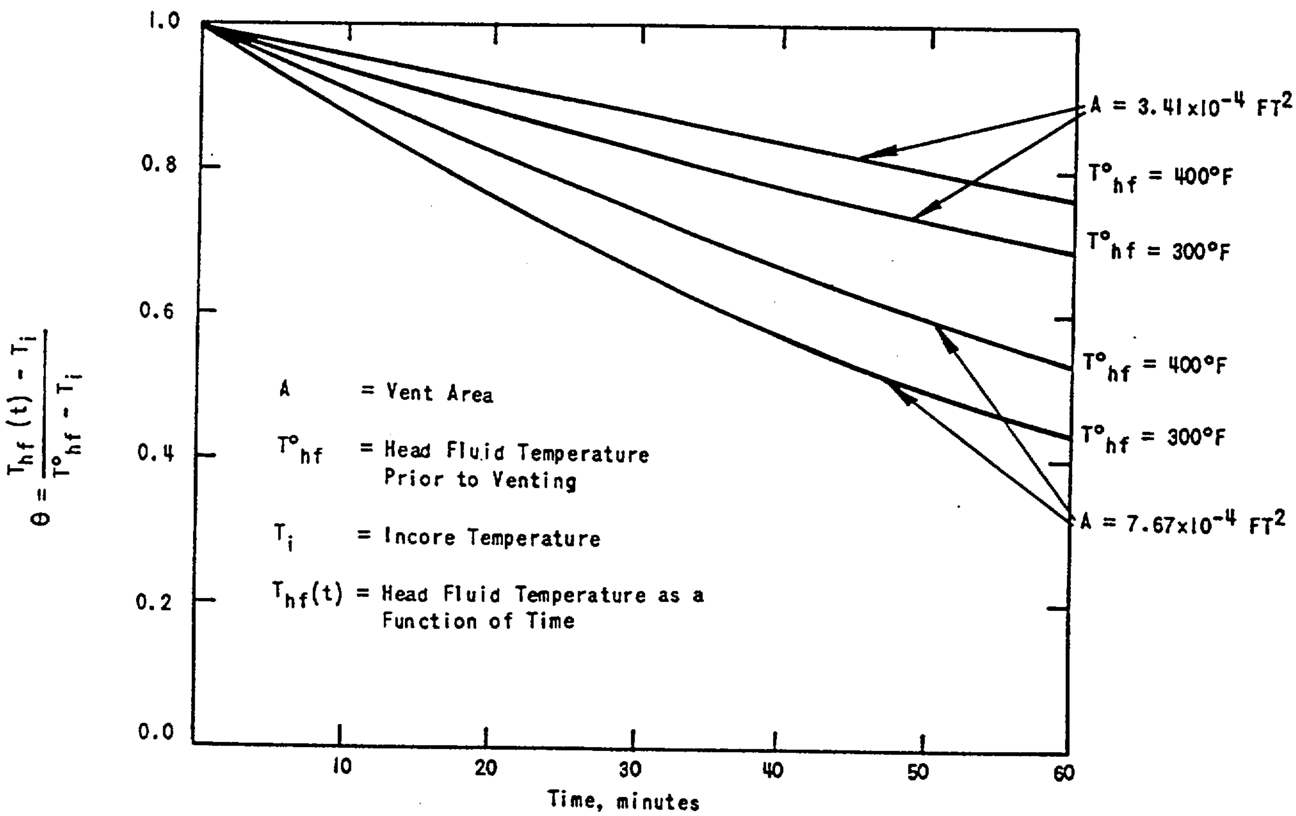


Figure III.G-7 PORV and HPI Mass Flow Rates During HPI Cooling With 1 HPI Pump

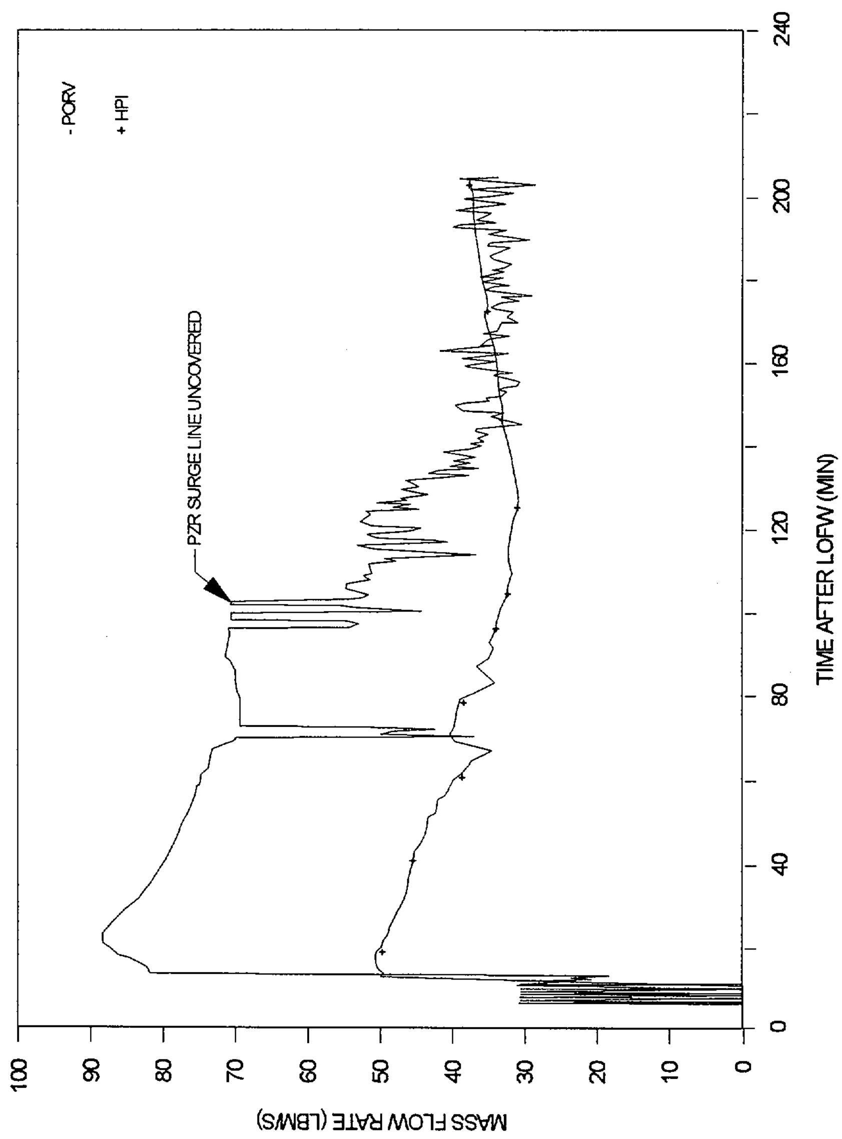


Figure III.G-8 Core Exit Temperature During HPI Cooling With 2 HPI Pumps

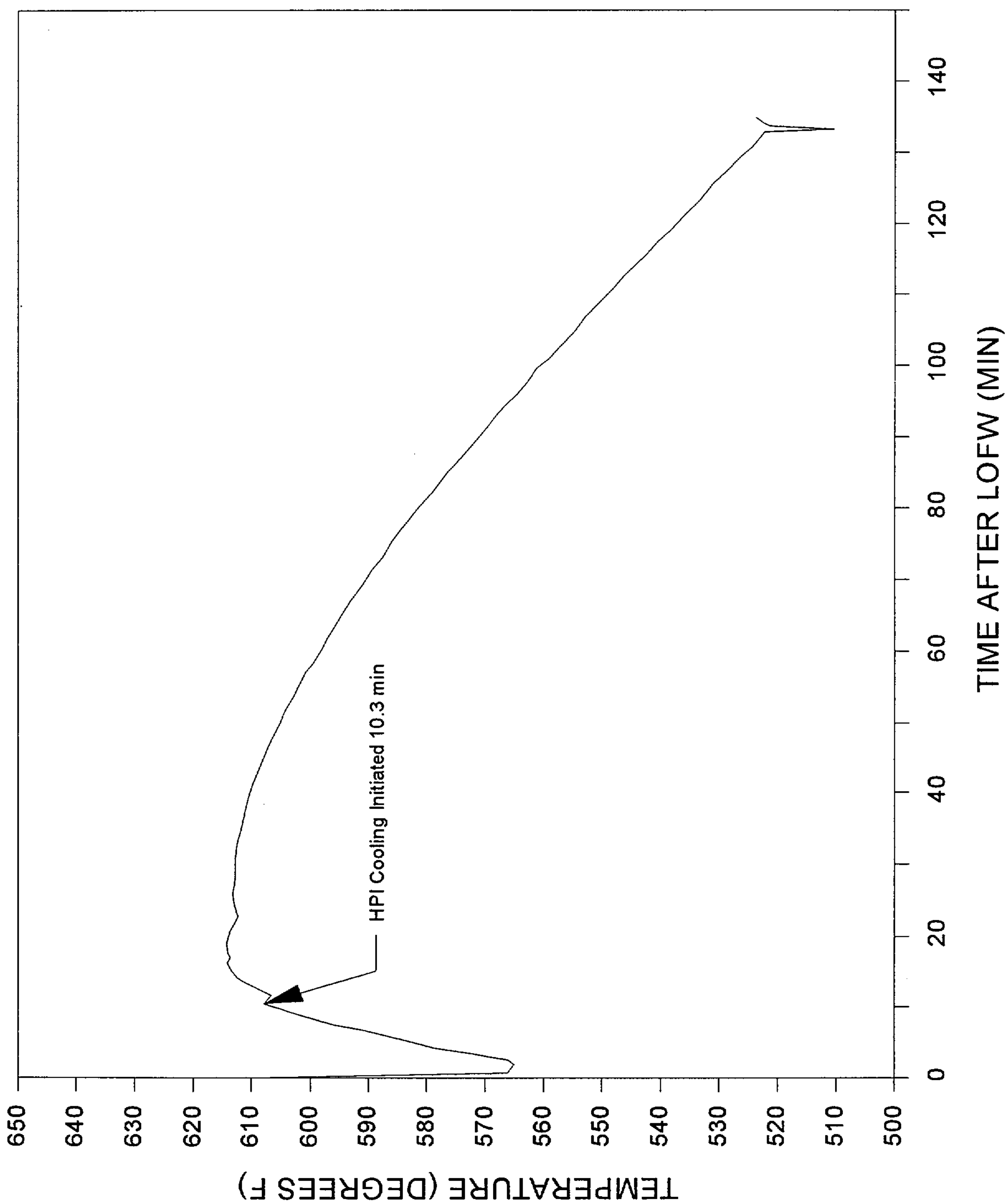


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Figure III.G-9 Core Exit Temperature During 2 Pump HPI Cooling with the PORV Cycling

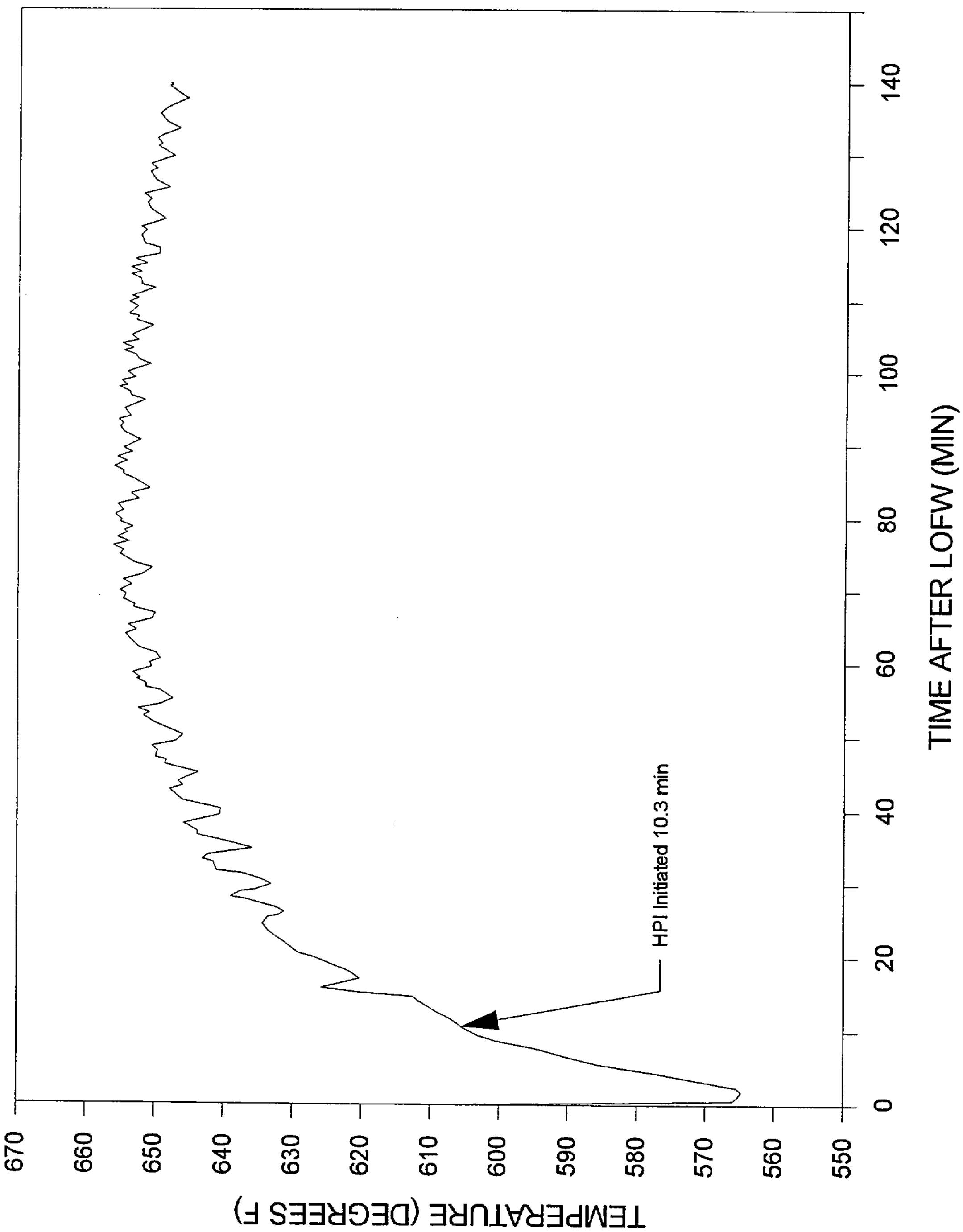

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Figure III.G-10 Primary System Response During HPI Cooling with 1.0 ANS5.1 of 1979

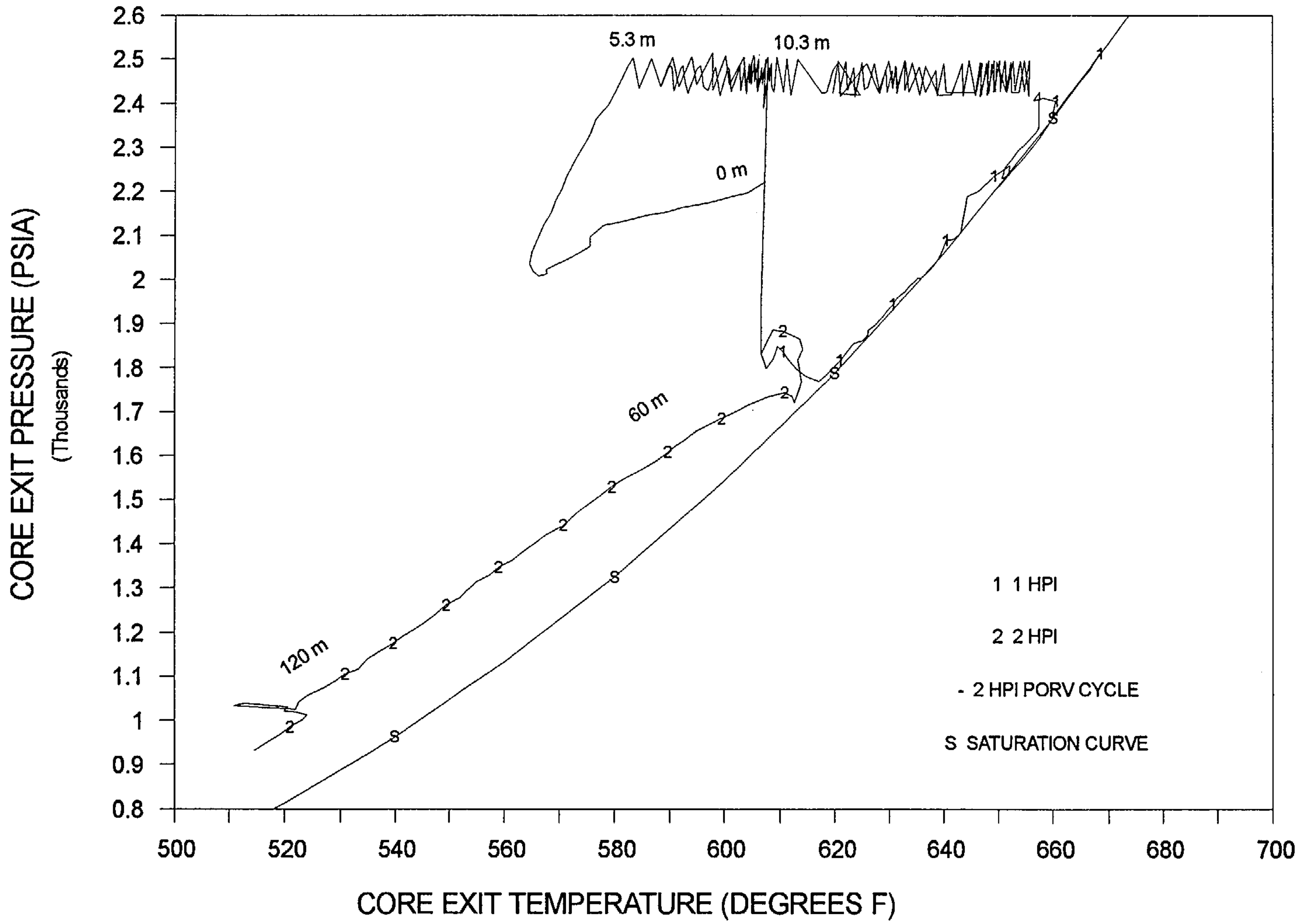


Figure III.G-11 Core Exit Temperature During HPI Cooling with 1 HPI Pump

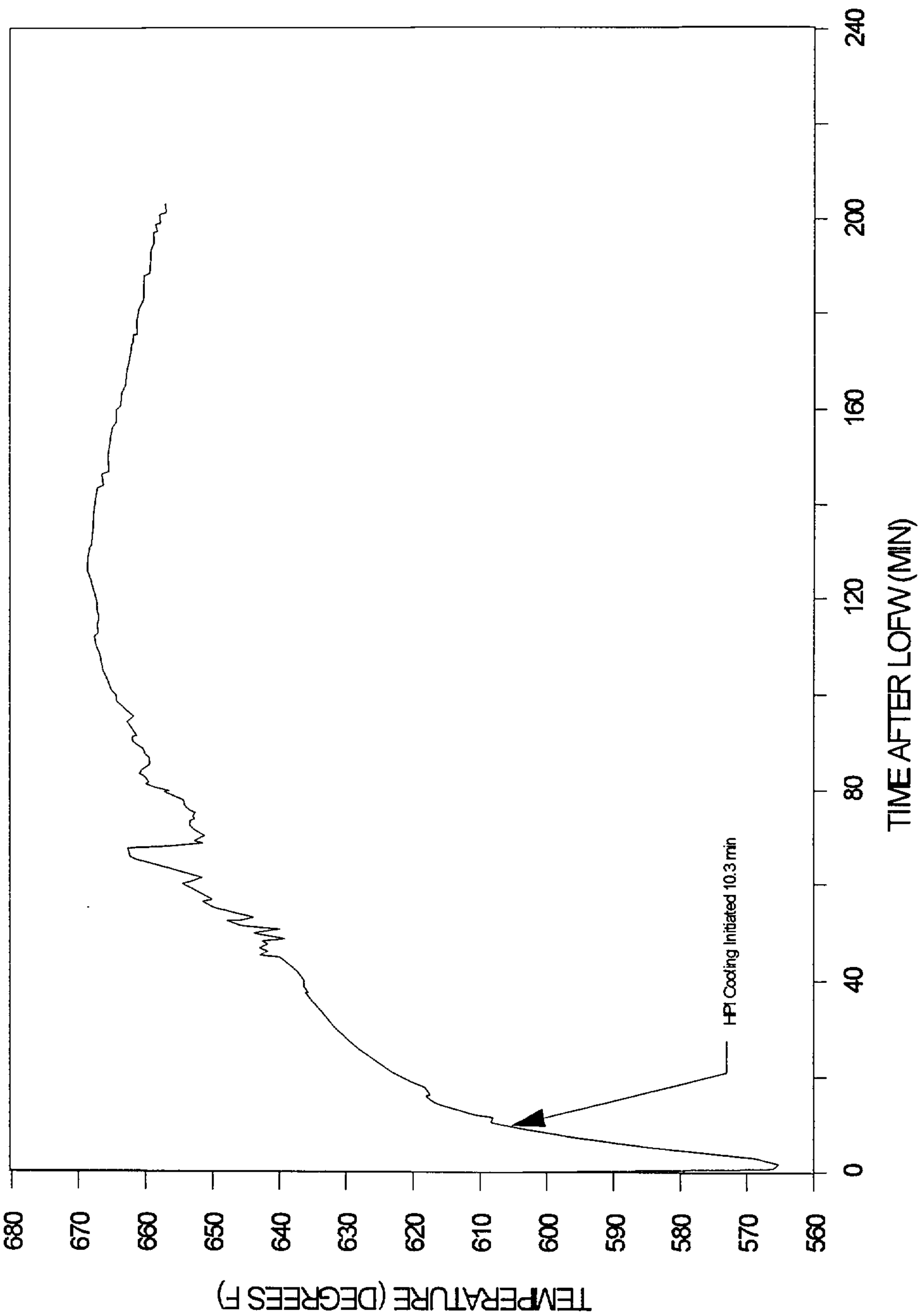


Figure III.G-12 Primary System Pressure During 2 Pump HPI Cooling with Low Decay Heat

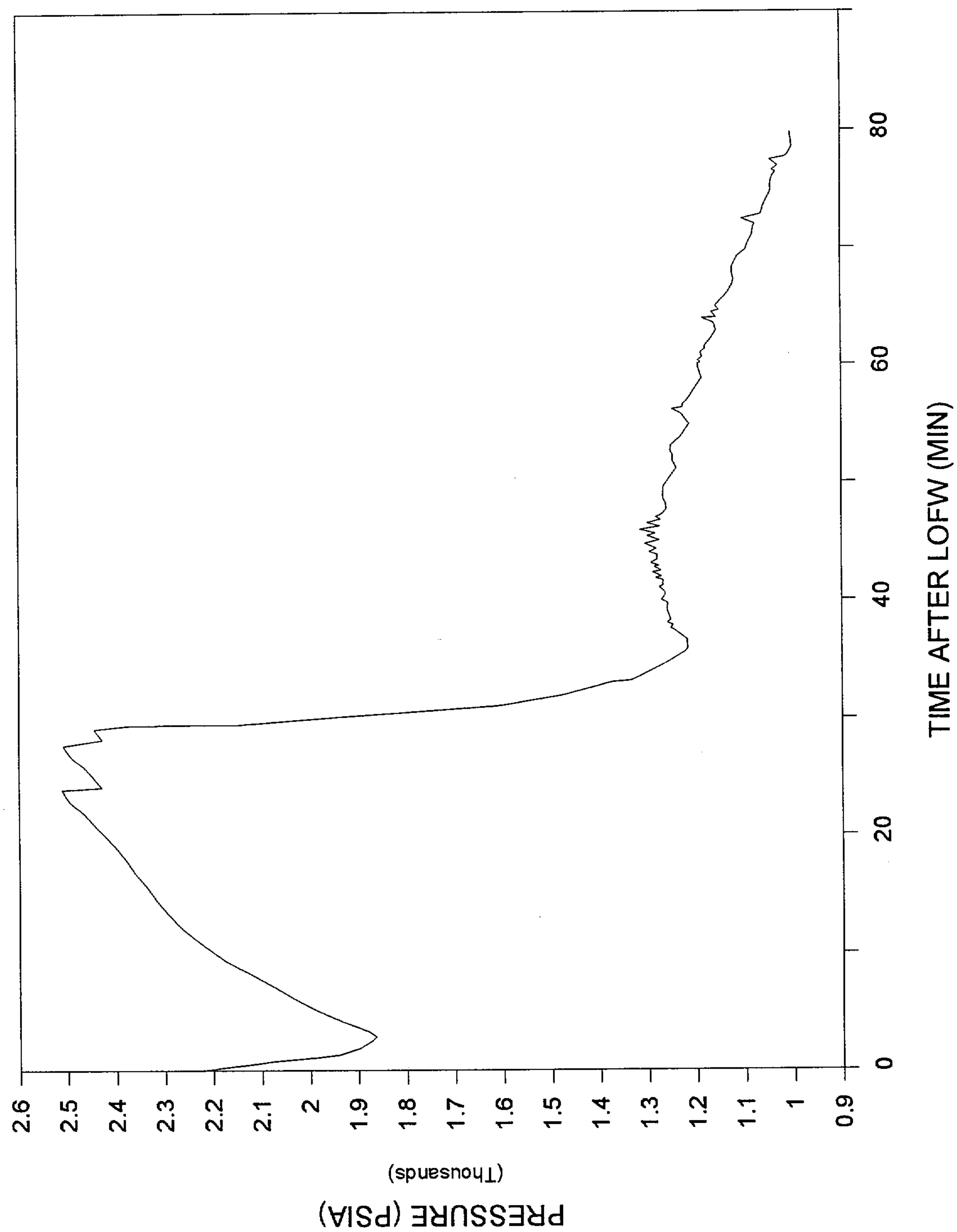


Figure III.G-13 Core Exit Temperature During 2 Pump HPI Cooling with Low Decay Heat

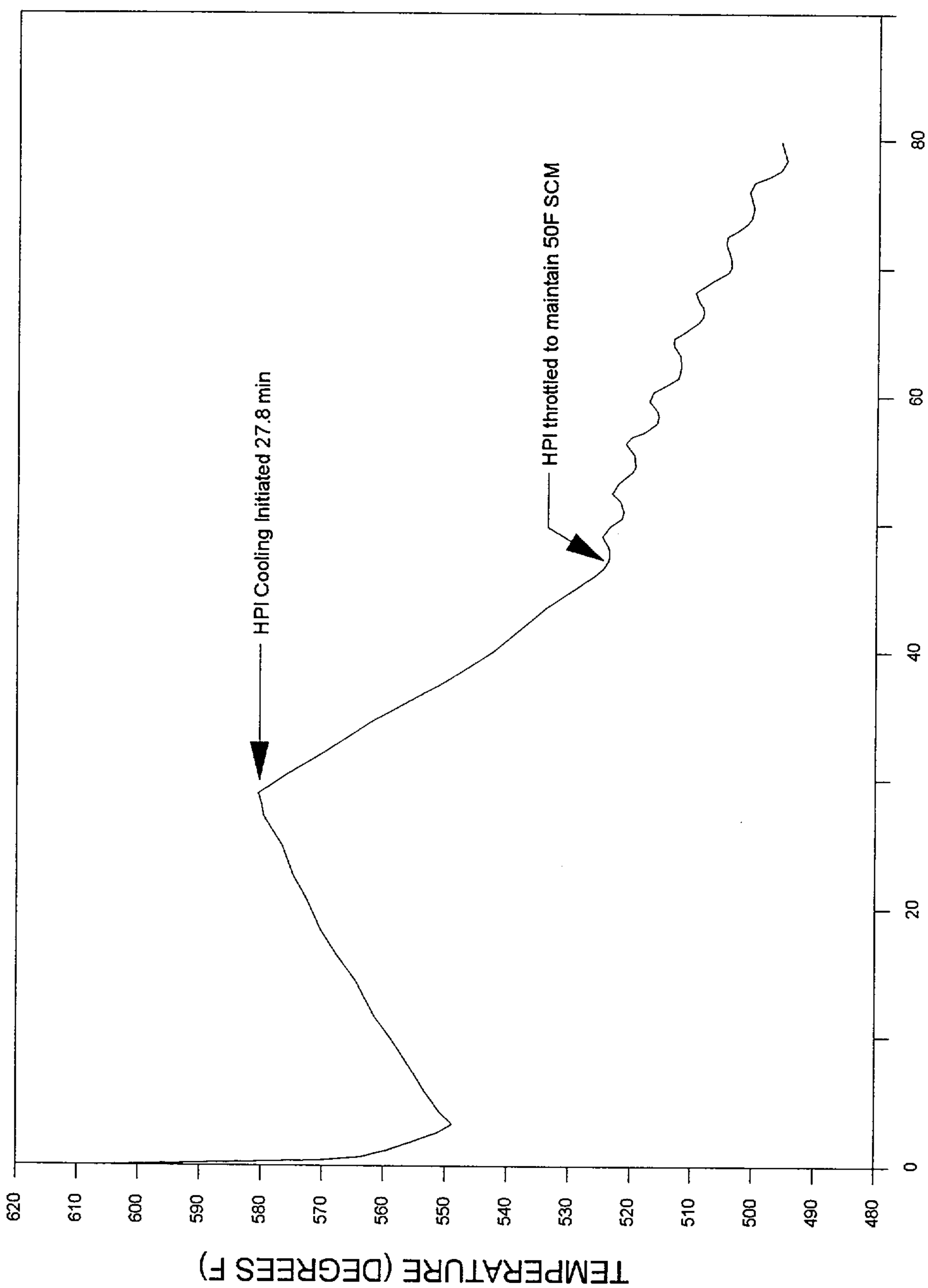
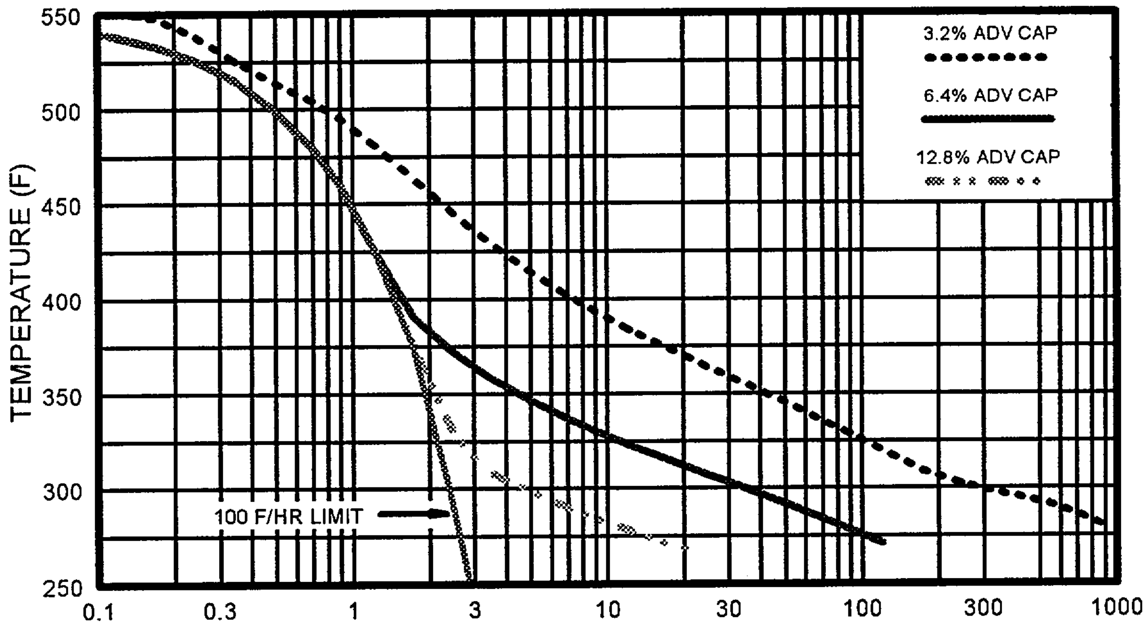
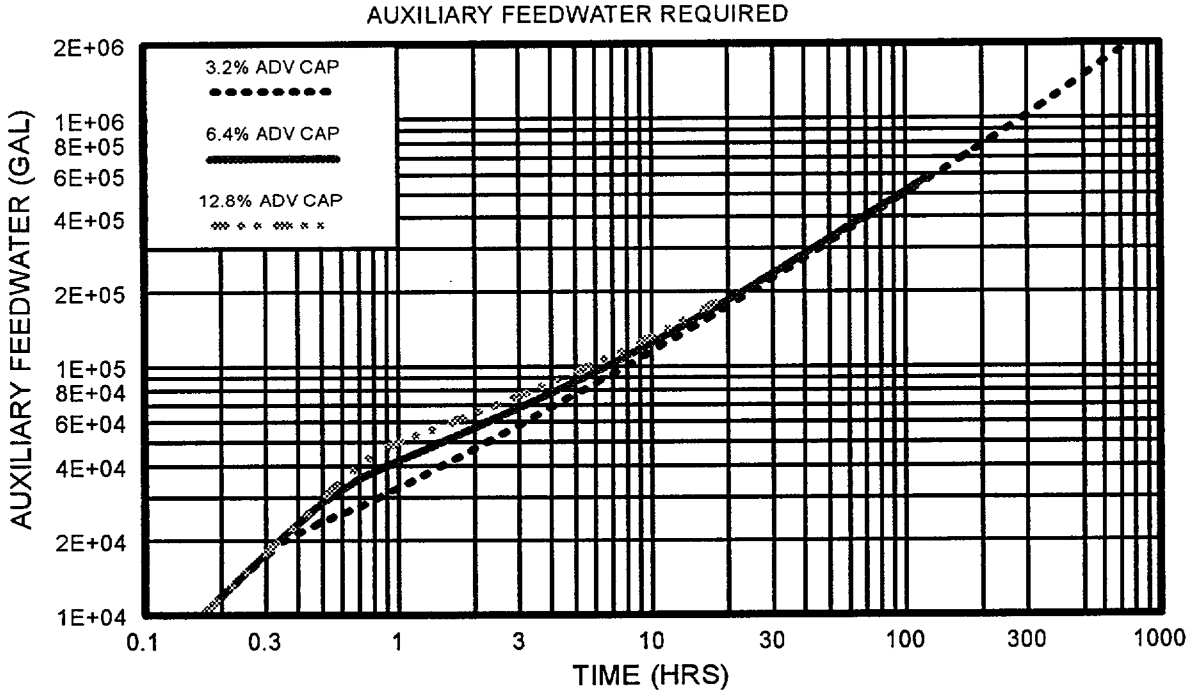


FIGURE III.G - 14 NATURAL CIRCULATION COOLDOWN TIME AND CONDENSATE REQUIREMENTS

NATURAL CIRCULATION COOLDOWN
PRIMARY SYSTEM TEMPERATURE



NATURAL CIRCULATION COOLDOWN
AUXILIARY FEEDWATER REQUIRED



Chapter III.H

Reactor Building Control

1.0 INTRODUCTION

This chapter provides technical guidelines for Reactor Building Control during abnormal transients (applicable to large dry containments).

1.1 Concerns and Objectives

1.1.1 Concerns

Two basic concerns regarding Reactor Building Control are:

- Maintaining Adequate Core Cooling

  Inadequate Core Cooling (ICC) can cause excessive amounts of hydrogen, radiation and energy to be released to the Reactor Building. This will place added demand on Reactor Building Control equipment and operator actions. Consequently, the best way to avoid this added demand is to provide adequate core cooling.

- Isolating a Steam Generator with a Broken Steam or Feedwater Line Inside the Reactor Building

  Feed and steam lines of the affected steam generator should be isolated as quickly as possible to limit mass and energy release to the Reactor Building.

1.1.2 Objectives

The two basic objectives of Reactor Building control are:

- Provide Reactor Building Isolation Control to limit the radiation released from the Reactor Building and

- Provide Reactor Building Environmental Control to reduce the Reactor Building pressure, temperature, hydrogen, and gaseous radiation and to control the Reactor Building Emergency Sump water chemistry and level.

2.0 DIAGNOSIS AND CONTROL OF THE REACTOR BUILDING DURING ABNORMAL TRANSIENTS

This section summarizes the recommended guidance to be used in dealing with abnormal Reactor Building conditions. Figure III.H-1 provides a basic action decision logic chart. These actions are performed when needed and concurrent with other abnormal transient mitigating actions.

This Reactor Building Control guidance applies whenever abnormal Reactor Building conditions exist or are anticipated.

Abnormal Reactor Building conditions are indicated by:

- Abnormally high Reactor Building pressure
- Abnormally high Reactor Building temperature
- Abnormally high Reactor Building radiation

Abnormal Reactor Building conditions are anticipated by:

- Low RCS pressure ES actuation
- Performing operator actions which will create abnormal Reactor Building conditions.

Reactor Building Control is a two phase process, the Reactor Building is isolated and the Reactor Building environment is controlled as needed.

Reactor Building isolation is done first because it is directly associated with the primary function of the Reactor Building which is to contain radiation.

2.1 Reactor Building Isolation Control

Reactor Building isolation control actions are required if any of the following conditions occur:

- High Reactor Building pressure
- Low Reactor Coolant System pressure
- High Reactor Building radiation

In addition, the need for Reactor Building Isolation Control should be considered when performing an action which could create these conditions and if warranted, then the Reactor Building should be isolated. Two examples of actions which could cause these conditions are sustained opening of RCS high points vents and initiating HPI cooling.

The parameter values and instrumentation used to indicate these conditions are plant specific and therefore, are not provided in this text.

The Reactor Building Isolation Control actions are plant specific. However, in general, they are as follows and may be automatic or manual:

- Operate the Reactor Building Isolation System to:

  Isolate non-essential Reactor Building penetrations and

  Selectively operate essential Reactor Building penetrations.

- Start Reactor Building Leakage Ventilation Systems

These actions are for preventing and controlling radiation leaving the Reactor Building through fluid system penetrations and to process radiation leaking through non-fluid system penetrations.

2.2 Reactor Building Environment Control

Reactor Building Environment Control actions are required if any of the following conditions occur:

- high and high-high Reactor Building pressure
- high Reactor Building temperature
- high Reactor Building radiation
- high Reactor Building hydrogen
- high or low Reactor Building Emergency Sump level
- low Reactor Building Emergency Sump water pH
- low Reactor Building Emergency Sump water boron concentration

The parameter values and instrumentation used to indicate these conditions are plant specific.

If any of these conditions occur, appropriate actions must be taken to return the parameter to within acceptable limits. The specific limits and actions to be taken depend on the plant design. However, in general, the following actions are taken:

- If the Reactor Building temperature is high or the RB pressure is high or high-high, then:

  a. operate the Reactor Building Heat Removal Systems to remove energy and iodine from the Reactor Building The RB coolers are started on high RB pressure and/or temperature The RB Spray is started on high-high RB pressure

  b. reduce the amount of energy being released to the Reactor Building

- If the Reactor Building Radiation level is high, then:

  a. a benefit of operation of the Reactor Building Coolers and Spray is the removal of some of the iodine and other airborne radiation from the Reactor Building atmosphere and

  b. limit the amount of radiation being released to the Reactor Building by providing adequate core cooling

- If the Reactor Building Hydrogen Concentration is high, then:

  a. operate the Combustible Gas Control System to maintain the hydrogen gas concentration below the flammability limit and

  b. limit hydrogen generation due to core metal-water reactions by providing adequate core cooling

- Maintain the Reactor Building Emergency Sump water level between acceptable high and low levels.

- Maintain the Reactor Building Emergency Sump water chemistry at appropriate pH and boron concentrations.

These control actions are to protect and to promote proper operation of the Reactor Building systems, components, and structures used for mitigating the abnormal transient.

Maintaining adequate core cooling reduces the amount of radiation in the Reactor Building available for leaking or emitting from the Reactor Building.

Some of the actions stated above will affect more than one of the Reactor Building parameters. For example:

- Operating the Reactor Building coolers and fans will decrease the Reactor Building pressure and temperature while also reducing the amount of Reactor Building airborne radiation.

- Operating the Reactor Building Spray will reduce Reactor Building temperature and pressure. It is the condensation of steam, caused by Reactor Building Spray that reduces the Reactor Building pressure. This causes a decrease in the partial pressure of the steam with no attendant decrease in the partial pressure of the H2. Thus operation of Reactor Building Spray, can cause an increase in the relative H2 concentration.

3.0 REACTOR BUILDING CONTROL TECHNICAL BASES

This section provides bases for Reactor Building Control limits and actions.

Instrumentation used to monitor Reactor Building parameters should be capable of operating in a post-accident environment.

3.1 Reactor Building Isolation Control

The Reactor Building must be isolated when conditions exist for a potentially abnormally high radiation release from the Reactor Building. The Reactor Building isolation actions consist of the following:

- Operating the Reactor Building Isolation System to:

Isolate non-essential Reactor Building penetrations i.e. those which are not essential to the mitigation of the abnormal transient and

Selectively open and close essential Reactor Building penetrations as needed for mitigation of the abnormal transient.

- Start Reactor Building Leakage Ventilation Systems.

A potential for abnormal radiation release from the Reactor Building exists and the Reactor Building must be isolated when any of the following conditions exist:

- High Reactor Building Pressure Condition

- The Reactor Building pressure is the driving force which pushes the radiation containing gases and liquids out of the Reactor Building. Consequently, as the Reactor Building pressure increases, the leak rate of radioactive materials will increase.

The Reactor Building pressure for initiating Reactor Building isolation should be as low as permitted by normal operating conditions, i.e., so the value is not exceeded during normal pressure variations and considering instrument inaccuracies.

- Low Reactor Coolant System Pressure Condition

  A low Reactor Coolant System pressure indicates a possible LOCA. The LOCA is the one abnormal transient which can cause both high Reactor Building radiation and high Reactor Building pressure.

  The RCS pressure for initiating Reactor Building isolation should be a value indicative of a LOCA, but should not be a value exceeded during normal RCS transients and should consider instrument inaccuracies.

- High Reactor Building Radiation Condition

  If the radiation level in the Reactor Building is too high then any gas or liquid leaking from the Reactor Building may contain excessive radiation per standard volume of leakage. Therefore, a small amount of leakage can give a large release of radioactive material.

  The radiation level for initiating Reactor Building isolation should be set at a value that is not exceeded due to normally expected variations in background radiation and instrument inaccuracies.

3.1.1 Isolate Non-Essential Penetrations

Each Reactor Building penetration should be classified as either one used by an essential fluid system or one used by a non-essential fluid system. The Reactor Building Isolation System, should be designed to automatically isolate all non-essential fluid system penetrations. The Isolation System monitors the Reactor Building pressure and Reactor Coolant System pressure. It may or may not monitor Reactor Building radiation. However, any system lines which provide an open path from the Reactor Building to the environs, such as purge and vent lines, should be equipped with a radiation monitor to automatically isolate the penetration on high radiation. Consequently, the Isolation System should automatically isolate the non-essential fluid system penetrations if a high Reactor Building pressure or if a low Reactor Coolant System pressure limit is reached. Reaching a high Reactor Building radiation limit may or may not cause automatic isolation. However, if only a high Reactor Building radiation limit is reached for an Isolation System not designed to isolate on a high radiation limit or if the Isolation System fails to operate automatically, then the operator must manually isolate the non-essential Reactor Building penetrations.

If an automatic Reactor Building isolation valve does not close, the operator should apply a manual signal to close the valve. If the manual signal does not close the valve, then check its redundant isolation valve to see if it has automatically closed. If at least one valve has closed for each Reactor Building penetration, then no other immediate action is required. If both valves on a penetration fail to close, then follow the system pipe out from the penetration to the next remotely controlled valve (or manual valve if readily accessible) and close it.

3.1.2 Selectively Operate Essential Penetrations

The essential fluid systems include Engineered Safety Features Systems, systems needed for safe shutdown of the plant, and other fluid systems which are essential to abnormal transient mitigation.

During and after abnormal transients, the operator will need to use essential fluid systems which penetrate the Reactor Building to mitigate the abnormal transient. The essential penetrations may be initially open or closed or may be automatically opened or closed depending on the function of the associated system. Consequently, the operator may have to selectively operate the Reactor Building Penetration isolation valves as he chooses between the need to isolate the Reactor Building penetration and to operate the fluid systems. Reactor Building penetrations should be opened on a valve-by-valve or a line-by-line basis while monitoring for penetration leakage outside the Reactor Building. The specific penetrations and actions depend on the plant design. Some examples of when opening or closing penetrations would be desirable are as follows:

- The RC pumps will be manually tripped if a loss of subcooling margin occurs and the RC pump auxiliary systems may become automatically isolated. A RC pump bump or restart (if restart criteria of IV.A are met) may eventually be desired. However, RC pumps should not be bumped or restarted until the RC pump auxiliary systems are reestablished. Re-establishing the services as soon as possible, rather than waiting until the RCP is needed, may be desirable to help protect the RC pump.

- Cooling water may have to be reestablished to the letdown coolers before letdown flow is reestablished for RC inventory control and boron measurements.

- The Reactor Building Emergency Sump lines may need to be opened during a LOCA to provide core recirculation flow with the LPI system.

- The DHRS suction line from the RCS may need to be opened to provide long term cooling or to prevent boron precipitation.

- The cooling water lines to the Reactor Building Emergency Coolers remain open following a LOCA. Some of these penetrations would need to be isolated if a cooler should develop a significant leak because the cooling water is not borated and would dilute any borated water collected in the Reactor Building Emergency Sump.

- If a steam leak occurs inside the Reactor Building, the operator may need to stop feedwater flow to the leaking Steam Generator to prevent excessive mass and energy release to the Reactor Building. Although the steam leak can cause Reactor Building isolation on high pressure, radioactive fluid is not added to the Reactor Building as with a LOCA. Consequently, Reactor Building isolation due to a steam leak inside the Reactor Building does not carry the same offsite release significance that it does for a LOCA.

- The cooling water to the Pressurizer Quench Tank could be reopened to remove tank energy if a Pressurizer relief or safety valve discharge causes the Quench Tank temperatures to increase.

3.1.3 Starting Reactor Building Leakage Ventilation Systems

The Leakage Ventilation System collects and processes leakage from the Reactor Building. Consequently, this system should be started or verified operating whenever a significant positive pressure exists in the Reactor Building which could potentially force Reactor Building leakage. These systems can include penetration room fans, auxiliary room fans and filters, etc.

3.2 Control The Reactor Building Environment

After an abnormal transient, the environment inside the Reactor Building needs to be controlled to reduce and/or eliminate failures of equipment, systems, and structures (including failure of the Reactor Building) required to control the environment and to mitigate the abnormal transient. Reactor Building Control requires controlling the following parameters to bring them within acceptable limits:

- Reactor building pressure and temperature
- Reactor building radiation
- Reactor building hydrogen
- Reactor building emergency sump level
- Reactor building emergency sump chemistry

3.2.1 Reactor Building Pressure and Temperature Control

Water mass and energy is released to the Reactor Building during a loss-of-coolant accident (LOCA) or a Secondary System break inside the Reactor Building. This release can cause the Reactor Building pressure and temperature to increase.

This elevated Reactor Building pressure and temperature can cause:

- The design pressure and temperature of the Reactor Building and equipment to be exceeded.
- The driving force (i.e., RB pressure) for Reactor Building leakage to increase.
- Degradation of equipment in the Reactor Building.

Consequently, the Reactor Building pressure and temperature must be controlled to bring it within acceptable limits.

The Reactor Building pressure and temperature is controlled by the Reactor Building Heat Removal Systems. These systems remove heat from the Reactor Building causing a simultaneous reduction in Reactor Building pressure and temperature, i.e., if the temperature is reduced the pressure will also be reduced and vice versa.

When mass and energy is released to the Reactor Building by a LOCA or a Secondary System break inside the Reactor Building, the steam released will expand, cool and depressurize. In contrast, the Reactor Building air will heat up and pressurize. The decreasing steam temperature and increasing air temperature will come to equilibrium at a common temperature. This temperature and the Reactor Building volume will determine the initial Reactor Building pressure. The pressure will be the sum of the partial pressure due to air and the partial pressure due to the steam. The Reactor Building pressure and temperature will continue to increase until the energy release is stopped or the Reactor Building Cooling Systems start removing as much energy as is being added.

The Reactor Building Heat Removal System is started either automatically or manually. The Reactor Building Heat Removal System is comprised of the Reactor Building Emergency Coolers and the Reactor Building Spray System.

If a high Reactor Building pressure or high temperature limit is reached, the Reactor Building Emergency Coolers should be operated to cool and depressurize the Reactor Building atmosphere.

If the Reactor Building Emergency Coolers do not keep the Reactor Building pressure below a predetermined high-high pressure limit, then the Reactor Building Spray System should be started to cool and depressurize the Reactor Building atmosphere.

The Reactor Building Spray System flow should be stopped as soon as both the Reactor Building pressure/temperature reduction and the iodine removal objectives (if applicable, see section 3.2.2 on RB Radiation Control) have been met.

Ambient heat losses from the Reactor Building will inherently assist pressure reduction but the effect is small and cannot be expected to mitigate pressure increases caused by rapid energy releases.

In addition to removing energy from the Reactor Building, the amount of energy being added to the Reactor Building should be limited by actions such as:

- Minimizing feedwater addition to a steam generator which has a break inside the Reactor Building. The need for core cooling, which takes precedence, may require adding feedwater to a steam generator.

- Increase the heat removal by the LPI cooler (if in operation).

- Increase the heat removal by the steam generators (if possible).

- Isolate any break in the RCS if possible.

The operator should rely on Reactor Building heat removal systems to reduce pressure. Do not attempt to reduce Reactor Building pressure by opening Reactor Building purge valves. The valves may not operate at a high differential pressure and if they do, they may not close which could release large quantities of radioactive material after a LOCA. Contrary to a LOCA, a steam line break inside the Reactor Building is not expected to release radiation, however, a steam line break should not increase the pressure enough to reach the design pressure limit, so there would be no desire to open a purge valve after a steam line break. If the Reactor Building Heat Removal System operates properly in large dry Reactor Buildings, then there is only a low probability for the Reactor Building ultimate capacity for pressure temperature loads to be exceeded per NUREG 1037. Consequently, opening a purge valve to limit pressure is considered unnecessary.

When the BWST empties, the suction for the Low Pressure Injection and the Reactor Building Spray Systems will need to be switched from the BWST to the Reactor Building Emergency Sump. This re-configuration can cause some perturbations in RB pressure and temperature and in RCS cooling. The sump water will be considerably warmer than the BWST water and the available NPSH for the RB spray and LPI pumps will be less than the NPSH provided by the BWST. These factors will reduce the effectiveness of RB spray somewhat and, even with the DHR coolers on line, may increase the temperature of the LPI entering the vessel. This may result in an initial increase in RB temperature and pressure.

However, energy removal from the RB will increase following switchover to the sump. Before switchover, the LPI was adding mass to the RB and all of the mass and energy release due to the break was being contained in the RB except for the heat removal by the RB coolers. Following switchover, the LPI coolers will begin to remove energy from the RB by cooling the sump water before reinjection to the vessel. The RB coolers are also more efficient at higher temperatures. When the Reactor Building pressure increases above a certain plant specific value the Emergency Cooling Fan motor speed may have to be reduced. This action, which may be automatic, is to prevent over heating the fan motor by circulating the Reactor Building atmosphere which has been made denser by the increased pressure due to the addition of water vapor from the LOCA or steam line break.

When the suction for the Reactor Building Spray System is switched from the BWST to the Reactor Building Emergency Sump, the Spray pump discharge flow rate may have to be throttled to satisfy NPSH requirements of the spray pump. This is due to a decrease in the elevation head of suction fluid and/or an increase in the vapor pressure of the suction fluid. This is a plant-specific requirement. LPI flows, and HPI flows if in piggyback operation, should also be verified and adjusted as necessary following switchover to the sump.

3.2.2 Reactor Building Radiation Control

The objective of Reactor Building radiation control is to limit the radiation released to the Reactor Building and to keep the radioactive materials which leak from the RCS out of the Reactor Building atmosphere and in the Reactor Building sump water.

If a high Reactor Building radiation level is reached, the Reactor Building Cooler System is started to reduce the radiation in the RB atmosphere. This action will impact radiation particles onto the cooler surfaces and condense the Reactor Building steam such that radioactive materials are washed into the emergency sump water. The effect is to reduce airborne radiative materials available for leaking from the Reactor Building.

The Reactor Building Spray is required to start on high-high RB pressure and remain on until the RB pressure is reduced to a specified value in order to remove RB heat. If the RB Spray is also required for fission product removal (i.e. per Chapter 15 of the SAR), then, after starting on high-high RB pressure, the Reactor Building Spray System should re main operating until the iodine removal objective is also met (which may be 2 hours of continuous operation based on the two hour iodine dose limits at the site boundary). The RB spray should not be started except on high-high RB pressure condition in order to avoid equipment damage from the RB spray water. However, after the RB spray has been used to meet the RB heat removal and iodine removal objectives, then the RB Spray System can be operated as desired to remove fission products from the Reactor Building atmosphere.

Checks should be made for inadequate core cooling and appropriate actions to ensure core cooling should be made. The most important step in limiting the amount of radiation released to the Reactor Building is to provide adequate core cooling.

The noble gas nuclides -- primarily Kr-85, Kr-88, Xe-13lm, Xe-133m, and Xe-133 -- will always follow the steam and/or coolant flow and will accumulate wherever there is a gas phase, i.e., in the pressurizer steam space, in the makeup tank cover gas, or in the Reactor Building atmosphere. A significant fraction of all noble gas nuclides will be soluble in the reactor coolant while the system is at a high pressure, but the gas will rapidly leave the liquid phase upon depressurization. After 10 to 20 minutes at atmospheric pressure, less than a few percent will remain in solution. All noble gases are chemically inert, so there is no effective way to remove them other than to attempt to contain them and wait for decay. After a period of approximately 60-70 days, the remaining noble gas activity is so small that it no longer presents a significant offsite radiological risk.

Figure III.H-3 shows the response of the Reactor Building radiation monitors following a release of reactor coolant through a pressurizer safety valve. The release was terminated (safety valve closed) ~2 hours after initiation at time 0. There are several important observations that can be made based on this figure:

- The fuel handling bridge monitor was reading about a factor of 500 lower than the Reactor Building dome monitor. Apparently, the hot steam and air carry the activity to the top of the Reactor Building; thus, even though the bridge monitor and dome monitor are both exposed to large gas volumes in the Reactor Building there is not enough initial mixing to prevent radiation dose rates being several orders of magnitude different.

- The Reactor Building incore instrument area monitor responded to the decay of the N-16 activity immediately after reactor trip, then eventually climbed to correspond to the dome monitor reading. The decrease in both the dome monitor reading and the Reactor Building incore instrument area monitor reading corresponds to the mixing rate provided by the Reactor Building fan-coolers (there were 3 fans in operation at half speed).

- The core was properly cooled so that no core damage occurred. However, sufficient radioactive material was released to cause a significant change in the Reactor Building radiation monitor readings.

- The Reactor Building radiation had significant concentration gradients which lasted for several hours and therefore the assumption of a well mixed building atmosphere cannot be justified on the basis of the fan-cooler operation until several hours after a LOCA. The decrease in both the dome monitor reading and the RB incore instrument reading corresponds to the mixing rate provided by the RB fan coolers.

Iodine Behavior

The behavior of iodine nuclides (primarily I-131, I-133, and I-135) is complicated by the fact that the iodine can exist in several different chemical forms, each of which has somewhat different behavior characteristics.

Elemental iodine in a dry environment is very volatile at all temperatures above room temperature. If water is present, the elemental iodine will quickly react with it in the following manner:

$I_2 + H_2O \rightarrow H^+ + I^- + HOI$

$3HOI \rightarrow 3H^+ + 2I^- + IO_3$

The first of these reactions is very rapid; the second is much slower. There are two things to note about these reactions:

- They produce hydrogen ions, which tend to make the solution more acidic, so the reaction will proceed more rapidly if the solution is alkaline (basic).

- If the reactions went to completion, there would be no iodine activity in the gas phase. In most reactor environments some iodine (0.01 to 0.1%) is always detectable in the gas phase, therefore, there is speculation that HOI (hypoidous acid) is somewhat volatile.

Sodium hydroxide may be added to the Reactor Building Emergency Sump water. This enhances the iodine removal rates because it raises the pH.

Whenever elemental iodine (I_2) becomes airborne as a vapor, it can be removed very quickly by the Reactor Building Spray. The removal half-life is approximately 2 to 3 minutes.

Charcoal filters can remove elemental iodine very effectively. Contamination from previous operating of the charcoal filters does affect the removal effectiveness to some degree, but in general the removal effectiveness remains high. If gross condensation of steam occurs in the charcoal bed, the pore structure of the charcoal will become clogged with water and the absorption effectiveness of the charcoal will be destroyed. (An important point to remember about charcoal is that it acts to lower the vapor pressure of materials passing through it; therefore, condensation could occur at relative humidities of about 90 percent.) Following a loss of coolant accident (LOCA), hydrogen gas may accumulate within the Reactor Building. If a sufficient amount of hydrogen is generated, it may react with the oxygen present in the Reactor Building atmosphere. This is a concern because the reaction could over-pressurize the Reactor Building or damage systems, components and structures used in mitigating the abnormal transient. Consequently, the hydrogen gas must be managed to limit these reactions.

3.2.3 Reactor Building Hydrogen Control

Following a loss of coolant accident (LOCA), hydrogen gas may accumulate within the Reactor Building. If a sufficient amount of hydrogen is generated, it may react with the oxygen present in the Reactor Building atmosphere. This is a concern because the reaction could over-pressurize the Reactor Building or damage systems, components and structures used in mitigating the abnormal transient. Consequently, the hydrogen gas must be managed to limit these reactions.

The significant hydrogen that can accumulate in the Reactor Building comes from:

- Metal-water reaction involving the zirconium fuel cladding and the reactor coolant.

  The amount of hydrogen produced by the metal water reaction is a function of the ECCS performance. The ECCS is designed to limit the fuel element cladding temperature to 2200°F per 10CFR50.46. This will limit the amount of metal-water reaction which will occur. The amount was determined to be .53% for raised loop plants and .56% for lower loop plants. This is less than the limit, specified in 10CFR50.46. The limit is 1% of the hypothetical amount that would be produced if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react.

However, if the ECCS does not adequately cool the core, the quantity of hydrogen produced by the metal water reaction can be significantly larger causing it to be the major source of hydrogen in the Reactor Building and to be produced very quickly.

- Radiolytic decomposition of the post-accident emergency cooling solutions.

  The radiolytic decomposition will occur in the coolant adjacent to the core and in the Reactor Building sump. This is a relatively slow process as illustrated in Figure III.H-4. This figure shows a calculated hydrogen increase due to radiolytic decomposition in a typical Reactor Building following a maximum hypothetical accident.

- Corrosion of metals by solutions used for emergency cooling or Reactor Building Spray.

  The metals from which corrosion contributes significantly to hydrogen production are aluminum and zinc. The zinc can be from cable trays, duct work, galvanized surfaces and zinc base paints. Aluminum can be from the CRDMs and other equipment. This is a relatively slow process requiring over a week to produce a significant amount.

The hydrogen reactions in the Reactor Building are limited by keeping the volume percent of hydrogen in the Reactor Building atmosphere to a value below which the hydrogen reacts, i.e., burns. The lower flammability limit is 4 volume percent hydrogen in an air-hydrogen mixture. For a concentration of hydrogen greater than about 6 volume percent, it is possible for the total accumulated hydrogen to burn. For hydrogen concentrations in the range of 4 to 6 volume percent, partial burning is more likely because in the 4 to 6 percent range the rate of flame propagation is less than the rate of rise of the flammable mixture. Therefore, the flame can propagate upward but not horizontally or downward. Consequently only a fraction of hydrogen will burn.

A LOCA also adds steam to the Reactor Building atmosphere. The steam dilutes the air-hydrogen mixture causing the flammability limit for a volume percent of hydrogen to increase as shown in figure III.H-2. Above approximately 55% volume steam no hydrogen burn will occur.

As required by 10CFR50.44, "Standards for Combustible Gas Control System in Light Water Cooled Power Reactors," equipment is available for:

- measuring the hydrogen concentration in the Reactor Building

- insuring a mixed atmosphere in the Reactor Building and

- controlling the combustible gas concentration in the Reactor Building.

When hydrogen could be present in the RB, as a result of a LOCA, the hydrogen monitor should be verified as operating or be placed in service. The hydrogen monitor is used to measure the volume percent of hydrogen in the Reactor Building atmosphere. Reactor Building hydrogen samples are dried so that only the air and hydrogen content of the Reactor Building air-steam-hydrogen mixture is analyzed. Therefore, the hydrogen monitor will indicate a conservatively high % volume of hydrogen, i.e., if the steam volume is removed from the sample then the % hydrogen volume of the sample increases. Therefore, the Combustible Gas System may be started earlier than needed but that would be conservative. The Reactor Building Hydrogen concentration should be periodically analyzed following a LOCA to determine the quantity and rate of hydrogen accumulation in the Reactor Building.

Measurements of the hydrogen concentration can be used to determine when hydrogen removal will be necessary and what capacity will be required. This information is especially important for determining when a portable hydrogen recombiner must be obtained, to determine how early the hydrogen removal process must be started to prevent the peak hydrogen concentration from exceeding the flammability limit and to determine how long a Reactor Building hydrogen purging operation can be post-poned to allow for radioactive decay of the Reactor Building atmosphere.

The Reactor Building atmosphere is mixed by the Reactor Building cooler fans and/or recirculation fans. The Reactor Building atmosphere should be mixed to disperse any localized high concentrations of hydrogen and to create a homogeneous mixture for sampling and purging of the Reactor Building atmosphere. Homogeneous mixing of the RB may take several hours, therefore, mixing should start immediately after a LOCA has occurred. Figure III.H-3 shows that it took several hours to mix the radioactivity in the Reactor Building atmosphere following an actual HPI cooling event and is also a good indication of how long it can take to mix the hydrogen.

The Combustible Gas Control System can consist of a combination of hydrogen recombiners, a hydrogen purging system and a Reactor Building Repressurization System. The Combustible Gas System is designed to maintain the Reactor Building Hydrogen Concentration below the flammability limit during a LOCA. The flammability limit should be 4 volume % hydrogen concentration if burning is to be avoided when more than 5 volume % oxygen is present. This flammability limit may be increased to 6 volume % with the assumption that the 2 volume % excess would burn in the Reactor Building if the effects of the resultant energy and burning do not create conditions exceeding the design conditions of either the Reactor Building or the safety equipment necessary to mitigate the consequences of the LOCA.

The amount of metal-water reaction produced hydrogen which the Combustible Gas Control System was designed to accommodate was based on the design criteria of 10CFR50.44 "Standards for Combustible Gas Control System in Light Water Cooled Power Reactors." The criteria states the assumed metal-water hydrogen production should be 5 times the maximum calculated reaction under 10CFR50.46 (which assumes the hydrogen produced in 2 minutes of metal-water reaction from either 5% of the cladding or that amount that would be evolved from a core-wide average depth of reaction into the original cladding of .00023 inch, whichever is greater). Although this assumes a more degraded condition of the reactor core than the ECCS design basis permits, it does not involve a total failure of the ECCS. Therefore, the metal-water hydrogen production could be much larger, exceeding the capacity of the Combustible Gas Control System, if the ECCS failed to meet design requirements.

When using a Repressurization System to dilute the hydrogen concentration, the Reactor Building pressure must not be re-pressurized beyond 50 percent of the Reactor Building design pressure as required by 10CFR50.44. This limit is specified because any pressure increases resulting from a hydrogen burn will be added to the existing pressure in the Reactor Building, and the Reactor Building leak rate will increase with increasing Reactor Building pressure.

When using a hydrogen purge system the resulting radiation release should not exceed the radiation limits specified in 10CFR50.44 for all points beyond the exclusion area boundary and at the low population zone outer boundary. Consequently, purging should be monitored and should be slowed or stopped if the radiation release rate exceeds permissible values. Do not operate the hydrogen purge system unless environmental conditions are within the design limits of the hydrogen purge system. This is to preclude the hydrogen purge valves failing open because their design limits are exceeded which could create an unisolable flow path from the Reactor Building atmosphere to the outside atmosphere.

Using the Reactor Building spray can lead to combustible hydrogen concentrations. The relatively cold spray water can remove the steam in a hydrogen, steam and air mixture causing the volume percent of hydrogen to increase to the flammability limit. The Reactor Building Emergency Coolers will also remove steam from the atmosphere and, therefore, one could assume that their operation could also lead to combustible hydrogen concentrations as could the spray. However, the Reactor Building Heat Removal System should be operated since it will remove the energy produced by a hydrogen burn and the hydrogen burn in itself will help prevent the accumulation of large amounts of hydrogen which could cause worse damage if burned later in the transient.

If the hydrogen analyzer measures a hydrogen concentration below the flammability limit then spray operation should not cause a flammable mixture. This is because the

Hydrogen analyzer determines the percent volume of Hydrogen for a dry hydrogen-air-mixture (i.e. the hydrogen concentration with the steam removed.)

Hydrogen may accumulate at the high points inside the Reactor Coolant System. This hydrogen should be vented slowly if it is not interrupting core cooling. If the hydrogen was vented to the Reactor Building too rapidly, it could exceed the capacity of the Combustible Gas Control System. While the hydrogen is in the RCS it will not burn because the oxygen content is too small. Also while the hydrogen gas is in the RCS it will occupy a relatively small volume if the RCS pressure is kept high (e.g. 100,000 SCF occupies only 1228 FT^3 at 2200 PSIG and 450°F). However, the hydrogen gas can interfere with natural circulation Steam Generator cooling of the RCS if a sufficient amount is present to block the top of the RCS hot leg pipes. Adequate core cooling is more important than storing hydrogen in the hot leg pipes. In addition, inadequate core cooling can cause an increased generation of hydrogen.

Therefore, the RCS hot legs should be vented as necessary during natural circulation to minimize the potential of losing natural circulation due to gas buildup, and as necessary to restore natural circulation when no heat transfer exists. The pressurizer and an idle loop (while the other loop is providing adequate heat removal) may also be vented, but the venting should be performed slowly, while monitoring RB H2 concentrations, to prevent exceeding the capacity of the Combustible Gas Control System.

Reactor Building hydrogen purge systems use charcoal beds to remove radioactive particles. These particles will add heat to the charcoal as they decay. Consequently, the temperature of the charcoal beds will have to be monitored and if it gets too high the flow rate through the bed will need to be made continuous and/or increased to help cool the charcoal. This increased flow may require reducing the specific activity by diluting the flow with the outside air. The allowable charcoal bed temperature and cooling method is plant specific.

3.2.4 Reactor Building Emergency Sump Level

The sump water level should be maintained high enough for LPI or Reactor Building spray recirculation flow, but not so high that it submerges equipment important to core heat removal or Reactor Building control. The appropriate levels are plant specific. If the water level is too low, more borated water should be added. If it becomes too high consideration of lowering sump level should be made depending on the core cooling method being used (sump recirculation or DHR) and on the amount of radiation in the Emergency Sump Water.

If the Reactor Building Emergency sump level is too high and the Sump water radiation level is low enough, then the excess sump water may be drained from the Reactor Building using either the normal sump drain or Emergency Sump drain. The operator should also check for the cause of the excess water level. If other fluid systems are leaking into the sump, attempt to isolate them. These could be:

- Reactor Building emergency cooler cooling water
- Main or auxiliary feedwater
- Component cooling water
- Steam line

If the Reactor Building Emergency Sump water level is too low, then borated water should be added to the Reactor Building sump through the HPI or LPI flow.

The operator should check for the cause of the low level. The low level could be caused by a Steam Generator tube rupture, inadvertent pumping or draining from the sump or a break in the LPI or spray recirculation line outside the Reactor Building

3.2.5 Emergency Sump Chemistry Control

The Reactor Building Emergency Sump water boron concentration and pH should be maintained within acceptable values.

pH

The Reactor Building Emergency Sump water following a LOCA will be acidic due to the large amount of boron. The pH should be increased to at least a pH of 7.0 to reduce stress corrosion cracking and other adverse chemical effects. For long term iodine retention with no significant re-evolution, the equilibrium sump pH should be above 8.5. However, for pH values above 7.5, consideration should be given to increased rates of hydrogen production from corrosion of aluminum in the Reactor Building.

Boron

If the Reactor Building Emergency Sump boron concentration is low the operator should attempt to locate and correct the cause and increase the boron concentration if needed to maintain adequate core shutdown margin. Such possible causes are boron precipitation in the RCS or non-borated fluid systems leaking into the Reactor Building Emergency Sump. This could be:

- Reactor Building Emergency Cooler water leak
- Main or auxiliary feedwater leak

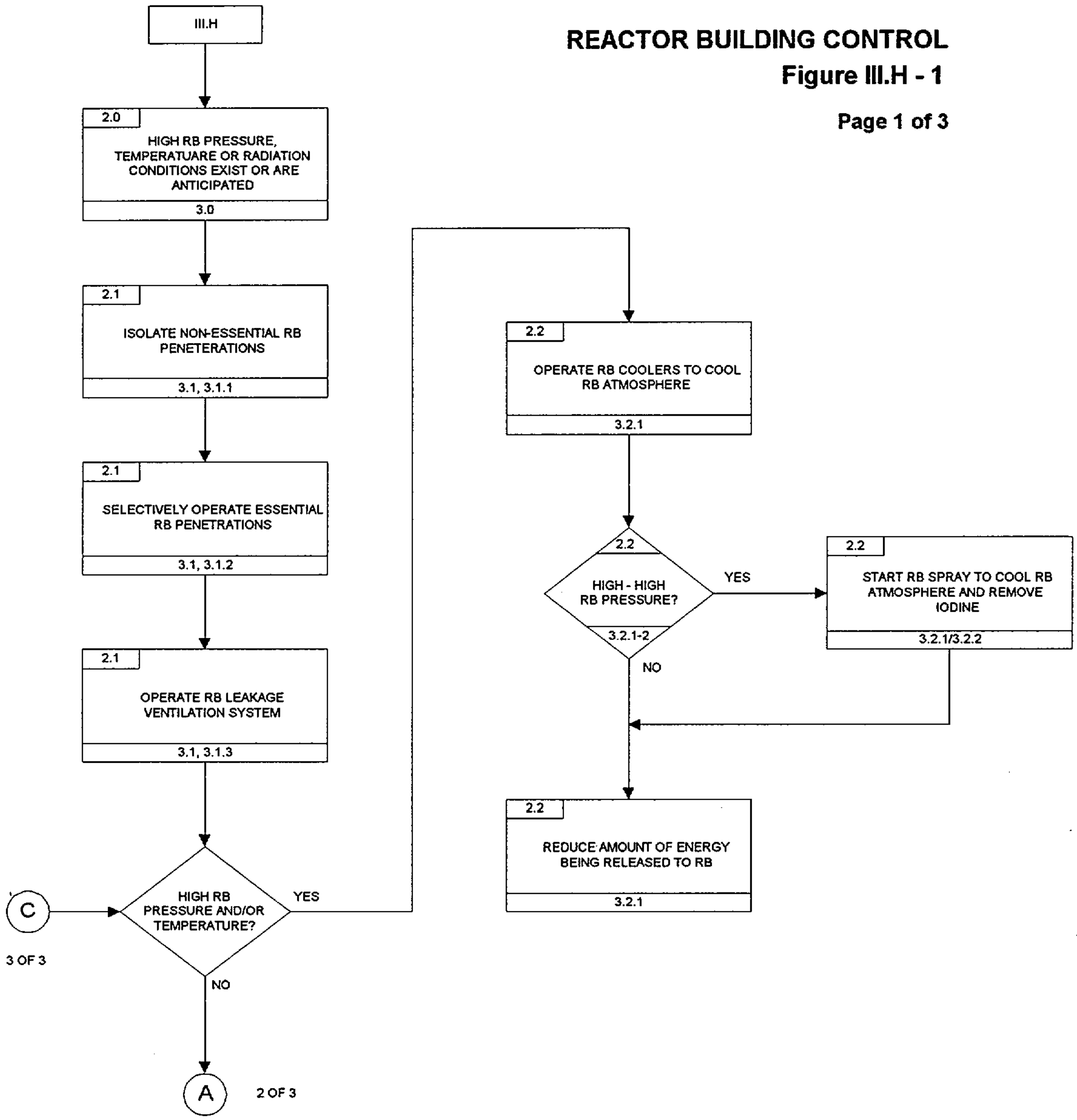
- Component cooling water leak

- Steam line leak

The Emergency Sump boron concentrations should not be increased if the decrease was due to boron precipitation in the core. This would aggravate the boron precipitation problem. This situation would be characterized by a decreasing boron concentration without an increase in sump water inventory. Should this occur, the operator should verify that the actions to prevent boron precipitation have been taken.

REACTOR BUILDING CONTROL
Figure III.H - 1

Page 1 of 3



REACTOR BUILDING CONTROL

Figure III.H - 1

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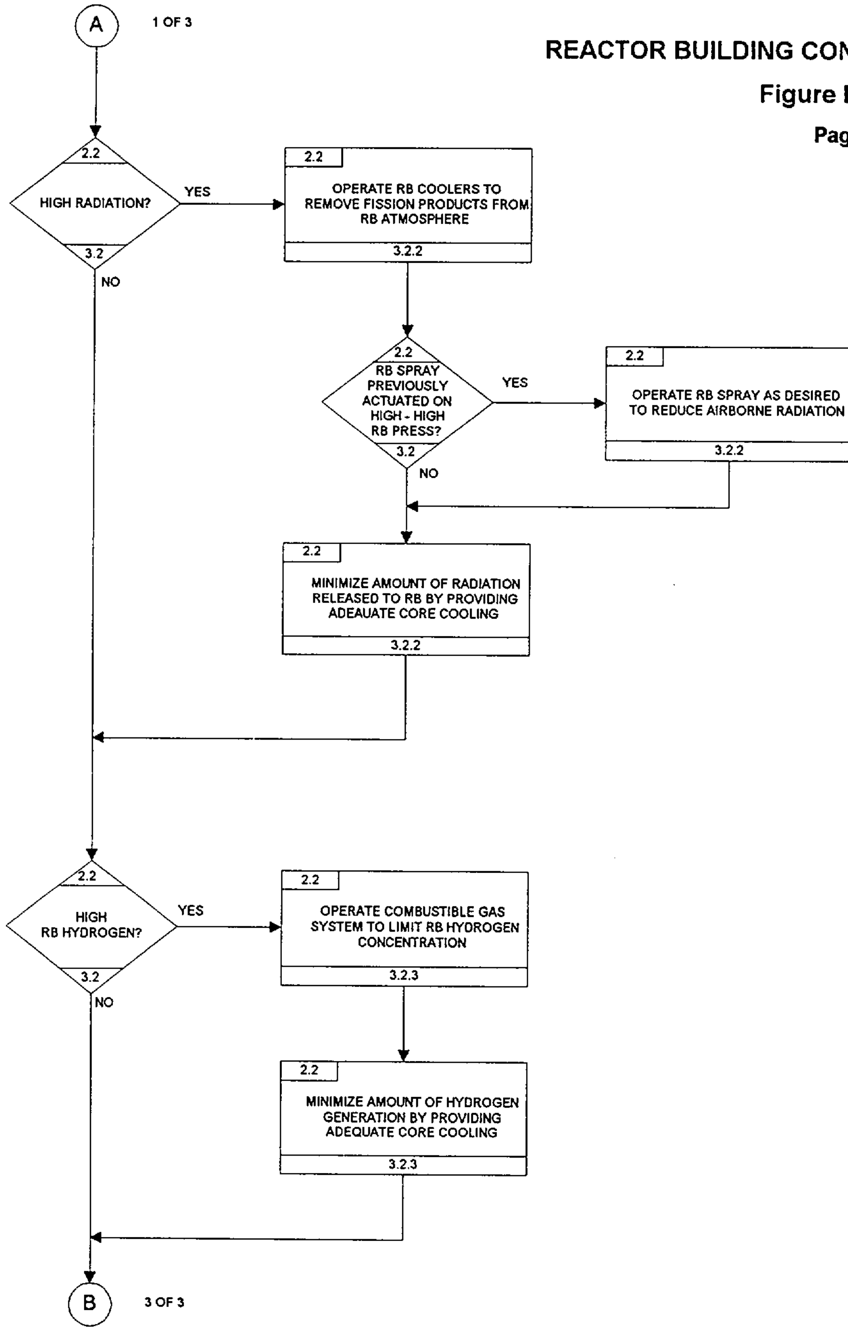

REACTOR BUILDING CONTROL

Figure III.H - 1

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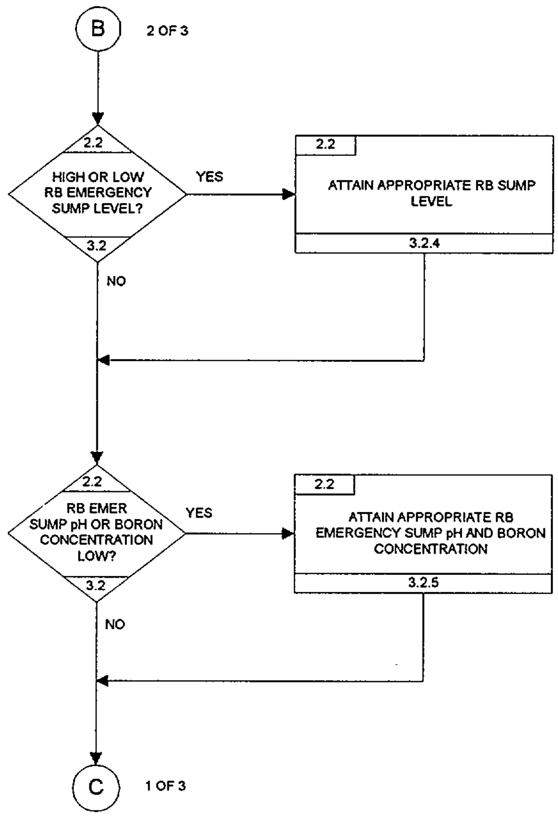


Figure III.H-2 Flammability Limits of Hydrogen, Air and Steam Mixtures

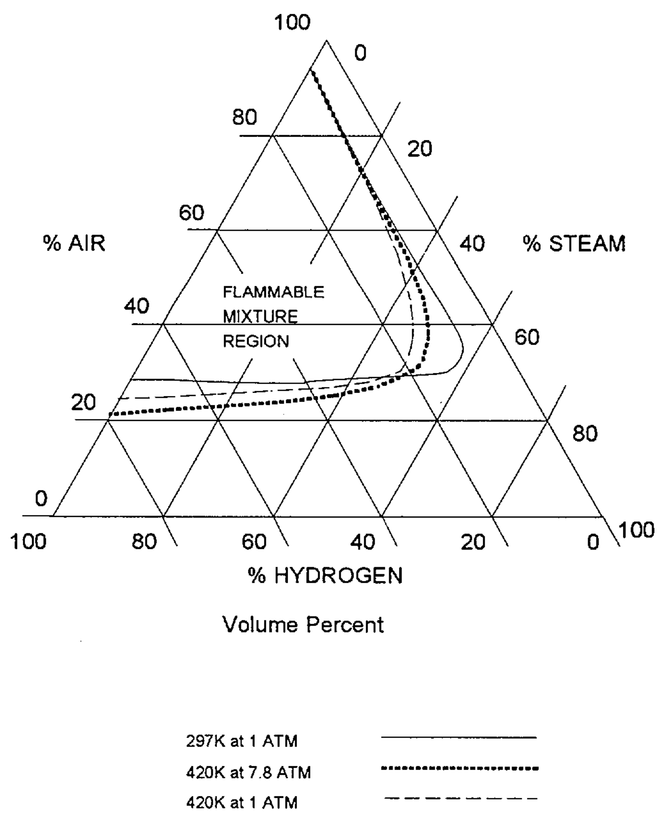


Figure III.H-3 Reactor Building Radiation Monitor
Response for Release Of RC
Through A Pressurizer Safety Valve

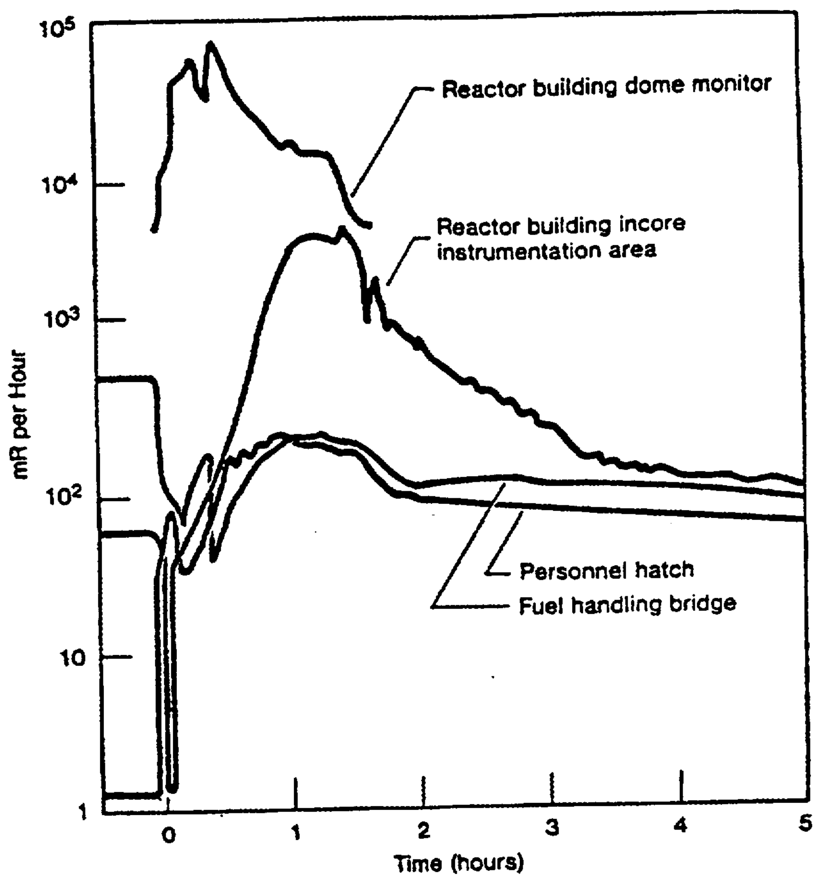
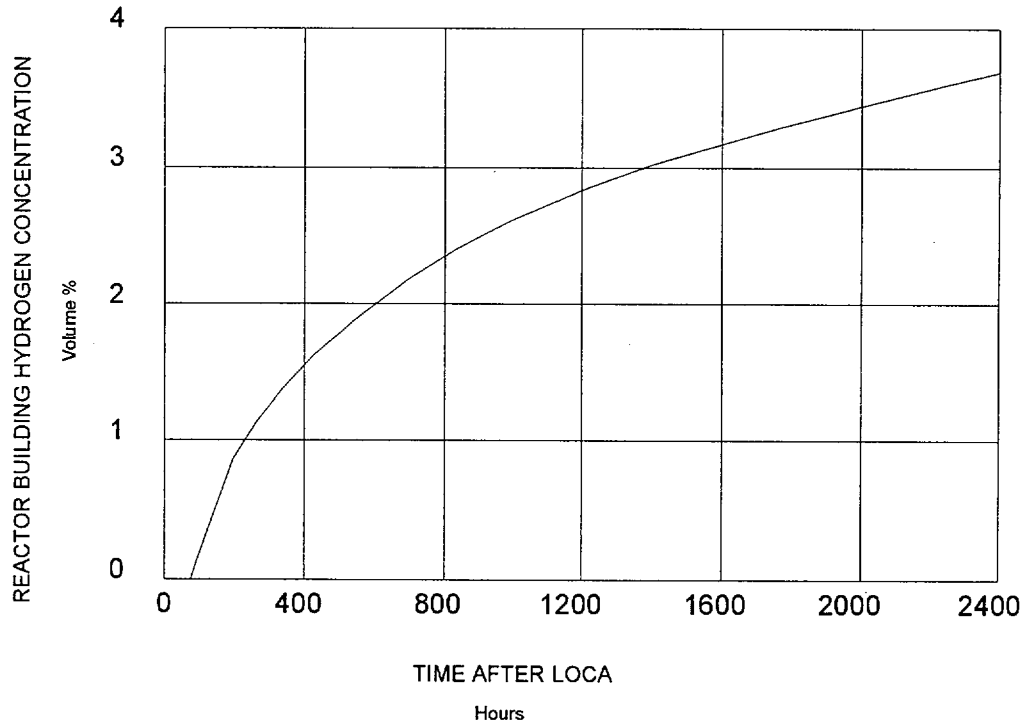


Figure III.H-4 Reactor Building Radiolytic Hydrogen Concentration Following A Maximum Hypothetical Accident

(Reactor Building Free Volume is 2 million cubic feet)



Part IV

EQUIPMENT OPERATION

IV.A
Reactor Coolant Pumps

1.0 INTRODUCTION

The following guidelines for RCP operation provide guidance on when to trip, restart or bump RCPs. Unless superceded by guidance in this document, normal RCP limits and precautions always apply.

2.0 RC PUMP TRIP GUIDELINES

The following guidelines state when and how many RCPs should be tripped.

2.1 Loss of Subcooling Margin

When the adequate SCM is lost, all RCPs must be tripped immediately. Because of the importance of tripping RCPs immediately upon loss of SCM, this action must be performed immediately, regardless of other circumstances (except, of course, that the reactor has been verified shutdown before entering actions for a loss of SCM). However, there are exceptions as discussed in section 2.2.

The reason for tripping all RCPs is as follows:

Analysis has determined that an early trip of RCPs is required to prevent possible core damage. This analysis used conservative Appendix K assumptions with the objective of meeting the requirements of 10CFR50.46. Using conservative Appendix K assumptions, it was shown that RCPs must be tripped within two minutes after losing SCM to prevent the RCS from evolving to a high enough void faction such that the core would be uncovered if the RCPs were tripped at a later time (using realistic assumptions, the maximum allowed time for tripping the RCPs was 10 minutes). This analysis showed that continued RCP operation could allow the RCS to evolve to a void fraction of 70% or greater if a certain range of break sizes were present. If the RCPs were tripped when the void fraction was 70% or greater, core uncovery would occur. Since RCP trip later in time cannot be absolutely prevented, it is necessary to trip RCPs before the RCS void fraction could increase to 70%. Once RCPs are tripped, the rate of loss of RCS inventory is reduced to the point where HPI (along with SGs in some cases) can keep the core covered.

The two-minute criterion is used in these guidelines rather than ten minutes for three reasons. First, the realistic analysis assumed full flow from two HPI pumps. For the scenario where both HPI pumps start but for some reason full HPI flow does not exist, the process of achieving and verifying full HPI flow may well take more than two minutes. If, in fact, full HPI flow cannot be obtained, then the risk of core uncovery exists if the RCPs are tripped later that two minutes. The second reason is the complexity and likelihood for confusion if the RCP criteria had both a 2-minute and a 10-minute criterion. Finally, the RCP trip on loss of SCM is expected to be an immediate action due to the potential consequences of not performing the trip when required and to eliminate/reduce time-based decisions. Use of a 10-minute criterion would detract from this intent.

2.2 Exceptions to RCP Trip Criterion

It is important to trip RCPs to minimize RC inventory loss as discussed in Section 2.1 and there are times when the RCPs would normally be tripped to prevent mechanical damage. However, there is one case when the RCPs must not be tripped: If the RCPs were not tripped immediately upon the loss of SCM, then they must be operated even though RCP damage is possible.

If all the RCPs are not tripped immediately upon loss of SCM (i.e., within two minutes) then it is possible, for a certain size small break, for a high void fraction to evolve in the RCS after that time. Tripping all the pumps at this later point in time could cause core uncovery and ICC. Consequently, the operator must make sure that cooling water and seal injection are supplied to the running RCPs to prevent RCP damage. These services must be maintained for several hours. To prevent mechanical damage to all the RCPs only two RCPs, one in each loop, should be operated. If they fail, the two pumps which were idle should be started even if mechanical damage is again likely. In this case, the running RCPs must be tripped if core conditions reach the Severe Accident Region of Figure III.F-1.

In addition, there is one case when the RCP(s) do not need to be tripped immediately. If SCM is lost immediately following RCP restart, then the RCP(s) do not need to be tripped immediately but must be tripped if SCM is not restored within two minutes. If SCM is lost when an RCP is restarted then the most probable cause for the loss of SCM is collapsing of a steam void and/or RC contraction rather than a concurrent LOCA. However, to account for the possibility of a simultaneous LOCA, the RCP(s) are required to be tripped if SCM is not regained within two minutes. The two minutes is based on the LOCA analyses as discussed in the previous section.

2.3 HPI Cooling

During HPI cooling the number of operating RCPs should be reduced to one. This will reduce the amount of RCP heat input to the RC. The operating RCP will provide thermal and chemical mixing of the RC. This is especially important for PTS concerns. Refer to Chapter IV.G for a discussion of PTS guidance. Operating the RCP allows normal RC loop Tcold to be used for maintaining RCS pressure temperature limits.

Depending on plant conditions, the RCS may continue to heat up. This will continue until HPI flow is sufficient to remove decay heat. In this case, RCS heating up, the last running RCP must be tripped before the SG tubes reach the compressive tube-shell ΔT limit (see Chapter III.C paragraph 2.3).

2.4 ICC

RCPs may be running during a cooldown following an ICC transient. In this case, whenever LPI has been flowing in each line at a rate in excess of the minimum required LPI flow rate listed in Chapter IV.B, any running RCPs should be secured.

2.5 RCS COOLDOWN

During RCS cooldown, 1 RCP should be tripped prior to decreasing RC temperature below the plant specific core lift limit. This action prevents movement of fuel assemblies that could occur from RC flow as its density increases during cooldown.

2.6 SG TUBE TO SHELL ΔT

In general, the RCPs should not be tripped due to reaching the SG tube-shell ΔT limits unless no other actions are available. This is especially true if at least one SG is available for heat transfer since the RCS cooldown rate should be sufficiently controllable to maintain the tubes in an idle SG within limits. Specific guidance on tripping RCPs based on SG tube-shell ΔT limits is provided in Chapter IV.K.

3.0 RCP RESTART OR BUMP

Benefits of Restarting or Bumping RCPs

There are several conditions where it may be beneficial to restart or bump RCPs. RCP operation provides the following:

- Helps to promote thermal and chemical mixing and better temperature indication.
- Helps to restart natural circulation (overcome thermal stratification).
- Restarts in the right combination may restore pressurizer spray which enables better control of RCS pressure.
- Allows faster cooldown.

However, the restrictions on RCP restart provided in Section 3.1 supercede when they apply.

3.1 RCP Restart/Bump Boron Dilution Considerations

This section, i.e., 3.1, 3.1.A, 3.1.B and 3.1.C, provides RCP restart/bump considerations associated with positive reactivity insertions. Other RCP restart/bump considerations are presented in section 3.2.

Certain transient conditions can result in localized boron dilution in the RCS. A restart of an RCP with sufficient localized deboration could result in a return to criticality. The conditions can develop whenever RCS voids exist. This discussion addresses deboration related RCP criteria in terms of RCP restart. However, the criteria also apply to RCP bumps.

There are three basic mechanisms that can lead to localized boron dilution during transient mitigation. First, during BCC, highly deborated water accumulates in the SG tubes, outlet plenum, and cold leg pump suction piping. Sufficient quantity to result in recriticality on pump restart can accumulate in 15 minutes or less of BCC operation. BCC can occur during SBLOCA mitigation and restoration of SG heat transfer following saturation due to either sustained loss of heat transfer or HPI cooling. Second, during SBLOCAs, the RV downcomer can become partially voided. HPI flow into the downcomer can condense steam exiting the RV vent valves, thus diluting the downcomer boron concentration. And third, RCS voiding (hot legs and RV head), which can occur due to SBLOCAs, sustained loss of heat transfer, single loop NC and/or HPI cooling, results in steam voids largely depleted of boron. An RCP restart can collapse voids by cooling in the SG tubes or by condensation by interaction with subcooled RC. The collapse of the void results in a quantity of relatively deborated water. A given void volume will produce smaller quantities of deborated water at lower RC pressures.

In addition to these three basic mechanisms, another positive reactivity insertion mechanism considered is the collapse of localized core boiling on RCP restart. Localized core boiling can exist even with the average core outlet temperature adequately subcooled. Replacing the localized voids with subcooled liquid following RCP restart inserts positive reactivity.

The criteria for RCP restart are primarily concerned with the three dilution mechanisms and the collapse of localized core boiling, although other factors are also considered. The criteria are conservative to preclude recriticality, and their application should also be conservative, i.e., <u>if in doubt, do not start an RCP</u>. The three mechanisms described above all require RCS voiding as a precursor. Therefore, the RCP restart criteria apply anytime that a loss of SCM has occurred. Additionally, the appropriate criteria apply whenever HPI cooling has occurred without forced flow, even if core exit SCM had not been lost, unless it can be determined that hot leg and RV head voids do not exist.

These RCP restart/bump criteria are based on the Davis Besse cycle 11 core design because it bounds current core loads in terms of excess positive reactivity, considering minimum allowable BWST concentration are critical boron concentrations. The criteria would require modification for any future core load that contains more excess reactivity than Davis Besse cycle 11. The applicability of the criteria must be verified at every reload.

3.1.A Criteria for RCP Restart/Bump Following Loss of SCM (other than HPI Cooling)

An RCP can only be restarted following restoration of SCM IF one of the following sets of conditions exist:

1. Stable, subcooled two-loop natural circulation has been verified to exist for at least 60 cumulative[a)] minutes AND

   Core exit subcooling (actual)[b)] is greater than or equal to 30°F[c)] AND

   RC pressure is greater than 200 PSIA[c)].

2. Stable, subcooled single-loop natural circulation has been verified to exist for at least 210 cumulative[a),d)] minutes AND

   Core exit subcooling (actual)[b)] is greater than or equal to 25°F AND

   RC pressure is greater than 150 PSIA AND

   HPI flow has been maintained greater than or equal to 900 GPM[d)] for the full 210[d)] minutes AND

   The RCP to be started must be in the loop with natural circulation.

NOTES

a) Continuous NC flow for the period is preferred, but cumulative is sufficient, provided SCM is not lost and no boron dilution mechanism occurs during the periods when NC cannot be verified. Verification of NC flow may be difficult if decay heat is very small or if a break or HPI cooling exists. If in doubt, assume NC does not exist.

b) Actual subcooling means the plant-specific minimum SCM value plus the additional subcooling specified; e.g., actual subcooling of 25°F would mean 55°F indicated subcooling if the plant-specific minimum SCM is 30°F.

c) The two-loop NC conditions of 30°F and 200 PSIA can be relaxed to 25°F and 150 PSIA if the RCP will not be started until at least two hours after reactor trip.

d) The time specified for single loop NC should be increased by a factor equal to the ratio of the required 900 GPM to the actual HPI average flow. For example, if the average HPI flow over the duration of single loop NC is 600 GPM, then the minimum time required for single loop NC should be increased to 315 minutes (210 x 900/600). However, if the actual average HPI has exceeded 900 GPM, then the minimum time should remain at 210 minutes.

These criteria are based on considerations associated with stable subcooled two and single loop NC. For stable subcooled two-loop NC the requirement for 60 cumulative minutes of verified NC flow in both loops ensures that at least one complete loop transport time has passed, even with low decay heat. The requirements for an actual subcooling of at least 30°F and an RC pressure of at least 200 PSIA ensure that subcooled localized core boiling does not exist. The relaxation of these requirements to 25°F and 150 PSIA at > 2 hours after trip accounts for the decrease in decay heat, and the attendant increase in the margin to core boiling.

For stable subcooled single-loop NC the requirements for 210 cumulative minutes of verified NC flow in one loop and a continuous HPI flow of at least 900 GPM ensure adequate boration of the active loop. When the RCP is started in the active loop, idle loop fluid will mix with active loop fluid in the RV outlet plenum. The idle loop fluid is assumed to be highly deborated, therefore the active loop must have a sufficiently high boron concentration prior to the pump start to preclude dilution to the point of recriticality after pump start. In addition, the time and HPI flow requirements ensure adequate boration for subsequent RC cooldown to < 70°F. The requirements for an actual subcooling of at least 25°F and an RC pressure of at least 150 PSIA ensure that subcooled localized core boiling does not exist. These criteria are relaxed from the two-loop criteria since the time requirement for cumulative single-loop NC ensures at least two hours have passed since the trip.

3.1.B <u>Criteria for RCP Restart/Bump During HPI Cooling</u>

The criteria for restarting an RCP during HPI cooling (i.e., HPI cooling, no LOCA) assume that SCM had been lost for a period of time following initiation of HPI cooling or that RCS voids exist.

1. A RCP may be restarted during HPI cooling <u>IF</u> all of the following conditions are satisfied:

   a. No SG having a loop void was fed while RCPs in that loop were off, <u>AND</u>

b. Core exit SCM exists, AND

c. RCS pressure is maintained per the following applicable values:

NO LOOP VOIDS	VOID IN ONE LOOP	VOID IN TWO LOOPS
< 2000 PSIA	< 700 PSIA*	< 500 PSIA*

* Subsequent RCP starts/bumps must adhere to these RCS pressure limits as long as one or two loop voids exist. When there are no loop voids, then the assumed RV head void limits subsequent RCP starts to < 2000 PSIA (assumes total head void not condensed on start of 1st RCP).

2. If either SG has been fed while RCPs were off with a coincident loop void, then the NC Criteria for RCP Restart/Bump Following Loss of SCM (other than HPI Cooling) in 3.1.A apply.

The requirement that no SG with a loop void has been fed while the RCPs in the associated loop were off is based on the fact that deborated RC in the SG tubes and RC cold legs is not assumed in the HPI cooling RCP restart criteria. If either SG had been fed during this period, then deborated RC could exist in these regions. This assumes that the RCPs were off due to a loss of core exit subcooling (probable), or that a large enough hot leg void existed, with core exit subcooling, to allow BCC in the presence of EFW flow. This criterion is tied to RCP and EFW status for simplicity and conservatism. If this criterion is not met, then the two-loop or single-loop NC criteria apply.

The requirement for core exit subcooling is intended to limit the possible size of the loop void prior to RCP restart. Core exit subcooling is required anyway for RCP restart, thus this criterion does not provide any further restrictions. The requirement for additional subcooling used in the NC cases is not required for the HPI cooling case. This is because the liquid RC replacing the subcooled localized boiling voids in the HPI case is at a higher average boron concentration, thus introducing less positive reactivity than assumed in the NC cases.

The requirement that RCS pressure be limited during RCP start limits the quantity of possible condensate following the collapse of RCS voids on RCP start. The criteria are based on analytical results that considered voids in the RV head and both hot legs. For events where SCM was not lost, the analysis assumed that a void would form in the RV head. For events that lead to loss of SCM, the analysis assumed that voids would form in the RV head and both hot legs. It was further assumed that if either hot leg contained voids, the RV head would also be voided (i.e., as a precursor condition to loop void formation). These voids, RV head and hot leg voids, were then assessed to determine the possible positive reactivity effects on core shutdown margin caused by their condensation.

The RCS pressure criteria assure that the positive reactivity insertion associated with this condensation remains within acceptable limits.

RCP restart with a void in the RV head must also consider the limits discussed in section 4.0 of Chapter IV.K.

The quantity of condensate possible following RCP start is dependent on many factors including such things as initial void volume, average RC temperature, SCM and RCS pressure. Determining void volume and the RC temperature profile prior to RCP start may not be possible with any degree of accuracy. Limiting RCS pressure during RCP start to that specified provides an acceptable upper bound on the possible condensate volume and, therefore, its associated positive reactivity insertion effect. Analysis indicates that these RCS pressure criteria will maintain positive reactivity insertions within acceptable limits. This method simplifies the criteria and uses criteria that can be readily assessed.

An RCP restart in a voided loop will result in pushing a mixture of saturated water and steam into the SG and its cold leg. As the water in the cold leg is pumped into the reactor vessel, it could be replaced by a two phase mixture (or saturated water) which can lead to pump cavitation and may require tripping the pump. Additionally, if SCM is subsequently lost and not recovered within two minutes, the RCP must be tripped.

3.1.C Criteria for RCP Restart/Bump During NC (SCM not lost/HPI cooling has not occurred)

During NC it is possible for a void to form in the RV head and an idle loop. For this situation, i.e., NC with RCS void(s), the following RCP restart guidance applies:

1. A RCP in an active loop may be restarted during NC IF all of the following conditions are satisfied:
   a. A SG with a loop void was not fed while RCPs were off in that loop, AND
   b. Core exit SCM was not lost, AND
   c. RCS pressure is less than the following applicable values:

NO RV HEAD OR LOOP VOIDS	RV HEAD VOID	RV HEAD AND LOOP VOID
N/A	< 2000 PSIA	< 700 PSIA

2. If SCM was previously lost (and now restored), then the NC Criteria for RCP Restart/Bump Following Loss of SCM (other than HPI Cooling) in 3.1.A apply.

For single loop NC, starting an RCP in the active loop allows condensate caused by reverse flow through the idle loop to mix with core outlet liquid circulated through the core via the active loop. This provides a slower, more gradual mix of condensate due to an idle loop void than would be experienced by a pump start in the idle loop. For this reason, an RCP should be started only in the active loop. A second RCP may be started in the active loop after RCS conditions stabilize following the initial pump start. This may cause more rapid condensation of any remaining loop void and could possibly lead to loss of SCM. If SCM is subsequently lost and not recovered within two minutes, any running RCPs must be tripped.

The requirement that RCS pressure be limited during an RCP start limits the quantity of possible condensate following the collapse of a loop and/or RV head void on RCP start. The analysis conservatively assumed that if a loop void exists, an RV head void will also exist (i.e., as a precursor condition to loop void formation) and that the positive reactivity associated with the condensation of all these voids will be inserted on pump start. In reality, it is possible to void an inactive loop without voiding the RV head. For this reason, application of the RV head void RCS pressure limit (2000 PSIA) need only be applied if an RV head void could exist. RVLIS instruments may indicate the existence of such a void. However, if RCS pressure has previously decreased (e.g., due to a post-trip transient) to less than RV head P_{sat} and it is uncertain whether or not an RV head void exists, then it should be assumed that an RV head void exists.

The requirement that a SG with a loop void not be fed while the RCPs in the associated loop were off is based on the fact that deborated RC, i.e., from BCC, in the SG tubes and RC cold legs is not assumed in the associated reactivity insertion analysis.

RCP restart with a void in the RV head must also consider the limits discussed in section 4.0 of Chapter IV.K.

The quantity of condensate possible following RCP start is dependent on many factors including such things as initial void volume, average RC temperature, SCM and RCS pressure. Determining void volume and the RC temperature profile prior to RCP start may not be possible with any degree of accuracy. Limiting RCS pressure during RCP start to < 700 PSIA (RV head and loop void) and < 2000 PSIA (RV head void only) provides an acceptable upper bound on the possible condensate volume and, therefore, its associated positive reactivity insertion effect. After starting the first RCP, subsequent RCP starts must still consider RCS pressure criteria. That is, as long as the applicable condition exists (loop void and/or RV head void), the associated RCS pressure criteria must be met prior to any additional RCP starts.

3.2 RCP Restart/Bump System Considerations

This section, i.e., 3.2, 3.2.A, 3.2.B, and 3.2.C, provides RCP system associated restart/bump considerations other than boron dilution. RCP restart/bump consideration for possible positive reactivity insertion due to boron dilution are presented in section 3.1 and if applicable, the restrictions on RCP restart in section 3.1 supercede.

RCP services including power, seal injection, seal return, cooling water and lube oil must be established prior to starting RCPs to prevent pump and motor damage. Also, to prevent pump damage, adequate NPSH must be established prior to RCP start. RCPs should be started and operated in accordance with plant specific procedures.

Reestablishing pressurizer spray could be a concern. The possibility exists that during previous LOCA mitigation the spray and spray block valves were closed. This may have isolated an RCS leak in the spray line between the two valves or terminated depressurization due to a stuck open spray valve. If so, reopening the pressurizer spray block valve to re-establish pressurizer spray could result in re-establishing the LOCA or uncontrolled spray flow. Consequently, the pressurizer spray block valve should be opened and RCS pressure monitored to ensure that RCS depressurization does not occur. If the depressurization does occur, the spray block valve must be re-closed. Further control of RC pressure will then be by use of pressurizer vent/PORV.

When the first RCP is started, SG pressure should be adjusted with the TBVs/ADVs to allow heat transfer without causing excessive primary-to-secondary cooling (overcooling). SG level will swell initially due to the rapid increase in heat transfer to the SG when the RCP is started. If the SG levels had been at the loss of SCM setpoint and are still high, even though primary-to-secondary heat transfer via NC is occurring, then it may be preferable to allow SG levels to decrease by boil-off before starting the first RCP. Once an RCP is started, assuming no loop voids exist, reverse flow should occur in the opposite loop establishing heat transfer in that loop also. For this reason, this swell phenomena is expected to be either non-existent or insignificant when additional RCPs are started.

HPVs may have been opened in an attempt to eliminate a loop void. If so, and an RCP is started, the HPVs will discharge liquid. This is an unnecessary loss of inventory and energy deposition to the RB; hence, HPVs should be closed prior to starting RCPs.

The decision of whether or not to restart/bump RCPs depends upon the condition of various plant systems including those associated with the RCPs, RCS and SGs. Two important system considerations are PTS and SGTR. RCP operation is especially important for PTS concerns, as discussed in Chapter IV.G, and restarting RCPs provides optimum control over RCS cooldown. Additional systems considerations are provided in the remainder of this section. Chapter IV.K provides additional considerations for starting RCPs with a void in the RV head.

3.2.A <u>RCP Restart/Bump With SCM and NC (includes loop and RV head voids)</u>

As long as SCM has not been lost and the boron dilution consideration criteria of 3.1 are met, RCPs may be restarted/bumped. Starting one or more RCPs (forced flow) increases primary to secondary heat transfer and adds pump heat to the RCS. Therefore, after starting RCP(s), the TBVs/ADVs should be adjusted as necessary to continue the cooldown within the appropriate cooldown rate.

No Indication of RCS Voids

If there are no RCS voids, then when the first RCP is started, the RC pressure and pressurizer level should decrease as T_h approaches T_c. As each subsequent RCP is started, one at a time, a slight pressure spike may occur in the RCS. This pressure spike will be around 20 to 50 PSI and is noticeable in RCS pressure as well as pressurizer level. However, RCS pressure should stabilize quickly at the previous value.

Indication of the Existence of a Loop Void

RC flow through the idle loop will not occur unless the idle loop void is relatively small, i.e., the void does not extend much below the hot leg "U" bend. However, if starting a pump does cause water flow through the idle loop then T_{hot} in the active loop may increase initially. This is due to hot water from the opposite hot leg mixing with the core exit water (in the upper plenum cylinder), thereby raising the water temperature above the core exit temperature before it reaches the hot leg RTD. This effect is only temporary and T_{hot} will decrease within several seconds after RCP restart. The increase in primary flow will also improve SG heat transfer in the active loop. SG pressure will initially increase due to the increased heat transfer and the delta T across the core will decrease due to increased primary flow. Core subcooling may increase, as the core outlet temperature decreases due to the increase in RCS flow, at a faster rate than RC pressure decreases. A slight decrease in the active loop SG level may occur as heat transfer increases resulting in a higher secondary water boil-off. RCS pressure and pressurizer level will decrease on pump restart. The pressurizer level and RCS pressure response will be primarily due to RC temperature decrease.

Indication of the Existence of a Head Void

If RCS pressure does not respond to pressurizer actions after verifying subcooled natural circulation, then it should be assumed that an RV head void exists. The creation of an RV head void would have been indicated by a sudden increase in pressurizer or MU tank level while lowering RCS pressure during cooldown. If the RCS pressure had been decreased quickly below the saturation pressure for the initial temperature in the RV head, then it is likely that voids are present in the RV head.

Once the presence of a RV head void has been determined, the RV head vent can be opened to purge the steam from the RV head and provide some cooling to the RV head. However, if RV head vents are unavailable, or it is not desirable to open the RV head vent due to discharging steam to the RB, then an RCP can be started to enhance removal of the RV head bubble. Before starting the RCP, the pressurizer level should be increased to about 75% full scale and SCM increased to the minimum value plus about 20°F. Lower values of subcooling can be used if, for example, a SGTR exists. Less subcooling increases the probability of losing SCM on RCP restart, but a RCP restart with an RV head void is less likely to result in a loss of SCM than a restart with a loop void. If RCPs are "off" and HPI is "on," then the PTS guidance requires the core outlet temperature to be kept near the SCM limit. Therefore, the subcooling should not be increased above the minimum value if RCPs are "off" and HPI is "on." After increasing pressurizer level, the pressurizer should be allowed to come to saturated conditions before starting the RCP.

After establishing SCM and pressurizer level increase and the RCS reaches equilibrium, then one RCP should be restarted after initiating MU or HPI (assists PZR inventory and SCM which may decrease due to void collapse and RCS contraction). The RCP restart should not cause a loss of SCM. However, if SCM is lost, the RCP must be tripped (if SCM not regained within two minutes) and full HPI flow must be established to restore SCM. A sudden RCS pressure decrease of 100 PSI or more should be expected upon restarting an RCP with a void in the upper RV head region.

This sudden RCS depressurization is primarily due to RCS contraction as Thot decreases but some depressurization is due to some of the steam condensing in the RV head as cooler water is forced into the RV head region. Even if it is expected that attempting to run an RCP will cause the RCS to depressurize to a saturated condition, it is still desirable to start an RCP in an attempt to regain RCS pressure control. Condensing the steam voids will allow more HPI flow into the RCS, and will reduce the size of the steam void. HPI flow eventually will again restore SCM. Once the SCM is restored, another RCP may be restarted after reestablishing the previously required conditions. Each RCP should not be started more frequently than motor starting limits allow.

3.2.B <u>RCP Restart/Bump With SCM and “No” NC</u>

In this case a lack of primary to secondary heat transfer exists, which is due to a lack of SG heat sink, steam voids in the hot legs or thermal stratification blocking natural circulation. As discussed previously, if RCS voids exist (RV head and/or hot legs), an RCP must not be started/bumped unless the applicable criteria of 3.1 are met. Section 3.5 of Chapter III.C, Lack of Adequate Primary to Secondary Heat Transfer, provides additional details for starting an RCP when there are no loop voids.

The RCP may be started and left running if the RCS SCM is not lost for longer than two minutes.

During HPI cooling, one RCP should be started in accordance with the criteria of 3.1. Starting one RCP will promote fluid mixing and reduce the thermal stress on the RV. However, the PTS guidance must still be observed.

3.2.C RCP Restart/Bump With RCS Water Solid

When an RCP is started with the SG(s) available, Thot and Tcold will approach the SG saturation temperature. This will cause the RC pressure to either increase or decrease depending on whether the weighted average RC temperature was higher or lower than the SG saturation temperature prior to starting the RCP. The magnitude of the pressure change will depend on the magnitude of the change in the weighted average RC temperature. The rate of RCS pressure change is dependent on the rate of heat transfer to the SG(s). This depends on the SG water inventory. The rate is faster for larger SG water inventories.

For example, when an RCP is started while in natural circulation, Thot will decrease toward Tcold. Tcold will remain slightly above the SG saturation temperature. The resulting decrease in the weighted average RC temperature will cause the RC pressure to decrease. Pressurizer pressure will decrease approximately 100 to 200 PSI if a RCP is started in a raised loop plant while in natural circulation with 4% decay heat and SG level at the natural circulation setpoint (this total pressure change includes the pressure increase due to the pump head). For this case, the pressure decrease will take about 11 seconds. The RC pressure should be adjusted prior to starting an RCP to provide margin in both directions in an attempt to avoid opening the pressurizer relief valves, if the RC pressure increases, or to avoid losing the SCM (or RCP NPSH) if the RC pressure decreases. When in natural circulation and PTS has not been invoked due to RCPs off and HPI on, the RC pressure should be increased at least 200 PSI above the SCM limits before starting an RCP.

During natural circulation the initial weighted RC average temperature can be determined and appropriate adjustments can be made in RC pressure before starting an RCP. However, following idle loop operation or HPI cooling, determining the weighted average RC temperature can be more difficult because of more extreme variations in RC temperature distributions. This makes measuring and averaging the temperature difficult. These modes of operation can also cause the weighted average RC temperature to be significantly different from the SG saturation temperature which can cause significant pressure changes when a RCP is started. Consequently, making adjustments in RC pressure prior to RCP restart requires more consideration when recovering from idle loop operation or HPI cooling. For example, RC pressure should be adjusted to maximize the margin between the appropriate limits such as pressurizer safety valve setpoint and the SCM limit.

If a RCP is started without a SG available, heat transfer to the SG will not occur. Consequently, the weighted average RC temperature will change very little since the resulting RC pressure changes may be due only to the RCP head.

3.2.D SG Tube-Shell ΔT

In general, a RCP should not be bumped or started if it will result in exceeding SG tube-shell ΔT limits, unless the RCP is needed to aid restoration of adequate core cooling. For example, during HPI cooling with a dry SG, starting an RCP could result in exceeding either the compressive or tensile limit, depending on the shell ambient losses and current core outlet temperature. In this case, adequate core cooling exists, so the RCP should not be started if either limit will be exceeded. It may not be possible to ensure the limits will not be exceeded, at least temporarily, prior to RCP start due to the potential for large temperature gradients during HPI cooling. Prior to RCP start, core exit temperature should be used as an approximation of the RC average temperature following restart. If in doubt, and the RCP is not needed for adequate core cooling, then the RCP should not be started.

Conversely, there may be instances where the tube-shell ΔT in an idle SG is excessive and starting the RCP may improve the tube-shell ΔT. Chapter IV.K provides guidance on estimating the tube-shell ΔT in a stagnant loop. This situation could occur, for example, during HPI cooling where the core outlet to SG shell temperature difference is within the tube-shell ΔT limits, while the calculated tube-shell ΔT in the idle SG is excessive. In this situation, starting an RCP would improve the tube-shell ΔT. It could also occur during HPI cooling with an SG available for heat transfer or during single loop natural circulation, since restoration of forced primary flow and SG heat transfer should allow control of the idle SG tube-shell ΔT.

Chapter IV.B

HPI/LPI/DHRS/CF Operation

1.0 INTRODUCTION

This chapter discusses the technical bases for the guidelines that use the following systems for transient mitigation:

A. High Pressure Injection System (HPI) which is discussed in sections 2.A and 2.B (Note: due to significant design differences, two sections are provided; 2.A is generic except Davis-Besse and 2.B is Davis-Besse specific).

B. Low Pressure Injection System (LPI) which is discussed in section 3.0.

C. Decay Heat Removal System (DHRS) which is discussed in section 4.0.

D. Core Flood Tank System (CFT) which is discussed in section 5.0.

In addition to discussing technical bases associated with specific systems, this chapter also discusses some general technical bases which involve more than one of these systems. These technical bases include the following:

E. Boron precipitation which is described in section 6.0.

2.A HPI SYSTEM OPERATION (for all plants except Davis-Besse)

The HPI system is used to:

A. Makeup for lost RCS inventory due to a LOCA.

B. Makeup for RC contraction due to excessive cooling of the RCS.

C. Provide a backup method of core cooling when the SGs do not provide adequate heat transfer.

D. Provide boration of RCS.

The HPI flow rate to the RCS should be started, maximized, throttled or stopped depending on certain existing conditions. The following sections will discuss when, how and why each of these actions are to be made. In addition, each action will be stated as mandatory (must) or desirable (should). If a conflict exists between a mandatory and a desirable action, the mandatory action takes priority.

2.A.1 Definitions

The actions to control HPI flowrate are based on certain conditions. Some of these conditions need to be defined in order to correctly understand when and how to control the HPI flow. These conditions are defined below:

A. Loss of Subcooling Margin

The subcooling margin (SCM) is considered lost whenever the RC pressure and temperature relationship is below the RC SCM limit as measured at the location or locations of concern.

B. Subcooling Margin Exists

SCM exists whenever the RC pressure and temperature relationship is equal to or more subcooled than the SCM limit as measured at the location or locations of concern.

C. Normal Makeup Capacity

Normal MU capacity is defined as the maximum expected water addition to the RCS through the MU line with the letdown line isolated. This amount will vary with RC pressure.

D. Feedwater Available to a Steam Generator

FW is available if FW flow rate is adequate to meet all SG level and FW flow requirements.

E. HPI Cooling

This is a method of removing core heat by adding low enthalpy HPI fluid to the RCS while removing high enthalpy fluid from the RCS to the RB. This method of cooling is used when inadequate primary to secondary heat transfer exists.

2.A.2 Initiating HPI

HPI is initiated by starting two HPI pumps taking suction from the BWST and pumping to the RCS through all available injection nozzles. HPI should be manually started if automatic initiation has not already occurred.

2.A.2.1 HPI MUST be INITIATED whenever loss of SCM occurs.

When SCM is lost, HPI flow to the RCS is required.

2.A.2.2 HPI flow SHOULD be ESTABLISHED during reactor shutdown with a SGTR if normal MU cannot maintain desired pressurizer level.

This action is taken as necessary to maintain a sufficient pressurizer water volume so that, should a reactor trip occur during the shutdown, the associated sudden decrease in the RC temperature will not cause a loss of adequate SCM due to the decrease in the pressurizer level.

2.A.2.3 HPI MUST be INITIATED as part of the HPI cooling process whenever Primary to Secondary heat transfer is not adequate and FW is not available.

Refer to Chapter III.G for the discussion of HPI cooling.

2.A.3 Full HPI Flowrate

2.A.3.1 Whenever SCM is lost, full HPI flow MUST be provided to the RCS until HPI termination criteria are met.

A. Full HPI flow is established to provide maximum core heat removal. HPI will provide heat removal from the core by continual addition of low enthalpy water to the RCS. This requires a concurrent break or opening in the RCS for removal of the high enthalpy RC to allow addition of the low enthalpy HPI.

B. Full HPI flow is required to restore SCM as quickly as possible. As long as SCM exists the core is assured of being covered making the core adequately cooled. Therefore, it is important to reestablish SCM as quickly as possible.

C. Full HPI flow is required to provide subcooled RC for primary to secondary heat transfer. If the SGs are available for heat removal, then adding water to the RCS will replenish the heat transfer medium for primary to secondary heat transfer.

D. Full HPI flow is achieved by operating two HPI pumps and balancing the HPI flow. The HPI valves should be verified open or opened as necessary to ensure full flow. The intent of balancing the HPI flow is to address such failures as a break in the HPI injection line. These failures will cause imbalances in the HPI flow with the result that the HPI to the RV may not be as large as possible. For example, if an HPI line break exists, the broken line may have a much higher flow rate than in each of the unbroken lines.

If the flow only in the broken line is throttled more flow will go through each of the other lines to the RCS and less HPI water will be lost out the broken line. The intent of balancing the flow is to increase the total flow reaching the RCS and not to try to make the flow through each flow path exactly equal. Balancing may or may not be inherent in the HPI system design by use of cross-connected injection lines, venturi flow nozzles, orifices, preset valve positions etc.

E. The HPI pump flow rate should not be allowed to exceed the maximum allowed pump flow rate. The HPI system design may inherently prevent excessive pump flow.

F. When using T_{hot} as an indication of loss of SCM, the corresponding loop must have loop flow. This is to avoid requiring full HPI flow when adequate core cooling exists. This can occur in two situations. First, during single loop natural circulation, the operating loop can provide adequate core cooling while the idle loop can saturate as the RC is depressurized during the cooldown.

Second, during HPI cooling, both RCS loops can saturate while the HPI is providing adequate core cooling as indicated by the incore T/Cs.

2.A.4 Throttling HPI Flow

In general, throttling of HPI is permissible whenever SCM exists. Pressurizer level should not be used as a prerequisite for HPI throttling. Throttling means to reduce the HPI flow rate below the maximum flow rate. This can be done by regulating HPI flow valve positions and/or stopping an HPI pump and/or use of HPI recirculation flow. In general, HPI flow may be throttled anytime SCM exists as indicated by the incore T/Cs with one exception noted below. HPI flow must not be throttled when the RC SCM is lost.

When the HPI flow is throttled, the pump flow rate should not be throttled below the [minimum allowed pump flow] rate. The HPI recirculation lines may be available to provide the minimum required HPI flow rate. If the recirculation lines discharge to the MU tank, the MU tank inventory will need to be controlled. This is especially true if HPI/LPI "piggyback" operation is in progress. When throttling HPI flow to control RC pressure, care should be taken not to allow the RC pressure to drop below:

A. The SCM limit.

B. RCP NPSH requirements if a RCP is operating.

If a SGTR exists, another consideration exists. Maintaining the primary to secondary system pressure differential as low as possible is desirable to reduce primary to secondary leak rate. Refer to Chapter III.E.

If, during HPI cooling, the PORV is being cycled either manually or automatically, then HPI cannot be throttled until core outlet temperature is decreasing and SCM exists. This is covered in more detail in Chapter III.G, section 3.9.1.

2.A.4.1 <u>HPI flow MUST be THROTTLED to prevent overpressurizing the RCS when SCM exists by keeping the RC pressure below the NDT and within the PTS guidance as applicable. (See Chapter IV.G)</u>

A. If a pressurizer steam bubble exists, rapid filling of the pressurizer and the resulting pressurizer steam bubble compression can cause the RC pressure to increase. Increasing the RC temperature will also cause the pressure to increase.

B. If the pressurizer is full of water (water solid), either because the pressurizer steam bubble cannot be maintained (i.e., pressurizer heaters are inoperable or the pressurizer has a small leak), or HPI cooling is in progress, the RC pressure is increased when the HPI volume flow rate going into the RCS exceeds the RC volume flow rate leaving the RCS or when the RC temperature is increasing.

C. This action applies if SCM exists as measured by the incore T/C. T_h and T_c can still indicate a loss of SCM. This accounts for the possibility of an area of the RCS not having SCM established while the core is being adequately cooled.

D. During a PTS transient HPI flow must be throttled to prevent excessive subcooling by keeping the core outlet temperature near the SCM limit.

2.A.4.2 <u>The HPI flow SHOULD be THROTTLED to keep the pressurizer level near the normal operating level setpoint when SCM exists</u>.

A. If the pressurizer level is too high, the RCS is susceptible to rapid pressure increases which can cause undesirable opening of the pressurizer relief valves and relief of two-phase and subcooled water. If the pressurizer water level is too low, the RCS is susceptible to large, rapid decreases in pressure which can cause a loss of SCM. Also, the level should be high enough for pressurizer heater operation. The level should account for possible instrument errors including elevated RB temperatures as applicable.

B. If a leak exists in the pressurizer, maintaining a pressurizer level may not be possible and the pressurizer may fill solid if the RC is being kept subcooled.

C. Throttling HPI for the reasons discussed is expected during a SBLOCA or after an overcooling transient; e.g., the SBLOCA can initially be larger than the MU system capacity causing the pressurizer level to drop. HPI will be started with a flow rate greater than the SBLOCA leak rate causing the pressurizer to refill. The SBLOCA can also initially be larger than the HPI capacity. However, when the RC pressure decreases, the HPI flow rate will increase causing the pressurizer to fill.

D. If the pressurizer drains due to overcooling, HPI can rapidly refill the pressurizer once the overcooling stops. HPI flow will need to be reduced significantly or stopped.

E. Continued filling will cause unnecessary valve operation and fluid release through the pressurizer relief valves. Too much fluid release can overfill and overpressurize the pressurizer relief (or quench) tank.

F. If core cooling is provided by HPI cooling, then pressurizer level cannot be maintained. In this situation, HPI is throttled to prevent overpressurizing the RCS and to limit the cooldown rate (only if SCM is maintained).

2.A.5 Stopping HPI Flow

2.A.5.1 HPI flow SHOULD be STOPPED and normal MU flow control started if the RC leak rate and contraction rate is within the normal makeup flow capacity, adequate SCM exists, and HPI cooling is not required .

A. When stopping HPI while a leak exists in the RCS, the MU pumps must be able to take suction from the BWST or RC bleed tanks. However, if the BWST and bleed tanks are empty, the MU pumps must be able to take suction from the LPI discharge.

B. Normal MU flow control is preferred because the system provides automatic volume control.

C. The RC leak rates and contraction rate should be verified to be within normal MU flow capacity as indicated by pressurizer level.

D. Normal letdown and use of the MU tank may also be started along with normal MU flow control depending on existing plant conditions; e.g., if the RC radiation level is high then letdown should be isolated.

2.A.5.2 HPI flow SHOULD be STOPPED if ICC conditions do not exist AND the LPI flow rate is equal to or greater than:

Plant	Min. Required LPI Flow
177FA NSS except ANO-1	1000 GPM/line
ANO-1 with 2 LPI pumps running	2630 GPM/pump
ANO-1 with 1 LPI pump running	3020 GPM total pump flow

The intent of this criterion and the criterion of 2.A.5.3 is to terminate HPI <u>if it is no longer needed</u> for accident mitigation. However, if there is insufficient evidence that HPI is no longer needed, the continuation of HPI flow for assured core cooling takes precedence over the desire to terminate HPI flow. Since it is the intent of these guidelines to minimize the use of piggyback operation, HPI should be allowed to continue until switchover to RB emergency sump suction is required even if the criteria are satisfied while still on the BWST.

A. This condition is applicable to larger size LOCAs when the RCS depressurizes sufficiently to allow the specified LPI flow rates. The intent is to terminate HPI flow if possible. Terminating HPI flow prevents the added actions of aligning for piggyback operation and prevents pumping RB emergency sump water with the HPI pumps. This limits the transporting of radioactive RB emergency sump water outside of the RB. Also, it is possible that recirculating debris (e.g., fine silt type material) from the emergency sump through the HPI pumps might cause some pump degradation after initial mission times are fulfilled. This would be prevented if piggyback operation can be precluded. However, if neither the above flow rates can be achieved nor SCM regained per section 2.A.5.3, then HPI/LPI piggyback operation will be required.

B. The LPI flow rate is required in each line in the event that a break exists in one of the LPI/CF lines. If LPI flow exists in only one line, it is possible that some or all of the LPI flow is being lost out the break. It is not possible to ensure adequate LPI flow from one line to the RV exists while saturated, therefore sustained HPI flow would be required. Adequate LPI flow through one line could <u>appear</u> to exist if the HPI were terminated without resulting in an increase in RC temperature or pressure. However, this could be due to boiling off of the existing RC inventory, with the inadequate LPI flow not becoming evident until the core uncovers and the core outlet becomes superheated. The existence of the minimum required flow in both LPI lines ensures the flow from at least one line is reaching the RV.

C. The flow rate value provides some margin over the minimum LPI flow required to accommodate core boiloff, i.e., remove decay heat, and assure RV refill. In addition, the typical LPI pump head curve is fairly flat from shutoff head to 1000 GPM such that only a few psi increase in RC pressure can significantly reduce LPI flow. Thus requiring flow of at least 1000 GPM provides some margin to loss of LPI flow due to an RC pressure increase. RC temperature and pressure may increase following switchover to the emergency sump due to an increase in LPI temperature caused by elevated emergency sump temperatures.

D. The flow rates listed above DO NOT include allowances for instrument errors. Errors should be accounted for in deriving plant specific values for the procedures. The values DO account for the sensor location and LPI system configuration; this is the basis for the difference between the ANO-1 values and the value for the other

177FA plants. The ANO-1 configuration includes a passive LPI line cross-connect with flow measurement upstream of the cross-connect. Because of this, flow to both LPI lines is assured and the criterion is based on pump flow (i.e., not accounting for instrument errors, a total pump flow of 3020 GPM, with one LPI pump running, ensures at least 1000 GPM through the intact LPI line).

E. It is normally expected that a break scenario will follow one of two paths:

1. The break will be large enough to pass the required minimum LPI flows allowing HPI termination.

2. The break size will be small enough to allow restoration of SCM to allow HPI termination per section 2.A.5.3.

However, some break sizes, decay heat levels, etc., may be such that the RCS remains saturated for a period of time with LPI flows less than the required minimum flow rates listed above. In these cases, the PORV may be opened in an attempt to increase LPI flow. If LPI flow is still less than the minimum required when it becomes necessary to switch suction to the RB emergency sump, then full HPI flow will be required on LPI piggyback and the PORV should be closed. If SCM is restored during this process, then the criteria of section 2.A.5.3 apply. HPI should not be throttled in an attempt to increase LPI flow while the RCS is saturated. The reason for this is the same as that associated with not terminating HPI if LPI flow exists in only one line (see discussion at B above). Specifically, throttling HPI while saturated, and without the required minimum LPI flow, could result in a net inventory loss and core uncovery.

F. If core exit thermocouples indicate ICC conditions, then full HPI flow must be maintained even if the minimum LPI flow rates exist.

G. These criteria, i.e., ICC does not exist <u>and</u> LPI flow in each line ≥ [plant specific flow rate], continue to apply, following emergency sump switchover, to allow subsequent termination of HPI when the criteria are satisfied.

2.A.5.3 <u>HPI flow SHOULD be STOPPED before switching LPI suction to the RB emergency sump when SCM exists, IF LPI flow can maintain core cooling and SCM.</u>

A. The intent is to avoid unnecessary HPI/LPI piggyback operation for cases where the break size may not be large enough to pass the LPI flow rates required by section 2.A.5.2.

B. This applies once LPI flow has been established with SCM. In order to demonstrate that the LPI flow is sufficient, HPI flow should be throttled while maintaining LPI flow and SCM. If the HPI flow can be throttled to the [minimum allowable pump flow] with SCM and stable or decreasing core outlet temperature, then HPI can be terminated.

C. Once the criteria are satisfied, i.e., HPI flow throttled to the [minimum allowable pump flow] and LPI flow is maintaining core cooling, then HPI flow should be maintained at the

[minimum allowable pump flow]. If SCM is lost or core outlet temperature begins to increase, then full flow from two HPI pumps must be restored. HPI/LPI piggyback operation will be required if the criteria can not be satisfied. If the criteria are satisfied, then the HPI may be terminated.

D. If the criteria cannot be met before emergency sump switchover, then the criteria continue to apply following emergency sump switchover to allow subsequent termination of HPI when the criteria are satisfied.

2.B MU/HPI SYSTEMS OPERATION (Davis-Besse only)

The MU/HPI systems are used to:

A. Makeup for lost RCS inventory due to a LOCA.

B. Makeup for RC contraction due to excessive cooling of the RCS.

C. Provide a backup method of core cooling when the SGs do not provide adequate heat transfer.

D. Provide boration of RCS.

The MU/HPI flow rates to the RCS should be started, increased to full flow, throttled or stopped depending on certain existing conditions. The following sections will discuss when, how and why each of these actions are to be made. In addition, each action will be stated as mandatory (must) or desirable (should). If a conflict exists between a mandatory and a desirable action, the mandatory action takes priority.

2.B.1 Definitions

The actions to control MU/HPI flowrates are based on certain conditions. Some of these conditions need to be defined in order to correctly understand when and how to control the MU/HPI flow. These conditions are defined below:

A. Loss of SCM

SCM) is considered lost whenever the RC pressure and temperature relationship is below the RC SCM limit as measured at the location or locations of concern.

B. SCM Exists

SCM exists whenever the RC pressure and temperature relationship is equal to or more subcooled than the SCM limit as measured at the location or locations of concern.

C. Normal Makeup Capacity

Normal MU capacity is defined as the maximum expected water addition to the RCS through the MU line with the letdown line isolated. This amount will vary with RC pressure.

D. Feedwater Available to a Steam Generator

FW is available if FW flow rate is adequate to meet all SG level and FW flow requirements.

E. MU/HPI Cooling

This is a method of removing core heat by adding low enthalpy HPI and/or MU fluid to the RCS while removing high enthalpy fluid from the RCS to the RB. This method of cooling is used when inadequate primary to secondary heat transfer exists.

2.B.2 Initiating MU/HPI

If feedwater is available, then MU/HPI flow is initiated as follows:

When the RCS pressure is greater than the 1650 psig SFAS trip setpoint then:

a. provide full MU flow with both MU pumps through both the normal and alternate MU lines (e.g., open the alternate MU injection lines and open the makeup control valve bypass valve) in the MU/LPI piggyback mode (i.e. MU pumps taking suction from the LPI pump discharge) and

b. operate both trains of LPI in the injection mode.

Note: do not use both MU injection lines unless both MU pumps are operating with suction from the BWST or LPI pump discharge.

When the RCS pressure is less than or equal to the 1650 psig SFAS trip setpoint then:

a. operate both trains of HPI in the injection mode.

b. operate both trains of LPI in the injection mode.

If feedwater is unavailable, then all the above actions are taken to initiate MU/HPI flow, regardless of RCS pressure, and HPI is operated in the HPI/LPI piggyback mode. In addition the MU pump recirculation lines are isolated. Whenever HPI is in piggyback operation and LPI flow to the RCS begins, HPI must be realigned to the BWST if the BWST is still in use. This provides greater total injection flow and is required by ECCS analyses.

2.B.2.1 <u>MU/HPI MUST be INITIATED Whenever Loss of SCM Occurs.</u>

2.B.2.2 <u>MU/HPI must be INITIATED as part of the MU/HPI cooling process whenever primary to secondary heat transfer is not adequate and FW is not available;</u>

Refer to Chapter III.G for a discussion of MU/HPI cooling.

2.B.3 <u>Full MU/HPI Flowrate</u>

2.B.3.1 <u>Whenever SCM is lost, full MU/HPI flow MUST be provided to the RCS until HPI termination criteria are met.</u>

A. Full MU/HPI flow is established to provide maximum core heat removal. MU/HPI will provide heat removal from the core by continual addition of low enthalpy water to the RCS. This requires a concurrent break or opening in the RCS for removal of the high enthalpy RC to allow addition of the low enthalpy MU/HPI.

B. Full MU/HPI flow is required to restore SCM as quickly as possible. As long as SCM exists the core is assured of being covered making the core adequately cooled. Therefore, it is important to reestablish SCM as quickly as possible.

C. Full MU/HPI flow is required to provide subcooled RC for primary to secondary heat transfer. If the SGs are available for heat removal, then adding water to the RCS will replenish the heat transfer medium for primary to secondary heat transfer.

D. Full HPI flow is achieved by operating two HPI pumps with their associated HPI valves opened. It is recommended that the HPI pumps be piggy-backed on the LPI pumps from the BWST to increase the HPI discharge pressure.

If only one HPI pump is operating, then HPI flow should be balanced between the two injection lines. The intent of balancing the HPI flow is to address such failures as a break in the HPI injection line. These failures will cause imbalances in the HPI flow with the result that the HPI flow to the RCS may not be as large as possible. For example, if an HPI line break exists, the broken line may have a much higher flow rate than the unbroken line. If HPI flow is throttled only in the broken line, then more flow will go through the unbroken line to the RCS and less HPI water will be lost out the broken line. The intent of balancing the flow is to increase the total flow reaching the RCS and not to try to make the flow in each line exactly the same.

Balancing should be accomplished by throttling only the high flow line and not throttling it below the value on Figure IV.B-1. Figure IV.B-1 is based on the throttling limit associated with aligning the HPI pump suction directly to the BWST, i.e., it is not based on aligning the HPI pump in the piggy-back mode (note: Figure IV.B-1 does not include process or instrument errors).

The analytical basis of Figure IV.B-1 ensures that adequate HPI flow will be injected into the RCS even if one of the active HPI lines is broken. The reason for limiting the throttling of the high flow line to values ≥ the limit of Figure IV.B-1 is the possibility of an HPI line pinch break. Such a break can cause the failed line, i.e., broken HPI line, to pass less flow than the unbroken line. Since the unbroken line will indicate higher flow than the broken pinched line, the unbroken line will be throttled. Throttling in accordance with Figure IV.B-1 ensures that the flow rate through the unpinched line, i.e., the unbroken line, will remain high enough to accommodate the full range of HPI line breaks.

E. The HPI pump flow rate should not be allowed to exceed the maximum allowed pump flow rate of 950 gpm. This should only be a concern during piggyback operation.

F. When using T_{hot} or T_{cold} as an indication of loss of SCM, the corresponding loop must have loop flow. This is to avoid requiring full HPI flow when adequate core cooling exists. This can occur in two situations. First, during single loop natural circulation, the operating loop can provide adequate core cooling while the idle loop can saturate as the RC is depressurized during the cooldown.

Second, during HPI cooling, both RCS loops can saturate while the HPI is providing adequate core cooling as indicated by the incore T/Cs.

2.B.4 Throttling MU/HPI Flow

The only requirement to allow throttling of HPI is SCM. Pressurizer level should not be used as a prerequisite for HPI throttling. Throttling means to reduce the MU/HPI flow rate below the full flow rate. This can be done by regulating MU/HPI flow valve positions and/or stopping an HPI or MU pump and/or use of HPI recirculation flow. In general, MU/HPI flow may be throttled anytime SCM exists as indicated by the incore T/Cs. MU/HPI flow must not be throttled when the RC SCM is lost. When the HPI flow is throttled, the pump flow rate should not be throttled below the minimum allowed pump flow rate of 35 gpm when the pump recirculation valve is closed. The HPI recirculation lines may be available to provide the minimum required HPI flow rate.

When throttling MU/HPI flow to control RC pressure, care should be taken not to allow the RC pressure to drop below:

A. The SCM limit.

B. RCP NPSH requirements if a RCP is operating.

If a SGTR exists, another consideration exists. Maintaining the primary to secondary system pressure differential as low as possible is desirable to reduce primary to secondary leak rate. Refer to Chapter III.E.

2.B.4.1 MU/HPI flow MUST be THROTTLED to prevent overpressurizing the RCS when SCM exists by keeping the RC pressure below the NDT or PTS limit as applicable. (See Chapter IV.G)

A. If a pressurizer steam bubble exists, rapid filling of the pressurizer and the resulting pressurizer steam bubble compression can cause the RC pressure to increase. Increasing the RC temperature will also cause the pressure to increase.

B. If the pressurizer is full of water (water solid), either because the pressurizer steam bubble cannot be maintained (i.e., pressurizer heaters are inoperable or the pressurizer has a small leak) or MU/HPI cooling is in progress, the RC pressure is increased when the MU/HPI volume flow rate going into the RCS exceeds the RC volume flow rate leaving the RCS or when the RC temperature is increasing.

C. This action applies if SCM exists as measured by the incore T/C. T_{hot} and T_{cold} can still indicate a loss of SCM. This accounts for the possibility of an area of the RCS not having SCM established while the core is being adequately cooled.

D. During a PTS transient HPI flow must be throttled to prevent excessive subcooling by keeping the core outlet temperature near the SCM limit.

2.B.4.2 The MU/HPI flow SHOULD be THROTTLED to keep the pressurizer level near the normal operating level setpoint when SCM exists.

A. If the pressurizer level is too high, the RCS is susceptible to rapid pressure increases which can cause undesirable opening of the pressurizer relief valves and relief of two-phase and subcooled water. If the pressurizer water level is too low, the RCS is susceptible to large, rapid decreases in pressure which can cause a loss of SCM. Also, the level should be high enough for pressurizer heater operation. The level should account for possible instrument errors including elevated RB temperatures as applicable.

B. If a leak exists in the pressurizer, maintaining a pressurizer level may not be possible and the pressurizer may fill solid if the RC is being kept subcooled.

C. Throttling MU/HPI for the reasons discussed is expected during a SBLOCA or after an overcooling transient; e.g., the SBLOCA can initially be larger than the MU system capacity causing the pressurizer level to drop. HPI will be started with a flow rate greater than the SBLOCA leak rate causing the pressurizer to refill. The SBLOCA can also initially be larger than the combined MU/HPI capacity. However, when the RC pressure decreases the MU/HPI flow rate will increase causing the pressurizer to fill.

D. If the pressurizer drains due to overcooling, MU/HPI can rapidly refill the pressurizer once the overcooling stops. MU/HPI flow will need to be reduced significantly or HPI stopped.

E. Continued filling will cause unnecessary valve operation and fluid release through the pressurizer relief valves. Too much fluid release can overfill and overpressurize the pressurizer relief (or quench) tank.

F. If core cooling is provided by MU/HPI cooling, then pressurizer level cannot be maintained. In this situation, MU/HPI is throttled to prevent over pressurizing the RCS and to limit the cooldown rate (only if SCM is maintained).

2.B.5 Stopping HPI Flow

2.B.5.1 HPI flow SHOULD be STOPPED and normal MU flow control started if the RC leak rate and contraction rate is within the normal makeup flow capacity, SCM exists, and MU/HPI cooling is not required .

A. When stopping HPI while a leak exists in the RCS, the MU pumps must be able to take suction from the BWST or RC bleed tanks. However, if the BWST and bleed tanks are empty, the MU pumps must be able to take suction from the LPI discharge.

B. Normal MU flow control is preferred because the system provides automatic volume control.

C. The RC leak rates and contraction rate should be verified to be within normal MU flow capacity as indicated by pressurizer level.

D. Normal letdown and use of the MU tank may also be started along with normal MU flow control depending on existing plant conditions; e.g., if the RC radiation level is high then letdown should be isolated.

2.B.5.2 HPI flow SHOULD be STOPPED if ICC conditions do not exist AND the LPI flow rate is equal to or greater than 1000 GPM/line.

The intent of this criterion and the criterion of 2.B.5.3 is to terminate HPI if it is no longer needed for accident mitigation. However, if there is insufficient evidence that HPI is no longer needed, the continuation of HPI flow for assured core cooling takes precedence over the desire to terminate HPI flow. Since it is the intent of these guidelines to minimize the use of piggyback operation, HPI should be allowed to continue until switchover to RB emergency sump suction is required if the criteria are satisfied while still on the BWST.

A. This condition is applicable to larger size LOCAs when the RCS depressurizes sufficiently to allow the specified LPI flow rates. The intent is to terminate HPI flow if

possible. Terminating HPI flow prevents the added actions of aligning for piggyback operation and prevents pumping RB emergency sump water with the HPI pumps. This limits the transporting of radioactive RB emergency sump water outside of the RB. Also, it is possible that recirculating debris (e.g., fine silt type material) from the emergency sump through the HPI pumps might cause some pump degradation after initial mission times are fulfilled. This would be prevented if piggyback operation can be precluded. However, if neither the above flow rates can be achieved nor SCM regained per section 2.B.5.3, then HPI/LPI piggyback operation will be required.

B. The LPI flow rate is required in each line in the event that a break exists in one of the LPI/CF lines. If LPI flow exists in only one line, it is possible that some or all of the LPI flow is being lost out the break. It is not possible to ensure adequate LPI flow from one line to the RV exists while saturated, therefore sustained HPI flow would be required. Adequate LPI flow through one line could appear to exist if the HPI were terminated without resulting in an increase in RC temperature or pressure. However, this could be due to boiling off of the existing RC inventory, with the inadequate LPI flow not becoming evident until the core uncovers and the core outlet becomes superheated. The existence of the minimum required flow in both LPI lines ensures the flow from at least one line is reaching the RV.

C. The flow rate value provides some margin over the minimum LPI flow required to remove decay heat in order to assure refill. In addition, the typical LPI pump head curve is fairly flat from shutoff head to 1000 GPM such that only a few psi increase in RC pressure can significantly reduce LPI flow. Thus, requiring flow of at least 1000 GPM provides some margin to loss of LPI flow due to an RC pressure increase. RC temperature and pressure may increase following switchover to the emergency sump due to an increase in LPI temperature caused by elevated emergency sump temperatures.

D. The flow rate stated above DOES NOT include allowances for instrument errors. Errors should be accounted for in deriving plant specific values for the procedures. The values DO account for the sensor location and LPI system configuration.

E. It is normally expected that a break scenario will follow one of two paths:

1. The break will be large enough to pass the required minimum LPI flows allowing HPI termination.

2. The break size will be small enough to allow restoration of SCM to allow HPI termination per section 2.B.5.3.

However, some break sizes, decay heat levels, etc., may be such that the RCS remains saturated for a period of time with LPI flows less than the required minimum flow rates listed above. In these cases, the PORV may be opened in an attempt to increase LPI flow. If LPI flow is still less than the minimum required when it becomes necessary to switch suction to the RB emergency sump, then full HPI flow will be required on LPI piggyback and the PORV should be closed. If SCM is restored during this process, then the criteria of section 2.B.5.3 apply. HPI should not be throttled in an attempt to increase LPI flow while the RCS is saturated. The reason for this is the same as that associated with not terminating HPI if LPI flow exists in only one line (see discussion at B above). Specifically, throttling HPI while saturated, and without the required minimum LPI flow, could result in a net inventory loss and core uncovery.

F. If core exit thermocouples indicate ICC conditions, then full HPI flow must be maintained even if the minimum LPI flow rate exists.

G. These criteria, i.e., ICC does not exist and LPI flow in each line ≥ 1000 GPM, continue to apply, following emergency sump switchover, to allow subsequent termination of HPI when the criteria are satisfied.

2.B.5.3 HPI flow SHOULD be STOPPED when SCM exists, IF LPI flow can maintain core cooling and SCM.

A. The intent is to avoid unnecessary HPI/LPI piggyback operation for cases where the break size may not be large enough to pass the LPI flow rate required by section 2.B.5.2.

B. This applies once LPI flow has been established with SCM. In order to demonstrate that the LPI flow is sufficient, HPI flow should be throttled while maintaining LPI flow and SCM. If HPI flow can be throttled to the minimum allowable pump flow rate of [plant specific flow rate] with SCM and stable or decreasing core outlet temperature, then HPI can be terminated.

C. Once the criteria are satisfied, i.e., SCM exists and LPI flow can maintain core cooling and SCM, then HPI flow should be maintained at the minimum allowable pump flow rate of [plant specific flow rate] until emergency sump switchover is required. If SCM is lost or core outlet temperature begins to increase, then full flow from two HPI pumps must be restored. HPI/LPI piggyback operation will be required if the criteria can not be satisfied before emergency sump switchover is required. If the criteria are satisfied, then the HPI may be terminated.

D. If the criteria cannot be met before emergency sump switchover, then the criteria continue to apply following emergency sump switchover to allow subsequent termination of HPI when the criteria are satisfied.

3.0 LPI SYSTEM OPERATION

In general, the LPI system is used to:

A. Makeup for lost RCS inventory due to a LOCA.

B. Provide post LOCA core cooling.

C. Provide RB emergency sump water to the HPI suction.

D. Increase MU and HPI flow (Davis Besse).

3.1 LPI MUST be initiated whenever any of the LPI initiation setpoints are reached .

The setpoints are those used by the safety features actuation system. LPI is initiated by starting two LPI pumps taking suction from the BWST first, or from the RB emergency sump as applicable, and pumping to the RCS. Proper actuation should be verified and actions taken if necessary.

If only one LPI pump is available, then the running pump should be aligned to both injection lines. This alignment may occur automatically due to passive cross-connects or may require a valve lineup. Providing flow to both injection lines ensures that the flow from at least one line is reaching the reactor vessel, in the event that the break is in one of the lines.

If the only running LPI pump is not aligned to both injection lines, then continued HPI operation will be required as long as the RCS is not subcooled. In addition, the CFT isolation valves must remain open until either subcooling or very low RC pressure is attained. It is possible that the one LPI line in use is also the source of the break, therefore it is necessary to maintain HPI and to ensure that the CFTs have fully discharged while the RCS remains saturated.

3.2 The LPI suction MUST be changed from the BWST to the RB emergency sump when switchover conditions are met .

The BWST water inventory remaining should provide sufficient time to make a transition to the RB emergency sump to prevent losing LPI suction water, provide adequate LPI pump NPSH and prevent air entrapment in the LPI flow. The switchover from the BWST to the RB sump must not be made before switchover conditions are met. The reason is that both LPI pumps may cavitate due to inadequate RB emergency sump level.

During BWST depletion, level increase in the RB emergency sump should be verified. If the RB sump level is not increasing as expected, then RC fluid may be leaking to an unrecoverable location such as in the case of a steam generator tube rupture or a leak in the auxiliary building. In this case, makeup to the BWST should be started. Management of the BWST inventory for a tube rupture is covered in Chapter III.E. If a leak exists outside the RB, it should be isolated as soon as possible.

When switchover to the RB emergency sump is made, the RB spray flow should be throttled back from full flow to lessen the possibility of pump cavitation, if possible considering the time available to complete the switchover. Once the switchover is completed, monitor LPI and RB spray pumps for signs of cavitation and throttle if necessary to maintain NPSH. Piggyback operation must be established (to allow HPI make up) if RCS pressure is > LPI system shutoff pressure or RCS pressure is too high to allow enough LPI flow rate to adequately cool the core.

Establishing RB emergency sump recirculation will result in radioactive liquid flow outside the RB (e.g., auxiliary building). Appropriate precautions should be taken for the potential exposure due to this flowpath and for the potential release of radioactive gas or liquid.

3.3 RCS Saturated With One LPI Pump Operable

With only one LPI pump operable and the RCS saturated at the core exit, an LPI discharge cross-tie valve should be opened. If LPI flow rate is less than [minimum flow rate] (Rule 2.0), then an HPI pump should be operated at full flow in the piggyback mode. Opening an LPI system discharge cross-tie valve provides flow to each LPI line and establishing HPI piggyback operations supplies HPI flow to all four cold legs. Either the LPI [minimum flow rate] or full HPI flow with the HPI pump operating in the piggyback mode will ensure adequate flow to the core in the event a LOCA has occurred in a CF injection line.

3.4 MU and HPI piggyback operation for Davis Besse

When providing MU or HPI flow, the LPI system is sometimes used to increase the MU and/or HPI flowrate by placing the LPI pumps in series with these pumps, i.e. piggyback operation, such that the LPI pump is discharging to the suction of these pumps. Section 2.B discusses when piggyback operation is used.

4.0 DHRS OPERATIONS

DHRS operations are outside the scope of the TBD. Nonetheless, this section provides important aspects, including some prerequisites that should be considered before using the DHRS following LOCA and HPIC cooldowns.

DHRS operations are generally initiated when conditions permit during a cooldown. However, if the RC is highly radioactive, consideration should be given to continued use of the SG(s) for heat removal rather than spreading the radioactive RC to other fluid systems outside of the RB.

4.1 DHRS Operations Prerequisites

4.1.A SCM Must Exist

Whenever SCM does not exist, the LPI system must not be aligned to the DHR mode. In this situation LPI [minimum flow rate] (Rule 2.0) or full HPI flow with an HPI pump operating in the piggyback mode must be maintained (3.3).

4.1.B Approximately Equal LPI Flows

If both LPI trains do not exhibit approximately equal flow rates while in LPI mode, then DHRS operation should not be attempted. Approximately equal LPI flow rates indicate that a significant LPI/CFT line break does not exist, unless a high flow LPI line has been throttled significantly which could mask a disparity in injection flow rates. If this is the case, DHRS operations should not proceed until it is known that a significant LPI/CFT line break does not exist.

4.1.C Minimum Excess LPI Capacity

Once DHRS operations are established, SCM will be controlled by varying the make up flow being supplied to the RCS via the train operating in the LPI mode. This means that this pump must have enough excess capacity available, i.e., beyond what is necessary for RCS make up due to the break, to adequately control SCM during cooldown. For this reason, DHRS operations should not be attempted unless the total flow being pumped to the RCS from both LPI pumps is less than the capacity of one LPI pump at existing RCS pressure. This criteria is based on expected increases in LPI flow to accommodate RC density changes during the cooldown and provide some margin for unexpected pressure transients.

4.1.D Pressurizer Level On-scale

The train being aligned for DHR could be lost during or after DHR alignment if the available head in the hot leg, that provides suction to the pump, is not sufficient to prevent vapor formation in the pump suction. To help ensure adequate NPSH, for the LPI pump being aligned to the DHR mode, pressurizer level must be on-scale and maintained, before the LPI pump is aligned for DHR operations.

SCM in conjunction with pressurizer level on-scale reduces the likelihood that adequate NPSH would be lost when aligning an LPI pump for DHR. However, depending upon conditions, e.g., break location and flow dynamics, adequate NPSH could still be lost to the pump being aligned for DHR even when SCM is maintained. Therefore, the LPI pump being aligned for DHR should be carefully monitored and secured if signs of cavitation occur, e.g., low and/or erratic pump amperage and pump sounds indicative of cavitation.

4.2 DHRS Operations Considerations

The manner in which DHRS operation is achieved is situationally dependent. There are many postulated situations that may occur; however, this section is limited to providing guidance based on certain expected and plausible post-LOCA and HPIC cooldown situations. It is not intended to be inclusive of all possible situations.

4.2.A One LPI Pump Operable

Post-LOCA Cooldown

With only one LPI pump operable, DHRS operations may be possible if there is no requirement for RCS makeup from the LPI system, i.e., RCS MU requirements are ≤

normal MU system capacity and SGs are providing heat transfer. For such situations, if the normal MU system is available and is in operation, DHRS operations can be attempted. In this situation, a fairly normal plant configuration will have been established and it is likely that successful DHRS operations will be achieved. SG core cooling should be maintained until it is known that DHRS operations have been successful.

If SCM is lost during transition to DHRS operations, then the LPI pump must be realigned to the LPI mode (3.3).

Depending upon event specific conditions (e.g., break location, size and flow dynamics) adequate NPSH could be lost to the LPI pump when aligning it for DHRS operations. For this situation, i.e., RCS makeup < normal MU, the leak size makes this very unlikely; however, it must still be considered, especially given that there is only one LPI pump available. While maintaining SG core cooling, the LPI pump should be aligned in the DHR mode and carefully monitored for signs of cavitation. If any signs of cavitation are exhibited, the pump should be immediately secured and, if accessible, vented. It is recommended that DHRS operations not be attempted again until another LPI pump is operable and RCS P-T conditions have significantly improved to increase NPSH. Increasing NPSH via improved RCS P-T conditions increases margin to cavitation on subsequent attempts to establish DHR.

Should there be a subsequent loss of SCM following initiation of DHRS operations, the DHR train must be restored to the LPI mode (3.3).

Post-HPIC Cooldown

This discussion assumes there is no LOCA.

If RCS conditions that allow transition to DHRS operations are established before HPI must be piggybacked to LPI (i.e., before sump switchover), then DHRS operations with only one LPI pump may be possible. Prior to attempting DHRS operations, it should be confirmed that sufficient BWST inventory remains to accommodate the time necessary to establish DHRS operations without interrupting core cooling. The concern here is that core cooling not be interrupted during transition to DHRS operations, which would be the case if the HPI pump suction were aligned to the operable LPI pump (sump switchover has occurred) and DHRS alignments attempted. Therefore, if HPI is operating in the piggyback mode on the only available LPI pump, then attempts to establish DHRS operations would require temporary cessation of core cooling and are not recommended. In this situation, it is recommended that attempts to establish DHRS operations be postponed until either another LPI pump becomes available or SG heat transfer has been restored.

4.2.B Two LPI Pumps Operable

Post-LOCA Cooldown

When two LPI pumps are operable it may be possible to establish DHR operations concurrent with a LOCA even for breaks that require makeup at rates > the normal MU system capacity. In order for DHR operations to be successful, the RCS must be subcooled and there must be adequate excess LPI flow available to control SCM once DHR is established. SG core cooling should be maintained until it is known that DHRS operations have been successful.

During the transition to DHRS operations, SCM should be monitored. If SCM cannot be maintained, e.g., when the LPI pump is stopped in preparation for its DHR alignment or during subsequent DHR operations, then full LPI with both trains should be re-established or an LPI cross-tie valve opened. If LPI [minimum flow rate] cannot be established (Rule 2.0), then HPI must be re-established.

Depending upon conditions (e.g., break location, size and flow dynamics) adequate NPSH could be lost to the pump being aligned for DHR operations. This is possible even with SCM and can lead to steam-binding of the pump. Should this occur without a coincident loss of SCM, the pump should be stopped and vented, if accessible. It can then be used in additional attempts to provide DHR, placed back into the LPI mode or placed in the LPI standby mode (satisfactory since SCM exists with one LPI pump in operation).

Post-HPIC Cooldown

With two LPI pumps operable, transition to DHRS operations should be possible. When making this transition, DHRS operations should be established prior to terminating HPIC.

5.0 CORE FLOOD TANK OPERATION

5.1 The core flood tank isolation valves SHOULD be closed if SCM does not exist when the LPI flow rate is equal to or greater than:

Plant	Min. Required LPI Flow
177FA NSS except ANO-1	1000 GPM/line
ANO-1 with 2 LPI pumps running	2630 GPM/pump
ANO-1 with 1 LPI pump running	3020 GPM total pump flow

A. Leaving the core flood tank isolation valves open will not interrupt core cooling, therefore closing them is not mandatory. During a larger size break LOCA, the core flow will be sufficiently turbulent that adequate core heat transfer will exist even with entrained nitrogen. The nitrogen may accumulate in the hot legs and SG tubes, but the SGs are not used for heat removal for larger size breaks. In addition, the time available during a larger size break is insufficient to preclude nitrogen entrainment.

During a smaller size LOCA, the minimum core inventory occurs later in time when the decay heat is lower. The nitrogen addition rate from the CFTs would be slow, and the core is submerged such that adequate core heat removal exists. However, closing the CFT isolation valves to prevent nitrogen addition is desirable.

This will ensure that SG heat transfer is not degraded by nitrogen and reduces waste gas management.

B. Ideally, during a LOCA the CFTs would be isolated just prior to nitrogen injection by use of CFT level. This instrumentation is not specified in this guideline because the accuracy may be degraded by the RB environment and the value of interest is at the low extreme of the scale. LPI flow, which is dependant upon RC pressure, provides a reliable means of determining when CFT isolation valves may be closed. This is because these instruments are located outside the RB and the value of interest is not near either end of the scale. However, this does not preclude the use of CFT level indication if a plant determines it to be suitable for this application.

RC pressure must decrease to approximately 140 psig before nitrogen injection to the RCS will occur. However, the required LPI flow rate, i.e., to allow closure of CFT isolation valves, should exist above this pressure.

It should be noted that the LPI flow rate for a given RC pressure will decrease as BWST level decreases. Also, the pressure at which the CFT empties could increase due to ambient heating of the nitrogen. For these reasons, some nitrogen may be injected into the RCS but the amount will be minimal and is not expected to adversely impact core cooling.

C. If SCM is restored, then section 5.2 applies.

D. The LPI flow requirement is based on CFT line break analyses and typical CFT discharge profiles. While the CFT line break analyses did not take credit for LPI flow, it did assume injection of the water in one CFT through the intact line. This intact line provides a flowpath for LPI to discharge to the core, thus providing adequate core cooling if the specified value is achieved. Because it cannot be determined which CFT line is intact, the specified flow rate must be supplied from each LPI line to ensure adequate core cooling. Once LPI is flowing at the specified rate in both LPI lines, the passive CFT function is no longer required and the CFTs may be isolated.

The specified LPI flow rate provides some margin above the minimum flow required to just make up for boil-off, thus ensuring RV refill. The flow rates are also consistent with the flow rates required for HPI termination, allowing the use of a single setpoint.

E. If it is not possible to align LPI flow to both injection lines, then the CFTs can be isolated when RC pressure is less than 135 psig, adjusted downward as necessary for errors. This provides additional assurance that the intact CFT has fully injected to be consistent with the analyses. This may result in slightly larger volumes of nitrogen injection, but nitrogen injection is a secondary concern and will not adversely impact core cooling.

5.2 <u>The core flood tank isolation valves SHOULD be closed if SCM exists when RC pressure is < [allowable pressure for CFT isolation] if RC pressure is being controlled.</u>

If SCM exists and RC pressure is being controlled and is less than the [allowable pressure for CFT isolation], then the CFT isolation valves should be closed to prevent interference with RCS depressurization. The core is being cooled and RC pressure control exists, therefore the CFTs are not needed. If SCM is lost after the CFTs have been isolated, the CFT isolation valves should be reopened unless the conditions of 5.1 have been satisfied. In the case of transients involving HPI, RC pressure is considered to be controlled if HPI is being throttled to maintain minimum SCM.

6.0 <u>POST-LOCA BORON PRECIPITATION PREVENTION</u>

6.1 <u>An active means of boron dilution must be initiated if a loss of subcooling margin has existed for the [boron dilution time limit] and core outlet temperature, as measured by incore thermocouples, is:</u>

- ≤ 305°F for all plants except Davis-Besse
- ≤ 322°F for Davis-Besse

For CR-3, analyses have been performed for several of the possible boron dilution methods, and the time to initiation is dependent on the method chosen.

6.1.1 <u>Background</u>

Analyses indicate that certain kinds of RCS breaks, or LOCAs, can lead to significant boron concentration increases in the RV. These increases can be large enough to cause the boron to precipitate out of the RC and possibly cause blockage of flow channels. The boron will begin to precipitate out of the RC when the boron concentration reaches the solubility limit for existing RC temperature conditions. It should be noted that this scenario can occur for some LOCAs even if all ECCS equipment operates as designed. Passive and active methods are available to prevent the boron concentration from increasing to the solubility limit.

6.1.2 Mechanism That Causes Increased Boron Concentration

The mechanism that causes the boron to increase is evaporation of RC. When a RCS break leads to saturated RC conditions, there will necessarily be steam formation in the core. As the RC vaporizes into steam nearly all of the boron remains behind in the liquid RC. As the steam exits the RCS and borated water is supplied to the RCS (via ECCS equipment), a feed and bleed mode is established. The feed stream is the borated ECCS water, and the bleed stream is the flow of steam (essentially unborated water) out of the RCS through the break. In this mode the RCS is operating as a distiller, or evaporator, where the concentration product is boron in the core region.

If the feed stream (ECCS injection) is insufficient to refill the RCS to the point where liquid RC is flowing out through the break, then the boron concentration in the core region will continue to increase. If the break size or location precludes total RCS refill, the core concentration will be controlled by liquid flow through the core. If the core remains saturated, boron concentration control may be needed. If core boiling is suppressed, liquid flow through the core has been established. The RV boron concentration will decrease and approach the concentration of the ECCS supplied water (BWST or sump).

6.1.3 Effect Of Leak Location On RCS Boron Concentration

Hot leg breaks - Breaks in the hot leg and Pressurizer will readily establish a continuous liquid flow through the core. The break may or may not be able to pass all the available ECCS injection flow rate. This situation establishes a feed (ECCS or sump concentration fluid into the RCS) and bleed (fluid at RCS boron concentration out the break) mode of operation. The core boron concentration will approach the feed concentration, but excessive core boron concentrations are prevented and the solubility limit is not reached. This conclusion is true for the entire spectrum of hot leg breaks.

Cold leg breaks – Breaks in the cold leg may or may not pose boron precipitation concerns. If the break size and/or location allows RCS refill, such that the same liquid that flows through the core also flows out the break, then boron precipitation is not expected to be a concern. Some breaks will result in most of the ECCS flow bypassing the core and flowing out the break. The only flow through the core will be that which makes up for boiloff. These breaks may pose boron concentration concerns.

Certain through the RVVVs and cold leg breaks evolve to a pot boiling mode where steam that forms in the core passes out through the break, but there is no accompanying RC liquid flow through the core. All of the decay heat is removed by steam generation in the core. The ECCS injection provides only enough liquid to the core to make up for core boiling; the remainder of the ECCS injection bypasses the core via the inlet plenum and flows out the break. Because of the leak "size and location" (larger break located at the bottom of the cold leg pipe), the level in the plenum cylinder cannot rise to the point where liquid can flow through the core, out the large holes in the outlet plenum, or through the RVVVs and out the break. With no liquid RC flowing through the core and out the break, the core will remain saturated and the boron concentration will continue to increase. Establishment of a small liquid throughput will prevent the solubility limits from being reached. Higher liquid throughputs may allow SCM to be regained.

6.2 Post LOCA Boron Precipitation Analysis

Criterion 5 of 10CFR50.46 requires that after successful initial operation of the ECCS, the core temperature shall be maintained at an acceptably low value, and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core. This situation is normally characterized as establishing a mode of "long term" cooling. One element of the long term cooling mode is the need to prevent precipitation of boron in the core and RV.

Analyses of the potential for this kind of post-LOCA boron precipitation were performed. Among other objectives, these analyses sought to determine when and/or under what conditions boron concentration in the core could reach the solubility limit, i.e., point where precipitate could form. This information would then be used to indicate when and under what circumstances operators must take action to provide an active means of boron dilution that can prevent boron concentration from reaching the solubility limit.

Analyses indicate that the most limiting condition for LOCAs is a large break in the cold leg piping located at the RCP discharge. This situation places the core in a pot boiling mode with all the decay heat removed by the generation of steam. The steam forming in the core area passes out through the break via the RVVVs. Boron concentrates in the core area (the pot) and refill may not be possible. Hence, boron concentration increase will continue as long as steam forms in the core. For this condition, due to the high steaming rates, the boron solubility limit can be reached in as short a time as the [boron dilution time limit] following initiation of the LOCA.

It has further been determined that the solubility limit cannot be reached as long as RCS conditions are:

- ≥ 305°F / 72 PSIA for all plants except Davis-Besse
- ≥ 322°F / 92 PSIA for Davis-Besse.

These limits are based on the assumption that the entire boron content of the BWST, the CFTs and the RCS could be concentrated into a core mixing volume. This liquid volume is based on the liquid mass of the region from the bottom of the core to the bottom of the large holes in the plenum cylinder considering the RV void fraction distribution. The difference in these limiting temperatures is the greater total amount of boron (in the BWST, CFTs and RCS) associated with Davis-Besse due to a higher power level for the core.

6.3 Boron Dilution Initiation Criteria

The response of RCS pressure and temperature can provide an indication of the size of a LOCA. However, there is currently no way to know the location of a LOCA such that it can be determined whether or not the break is in the hot or cold leg. Because of this, all LOCAs that cause an extended loss of subcooling margin must be treated as though boron precipitation could occur. This means that an active method of boron dilution must be initiated, unless other means exist, such as a correlation to RB sump boron concentration, to indicate that a dilution flow path is not required.

An active means of boron dilution must be initiated by the time inadequate subcooling margin has existed for [boron dilution time limit] and core outlet temperature, as measured by incore thermocouples, is

- ≤ 305°F for all plants except Davis-Besse
- ≤ 322°F for Davis-Besse

For CR-3, analyses have been performed for several possible boron dilution methods, and the time to initiation is dependent on the method chosen.

Once sump switchover has occurred if the elapsed time since loss of SCM is approaching the [boron dilution time limit] criterion and the active boron dilution method can be initiated at the existing RCS conditions, then the conservative approach would be to initiate it then, and not wait for the RCS temperature/pressure to continue to decrease. If the active dilution method cannot be initiated until a lower temperature is reached, then preparations should be made for its initiation when the allowable temperature is reached. However, the active boron dilution method must be initiated as soon as possible and before decreasing below the criterion.

6.4 Boron Dilution Methods

Boron dilution methods, both active and passive, are available for preventing boron precipitation. However, the NRC requires that an active method be established. Passive methods may be effective for limited durations. The available methods of providing an active means of boron dilution are plant specific. Each plant should determine its active methods and verify the effectiveness of each method. If possible, preference should be given to a method that does not require taking available ECCS equipment (such as an LPI train) out of service or compromise components (LPI pump or DH Cooler, etc.) needed for long-term cooling. This is not an all-inclusive list, but some of the active methods that may be available are the following:

6.4.1 Alignment of the decay heat drop line to the RB emergency sump

This alignment establishes a feed and bleed mode where liquid flows through the core to the hot leg to the RB sump through the decay heat drop line. The feed is the ECCS injection and the bleed is the RC liquid flow to the sump. As this continues, the core boron concentration will approach that of the ECCS injection (BWST or sump).

This alignment requires taking one LPI pump out of service. If a LPI pump is taken out of service, then either the LPI discharge lines must be cross-connected and provide the minimum required LPI flow through both lines or an HPI pump must be aligned on piggyback on the running LPI pump.

This alignment should take into consideration RCS pressure conditions and the resultant flow forces imposed on the RB sump screens or possible pipe loads from steam-water interactions in the DH piping. This alignment should also take into consideration RCS temperature conditions. It may be required when the RCS temperature is above the design temperature (though RCS pressure will be much less than the design pressure) for the DHR system piping and equipment. If so, an evaluation of the RCS temperature/pressure conditions on the DHR system should be made before implementing this method.

6.4.2 Hot leg injection via auxiliary pressurizer spray

Aligning the auxiliary pressurizer spray provides liquid flow to the core outlet. When the auxiliary spray flow rate exceeds the core boiloff rate, a level increase will occur in the plenum cylinder (core outlet area). Because the static level in the downcomer will not support the increased level in the plenum cylinder, a small liquid reverse flow through the core and out the inlet plenum occurs. This reverse flow initiates a feed and bleed process where the feed is the inflow from the pressurizer spray and the bleed is the flow out of the inlet plenum. When the excess spray flow carries out more boron than is concentrated in the core, a long-term boron dilution mechanism is achieved.

This alignment does not require termination of an LPI pump, but it may require throttling LPI flow to the RCS (or alignment of an HPI pump for DB) to generate higher auxiliary spray flow rates. Depending on the available auxiliary spray flow rate, this method may not be effective immediately after the LOCA. Limitations on the amount of throttling of LPI flow may further reduce the effectiveness of this method. This method also requires initiation with enough lead time to fill the Pressurizer before the core flow is needed.

6.4.3 Hot leg injection via reverse flow through the decay heat drop line

Certain plants may be capable of using the decay heat drop line to inject liquid into the hot leg to initiate a reverse core flow. This process is similar to hot leg injection via auxiliary pressurizer spray, except that much higher flow rates can be achieved.

Alignment of this method is such that flow is reversed through an idle LPI pump. This alignment requires that one LPI pump be taken out of service, the LPI cross-connect line be opened and provide the minimum required LPI flow through both lines, or an HPI pump be aligned on piggyback on the running LPI pump. LPI may need to be throttled to prevent pump runout with the decay heat drop line isolation valves opened. As in the method discussed in Section 6.4.1, the RCS temperature/pressure conditions on the DHR system need to be evaluated.

6.4.4 Hot Leg Flow Through The Decay Heat Drop Line Bypass

The decay heat drop line bypass (if available) can be used to take a small amount of high boron concentration liquid from the hot leg via a bypass flowpath. This liquid is mixed with the sump inventory diluting the liquid and then returning the inventory to the core via ECCS injection. This method does not require taking one LPI Train out of service. This method may be limited by RCS to Sump differential pressure and LPI pump NPSH requirements.

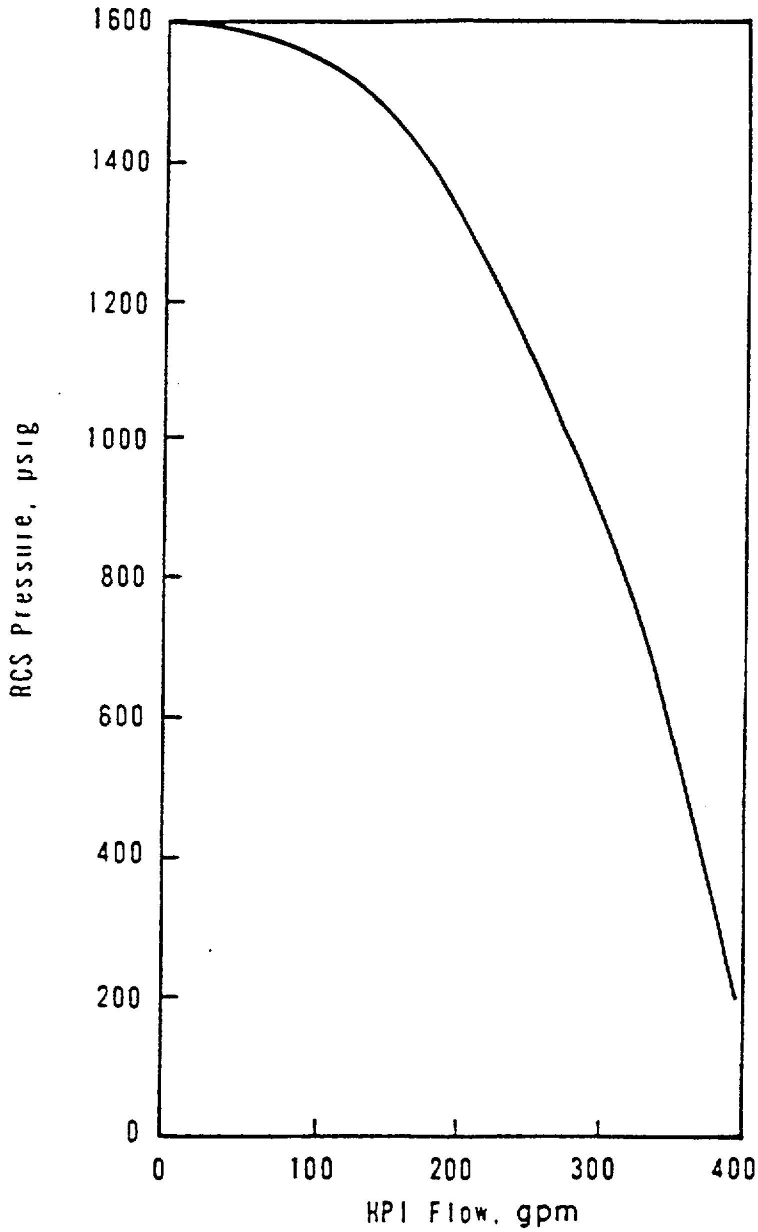
6.4.5 Passive methods

The passive methods are Reactor Vessel Vent Valve (RVVV) liquid overflow or droplet entrainment flow and hot leg gap flow. Neither of these methods is controllable and may not be continuously available for all LOCA scenarios. These passive methods can be effective for limited conditions and durations if one of the active methods cannot be implemented.

6.5 Monitoring RB Sump Boron Concentration

Monitoring the RB sump boron concentration, if possible is recommended. It would provide an indication of the effectiveness of the dilution method being used, and also the possibility of RB sump dilution due to passive methods. It may be possible to justify not initiating an active dilution method if the RB sump boron concentration is monitored. However, that justification should consider such factors as amount of time required to obtain feedback regarding the effectiveness of the passive dilution methods and the possibility of hold-up volumes.

Figure IV.B-1 HPI Throttling Limit (For High Flow Line)
For DB-1



Chapter IV.C
MFW/EFW System Operation

1.0 INTRODUCTION

Steam generator inventory control is one of the five control functions discussed in Chapter II.C. The SG inventory is controlled by EFW and MFW. This chapter will discuss special considerations associated with the operation of EFW and MFW.

In general, FW should be supplied only to SGs which can hold pressure (i.e., no significant unisolable steam leak). However, exceptions do exist and will be discussed in Section 5.0.

For the SGs that can hold pressure, this chapter will discuss:

a) SG water level requirements. (Subsection 3.0)
b) Excessive FW flow. (Subsection 4.1)
c) Initiating EFW flow. (Subsection 4.2)
d) Maximizing FW flow. (Subsection 4.3)
e) Throttling FW flow. (Subsection 4.4)

2.0 DEFINITIONS

2.1 Steam Generator That Can Hold Pressure

This is a SG without an unisolable steam leak or with a very small unisolable steam leak. A very small steam leak is one which itself cannot remove more energy than is being transferred to the SG; i.e., the steam leak cannot cause the RC to decrease in temperature.

2.2 Loss of Subcooling Margin

Refer to Chapter IV.B.

2.3 SG LEVEL SETPOINT DEFINITIONS

The following SG level setpoint definitions are used in this document:

A. Low Level Setpoint - This setpoint is used when RCPs are operating and the RCS has adequate SCM. However, this setpoint may be different depending on whether the MFW system or the EFW system is supplying FW.

B. Natural Circulation Setpoint - This setpoint is used when no RCPs are on and the RCS has adequate SCM.

C. Loss of Subcooling Margin Setpoint - This setpoint is used when SCM does not exist.

D. ICC Setpoint - This setpoint applies only to Davis-Besse and is used when the RC temperature and pressure is in region 3 of Figure III.F-1.

E. Shutdown - SG Overfill Setpoint - The SG level must be kept below this value to prevent water from entering the steam lines after a reactor trip.

F. EFW Start SG Level - This is the SG water level at which the EFW system starts following a loss of MFW.

3.0 STEAM GENERATOR WATER LEVEL

This section discusses the bases for SG level setpoints. Setpoint values are plant specific. In general, the SG water level is maintained only high enough for adequate primary to secondary heat transfer to limit unnecessary filling of the steam generator. The required SG water levels when two SGs are operating are discussed in the following sections. When only one SG is operating in natural circulation, raising the water level slightly higher may be beneficial. This action increases the heat removal ability of the one operating SG.

The rate at which the SG level setpoints are achieved is determined by the FW flow rate guidelines discussed in Section 4.0

3.1 SG Level With Operating RCP(s)

When using MFW or EFW and at least one RCP is on and SCM exists, the SG level SHOULD be controlled at or above the [low level setpoint].

This level is sufficient for removing core and RCP heat when the RC is subcooled and forced circulation of RC exists between the core and the SG.

3.2 SG Natural Circulation Setpoint

If all the RCPs are deenergized and the RC SCM exists, the SG level SHOULD be controlled at or above the [natural circulation setpoint].

The RC will have to flow between the core and the SGs by natural circulation. This requires a higher SG level than does forced-RC flow. The SG level must be high enough to create a SG heat sink thermal center sufficiently above the core thermal center to induce adequate natural circulation of the RC. Although obtaining the necessary SG levels is the preferred method for establishing natural circulation, adequate natural circulation can occur due to EFW flow only. For certain in-plant conditions (e.g., low decay heat level), it may not be necessary to increase SG levels as long as EFW flow is providing adequate heat transfer.

3.3 SG Loss of Subcooling Margin

If the RC SCM is lost, the SG level MUST be controlled at or above the [loss of subcooling margin setpoint].

This SG level is even higher than the natural circulation setpoint. When the RC SCM is lost, the RC has a potential of being saturated. Therefore, the SG water level is raised to the loss of SCM setpoint. This setpoint has been determined for a saturated RCS with steam in the hot leg pipes, for the case when core cooling is assisted by boiler condenser cooling. The core heats the surrounding water creating steam which flows through the hot leg pipes to the SGs where it is condensed. The resulting pool of water in the SG tubes must be higher than the elevation of the RCP internal spill-over so that the cold leg water will flow to the RV. For this to happen, the SG condensing surface has to be higher than the RCP internal spill-over. Also the condensing surface of the SG tubes must be adequate, combined with HPI cooling, to remove all the heat being generated by the core. The elevation of the EFW nozzles is high enough to provide the required condensing surface. The level setpoint is set high enough such that one SG can provide the required condensing surface during periods of no EFW flow.

3.4 If ICC conditions exist with an indicated fuel clad temperature greater than 1400°F the SG levels SHOULD be raised to the [ICC level setpoint]. (Only applicable to Davis-Besse)

The SG water level should be raised to the maximum level possible without causing water to enter the steam lines or losing SG level measurement or causing SG overfill protection system actuation; i.e., SFRCS trip on high SG level. This will provide the greatest SG condensing surface.

4.0 FEEDWATER CONTROL TO STEAM GENERATORS THAT CAN HOLD PRESSURE

This section applies only to SGs that can hold pressure. Special considerations for SG(s) that cannot hold pressure are given in Section 5.0.

The FW flow rate should be controlled to increase and decrease the SG level to obtain the required setpoint.

Guidelines are provided for controlling FW flow. Some guidelines are mandatory (must) while others are desirable (should). If a mandatory and a desirable guideline conflict, the mandatory guideline has priority.

Some utilities may be able to feed MFW to the EFW nozzles. For these plants, MFW flow through the EFW nozzles can be substituted for EFW flow in the guidelines.

If a SG becomes dry, then the flow limits of section 4.4.4 must be observed.

The level associated with a dry SG is a function of the pressure in the SG when the SG becomes dry. That is, at the point where a SG becomes dry, the indicated level is caused only by the head of steam between the level taps. This indicated "dry" level will vary directly with the pressure in the SG when it dries out and is expected to range from about 2 inches at very low SG pressure to about 14 inches at about 1000 PSIG.

Identification of a dry SG may also be possible by means other than use of SG level instruments. When a SG dries out, its pressure is expected to decrease. The rate of decrease of SG pressure depends upon steam demands and leaks associated with the SG. If a SG's pressure decreases due to loss of SG level, then RCS temperature is not expected to decrease as would be the case if the SG pressure decrease was due to a steam leak with adequate SG level.

4.1 Excessive FW

Excessive FW is an uncontrolled condition and must be stopped. It occurs when the FW addition causes the RC to overcool or the SG level to increase above the desired setpoint which, if not stopped, will cause the mass of water in the SGs to increase until water is carried over into the steam lines.

4.1.1 Excessive MFW

4.1.1.1 When the reactor is shutdown, the MFW flow MUST be controlled to prevent the SG level from exceeding the [shutdown-SG overfill setpoint].

When the reactor is shutdown the water level in the SGs must be kept below the main steam outlet nozzles while steaming so that the steam lines do not start filling with water. Note: The SG upper baffle has instrumentation holes which will allow water to flow through the baffle. Consequently, water can start to fill the space between the SG baffle and the SG shell without having to flow over the top of the baffle to fill this space.

Excessive MFW is undesirable for several reasons. It can cause the RCS to overcool, water release through the MSSVs, and the elimination of the SGs as a heat sink because they should not be steamed once they have filled.

As soon as the excessive MFW transient is identified, actions should be taken to quickly stop it because excessive MFW can fill the SGs quickly; e.g., water can start entering the steam lines in as little as 1 minute after a reactor trip if MFW flow is not reduced.

As the SG water volume approaches the [shutdown-SG overfill setpoint], the MFW pumps must be tripped to assure the SGs do not overfill. However, if the excessive MFW is discovered before the [shutdown-SG overfill setpoint] is reached, then the operator should try to stop the excessive MFW by closing the MFW isolation valves.

Tripping the MFW pumps will immediately stop MFW flow. However, this action causes all MFW flow to be discontinued. If only one SG is being overfed, it is preferred to stop MFW to only the overfed SG. By closing MFW isolation valves instead of tripping the MFW pumps the MFW flow can be continued to the other SG. Whenever FW is stopped to both SGs, FW flow (either MFW or EFW) should be restarted before both SGs are dry.

4.1.2 Excessive EFW

4.1.2.1 When the reactor is shutdown, the EFW flow MUST be stopped to the overfilling SG before the SG level reaches the [shutdown - SG overfill setpoint].

Excessive EFW can also cause SG overfill. Excessive EFW can cause significantly more overcooling for the same excess flow as MFW because the EFW sprays into the SG steam space rather than entering the SG water space and the EFW water is colder than MFW. However, EFW cannot fill a SG as fast as MFW flow because the EFW system has less flow capacity.

If excessive EFW occurs, the operator should try to regulate the EFW valves or pump speed to stop the overfeed and, if unsuccessful, stop the pumps and batch feed the SGs, e.g., starting and stopping EFW pumps as needed.

4.2 Initiating EFW

4.2.1 EFW MUST be started whenever MFW flow to both SGs is disrupted causing the SG water level to decrease to the [EFW start SG level setpoint].

This is to provide continued primary to secondary heat transfer.

4.2.2 <u>EFW MUST be started whenever there is inadequate primary to secondary heat transfer or whenever the SG level must be controlled at the [loss of subcooling margin setpoint]. This is because the EFW enters the SG above all operating setpoints.</u> Consequently, when EFW starts flowing the SG thermal center is rapidly raised higher than required without waiting for the actual SG water level to be raised to the desired setpoint.

4.2.3 <u>EFW MUST be started or MFW rerouted to the EFW nozzles when forced RC flow is lost</u>. This is to provide a smooth transition to natural circulation by raising the SG thermal centers.

4.3 <u>Maximizing EFW</u>

4.3.1 <u>Whenever there is inadequate primary to secondary heat transfer, EFW flow rate SHOULD be maximized without causing the SG pressure to go more than 100 PSI below the SG pressure control setting, until the required SG level setpoint is reached or adequate primary to secondary heat transfer is established.</u>

This is done to establish primary to secondary heat transfer as quickly as possible without overcooling the SG while heat transfer does not exist. For conditions where little or no core decay heat exists, almost no primary to secondary heat transfer is necessary. In these cases, only a very limited EFW flow will be necessary, and it must be carefully controlled to prevent depressurizing (overcooling) the SGs. Maximum EFW flow should be maintained less than [pump runout]. If the SG is dry, the flow limits in section 4.4.4 take precedance.

4.4 <u>Throttling EFW</u>

4.4.1 <u>If EFW flow should be added, it SHOULD be controlled so that a continuous EFW flow is provided and the SG level never decreases with an overall progression toward the required setpoint</u>.

Except when a minimum EFW flow must be provided for a loss of SCM (per Section 4.4.3), the SG level can be held constant as long as the EFW spray flow is removing adequate heat. SG levels and RCS temperatures provide indication of inadequate heat transfer. Insufficient EFW flow will result in decreasing SG levels and increasing RCS temperatures. SG pressures provide indication of excessive heat transfer when controlling EFW flow. Excessive EFW flow to raise SG levels too rapidly will result in depressurizing the SGs.

A continuous EFW flow will place the SG thermal center above all required SG level setpoints. The continuous flow will also reduce thermal cycles on the EFW spray nozzle. Therefore, if possible, a continuous EFW flow should be provided.

Holding the SG level constant instead of raising the SG level would be desirable during an overcooling. If the SG level is increased, the overcooling situation would become worse. For certain SGTR situations, the SG level does not have to be raised with EFW. The tube leakage will raise the level. Thus throttling EFW will delay the time when the SG will need to be steamed or drained for preventing the SG from exceeding the SGTR overfill limits. Refer to Chapter III.E for more information about SGTR and SG level control with a SGTR.

4.4.2 <u>The EFW flow rate SHOULD be throttled to prevent the SG pressure from dropping more than 100 PSI below the desired SG pressure control setting.</u>

Throttling EFW flow is done to prevent overcooling the RCS. The EFW flow can cause significant RCS overcooling because the EFW is significantly colder than SG fluid and it is sprayed into the SG steam space. For conditions where little or no core decay heat exists, almost no primary to secondary heat transfer is necessary. In these cases, only a very limited EFW flow will be necessary, and it must be carefully controlled to prevent depressurizing (overcooling) the SGs. However, the EFW flow must not be throttled below any flow rate required by section 4.4.3.

4.4.3 <u>Whenever SCM is lost, SG level(s) must be raised to the [loss of SCM setpoint] using EFW or MFW</u>.

If SCM is lost, then the [loss of SCM setpoint] is achieved as follows:

- When using EFW, it <u>must</u> be provided continuously at ≤ the [minimum fill rate (EFIC)] or at ≤ the [minimum total flow rate] until the [loss of SCM setpoint] is reached. EFW should not be throttled unless necessary.

	Loss SCM Setpoint	Minimum Total EFW Flow Rate	Minimum Fill Rate(EFIC)
Davis Besse	100 inches SUR	N/A	N/A
ANO-1 and CR-3	73% OR	400 GPM	2 inches/minute
ON-1,2 and 3	79% OR	400 GPM	N/A
TMI-1	70% OR	400 GPM	N/A

- When using MFW with the EFW nozzles a total MFW flow rate ≤ 600 GPM must be maintained until the [loss of SCM setpoint] is achieved.

- When using MFW with the MFW nozzles, the [loss of SCM setpoint] must be achieved within 25 minutes of loss of SCM.

Heat removal from the reactor coolant by the SGs is required for a range of LOCAs to satisfy the acceptance criteria of 10 CFR 50.46. For this range of LOCAs, the RCS inventory will decrease causing a loss of natural circulation, (i.e. during the transition from saturated natural circulation to boiler condenser cooling when the RCS water level is between the bottom of the hot leg bend and the EFW spray nozzles) resulting in a period of little primary to secondary heat transfer. This can cause the RCS to heat up and repressurize causing a decrease in HPI flow rate such that the HPI flow by itself may not be sufficient for keeping the core covered and adequately cooled. However, for this range of LOCAs, enough reactor coolant will be lost out the break, prior to any core uncovering, to provide a sufficient steam volume in the primary side of the SG tubes for boiler condenser cooling. This will provide a condensation surface for condensing the steam in the RCS and reducing the RCS pressure so that the HPI flow rate can be increased to a value where its heat removal rate will match the decay heat generation rate to assure peak clad temperatures (PCTs) remain within acceptable limits.

For smaller breaks, the inventory loss is compensated for by the MU/HPI systems, if actuated, with no loss of natural circulation. For larger breaks , the RCS will depressurize low enough with SG cooling to allow the HPI system to maintain sufficient liquid inventory in the reactor vessel to keep the core adequately cooled.

The required heat removal by the SGs can be induced by either spraying sufficient EFW into the SG(s) or by maintaining a sufficient volume of water in the SG(s) using either EFW or MFW.

Establishing the [loss of SCM setpoint] With EFW

When establishing the [loss of SCM setpoint], EFW should not be throttled unless it is necessary to maintain appropriate SG operations. Automatic EFW control systems should be allowed to function as designed to raise SG level to the [loss of SCM setpoint]. These systems should provide either level increases at prescribed rates or adequate flow rates until the required level is achieved. EFW manual flow control should only occur if either the automatic EFW control system is not functioning properly or if the SG becomes uncoupled (loss of heat transfer). For level rate control systems, among other possible failures, if the system does not initially feed due to a level error (actual level higher than target level), this is considered as not functioning properly. Even under manual flow control, full EFW flow should be provided unless throttling becomes necessary. Throttling could become necessary to control SG level at setpoint, to prevent exceeding pump runout limits, or to reduce the depressurization in an uncoupled SG. An uncoupled SG is identified by total EFW flow rate being greater than the total minimum EFW flow rate causing SG pressure to decrease substantially below RCS pressure.

The minimum EFW flow rates prescribed are for "total" EFW flow. This means that any combination of flow to the SGs may be established as long as total flow is not less than the plant specific minimum total flow rate. When feeding only one SG, e.g., due to a SGTR, then the minimum total EFW flow should be fed to that SG. In the event of a conflict between minimum EFW flow requirements for loss of SCM and maximum EFW flow requirements based on feeding a dry SG, minimum flow requirements for loss of SCM have precedence. The minimum total EFW flow rate assures adequate core heat removal while limiting excessive SG cooling and depressurization which could result in unnecessary tube stresses.

Licensing design bases LOCA analyses demonstrate that unthrottled EFW flow rates will remove sufficient heat from the RCS. However, unthrottled EFW flow can cause a problem because these LOCAs have a period of little primary to secondary heat transfer. During this period, unthrottled EFW spray flow could cause excessive SG cooling and depressurization which could result in unnecessary tube stresses. To reduce this problem, minimum total EFW flow rates have been established, using licensing design bases LOCA analyses assumptions.

Davis Besse need only feed to 100 inches SUR level, to achieve the [loss of SCM setpoint]. Because of this relatively low level, there is little time or need to throttle EFW before reaching the setpoint. For this reason, there is no minimum total EFW flow limit for Davis Besse and, therefore, Davis Besse should not throttle EFW flow.

TMI-1 should not throttle EFW flow in the unlikely event that only one motor-driven EFW pump is available. If both motor-driven pumps and/or the steam driven pump are available, then TMI-1 should only throttle EFW flow for the reasons discussed and must provide at least the minimum total EFW flow specified.

Plants with EFIC are required to have EFIC provide EFW to each SG at the following fill rates when the SG pressure is at 800 PSIG:

PLANT	MINIMUM FILL RATE AT 800 PSIG
AN0-1, CR-3	2.0 inches per minute

These fill rates will produce lower flow rates than the specific minimum total required EFW flow rates during periods of no heat transfer (no boiloff). However, as long as EFIC raises the SG level at these rates, manual EFW operation is not required. There are two primary reasons why this is acceptable. First, minimum total EFW flow rates are based on a SG pressure of 1000 PSIA while the EFIC control values are based on a SG pressure of 800 PSIG. The 800 PSIG pressure creates a larger temperature difference between the RCS and the SG than does 1000 PSIA and consequently a smaller required EFW flow rate.

EFIC automatically increases the EFW fill rate with increasing SG pressure such that for a given SG pressure, adequate EFW flow rates for LOCA concerns will be met. The 800 PSIG pressure was chosen for specifying the minimum fill rate requirement because it is the pressure at which EFIC control produces the minimum rate of heat removal. Second, EFIC will maintain a constant SG fill rate for a given SG pressure. It does this by varying EFW flow rate, based on SG pressure, to account for changes in the primary to secondary heat transfer, which is a function of RCS temperature and decay heat production. Consequently, EFIC will provide flow greater than the flow required to make up for boiloff in the SGs. As heat transfer increases, EFIC controlled flow will increase to makeup for boiloff and to continue the rate of level rise. This automatic increase in EFIC flow is the main reason why lower flow rates during periods of no heat transfer are acceptable.

When the [loss of SCM setpoint] is selected, the EFIC rate-limited follower will permit the SG level control setpoint to increase toward the selected [loss of SCM setpoint] at only 2 to 8 inches per minute depending on SG pressure. If the initial EFIC indicated SG level is below the selected SG level setpoint, an excessive main feedwater event could raise the indicated SG water level faster than the SG level control setpoint. After stopping the main feedwater overfill, the SG inventory should start boiling away causing the indicated level to decrease simultaneously with the setpoint increase. However, EFIC will not provide any EFW until the SG level control setpoint increases above the EFIC indicated SG level. Consequently, during a loss of subcooling margin, if the minimum required rate of SG level increase is not met when EFIC is controlling, then the operator will have to manually control EFW until the SG level control setpoint is above the EFIC indicated level and EFIC is subsequently verified as controlling properly.

Only one value of the minimum total EFW flow is provided for manual EFW operation to simplify the operator guidelines. The value is based on a SG pressure of 1050 PSIA which was chosen as a representative value of expected SG pressure post-LOCA which is a balance between being low enough to minimize the required EFW flow rate yet high enough to be conservative with respect to heat transfer rates.

If EFW through the upper nozzles is available, then it should be used to raise the SG levels to the [loss of SCM setpoint]. This is because condensation heat transfer area is available instantaneously when using EFW and provides a condensation heat transfer area greater than that associated with the loss of SCM pool height.

Establishing the [loss of SCM setpoint] With MFW

If EFW is not available, then MFW should be used to increase the SG levels to the [loss of SCM setpoint].

Using MFW with the EFW nozzles:

As with feeding EFW, when MFW is fed through the EFW nozzles at ≤ the prescribed flow rate, adequate decay heat removal capability is instantaneously established. This is because the combination of wetted tube area (condensation heat transfer area) and flow rate assure adequate decay heat removal to maintain PCTs within acceptable limits. The prescribed flow rate for MFW is greater than that for EFW due to a higher assumed enthalpy of the MFW.

When establishing MFW flow through the EFW nozzles, flow rates substantially greater than those associated with the EFW system are possible. For this reason, a flow rate of approximately the normal EFW full flow rate should be used (i.e., based on known decay heat removal requirements versus EFW full system flow capability). For example, if normal decay heat removal EFW full flow rate is ~ 800 GPM, then a total equivalent feed rate of ~ 4.0×10^5 LBM/HR should be provided to the SGs until the [loss of SCM setpoint] is achieved. There should be no throttling below this value unless necessary, e.g., MFW flow rate is causing the SG pressure to decrease substantially below RCS pressure. If throttling must be performed, then total MFW flow <u>must</u> not be reduced to < 3.0×10^5 LBM/HR (equivalent to ~ 600 GPM at assumed conditions) during the fill period. The minimum MFW flow rate prescribed, ≤ 600 GPM, is for "total" MFW flow. This means that any combination of flow to the SGs may be established as long as total flow is not less than the minimum total flow rate prescribed. When feeding only one SG, e.g., due to a SGTR, then the minimum total FW flow should be fed to that SG.

Using MFW with the MFW nozzles:

When using MFW through the MFW nozzles, the required condensation heat transfer area will not exist until the [loss of SCM level setpoint] is reached. For this reason, if MFW must be used and it cannot be fed through the EFW nozzles, then the [loss of SCM setpoint] <u>must</u> be established within 25 minutes following loss of SCM. Analysis indicates that if the [loss of SCM setpoint] is established within 25 minutes following loss of SCM, PCTs are assured of not exceeding acceptable limits. The following table provides representative flow rates to achieve the [loss of SCM setpoint] for some assumed delays in initiating MFW flow:

Time Delay Before Starting MFW Flow (minutes)	MFW Flow Rate Per SG: GPM	MFW Flow Rate Per SG: LBM/HR (x 10^5)
0	640	3.2
5	800	4.0
10	1067	5.34
15	1600	8.0
20	3200	16.0

It will likely be known early in the event whether or not the EFW (or MFW) is available via the EFW nozzles (generally EFW is addressed early in loss of SCM mitigation guidance). If this occurs, say within 5 minutes of the loss of SCM, then MFW flow rates of ~ 4 x 10^5 LBM/HR will accomplish the fill in the remaining 20 minutes. On the other hand, if delay in initiating MFW continues for 20 minutes, then the required fill rates are greater by a factor of four, but still represent only a fraction of the overall MFW capacity. Hence, there is still adequate time to achieve the required level, although there will be a greater degree of operator vigilance required to prevent overfill. If it is not known how much time has passed since losing SCM or there is any question as to how much time has passed, then SG levels should be raised to the [loss of SCM setpoint] as soon as possible without posing undue risk of overfill.

The 25-minute fill requirement is based on conservative analysis and represents a small fraction of possible LOCAs. While it is recognized that larger LOCAs (e.g., LOCAs that reduce and maintain RCS pressure to ≤ 600 PSIG) would not require SG heat transfer, there is no unequivocal way to know if a particular smaller break requires SG heat transfer. For this reason, the 25-minute fill requirement <u>must</u> be adhered to unless RCS pressure is < 600 PSIG and decreasing with full flow from 2 HPI pumps (CFTs should be discharging or empty) or LPI from two trains has been established and RCS pressure is not increasing. In this case, initiation of SG level increase may be delayed and, once commenced, may be increased over a longer time period. This is based on the consideration that use of MFW requires additional operator burden (manual operator action required) that, if not necessary, may be reduced or eliminated. However, SG levels should still be raised to the [loss of SCM setpoint], as time permits, without undue delay. This will make the SGs available should their use become necessary at a later time.

Instrument error has not been included in the determination of the loss of SCM setpoints, required AFW flow rates and SG fill rates specified above.

4.4.4 <u>Whenever feed flow is restored to a dry SG, the initial flow rate SHOULD be limited per Rule 4.0</u>

Rule 4.0 provides the following initial feed flow limits to a dry SG:

EFW nozzles, RCP on:	≤ 450 GPM
EFW nozzles, RCPs off:	≤ 200 GPM
MFW nozzles:	≤ 200,000 lbm/hr

The intent of the flow limits in Rule 4.0 is to minimize the potential for inducing excessive stresses in the SG as a result of refeeding from a dry condition. In this regard, the dry SG flow limits of Rule 4.0, when applicable, supercede all other flow limits except the minimum flow required for a loss of SCM specified in section 4.4.3 of this chapter and section 4.1 of Rule 4.0.

The dry SG flow limits apply to the initial feed flow rate until such time that heat transfer has been restored to the SG. Establishing feed flow to the dry SG may initially result in exceeding the normal tube-shell ΔT limits. However, once heat transfer has been restored, the flow rate can be adjusted as necessary to control cooldown rates and tube-shell ΔTs.

The dry SG flow limits of Rule 4.0 are derived from the more detailed limits provided in Chapter IV.K. The intent is to provide as few specific values for use in EOPs as possible, while still limiting the SG stresses. The more detailed limits in Chapter IV.K are designed for use in stable situations when core cooling is assured and it is desirable to restore operation of an SG. The detailed limits in Chapter IV.K are not suitable for real-time use during symptom mitigation, especially when restoration of adequate core cooling is the highest priority. The curves in Chapter IV.K are provided for utility use whenever it is deemed appropriate, but their use should not delay restoration of adequate core cooling.

The dry SG flow limits of Rule 4.0 are provided for three cases: use of the EFW nozzles with and without forced primary flow and use of the MFW nozzles. The flow limit figures in Chapter IV.K are based on analyses that used allowable tube loads for SG tubes that have experienced wall thinning but do not yet require plugging. Each of the three dry SG limits in Rule 4.0 are based on engineering judgement in applying the appropriate figures from Chapter IV.K. The EFW limit with forced primary flow (450 GPM) is based on Figures IV.K-1 and IV.K-5. As can be seen from those figures, the Rule 4.0 limit for this case is bounded for an SG with either a 0°F ΔT or under compressive loadings. In most cases during transient mitigation, refeeding a dry SG will occur with the SG tubes under a compressive load (i.e., positive tube-shell ΔT).

The EFW limit without forced primary flow (200 GPM) is based on Figures IV.K-3 and IV.K-7. In this case, the Rule 4.0 limit is not bounded by the figures unless the SG tubes are under a compressive ΔT of approximately 30°F - 70°F, depending on RCS pressure. This is acceptable for transient mitigation purposes for the following reasons:

1. Figure IV.K-3 is based on the assumption that heat transfer will not be restored to the SG until after the appropriate level setpoint is reached. This is a conservative assumption to bound cases where a substantial hot leg void may exist. If heat transfer is restored before raising the SG level to at least the natural circulation setpoint, the induced loading on the SG tubes will be less than assumed.

2. Restoring heat transfer to a dry SG in the EOPs is usually necessary to ensure adequate core cooling or to prevent potentially worse scenarios during, for example, a tube rupture. In these cases, normal tube loading limits are a secondary concern. In cases where the restoration of a dry SG is not required, it is assumed the restoration will be performed from a stable situation, in which case the figures from Chapter IV.K should be used.

3. Attempts to restore a dry SG in the EOPs should provide a reasonable success probability, thus sufficient EFW flow should be provided to enable restoration of heat transfer. Selecting a single flow limit for these cases that is bounded by Figures IV.K-3 and IV.K-7 would result in a very small flow limit that may not be sufficient to restore heat transfer.

4. The flow limits depicted in the Chapter IV.K figures are not absolute, zero-margin limits. Exceeding a limit on those figures does not equate to tube failure. The margins in these figures, coupled with conservative assumptions, like item 1 above, mean that post-transient evaluations of excursions beyond the curves in these figures may still show acceptable results. Any EOP scenario involving restoration of a dry SG will result in a post-transient stress evaluation.

The MFW limit (200,000 lbm/hr) is based on engineering judgement using the limits shown in Figures IV.K-2 and IV.K-4, the considerations of Figure IV.K-6, and the minimum flow required to keep the MFW nozzles full (section 5.6 of Chapter IV.K). The status of the SGs (intact or having an unisolable steam leak) may not be known when MFW is being restored to a dry SG. For an intact SG, the 400,000 lbm/hr limit from Figure IV.K-4 would be the limiting flow rate, especially since the SG tubes are more likely under compressive stress. For a SG with an unisolable steam leak, Figure IV.K-6 provides the estimated RCS cooldown rate for various MFW flow rates. While it is not desirable to initiate a rapid overcooling when re-establishing MFW to a SG, it is desirable to re-establish MFW at a rate that will ensure restoration of heat transfer and also minimize transient cycles on the MFW nozzles. A minimum flow rate of 160,000 lbm/hr is required to keep the MFW nozzles filled.

For early restoration of MFW to a dry, non-intact SG, the 100°F/hr cooldown rate would not be exceeded if the MFW flow rate is less than about 212,000 lbm/hr. For delayed restoration of MFW (about 2 hours post-trip), the 100°F/hr cooldown rate would not be exceeded if the MFW flow rate is less than about 155,000 lbm/hr. However, it would be more likely that the status of the SG is known for a delayed restoration and MFW flow could be throttled as soon as heat transfer is restored if the SG is not intact. This would be the expected response in any case, whether the SG is intact or not. Therefore, based on this information and reasoning, the MFW flow rate should be limited to between 160,000 and 212,000 lbm/hr. Using engineering judgement, a value of 200,000 lbm/hr was selected as the limiting MFW flow rate.

Transient data should be recorded any time a dry SG exists, including during the period of restoration of feed flow and primary to secondary heat transfer. The data recorded should allow a post-transient evaluation of the SG stresses, and as a minimum should include sufficient data to determine SG average shell temperature, average tube temperature, RCS pressure, feed flow rates and SG pressures.

5.0 INVENTORY CONTROL OF STEAM GENERATORS THAT CANNOT HOLD PRESSURE

When FW is introduced to a depressurized SG, EFW is preferred over MFW. If EFW is not available and FW must be added to the SG then MFW can be used if an RCP is running. In either case, FW must be added slowly (within the appropriate limits of section 4.4.4) and continuously to prevent RC overcooling and excessive thermal stress of the SG. EFW and MFW flow rate limits for trickle feeding are plant specific. A stress evaluation of the SG may have to be made before plant restart. The decision to feed a dry, depressurized SG should consider the location of the unisolable steam leak to ensure personnel and equipment safety. The following will discuss when and how to add FW to a SG that cannot hold pressure.

5.1 Required FW Flow Rates to SG(s) When Neither Can Hold Pressure

A total loss of steam pressure control exists whenever an unisolable steam leak exists in the available SGs. If this condition exists, the operator should perform the following (A stress evaluation of the SGs will have to be made before plant restart if the following actions are taken) if the steam leak is not in a location detrimental to personnel or key equipment:

1. Attempt trickle feeding available SGs - Maintain primary to secondary heat transfer by supplying EFW to available SGs within the appropriate limits of section 4.4.4 while attempting to stop the steam leak on at least one SG (e.g., manually isolate stuck open ADV, gag shut MSSV, etc.). Automatic FW control system will probably need to be bypassed to allow EFW flow to both SGs and to allow trickle feeding. One RCP per loop should be operating to limit overcooling the SG tubes.

2. Trickle feeding one SG - If one steam leak is inside the RB then that SG should have all FW flow stopped to prevent steaming to the RB. It may also be desirable to isolate FW flow to one SG in order to aid in repairs or if manual heat removal with the two SGs cannot be controlled. If one SG needs to be isolated then isolate FW to one SG and allow it to boil dry while continuing restricted EFW flow to the other SG and attempting to maintain controlled decay heat removal. Continue trying to stop the leak on at least one SG. If a forced cooldown situation exists, such as during a SGTR, the operator may

have to feed the other SG to maintain tube-to-shell delta T or RC loop flow if the RCPs are stopped.

3. <u>RB steam leaks</u> - If both SGs have significant leaks inside the RB, then it may be desirable to initiate HPI cooling and allow both SGs to boil dry.

   HPI cooling is used so that the water collecting in the RB emergency sump is borated. SG operation with a steam leak in the RB will result in non-borated water collecting in the RB emergency sump. Core cooling with recirculation from the RB emergency sump may become necessary.

4. <u>Trickle feeding with MFW</u> – If MFW can be supplied to the EFW nozzles, then trickle feeding should be performed as described for EFW. If the MFW nozzles are used, then trickle feeding should not be attempted unless RCP(s) operating. A level sufficient to promote natural circulation can not be achieved in this mode.

5. <u>Limitations on trickle feed</u> – If the steam leak is in a location that is detrimental to personnel or key equipment, or if the trickle feeding process cannot be controlled without continued overcooling of the RCS, then trickle feeding should be stopped and HPI cooling should be established. If HPI cooling can not be established, then trickle feeding should be resumed and controlled as much as possible until either the cooldown rate can be reduced to within limits or HPI cooling can be established.

5.2 <u>Feeding a Dry SG When the Other SG Can Hold Pressure</u>

Normally if only one SG can hold pressure the other SG should not be fed. It should be allowed to boil dry. However, certain circumstances may require feeding the SG with the unisolable steam leak. These are as follows:

1. <u>Natural Circulation Cooldown</u> - If a natural circulation cooldown is required, some SG cooling may be required to circulate the relatively hot water in the idle RC loop. If it is not circulated, a steam bubble will form in the hot leg as the RC is depressurized and will hinder further RCS depressurization. If idle loop voiding is not desired, then SG cooling should be established by adding EFW. Refer to chapter III.G.

2. <u>Excessive SG Tube-to-Shell Delta T</u> - If a forced circulation cooldown is required, the cooldown rate of the RCS may be faster than the dry SG shell cooldown rate. In order not to violate the SG tube-to-shell temperature difference limit, some FW should be added to the SG to assist in cooling the SG shell or the cooldown rate may be reduced.

3. ICC Heat Removal - If an ICC condition exists the operator should consider adding FW to the depressurized SG for additional RCS heat removal. This situation is unanalyzed.

Chapter IV.D
Incore Thermocouple

1.0 INTRODUCTION

There is one T/C in each self powered neutron detector (SPND) string. This T/C senses the core exit temperature. Because of their close proximity to the reactor fuel, they are the best method for determining the temperature of the fuel when the RC is saturated. Also, T_h and T_c RTDs may not give valid indications during saturated conditions.

During normal operation, a spread of up to 50°F is expected from the outer peripheral incore T/Cs to the center of the core incore T/Cs. The shape of the temperature profile will parallel the profile of the flux across the core during normal operation. After the reactor is tripped, the incore T/Cs should all read within about 10°F of each other.

2.0 USES OF INCORE THERMOCOUPLES

2.1 Detect Core Uncovering

2.1.1 Thermocouples vs. RTDs

Because of their location, the hot leg RTDs do not provide a true indication of core temperature if the RC is not circulating or if there has been a loss of SCM (RCS is saturated). As soon as RC flow ceases, the RTDs will not provide as accurate an indication of reactor core temperatures. Furthermore, if steam voids occur such that the hot leg RTDs are enveloped in steam, they are even less accurate as a temperature indication. The heat transfer from the steam to the RTD is poor. There is also the possibility of a hot leg break during saturated RCS conditions, whereby the hot leg RTD would not come in contact with water or steam which is actually flowing across the core. For all of the above conditions, the incore thermocouples remain valid. The incore T/Cs are the only valid core temperature measurement without RC circulation and should be the main indication when SCM does not exist (i.e., saturated conditions). Therefore, as soon as the SCM is lost, the incore T/Cs should be used for determining the reactor core temperature. Only after the RCS has become subcooled and natural circulation or forced circulation has been reestablished should the RTDs again be relied on as accurate indication of core temperature.

2.1.2 Determination of Incore T/C Temperature

Because of the normal gradients of temperature across the core, T/C readings should be averaged to determine the actual conditions in the RCS. As soon as the SCM is lost, an average T/C reading should be used to determine core outlet temperature. The method of averaging is plant specific, but the average should be derived from a number of high reading thermocouples to ensure timely detection and reaction to indications of a loss of SCM or superheat.

2.2 Indication of Natural Circulation

When the RCS is subcooled the relationship between the hot leg RTD reading and the incore T/C temperature is a good indication of natural circulation. The hot leg RTD indication should be within 10°F of the incore T/C reading when subcooled natural circulation is occurring.

If the RCS is saturated, the relationship between the hot leg RTDs and incore T/Cs cannot be relied upon to give a good indication of saturated natural circulation. When the RCS is saturated, the hot leg RTDs may track the incore T/Cs even when natural circulation does not exist. A divergence between the hot leg RTDs and incore T/Cs may indicate a loss of natural circulation, but the hot leg RTDs cannot be used to confirm natural circulation. Therefore, when the RCS is saturated incore T/Cs should be used to confirm natural circulation as discussed in Chapter II.B.

Chapter IV.E

High Point Vents

1.0 INTRODUCTION

Depending on the plant design, high point vents (HPVs) can be located at the top of both hot legs, on top of the RV head, and also on top of the pressurizer. Some of these HPVs are connected by drain lines to the quench tank, however, other HPVs discharge into the RB. The point where they discharge will determine whether or not they should be used for certain conditions. This chapter discusses the uses of the HPVs.

2.0 USE OF HIGH POINT VENTS (HPV)

2.1 Open HPVs During ICC Conditions

Use of the HPVs during the ICC condition can contribute significantly to restoring primary to secondary heat transfer, thereby regaining adequate core cooling. Once the fuel clad temperature increases to greater than 1400°F, clad oxidation begins which produces hydrogen gas and other noncondensables. These noncondensable gases will collect in the high points of the system, RV head and pressurizer. If sufficient quantities of noncondensable gases collect in the hot legs, natural circulation flow can be stopped. With the presence of noncondensable gases in the hot leg, boiler condenser cooling could be greatly impeded. It is therefore necessary to vent these noncondensables out of the primary system to allow a restoration of natural circulation/boiler condenser cooling. When the clad reaches a temperature of greater than 1400°F (shown on Figure III.F-1, Region 3) all HPVs should be opened.

2.2 Reclosing HPVs Upon Return From ICC

If adequate SCM is regained, all HPVs may be reclosed. Once SCM is regained all of the noncondensable gas production will have ceased. While there may be noncondensable gases left in the RCS, they should be entrained in the RC and not impede natural circulation flow. However as the RCS is depressurized, these gases will come out of solution. If natural circulation is lost at a later time or if boiler-condenser cooling is lost, it may be necessary to reopen the HPVs to remove any noncondensable gases left in the system. Opening HPVs at this time can also help to eliminate steam trapped in the top of the hot legs and thereby restore natural circulation.

If the RCS is brought back to saturation, then the RCS should be cooled and depressurized until the low pressure injection system is in operation. After the low pressure injection system is adequately cooling the core and RC pressure is decreased to less than 140 PSIG, then noncondensable gas production will have ceased. Consequently, it is allowable to close the HPVs once the low pressure injection system is operating with RC pressure less than 140 PSIG.

2.3 Other Uses of HPVs

There are several other uses of the HPVs which may be viable, depending on the severity of the situation, as well as the discharge points of the HPVs. Each of these situations and the appropriate use of the HPVs is discussed in the following:

A. Control of RCS Pressure

The pressurizer HPVs have a smaller capacity than the PORV. As long as adequate pressure control can be maintained, the pressurizer HPV should be used for controlling RCS pressure in situations where neither sufficient pressurizer spray or auxiliary pressurizer spray is available.

It is also possible that all HPVs could be opened to reduce RCS pressure. During PORV opened - HPI cooling, opening all of the HPVs would reduce RCS pressure, thereby allowing more HPI flow into the RCS. This may be especially advantageous where low head HPI pumps are used.

Pressure reduction in the RCS is also vital during HPI cooling with a solid SG which has a tube rupture in it. Opening the HPVs will augment RC depressurization during this situation. Refer to Chapter III.E for further details of HPV use and control during this situation.

B. Refill of a Voided Hot Leg

If the RCS had been saturated and steam voids collected in the hot leg impeding natural circulation flow, the HPVs could be used to restore natural circulation, provided the core has been restored to a subcooled condition. The HPVs could be opened in the top of the hot legs to allow the trapped steam voids to escape. This will allow HPI flow to refill the hot legs as long as RC pressure is maintained. If the core outlet is saturated, the HPVs may not remove a sufficient amount of steam to offset RCS steam production and allow refilling of the hot legs. However, they may help, and their use should not complicate restoration of heat transfer. When heat transfer is restored they should be closed.

C. Provide for RV Head Cooling During Natural Circulation

During a natural circulation cooldown, the RV head is expected to cool very slowly. If the natural circulation cooldown and depressurization is too rapid, steam voids may be formed in the RV head. These voids would be indicated by a loss of RCS pressure control and a sudden increase in pressurizer level. The RV head vent may be opened to provide some RV head cooling or to relieve steam if necessary. Refer to Chapter III.G.

The loop HPVs are normally used for these conditions when RCPs are not running in the same loop. Open loop HPVs should be closed prior to starting an RCP in that loop to minimize inventory loss.

Chapter IV.F

Containment Systems

1.0 INTRODUCTION

The containment systems are used for RB control. RB control consists of two basic objectives:

A. Limit leakage from the RB (RB isolation control).

B. Control the RB environment (RB internal environment control).

The systems available for RB control and their designs can vary significantly among plants. This chapter will discuss some situations which can be created by the NSS which need to be considered in RB control. The chapter will not discuss details of systems operations.

2.0 REACTOR BUILDING ISOLATION CONTROL

RB isolation control involves reducing and controlling leakage through the RB penetrations following a diagnosis of an abnormal condition. The control actions can include:

1) Verifying RB penetrations automatically isolate when required, e.g., penetrations closed on high RB pressure or on low RCS pressure.

2) Selectively isolating and unisolating penetrations as needed for abnormal transient operations.

3) Operating equipment in a secondary containment or auxiliary building to monitor and control leakage from the RB.

Specific parameters can be monitored that may indicate the need for full or partial RB isolation. These parameters may include:

- High RB radiation.

- High RB pressure.

- Low RCS pressure.

Each of the three conditions listed above relate to a potential release of radioactive material as follows:

1) High radiation - If the radiation level in the RB is abnormally high, then RB leakage may release excessive radioactive material.

2) High RB pressure - As the RB pressure increases, the leak rate of radioactive material may increase.

3) Low RCS pressure - Low RCS pressure indicates a possible LOCA. The LOCA can cause both a high RB radiation condition and a high RB pressure. This combination increases the potential for a radiation release.

During abnormal transients the operator may need to use some of the fluid system penetrations to help maintain core cooling and to control the RB environment. The RB isolation valves may have to be selectively operated as choices are made between the need for RB isolation and fluid system operation. The decision to open the valves should be accompanied by a judgement of possible consequences (e.g., the penetration path cannot be reclosed).

Cooling water systems to the RB can provide a path for radiation release from the RB space. This is unlikely since the cooling water systems do not normally carry radioactive fluid and many of the systems operate at a pressure which is usually higher than can occur in the RB.

3.0 RB INTERNAL ENVIRONMENT CONTROL

After an abnormal transient, the environment inside the RB can become harsh enough to cause failures or degradation of equipment.

The RB environment needs to be controlled to reduce the possibility of failures of equipment inside the RB. RB control includes controlling the following to bring them within acceptable limits:

A. RB pressure and temperature.

B. RB hydrogen concentration.

C. RB sump chemistry.

D. RB radiation.

E. RB sump level.

3.1 RB Pressure and Temperature

RB temperature and pressure are coupled together for a LOCA so that if the temperature is reduced the pressure will also be reduced and vice versa.

As the LOCA releases steam and water, this mixture heats up the RB atmosphere. The decreasing mixture temperature and increasing air temperature will come to equilibrium at a common atmospheric temperature. This temperature will determine the RB pressure. The pressure will be the sum of the partial pressures of air and steam.

Hydrogen burning or a steam line break can also cause containment pressure and temperature excursions.

The RB pressure and temperature must be reduced to:

A. Prevent exceeding the failure pressure and design temperature of the RB.

B. Reduce the driving force for RB leakage.

C. Prevent equipment damage.

The number of emergency coolers and sprays does not significantly affect the peak RB pressure for large LOCAs in which the peak pressure is reached soon after this equipment is actuated. On the other hand the peak pressure for a SBLOCA is very dependent upon the amount of cooling equipment in operation.

Large increases in RB temperature and pressure may not occur from SBLOCAs such as stuck open PORV. However, radiation can be released to the RB. Also, the RCS pressure may drop slowly causing automatic initiation of RB spray and coolers based on RC pressure to be delayed.

Normal operation of some systems may delay or prevent these parameters from reaching setpoints which actuate safety equipment. The RB coolers may provide sufficient cooling (in the normal mode) during a SBLOCA or secondary side line break inside the RB such that only a small RB pressure or temperature transient will occur. Consequently certain systems may be isolated on a radiation signal. The amount of energy being released to the RB may be reduced by:

1) Maintaining core cooling to keep the core covered.

2) Limit FW added to a SG which has a break inside the RB.

3) Increase the heat removal by the LPI cooler (if in operation).

4) Increase the heat removal by the SGs (if in operation).

5) Isolate any break in the RCS or SGs if possible.

Containment temperature can affect the operation of some equipment; consequently, if a high RB temperature is reached, the RB coolers should be started or verified operating to bring the temperature back within limits.

3.1.1 Pressure and Temperature Control With Equipment Failures

The primary method of reducing the RB pressure and temperature abnormal conditions is with the RB coolers in the emergency mode. If this equipment fails to keep the RB pressure below limits, backup cooling with the RB spray system could be used.

Failure of both containment coolers and sprays is not likely; however, were this to occur the effects on RB pressure and temperature for a LOCA would depend on the ability to remove heat through the SGs and, for a steam line break, would depend on the ability to stop FW to the broken SG.

3.2 Reactor Building Hydrogen Concentration

The sources of hydrogen following a LOCA will result in a time dependent build-up of hydrogen in the containment until control measures are taken. The sources are: a) radiolytic releases from the core and the RB sump, b) release from galvanized metals in the RB, c) release from zinc primer paint in RB, d) release from corrosion of aluminum, e) release from hydrogen dissolved in RCS, and f) release from any zirconium-water reaction in the core.

The extent of the Zr-water reaction is controlled by the ECCS performance. Consequently, if the core is adequately covered and cooled, the Zr-water reaction will be an insignificant source of hydrogen.

Possibilities exist for high local concentration or stratification. Flammability is dependent on the concentration and the concentration depends on how well the reactor building atmosphere is mixed.

Hydrogen burning will increase RB temperature and pressure. The most apparent feature of hydrogen burning is a sudden RB pressure spike with a return to a pressure only nominally higher than before the burn. The SG and RCS pressure indications will dip by about the same amount as the RB increases during the hydrogen burn since the low pressure side of these transmitters are vented to the containment.

The hydrogen concentration should be controlled if possible to either prevent or limit burning to prevent possible equipment damage within the RB.

After estimates of hydrogen concentrations have been made measures may be taken to control, if possible, any excessive concentrations.

The first method of hydrogen control in the RB is by mixing the RB atmosphere to prevent stratification at high RB elevations and any local concentration. This creates a more homogeneous mixture for sampling and for purging the hydrogen from the RB and reduces high product concentrations.

The second method of hydrogen control is reduction of RB hydrogen. Hydrogen recombining and purging are two methods for reducing hydrogen. The RB atmosphere activity and purge filter efficiency must be considered before purging hydrogen to the site atmosphere to stay within release rate limits.

3.3 Reactor Building Emergency Sump Chemistry

The RB emergency sump water boron concentration following a LOCA should not be diluted. This is to assure the recirculation water has sufficient boron to maintain the core subcritical. Boron dilution can be caused if a fluid system leaks non-borated water to the RB sump such as a FW leak or a leak in the service water. If this occurs the source of non-borated water should be isolated. Boron addition may be an option. Boron precipitation in the RV can also lower boron concentration in the RB sump. Appropriate actions should be taken to prevent boron precipitation in the RV. Refer to Chapter IV.B for instructions on preventing boron precipitation.

3.4 Reactor Building Radiation

The amount of radioactivity in the RB atmosphere or sump following an abnormal transient is dependent upon many factors such as the percent of defective fuel pins, the power history, time in core life, amount of RC leaked to the containment. A reduction in the amount of radioactive material released to the RB atmosphere helps to limit the amount of radioactive material that can be released offsite.

3.5 Reactor Building Sump Level

The best method of detecting an improper RB water or emergency sump level is by level instrumentation. The level of the BWST after ECC injection is also an indication of sump level unless a SGTR has occurred. Detection of a high RB water level by other than level instrumentation is more difficult and may not be confirmed until submerged equipment is damaged. High RB water level should not be a problem unless more water than that added from the BWST has been added to the RB. If this additional water was non-borated, then there will be boron dilution in the RB sump.

The water level should be maintained high enough for LPI or RB spray recirculation flow (NPSH), but not so high that it submerges equipment important to core heat removal or RB control. If the water level is at the low level limit, more borated water should be added. The operator should also check for a SGTR or some other possible source of water loss such as inadvertent pumping or draining from the sump or a break in LPI or spray recirculation line.

If the water level becomes too high, consideration of lowering it should be made depending on the core cooling method being used (sump recirculation or DHR). The amount of radiation in the sump must also be considered before attempting to remove any of the sump water.

Chapter IV.G

Reactor Vessel Pressure/Temperature Limits

1.0 INTRODUCTION

The fracture toughness, which is a measure of resistance to fracture of the RV, will vary during plant operation. The allowable RC pressures, determined for specific input transients, are based on several factors. The most influential factors are:

1. RV temperature - In general, fracture toughness will decrease with decreasing temperature.

2. Neutron irradiation - fracture toughness will decrease with accumulated irradiation.

In recognition of these varying factors, all RVs are operated within restrictions imposed by technical specifications. These restrictions assure that the RV will not be subjected, with a specified margin of safety, to fracture failure under combined thermal and mechanical loads.

The effects of thermal stress are maintained within acceptable limits by specifying maximum allowable RCS heatup and cooldown rates.

The effects of RV temperature and stress due to RV pressure are maintained within acceptable limits by specifying the maximum allowable RC pressure versus RC temperature.

The effect of neutron irradiation on the fracture toughness is accounted for by revising the Technical Specification limits periodically as the RV irradiation fluence accumulates.

2.0 PRESSURIZED THERMAL SHOCK OPERATOR GUIDANCE

In general, the RCS pressures and temperatures must be maintained within the Technical Specification RCS normal pressure-temperature (P-T) limits and associated cooldown rate limits. However, abnormal transients can result in violating the normal cooldown rate limits. If the normal cooldown rate limits are violated then Pressurized Thermal Shock (PTS) operator guidelines may need to be invoked.

Any cooldown which exceeds the Technical Specification RCS normal allowable cooldown rates, whether or not PTS guidance is invoked, will require a post transient fracture mechanics evaluation prior to returning to normal operation. However, if PTS guidance is invoked, the transient is more severe in regard to fracture mechanics.

2.1 Criteria for Invoking the PTS Operator Guidance

The PTS operator guidelines must be invoked whenever the following criteria are met, and once invoked the guidelines must remain invoked until an evaluation determines otherwise.

2.1.1 RC Pump-On or Natural Circulation with HPI-Off

If the Technical Specification RCS normal cooldown rate limit is exceeded (while an RCP is on or during natural circulation with HPI-off) when the RV downcomer fluid temperature is below 338°F, then PTS guidelines must be invoked.

Excessive cooldown rates do not require invoking the PTS guidelines when the RV downcomer fluid temperature is above 338°F. However, the operator is still required to try to maintain the cooldown rate within the Technical Specification RCS normal allowable rates.

With an RCP On or with natural circulation without HPI-On, the cold leg temperature sensors (Tcold) in the loop with the operating RCP or natural circulation flow can be used to provide an indication of the RV downcomer fluid temperature. Instrument errors must be accounted for. The 338°F value represents actual downcomer fluid temperature.

2.1.2 RC Pumps Off With HPI On

Whenever all the RCPs are off and HPI is on, then PTS guidelines must be invoked. "HPI-on" means one or more HPI pumps are on while taking suction from the BWST and injecting through one or more of the HPI valves. In addition, at DB-1, "HPI-On" can also mean the normal and alternate injection lines are in use with MU pump suction from the BWST.

2.2 PTS Guidance

Section 2.1 provides the criteria for invoking the PTS guidelines. This section provides the PTS guidelines. The PTS operator guidelines must be followed if the PTS operator guidelines are invoked.

PTS Operator Guidelines

Whenever PTS is invoked maintain core outlet temperature and pressure as close to the SCM limit as possible without violating required RCP NPSH, if an RCP is on.

By reducing core outlet temperature and pressure close to the SCM limit, RV stresses are reduced. Generally, the further SCM can be reduced the better. However, if an RCP is operating RCS pressure must not be reduced below required RCP NPSH values. The thermal mixing benefits (reduced RV thermal gradients) provided by the RCP outweigh any additional benefit of further reducing pressure, which could threaten RCP operations. If an RCP is not running, then further SCM reductions, i.e., to as close to the SCM limit as possible, are warranted. Should an RCP subsequently be started, RCS pressure should be increased only as necessary to satisfy RCP NPSH requirements.

If RCPs are off and HPI is on, then restart an RCP as soon as possible <u>if the RCP restart criteria in Chapter IV.A are met</u>. The operator instruction to increase the core outlet subcooling to 20°F before starting a RC pump does not apply when HPI is on without SG heat transfer. Increasing subcooling would aggravate the PTS condition and does not serve the purpose for which the instruction is intended. The intent is to prevent a loss of SCM when starting an RCP when primary to secondary natural circulation cooling exists which could lead to tripping the RCPs and a loss of the previously existing primary to secondary heat transfer. RCS pressure should be increased only as necessary to meet RCP NPSH requirements.

After restarting an RCP reduce the RCS pressure to near the SCM limit, if practical. Whenever PTS guidance is invoked, the subcooling should be minimized. Starting an RCP can cause an increase in subcooling. Therefore, if necessary minimize subcooling after starting an RCP.

Once invoked, the PTS guidelines must be followed for the remainder of the RCS cooldown unless an evaluation is performed to determine otherwise. This is true even if conditions change such as by reducing the cooldown rate to within the Technical Specification values or starting an RCP. Other than to satisfy RCP NPSH requirements, RCS pressure must not be increased while PTS is invoked.

The guidelines assume the Technical Specification RCS normal P-T limit is adjusted for plant specific instrument error and for pressure sensor location.

With an RCP on or with natural circulation without HPI on, the cold leg temperature sensors (T_{cold}) in the loop with the operating RCP or natural circulation flow can be used to provide an indication of the RV downcomer fluid temperature. Instrument errors must be accounted for.

Although holding ("soaking") the plant during cooldown helps relieve some of the significant thermal gradients due to the overcooling, soaking has not been analyzed as part of these guidelines and therefore, soaking cannot be used to undo the PTS guidance invocation.

The cooldown may need to be slowed or stopped to satisfy steam generator tube-to-shell differential temperature requirements if an overcooling has occurred.

2.3 Bases for the PTS Operator Guidelines

The guidelines were developed based on fracture mechanics analyses. The analyses assumed criteria of a) no initiation of flaw propagation, b) a postulated reactor vessel flaw with depths up to 1/8 of the wall thickness, c) the most limiting RV weld material, d) axial flaw orientation and e) the predicted accumulated neutron fluence for 32 Effective Full Power Years (EFPY).

Whenever the Technical Specification RCS normal cooldown rate limits are exceeded a post transient fracture mechanics evaluation must be performed prior to returning to normal operation.

2.3.1 RC Pump On or Natural Circulation with HPI Off

With either an RCP on or natural circulation with HPI off, the RV downcomer temperature can be inferred by the cold leg temperature detector in the RCS loop with flow. Consequently, the RCS temperature and pressure and cooldown rate can be monitored and controlled within values shown to be acceptable by fracture mechanics analyses.

A parametric fracture mechanics study determined that if the RCS pressure and temperature is kept below the Technical Specification RCS normal P-T limit then the RV downcomer fluid temperature may be cooled from operating temperature to 338°F at any cooldown rate without invoking PTS guidance. In addition, below 338°F, the cooldown can be continued at a cooldown rate equal to or less than the Technical Specification RCS normal cooldown rates without invoking PTS guidance. This study also determined that if the Technical Specification RCS cooldown rate is exceeded when the reactor vessel downcomer fluid temperature is below 338°F, then SCM must be maintained as close to the SCM limit as possible. Maintaining SCM close to the SCM limit reduces the potential for flaw propagation.

The PTS guidelines do not require a limit on RCS cooldown above 338°F RV downcomer fluid temperature. However, the cooldown rate should be reduced to within the Technical Specification RCS normal cooldown rates as soon as possible whenever the Technical Specification RCS cooldown rate is exceeded. This is to reduce the severity of the thermal stresses due to the transient.

The RV downcomer fluid temperature cannot be directly measured. However, with a RC pump on or with natural circulation without HPI on, the cold leg temperature sensors (Tcold) in the loop with the operating RC pump or natural circulation flow can be used to provide an indication of the RV downcomer fluid temperature. Instrument errors must be accounted for. With an RCP on, sufficient RC loop flow exists, even with HPI on, so that the cold leg temperature is representative of the RV downcomer temperature.

2.3.2 RCP Off with HPI On

Whenever all RCPs are off and HPI is on, the relatively cold HPI water can significantly cool the downcomer fluid. The resulting downcomer fluid temperature cannot be determined with existing RCS cold leg temperature instrumentation. In addition, analyses have shown that the temperature difference between the core inlet and outlet can increase significantly with time, especially with low decay heat. Consequently, the core outlet fluid temperature cannot be used for an indication of RV downcomer fluid temperature. The internals vent valves flow rate decreases with decreasing decay heat. Consequently, lower decay heat will provide less downcomer fluid mixing resulting in a cooler downcomer fluid temperature near the vessel wall. Therefore, the temperature difference between the downcomer fluid near the vessel wall and the core outlet temperature will become larger with decreasing decay heat. PTS guidance is always invoked whenever RCPs are off with HPI on because analyses show that excessive cooldown rates can occur and because the RV downcomer temperature cannot be measured. In addition, after being invoked, without being able to determine the reactor vessel downcomer fluid temperature, the prudent action is to keep the RCS pressure as low as practical.

Even with natural circulation flow, the downcomer temperature cannot be determined if HPI is on. The HPI fluid will mix with the RC resulting in a mixed fluid temperature which can be significantly less than the temperature of the RC. The two fluids mix downstream of the cold leg temperature sensors so that the resulting temperature cannot be measured.

The potential to initiate flaw propagation of pre-existing flaws during PTS events caused by HPI flow with no RCS loop flow has been investigated. The investigation considered various scenarios including high and low core decay heat and with and without HPI flow throttling. The results show that the potential to initiate flaw propagation increases with increased subcooling and with decreasing decay heat. (The amount of warm RV internals vent valve flow available for mixing with HPI flow entering the RV decreases with lower decay heat.) The potential to initiate flaw propagation is extremely low with high decay heat and the core outlet temperature maintained near the SCM limit. The potential to initiate flaw propagation is relatively high with low decay heat and the core outlet temperature near the Technical Specification RCS normal P-T limit. Although there is a potential to initiate flaw propagation for certain scenarios, flaw propagation is expected to arrest if the pressures and temperatures are kept below Technical Specification RCS normal P-T limit.

Maintaining RC pressure near the SCM limit minimizes the potential to initiate flaw propagation regardless of the event. Therefore, to minimize the potential to initiate flaw propagation for the RCP off with HPI on transient, the PTS guidelines require maintaining the RCS pressure and core outlet temperature as close to the SCM limit as possible.

Chapter IV.H

Equipment Operation During a Station Blackout (SBO)

1.0 INTRODUCTION

This chapter provides the technical bases for operation of plant equipment during a station blackout. The station blackout scenario includes the loss of all offsite power followed by a failure of the emergency power supplies to start and/or load. The purpose of this chapter is to provide general guidance on the operation of equipment needed to cope with a station blackout. The unavailability of backup equipment during a SBO results in a decrease of the normal "defense in depth" strategy which ensures that the best equipment available will be utilized should the preferred equipment fail. In this case operators are forced into using only that equipment which is operable during a SBO. It is vital, therefore, for operators to closely monitor this equipment and ensure its availability throughout the event.

The overall SBO coping strategy has been incorporated into Part III of this document in a manner which optimizes the use of plant equipment and core cooling. This chapter is intended to supplement the symptom oriented guidance by addressing issues which are SBO specific.

The guidance in this chapter is provided to ensure equipment availability for coping with a total loss of AC power (except battery-backed AC). This guidance is intended primarily for plants that do not have an alternate AC source. The existence of an available alternate AC source or dedicated systems which are independent of the normal and emergency sources may negate the need for some or all of these considerations, but it is recommended that they be considered as backup guidance in the highly unlikely event of the alternate AC source or dedicated system being unavailable. However, it must be recognized that battery-backed AC may be lost if the alternate AC source is unavailable due to the finite capacity of the battery-backed AC. Procedures for implementing this SBO guidance must consider plant specific battery capacity, i.e. if vital plant instrumentation and control is lost then implementing this SBO guidance may not be possible. The equipment which will be discussed in this chapter includes:

A. Emergency Onsite & Offsite Power Sources

B. Makeup/HPI System

C. EFW & Condensate System

D. Secondary Steam Pressure Control Systems

E. Plant Specific Items

1. Station Batteries

2. Instrument Air System

3. HVAC System

4. Containment Isolation

5. Heat Tracing Equipment

6. Lighting & Communication Equipment

F. Equipment Operation Upon Power Restoration

2.0 EMERGENCY ON-SITE & OFF-SITE POWER SOURCES

The ability to cope with an SBO is limited to factors such as RCS leakage, condensate inventory, air supplies, and battery capacity. The SBO is not successfully mitigated until sufficient AC power is available to allow operation of normal shutdown equipment such as makeup pumps. Therefore, actions to restore an AC power source should commence immediately. This source may be offsite power, emergency AC power (e.g., diesel generators) or an alternate AC power source.

In prescribing actions to restore AC power, plant procedures should consider the available resources and prioritize efforts as necessary to concentrate on the most readily available AC source. For example, if an offsite source is available but all feed lines are damaged, priority should be given to the least damaged line. Attempts to start a diesel generator should consider quantities of available air. Repeated starts should not be attempted if the probable cause of failure has not been addressed.

Dispatchers should give nuclear plants priority when restoring power. Similarly, transmission line repair crews should concentrate on restoring power feeds to the nuclear plants.

When restoring power to the on-site buses, the priority of the AC loads should also be considered. The most important loads to be restored are a RCS injection source (MU/HPI pump and associated valves or DHRS/LPI), a motor-driven EFW pump, secondary feedwater & steam pressure control valves, instrumentation if batteries are near depletion, battery chargers and appropriate cooling water systems. Automatic loading should either be defeated or reduced (i.e. disengage non-critical loads) prior to restoration of a limited AC power source to prevent a potential overload on restart.

3.0 MAKEUP/HPI SYSTEM

The ability to cope with a SBO is directly affected by the amount of RCS leakage which occurs during the event. Makeup and HPI pumps are unavailable during the total loss of AC power. It is necessary, therefore, to take steps to ensure primary inventory losses are minimized during the SBO. These steps include isolating all letdown flows and other known leak paths. The RCP seal return valves should be closed immediately. Attempts should be made to identify and isolate any other RCS leak paths which are contributing to losses. Chapter III.A section 3.3 provides the bases for not initiating a RCS cooldown if MU/HPI is not available to counter the resulting contraction volume. One of the reasons for this mitigation strategy is the assumption that during a SBO, minimal RCS leakage may occur. For small leak rates, it is possible to sustain subcooled natural circulation flow for a significant period of time. Any actions which can be taken to extend this time will increase the likelihood of recovering AC power before SCM is lost. However, if the SCM is lost then the RCS must be cooled down to get Core Flood System injection as discussed in Chapter III.B.

One of the most likely causes of RCS inventory loss is leakage through the RCP seals. Seal injection flow and component cooling water flow, for most plants, will not be available during a SBO to cool the seals and prevent them from being subjected to full RCS pressure. It is possible for the seals to degrade under those conditions. The station blackout analyses assumed a leakage rate of 25 gpm per pump in accordance with the NUMARC 87-00 assumption.

RCP seal leakage data is available for the plants that have installed or intend to install the Byron Jackson N-9000 seals in their pumps. A test was performed on an age-conditioned N-9000 seal cartridge to determine its ability to maintain integrity under simulated SBO conditions. The test simulated a loss of seal injection and component cooling water flow services to a RCP for approximately 8 hours. The cartridge was subjected to system pressures and temperatures which were similar to those expected during a SBO. The results indicated that seal integrity was maintained throughout the test. A constant 0.04 gpm leakage rate was observed during the majority of the test following controlled seal bleedoff isolation. A failure of a stationary seal face O-ring occurred near the end of the test but had little impact on the overall test results. This test showed that assumed leakage rates of 25 gpm per RCP are conservative for those plants which use the BJ N-9000 seal cartridge.

RELAP5 analyses of SBO were performed based on seal leakage rates of 25 gpm per pump plus maximum allowable technical specification leakage of 11 gpm (10 gpm identified plus 1 gpm unidentified). The results of the analyses indicate that the core will remain adequately cooled well beyond four hours. All plants will eventually be required to meet the criteria for a four hour coping duration or less or have an alternate source of AC power.

4.0 EFW & CONDENSATE SYSTEMS

Immediately after the loss of AC power the operators should verify start of the turbine-driven emergency feedwater pump and FW flow to both SGs. Except for plants with other AC-independent sources of feedwater, this pump is the most important piece of equipment for the duration of the SBO.

Procedures should exist to expedite resetting the pump turbine should it trip and pump operation should be closely monitored.

The loss of AC power will probably result in the loss of the main condenser. Therefore, condensate inventory supplies will be continually depleted as steaming to the atmosphere will be required. Alternative condensate supplies may need to be utilized to augment the normal supplies. Availability of these alternative supplies should be assured under SBO conditions.

Steam generator levels should be raised to the natural circulation setpoint to ensure a normal transition to natural circulation is achieved. This level provides sufficient pool height to maintain natural circulation during periods of no feed flow. However, additional considerations should be made for a station blackout. If possible, EFW flow rate should be throttled to prevent overcooling the SG and the resulting RC cooling. This is to prevent contraction of the RC which cannot be compensated for by the MU/HPI systems. However, SG pressure should return to the ADV (or TBV) setpoint once the SG level has reached the natural circulation setpoint and EFW is throttled to maintain level. This will allow the RC to reheat.

5.0 SECONDARY STEAM PRESSURE CONTROL SYSTEM

Steam generator pressure control during a SBO should be accomplished using atmospheric dump valves (ADVs) unless the condenser is available. SG pressure should be controlled to prevent a RCS cooldown. All unnecessary steam loads should be isolated from the SG as early as possible to minimize the potential for a cooldown due to steam leaks. The operability of the ADVs for the duration of the required coping period should be verified. It may be prudent to make provisions for manual manipulation of valve operators if required to cope with a SBO.

6.0 PLANT SPECIFIC ITEMS

There are several plant specific considerations that should be evaluated and addressed in SBO procedures to enhance the plant's ability to cope with a station blackout. These actions should be accomplished in parallel with actions to stabilize the NSSS and actions to restore AC power. The areas that should be considered are:

6.1 Station Batteries

Vital plant instrumentation will be powered by the station's battery-backed AC inverters. Long term resolution of SBO by individual utilities will ensure all plants have the capability to maintain necessary DC loads for the respective coping durations.

The TBD guidance provides a mitigation strategy for SBO conditions up to and beyond the SBO rule considerations including unavailability of the alternate AC source if used. Procedures for implementing this guidance must consider plant specific battery capacity, i.e., if vital plant instrumentation and control is lost then implementing this guidance may no longer be possible.

Non-essential DC loads should be predetermined and a procedure provided to ensure these loads are stripped from the DC busses as soon as possible during a SBO. This will extend the available battery life for the essential loads. In addition, consideration should be given to the possibility that DC power will not be available to flash diesel generator (DG) fields or close breakers in attempts to restore AC power.

6.2 Instrument Air System

Air supplies for key equipment required during a SBO must be evaluated and enhanced if necessary. If adequate air supplies cannot be verified for the duration of the SBO (coping duration is defined by individual utility), then provisions should be made for local, manual operation of the key control valves. As a minimum, continued operation of the ADVs and EFW control valves should be ensured. Consideration should also be given to the availability of air necessary for starting DGs.

6.3 HVAC System

The effects of the loss of heating, ventilation, and air conditioning should be evaluated for key equipment areas and areas which require prolonged access. Actions necessary to enhance environmental conditions should be specified (e.g., opening instrument cabinet doors to remove heat, closing or opening access doors as necessary, etc).

6.4 Containment Isolation

Each plant should have a list of valves to be closed during a SBO.

6.5 Heat Tracing Equipment

The loss of heat tracing should be evaluated both for equipment needed during the SBO (e.g., the condensate storage tank, Boric Acid Addition Tanks and suction lines to the EFW pump) and for potential problems following AC power restoration (e.g., the BWST and HPI pump suction lines). The evaluation should ensure prevention of line solidification and not rely on subsequent actions to free clogged lines.

6.6 Lighting and Communication Equipment

All areas requiring access to control the NSSS during the SBO and to restore AC power, should be evaluated to ensure that access is not unduly hindered due to the loss of AC power. In addition, adequate lighting and communications should be verified.

6.7 RC Pump Seals

The RCP seal return valves should be closed to reduce leakage from the RCS and to reduce hot RC flow through the seals for seal protection. The seal injection isolation valves should be closed if seal injection is lost to help protect the seals from subsequent sudden cold water injection.

7.0 EQUIPMENT OPERATION UPON POWER RESTORATION

Once a source of AC power becomes available, several precautions should be observed in loading AC-powered equipment and in recovering normal plant control:

A. Loading AC-powered equipment should be controlled considering equipment priorities, limitations on the AC source and available feed lines. Care should be taken to prevent overloading the AC source or the distribution to the load. The highest priority load will likely be an HPI pump, but this will be situationdependent. Automatic loading schemes should be overridden or reduced to help prevent source overload.

B. The potential for unwanted automatic equipment actuations should be considered, including the possible effects of de-energized or inaccurate signals feeding the automatic logic. For example, the time required for a transmitter to regain an accurate output may exceed the time required for the automatic actuation to occur.

C. If seal injection or component cooling water was not supplied to the seals during the SBO, the RC pumps should not be restarted. The sustained loss of seal injection and cooling water will require evaluation of pump seals before returning the RC pumps to service.

Seal injection flow should be restored gradually when an MU/HPI pump is available. Cooling water should also be restored very gradually to prevent thermal shocking of the seals.

D. If the RCS is still in natural circulation but voids exist, actions to eliminate voidsshould be taken in accordance with the guidance in Chapter III.G. If natural circulation or boiler condenser cooling does not exist, HPI cooling should be established in accordance with the guidance in Chapter III.C.

Chapter IV.I

Reactor Coolant Inventory Measurement Systems

1.0 INTRODUCTION

Depending on the plant design, RC inventory measurement systems may include pressurizer level (PZR LVL), reactor coolant inventory trending system (RCITS), hot leg level (HLL), reactor vessel head level (RVL), incore thermocouples (incore T/Cs) and/or subcooling margin (SCM) monitors. Some of these systems have limitations on their usefulness for transient mitigation. This chapter discusses the use and limitations of the RC inventory measurement systems.

2.0 USES OF RC INVENTORY MEASUREMENT SYSTEMS

RC inventory is the volume of fluid in the reactor coolant system. The volume is affected by changes in mass and density. Mass can be varied by a loss of coolant accident, changes in HPI or MU flow, RC seal injection, seal return, and letdown. Density can be varied by changing RC temperature and pressure. Changes in RC inventory have two effects. A loss of mass affects the ability of the RC to transport heat from the core to the SG and a change in the volume of fluid can affect the ability of the pressurizer to control RC pressure. The RC inventory measurement systems are intended to provide the operator indications to determine if the RC inventory is sufficient for core cooling.

RC inventory is one of the five control functions used to regulate the heat transfer process as explained in Chapter II.C. Direct RC inventory measurements (RCITS, RVL & HLL) are used only when core cooling is assured and RC pressure and temperature are being controlled. RC inventory control is indirectly evaluated through the use of SCM and incore T/Cs. As long as sufficient SCM exists there is adequate RC inventory for core cooling. The lack of sufficient RC inventory as indicated by superheated incore T/Cs is used to identify the onset of ICC (Chapter III.F) and appropriate actions to mitigate this condition. RC inventory is controlled during a loss of SCM (Chapter III.B, Sections 2.3 and 3.2) by maximizing HPI/LPI flow and isolating possible leaks.

RCITS, RVL and HLL are not used for symptom recognition.

2.1 Pressurizer Level

Pressurizer level is an accurate measure of RC inventory only when the RCS is subcooled and there are no voids in the RCS other than in the pressurizer. Pressurizer level is the normal RC inventory monitoring system typically used as a control function when abnormal transients do not exist.

2.2 Hot Leg Level

Hot leg level is typically determined by measuring the DP between the head of water from the highest point of the hot leg (e.g., the high point vent line) to a point below the hot leg exit from the reactor vessel (e.g., the decay heat drop line). HLL is typically temperature or density compensated by use of the hot leg temperature measurement. During a loss of subcooling margin after the RCPs are tripped, the steam and water will separate creating a water level that can be measured via differential pressure. In this situation, HLL can be used to monitor the effects of mitigative actions. For example, HLL can be used as an aid to determine if adequate water level exists above the DHRS suction nozzle before initiating DHRS operation. However, whenever HLL is used caution must be exercised in interpreting the indication given by this instrument type. Differential pressure indications can be affected by temperature, pressure, and fluid flow such that the indication may be misleading.

2.3 Reactor Vessel Head Level

Reactor vessel level is typically determined by measuring the ΔP between the top of the reactor vessel head and the RC cold leg. RVL is typically temperature or density compensated using the incore T/C temperature. Because of reactor vessel head design and fluid flow characteristics, the fluid in that region cools at a much slower rate than the rest of the RCS, thus contributing to possible bubble formation in the head region. Any heat transfer upset resulting in a rapid depressurization of the RCS may lead to head void formation. After the RCPs have been tripped, it is possible to measure the voids with RVL. RV head level indication can be used to monitor the effect of mitigative actions.

During natural circulation cooldown, RV head voids may form. If so, RVL can be used to confirm this condition.

As discussed previously, caution must be exercised in interpreting the indication given by this instrument type. Differential pressure indications can be affected by temperature, pressure, and fluid flow such that the indication may be misleading.

2.4 Reactor Coolant Inventory Trending System

The typical reactor coolant inventory trending system (RCITS) makes a correlation between RCP motor power (current) and RCS cold leg temperature (water density) to derive the RC void fraction. This void fraction gives a relative indication of the status of RC inventory trend during RCP operations. RCITS is primarily designed to indicate the relative change in void fraction during continuous RCP operation from subcooled to saturated conditions and beyond, assuming a homogenous RC mixture. However, this system has limited use because the RCPs are tripped by procedure upon loss of SCM.

RCITS may provide useful data when in Region 2 or 3 of the ICC guidance if the RCPs were not tripped as required on loss of SCM. However, operation during ICC may not maintain a homogeneous mixture; therefore, at best, the RCITS can only provide relative information. No guideline actions are based upon absolute or trending RCITS indication. The single most important ICC indication remains the incore thermocouple readings. In addition, other indications, such as HPI flow, are used to verify the success of specific ICC actions.

2.5 Incore Thermocouple Temperature

Incore thermocouple temperature is used in place of hot leg or cold leg temperatures to assess the effect of heat transfer changes upon RC inventory. Although RC inventory can not be directly determined from incore T/Cs, the state of the RC covering the core can be determined thus the status (i.e., adequate or inadequate) of the RC inventory can be inferred. Incore T/Cs are plotted versus RCS pressure to determine the RCS P-T relationship to the saturation curve. They are the primary RCS temperature indication whenever SCM does not exist and are the only valid indication of the onset of ICC conditions. The incore T/Cs are also used to determine when SCM has been restored and to control the P-T relationship when RCPs are off and the PTS guidance is invoked.

Also, incore T/Cs are the best single indication of a loss of heat transfer while in natural circulation.

2.6 Subcooled Margin

The subcooled margin is the margin to saturation. A P-T above and to the left of the saturation curve may be considered subcooled. As long as the core is covered with reactor coolant, sufficient heat transfer from the core will occur to keep the core adequately cooled. As long as the reactor coolant is subcooled, the core will be covered. Therefore, the operator should assume that if sufficient margin to saturation does not exist, the core has a potential of not being adequately covered.

A plant specific error corrected saturation curve must be determined to account for instrument and process (e.g., the elevation head) errors. This curve is called a subcooled margin (SCM) curve. This curve may also include an arbitrary fixed margin to saturation to provide an additional buffer against accidentally crossing the saturation curve. Any of the RC core outlet temperatures (Thot or incore T/Cs) may be used with RC pressure to determine the proximity to the SCM curve until the SCM curve is reached by any P-T. Any time that the P-T decreases below the SCM curve, the RCS is to be considered saturated and only incore T/Cs vs RC pressure should be used for mitigative action. The reason for this is that the loop temperatures may not be representative of core cooling status; it is the core subcooling that is the important parameter. The P-T trace coupled with SCM provides much of the input required to follow the guidelines.

3.0 LIMITATIONS ON USE

RCITS is useful only following RCP restart operations and then RCITS can only be used to provide relative information following the restart. No guideline actions are based upon absolute or trending RCITS indication. If the guidelines are followed correctly and the RCPs are tripped within two minutes of a loss of SCM, RCITS will never display a valid void fraction because none will have existed during RCP operation. Most HLL and RVL designs are useful only during periods of no RCP operation because these instruments are based upon a static differential pressure head. Forced RCP flow introduces additional DP's into RVL and HLL that make the readings inaccurate. HLL and RVL may have an additional limitation if they are connected to the hot leg or RV head vent line. If so connected, the level indications will not be reliable while the vent is open. Caution must be exercised whenever DP measurements are used to determine fluid level because of the process errors and flow induced errors associated with these type instruments.

Incore T/Cs and subcooled margin have no restrictions upon their use. These indications are used for transient recognition, control and mitigation. All other RC inventory instruments (PZR level, HLL, RVL, & RCITS) are only used when core cooling is assured and relatively stable. These instruments may be useful in restoring the plant to a normal configuration. PZR level, HLL, RVL and RCITS are not used to dictate actions during transient mitigation.

Chapter IV.J

Loss of Decay Heat Removal System Operation

1.0 INTRODUCTION

A key safety function during shutdown operations is maintaining decay heat removal capability. The purpose of this chapter is to provide general guidance for responding to a loss of Decay Heat Removal System (DHRS) operation while the plant is shutdown. It is important to plan and control plant shutdown activities such that the potential for a loss of normal DHRS is minimized, one or more alternate cooling methods are maintained available at all times, and RB closure can be achieved if a sustained loss of DHR occurs. The alternate cooling methods that may be available for use depend on a variety of factors, including plant configuration, availability of systems and components, and time after shutdown.

A great deal of work has already been performed by the nuclear industry on the issue of shutdown safety. All utilities have been provided with guidance (NUMARC 91-06, Guidelines for Industry Actions to Assess Shutdown Management) to aid them in assessing and enhancing their current practices for planning and conducting (controlling) outages. Key issues are identified in five areas in NUMARC 91-06: decay heat removal capability, inventory control, power availability, reactivity control, and containment. The purpose of this chapter is not to repeat this overall guidance but to provide specific guidance regarding the availability and capability of alternate core cooling methods if the normal Decay Heat Removal System is lost.

Guidance on RB closure capability and RB cooling capability as they relate to these alternate core cooling methods is also provided. At those times when reduced RCS inventory conditions exist, it is necessary to ensure that RB closure can be achieved in sufficient time to prevent potential fission product release to the environment if an extended loss of DHR occurs. Initial steps to begin RB closure should be started as soon as a loss of DHR occurs during reduced RCS inventory operation rather than waiting to see if restoration of DHR occurs because RB conditions may hinder later RB closure. The actual time available to establish RB closure depends on decay heat level (time after shutdown) and available RCS inventory (e.g., full, loops drained, mid-loop operation, etc.). Figures IV.J-1 and IV.J-1A provide the time to boiling, and Figures IV.J-2 and IV.J-2A provide the time to core uncovery versus elapsed time after shutdown and initial RCS inventory conditions.

RB cooling capability is necessary during a loss of DHR when the RCS is open or vented in order to control RB pressure so that gravity feeding from the BWST is available as an alternative cooling mode for decay heat removal (see Section 3.3.3). Also, by maintaining RB cooling capability, the actual time available to personnel to be inside the RB is maximized. This may be important if manual actions in the RB are necessary to attempt to reestablish DHR cooling or if unexpected difficulties arise during RB closure efforts. RB cooling capability may not be available for the same reason that the loss of DHR has occurred (e.g., loss of AC power). For these reasons, steps to verify adequate RB cooling exists or steps to initiate, restore, or maximize RB cooling capability should begin as soon as a loss of DHR occurs.

2.0 LOSS OF DHRS

If one DHRS train is in operation and is lost, then it should be determined what caused the loss of the train and whether the redundant DHRS train can be placed into operation. For example, if the operating DHRS train is lost because of pump cavitation caused by vortexing due to inadequate RCS inventory, then the redundant DHRS train should not be placed into operation until adequate RCS inventory is restored. Once adequate RCS inventory has been restored, the redundant DHRS train can be placed in operation. The previously running DHRS train should be made ready for operation, if possible. If the redundant DHRS train cannot be placed in operation, then restarting the previously running DHRS train should be attempted, provided, in this example, that the train can first be properly vented and filled. If neither DHRS train can be placed in operation, an alternate cooling method for removing decay heat must be implemented until normal DHR can be reestablished. Once normal DHR has been reestablished, then, depending on the conditions in the RCS, the DHRS may have to be properly controlled to prevent exceeding applicable RCS cooldown limits (see Chapter IV.G).

3.0 IMPLEMENTATION OF ALTERNATE COOLING/MAKEUP METHODS

The matrix in Table IV.J-1 provides a list of some of the alternate cooling and makeup methods that may be available at the plants if normal DHRS cooling is lost. This matrix is a compilation of alternate cooling methods that were found in existing plant procedures plus one additional method: boiler-condenser cooling (BCC). Plant specific design differences may prevent the use of some of these methods.

Before implementing any of the cooling methods from Table IV.J-1 into plant emergency operating procedures, each utility should verify that the indicated lineups are possible at its plant, that adequate suction for the pumps exist, and that the available flow rates are adequate for the plant state. Figures IV.J-1 through IV.J-8 provide data to support these verifications for a "typical" plant. For example, Figures IV.J-3 and IV.J-3A provide the flow rate required to maintain the RC subcooled, and Figures IV.J-4 and IV.J-4A provide the flow rate to makeup for boil-off. Each utility should also investigate any other possible cooling methods not on this list that can provide the flow rates provided in these figures.

Some of the alternate methods in Table IV.J-1 use portions of the DHRS (e.g., some DHRS piping, DH coolers). Even though the normal DHRS system function may have been lost, prompting actions covered in this guidance, portions of the DHRS may still be available for use and should be considered when attempting to restore decay heat removal.

For the purposes of this guidance in identifying possible alternate core cooling methods, five basic plant states have been defined. These five plant states differ as to the status of the RCS as well as to the status of other plant systems and equipment which might be used. In order to provide defense-in-depth against a loss of normal DHRS, it is recommended that at least two diverse alternate cooling and makeup methods be maintained available for each plant state.

It is also suggested that at least one method that can be implemented with a loss of all AC power be available. BWST gravity feeding, BCC, and steaming the SGs (using the turbine-driven EFW pump for feeding the SGs if adequate steam pressure to run the EFW pump is or can be made available) currently exist as methods that could be implemented without AC power. It also may be possible to use the CFTs without AC power with some minor plant modifications. Each utility should define its criteria for needed alternate cooling and makeup methods, ensure they are available via administrative procedures, and implement them in its loss of DHRS procedure(s).

Each plant state and some of the alternate cooling or makeup methods that may be available for these plant states are discussed below. Again, before implementing any of these methods into plant emergency operating procedures, each utility should verify that the indicated lineups are possible at its plant(s), that adequate suction for the pumps exist, and that the available flow rates are adequate for the plant state. An important consideration in the evaluation of the feasibility of these lineups at the plant is the system interlocks that would need to be bypassed. Each interlock should be evaluated to determine those conditions for which it can be bypassed and those conditions for which it should not be bypassed (e.g., possibility of an interconnecting system LOCA due to excessive pressure from one system to another). Priorities, special factors, and bases which should be considered when choosing an alternate method to implement are discussed.

It is suggested that the following general priority scheme be adopted. For each of the five plant states, closed cycle cooling loops, open cycle cooling loops, and makeup methods may be available for core cooling and RCS makeup. For the purposes of this chapter, cooling loops, whether closed or open, refer to the primary side only. The highest priority should be those methods that are closed cycle cooling loops, if such methods exist for the specific plant state. Closed cycle cooling loops establish or maintain flow through the RV and core, and use heat exchangers (e.g., SGs, DH coolers, SF coolers) to remove decay heat. Closed cycle cooling loops also maintain the RC subcooled. RC is contained within the RCS and interconnecting systems and is not discharged to the RB. Thus, the RB environment is not adversely affected.

The next highest priority are those methods that are open cycle cooling loops. Like closed cycle cooling loops, open cycle cooling loops also establish or maintain flow through the RV and core. However, in open cycle cooling loops, the RC is not contained within the RCS and interconnecting systems. Instead, RC is discharged or leaked from the RCS and then circulated back to the RCS from its collection point (RB sump, for example). If heat exchangers are available, these cooling loops should provide sufficient flow rate through the RV to maintain the RCS subcooled.

One exception to the definition of open cycle cooling loop is the RV head off and refueling canal flooded configuration (SFC-6 in Table IV.J-1, which is also Plant State E that is discussed in Section 3.5). For the purposes of this guidance, this configuration has been defined as an open cycle cooling loop. In this configuration, water for core cooling is in direct contact with the RV and the core such that a "loop" does not need to be established. However, since the loop is open, decay heat would be transferred to the RB if no heat exchangers are available. This could adversely affect the RB environment.

The lowest priority methods are those that can only provide makeup to the RCS. Makeup methods are usually time-limited because there is no established "loop", and it may be difficult or impossible to replenish the suction source. Some makeup methods can maintain the core subcooled because they provide sufficient flow rate through the core. Other makeup methods may only be able to provide inventory to the RCS to makeup for core boil-off because their flow rate is insufficient to maintain the core subcooled or because their flow rate, while sufficient to maintain core subcooling, does not provide a flow path through the core. For these latter makeup methods, flow rates in excess of those necessary to make up for core boil-off would be wasted. Therefore, it is expected that makeup methods will only be used to make up for core boil-off in order to maximize the time the makeup source is available.

3.1 Plant State A: RCS Intact and Full With SGs Available

In Plant State A, the RCS is intact (the normal RCS pressure boundary exists), and the SGs are available for heat transfer. This plant state would occur during a cooldown and at the beginning and end of an outage, but it may also occur in the middle of an outage.

3.1.1 Plant State A Closed Cycle Cooling Methods

The preferred alternate cooling method for Plant State A is steaming the SGs, either to the condenser or to the atmosphere (SG-1 & SG-2 in Table IV.J-1). If Plant State A exists or can be established (e.g., refilling the RCS and making feedwater to the SGs available), this method will adequately remove decay heat as long as natural circulation of the RCS can be established and maintained. If there is expected to be a delay in establishing FW to the SGs, then, if possible, level in the SGs should be maintained as high as possible.

When heat transfer is restored to the SGs and steaming begins, SG pressure and RCS pressure and temperature will begin to increase. The magnitude of these increases is governed by the amount of decay heat and the capability of the steam relief system that is available. However, unless the SG(s) are supplying steam for the turbine-driven EFW pump, in which case SG pressure must be maintained high enough to maintain an adequate steam source for the pump, these increases are undesirable. Therefore, the TBVs and/or ADVs should be maintained wide open to maximize steam dump capability in order to maintain minimum possible RCS temperature and pressure conditions.

It may also be possible to cyclically fill and drain the SGs rather than steam them to provide RCS cooling (SG-3 in Table IV.J-1).

If steaming the SGs and establishing natural circulation is not possible, then other available closed cycle cooling methods should be considered. Figures IV.J-3 and IV.J-3A provide the flow rates required to prevent RCS heatup which should be used in evaluating these potential methods. One method uses an HPI pump to replace the DHRS pumps in a near-normal DHRS lineup; i.e., suction from the DH drop line, through the DHRS coolers (HPI-4 in Table IV.J-1). In this method, however, the discharge is into the RCS via the MU or HPI system injection lines rather than normal DHRS injection via the CFT injection line. Whenever HPI with suction from the BWST is used, the PTS guidance in Chapter IV.G must be followed. Since the suction source for this configuration is the RCS hot leg (DHRS drop line), the PTS guidance does not apply for this method.

Another method uses the Spent Fuel (SF) pumps to replace the DHRS pumps and the SF coolers to replace the DHRS coolers (SFC-2 in Table IV.J-1). The SF pumps take suction from the DH dropline and discharge into the RCS via the normal DH injection lines. Care should be exercised if lineups involving the SF pumps and pool are used because the SF pumps are needed to ensure necessary cooling in the SF pool.

3.1.2 Plant State A Open Cycle Cooling Methods

If no closed cycle cooling methods are available, then available open cycle cooling methods should be considered. Again, Figures IV.J-3 and IV.J-3A provide the flow rates required to prevent RCS heat up and should be used in evaluating these potential methods.

Two possible open cycle cooling methods are conventional HPI cooling (HPI-5 in Table IV.J-1) and LPI cooling (LPI-2 and LPI-3 in Table IV.J-1), where the HPI or LPI pumps take suction from the BWST or the RB sump (LPI cooling only) and discharge to the RCS, using the PORV to bleed from the RCS. When HPI cooling is used, care must be taken to properly throttle and control HPI flow rate to ensure that RCS pressure remains below the RV P-T limits because HPI flow rate may be greater than the PORV flow rate, especially at low RCS pressures. Also, whenever HPI with suction from the BWST is used, the PTS guidance in Chapter IV.G must be followed.

The PORV can also be used to control RCS pressure and as well as provide a relief path for RC. The low pressure threshold below which the PORV will not open should be noted so that alternative relief paths (e.g., HPVs) can be used, if necessary. Otherwise, the RCS will have to pressurize to the point where the PORV will open. RC discharged from the PORV will eventually collect in the RB sump and possibly be available for reinjection to the RCS. Depending on the power history (initial decay heat level), the time since shutdown, and the initial RCS temperature and pressure conditions, the PORV may not pass sufficient flow rate to allow HPI flow to maintain the initial RCS temperature. Without HPI throttling, RCS pressure will increase, possibly in excess of allowed RV P-T limits. Therefore, HPI flow must be throttled. Throttling HPI will cause RCS temperature and pressure to increase until the PORV can pass sufficient flow. Care must be taken to ensure that the RCS P-T remains within the allowed region if RCS heatup and pressurization occur. The RCS pressure is not expected to increase above 400 PSIG for maximum decay heat conditions and minimum time after shutdown (~72 hours). The ability of all valved-in temporary RCS connections to withstand such RCS pressure increases should be evaluated.

If the BWST is the suction source (e.g., HPI cooling), it may be necessary to use the RB Spray pump or LPI pump, if available, or other water sources to provide makeup to the BWST to maintain it as an adequate suction source. The only difference between LPI-2 and LPI-3 is the suction source for the LPI pump. The BWST is the source in LPI-2 while the RB sump is the source in LPI-3. Based on the discussion in the previous paragraph regarding RCS pressurization to about 400 PSIG if the PORV is used very early in a shutdown, the LPI system cannot be used until such time that the expected RCS pressurization remains below the shutoff head for the LPI pump. This is the case for Plant States A and B, where the PORV is the only relief path but not necessarily for Plant States C and D, where another vent path besides the PORV may be available and in use.

Another open cycle cooling method (Other-3 in Table IV.J-1) is similar to LPI-2 and LPI-3 except the RB Spray pumps are used instead of the LPI pumps. Again, as in LPI-2 and LPI-3, the PORV is used as necessary to control RCS pressure and provide a relief path for RC. Although the BWST is identified as the suction source for this method, it may be desirable to shift the suction source for the RB spray pumps to the RB sump rather than attempt to make up to the BWST from other water sources to maintain the BWST as an adequate suction source. Still another open cycle cooling method (SFC-3 in Table IV.J-1) uses the SF pumps taking a suction from the BWST with an RB Spray pump, if available, taking a suction from the sump to replenish the BWST. The PORV provides a relief path for the RC.

3.1.3 Plant State A: Makeup Methods

One method (SFC-1 in Table IV.J-1) uses the SF pumps or the BWST recirculation pump taking suction from the SF pool or the BWST and injecting to the RCS via the DHR piping. Another makeup method that may be available for injection to the RCS may be the

CFTs. If the CFTs are depressurized, the CFT isolation valves could be cracked open, after which the CFTs could be slowly pressurized to control flow to the RCS (CFT-1 in Table IV.J-1). Care should be exercised if the CFTs are used while they are fully pressurized to prevent rapid RCS pressurization and possible violation of the RV P-T limits.

3.2 Plant State B: RCS Intact But Not Full

The major difference between Plant State B and Plant State A is the RCS is no longer full. The RCS is no longer full because of RCS drain-down requirements (e.g., the RCS is drained down to some level required for the work being performed or is in the process of being drained down in order to perform that work). The SGs may or may not be available. However, for reasons discussed in Section 3.2.1 below with regard to BCC, it is recommended that the SGs be available when in Plant State B.

3.2.1 Plant State B Closed Cycle Cooling Methods

If Plant State A can be established (i.e., the RCS refilled), steaming the SGs to the condenser or to the atmosphere is the preferred alternate core cooling method (see Section 3.1.1). Whenever temporary connections are valved in, their ability to withstand possible RCS pressure increases should be included in the determination of the steps necessary to restore the RCS pressure boundary. If SG steaming is not available, then all of the Plant State A closed cycle cooling methods discussed in Section 3.1.1, with the possible exception of HPI-4 in Table IV.J-1, are also available for Plant State B. HPI-4 is probably not available due to inadequate NPSH for the HPI pump, but this should be verified by each utility.

If refilling the RCS is not possible, then BCC (SG-4 in Table IV.J-1) should be considered for core cooling. For example, if the RCS is drained down to mid-loop for maintenance, BCC may be the best (or only) core cooling option available because of the short amount of time before boiling and then core uncovery occur. Therefore, it is suggested that, until the RCS vent has been established and gravity feeding is possible, BCC should be maintained as an available backup core cooling method.

BCC occurs when RC is boiled in the reactor core, forming steam which then flows through the RCS hot leg piping to the SGs where it is condensed in the SG tubes. For this condensation of RC to occur, SG levels must be maintained above the RC water level in the SG tubes in order to provide a condensing surface for the RC steam. RCS pressure (and temperature) will increase during BCC. The amount of the increase depends on the area of condensing surface in the SGs. The presence of noncondensible gasses in the RCS will cause a larger RCS pressure increase in order to compress these gasses to achieve adequate condensation surface area. Once heat transfer begins in the SGs, steam pressure will increase and should be controlled in order to prevent RCS temperature (and pressure) increase and to maintain adequate pressure for the turbine-driven EFW pump, if necessary.

A basic sequence of events, with additional items that should be considered in order to establish BCC, is provided below. This sequence should ensure the ability to use BCC during those times where the RCS is drained:

1. Prior to draining the RCS or closing RCS openings in preparation for refill:

   a. Ensure both SGs are available with high levels established and a feedwater source capable of delivering approximately 100 GPM against 100 PSIG backpressure. At 48 hours after shutdown, 100 GPM flow rate is needed to remove core decay heat. With only one SG available with one ADV open, SG pressure is expected to increase to a maximum of 100 PSIG. EFW through the EFW nozzles is preferred in order to aid pool BCC if noncondensable gasses are present. The minimum steam pressure required to run the turbine-driven EFW pump must be considered when determining the availability of the SGs and the feedwater source if that pump is used. Loss of AC power should also be a consideration when determining the feedwater source. Finally, it may be necessary to drain the main steam lines to remove any water from the steam flow path prior to establishing that path.

   b. Ensure either the ADVs are available on both SGs or that a code safety valve can be removed on both SGs. While the TBVs/condenser may be initially available, a loss of AC power may cause a subsequent loss of condenser. It is possible to keep the SGs near atmospheric pressure if a code safety valve on both SGs or the TBVs/condenser are used. Using code safety valves will require that they be removed from the steam lines because of the difficulty and personnel safety hazard in manually opening them if they remain installed. If the code safety valves are removed and the vent path for steam is to the Auxiliary Building versus the atmosphere, this may cause Auxiliary Building pressurization concerns, problems with equipment and instrumentation in the Auxiliary Building, and may cause a personnel safety hazard. This issue should be evaluated by each utility before using the code safety valves. Finally, if only the ADVs are available and depending on their relief capacity compared to the MSSVs, they may not prevent some SG pressurization.

   c. Ensure all temporary RCS connections can be isolated if necessary. These temporary connections should be able to withstand approximately 40 PSIG if both SGs are available and approximately 130 PSIG if only one SG is available. These RCS pressures are based on assumed SG pressurization of about 15 PSIG (both SGs available, each with one ADV) and 100 PSIG(one SG available with one ADV).

2. If a loss of DHR occurs such that BCC will be used for core cooling:

   a. Open or verify open the hot leg high point vents (HPVs). The presence of air or noncondensable gasses in the RCS will require greater condensation lengths or higher RCS pressure in order to compress gasses to achieve adequate condensation surface for the same heat removal. Opening the HPVs should help remove gasses from the RCS, reducing the RCS pressurization.

      While it should be acceptable to maintain the HPVs open, the impact of steam relief to the RB should be considered. If this impact is undesirable, the HPVs can be closed and then reopened as necessary during BCC (e.g., due to RCS pressure increasing due to the presence of noncondensable gasses).

   b. Establish the steam relief paths for both SGs if possible.

   c. Line up the feedwater source to the SGs and begin feeding as necessary.

   d. Isolate temporary RCS connections that cannot withstand ~ 40 PSIG if both SGs are available and ~ 130 PSIG if only one SG is available.

   e. Monitor heat removal, SG and RCS pressures and temperatures. If possible, raise SG levels to reduce or minimize the RCS pressure increase if RCS pressure is a problem due to the temporary RCS connections.

3.2.2 <u>Plant State B Open Cycle Cooling Methods</u>

All of the Plant State A open cycle cooling methods discussed in Section 3.1.2 should also be available for Plant State B.

3.2.3 <u>Plant State B Makeup Methods</u>

If none of the closed cycle or open cycle cooling methods are available, alternate flow paths for RCS makeup may exist that should be attempted. In evaluating which method(s) should be attempted, not only must the flow path be available or capable of being made readily available, but also the flow rate needed to makeup for boil-off needs to be determined. Figures IV.J-4 and IV.J-4A provide the flow rates required to makeup for boil-off based on time after shutdown from full power. The method(s) chosen should be able to meet or exceed these needed makeup flow rates.

The use of the CFTs as discussed in Section 3.1.3 is also applicable to Plant State B. Another makeup method may be the use of throttled flow from the HPI pumps (HPI-3 in Table IV.J-1) as necessary to only makeup for boil-off. Throttling HPI flow to only makeup for core boil-off may be required to extend the time the BWST is available. This will require a steam relief path, such as the PORV, and may require some RCS repressurization. Whenever HPI with suction from the BWST is used, the PTS guidance in Chapter IV.G must be followed. It also may be possible to use the RB spray pumps, taking suction on the BWST, to makeup to the RCS, using the PORV as necessary to maintain RCS pressure (Other-3).

3.3 Plant State C: RCS Vented With RV Head Installed

The major differences between Plant State C and Plant State B are the RCS pressure boundary is not intact because an RCS vent path has been established, and the SGs are probably not available (e.g., open SG manway is the RCS vent or the nozzles dams are installed). The RCS vent has been established to allow for gravity feeding from the BWST (see Sections 3.3.2 and 3.3.3), and thus, the RCS pressure boundary cannot be restored in a timely fashion.

3.3.1 Plant State C Closed Cycle Cooling Methods

Alternate cooling method SFC-2, discussed for Plant State A in Section 3.1.1, is also available for Plant State C.

3.3.2 Plant State C Open Cycle Cooling Methods

All of the Plant State A and Plant State B open cycle cooling methods discussed in Sections 3.1.2 and 3.2.2 should also be available for Plant State C. Another method for Plant State C is LPI-1 in Table IV.J-1. Though it is listed as a separate method, LPI-1 is essentially the same as LPI-2, discussed in Section 3.1.2, except for the bleed path. LPI-1 uses the RCS vent path that is established for BWST gravity feeding capability while LPI-2 uses the PORV.

There are two additional open cycle cooling methods for Plant State C which may be available. Both these methods use the HPI pumps (HPI-1 and HPI-2 in Table IV.J-1). HPI-1 uses the BWST as the suction source for the HPI pump while HPI-2 uses the RB sump and the LPI pump in piggyback with the HPI pump as the suction source. Both methods relieve RC through the RCS vent path that is established for BWST gravity feeding capability. Since HPI-1 uses only the BWST, it may be necessary to make up to the BWST, either from the RB sump using the RB spray pump or from other sources. HPI-2 is initially HPI-1 but switches to the RB sump as the suction source rather than try to replenish the BWST to maintain it available as the suction source. Whenever HPI with suction from the BWST is used, the PTS guidance in Chapter IV.G must be followed.

3.3.3 Plant State C Makeup Methods

If none of the closed cycle or open cycle cooling methods are available, several alternate methods for RCS makeup should exist. Prior to including any of these methods into procedures, they should be evaluated to determine the availability of the flow path and the capability to deliver the flow rate needed to makeup for boil-off. Figures IV.J-4 and IV.J-4A provide the flow rates required to makeup for boil-off based on time after shutdown from full power. The method(s) chosen should be able to meet or exceed these needed makeup flow rates.

The use of the CFTs as discussed in Section 3.1.3 is also applicable to Plant State C. Another makeup method may be the use of throttled flow from the HPI pumps (HPI-3 in Table IV.J-1) as necessary to only makeup for boil-off. This may be required to extend the time the BWST is available. Whenever HPI with suction from the BWST is used, the PTS guidance in Chapter IV.G must be followed. It also may be possible to use inventory in the various Makeup and Purification System tanks (e.g., RCS Bleed Holdup tanks), Waste System tanks, and Condensate storage tanks if a boric acid flow path can also be established to borate these water sources as needed to prevent deborating the RCS. These methods are Other-1, Other-2, and Other-4 in Table IV.J-1.

Thus far, all of the cooling methods that have been discussed require active components (e.g., HPI pump or LPI pump). Depending on the status of the plant (e.g., loss of electrical power sources), all active alternative cooling methods may be lost. It would then be necessary to use a passive method if a flow path exists or can be established. One passive method that should be available is gravity feeding from the BWST to provide inventory to the RCS for core cooling (BWST-1 in Table IV.J-1). Gravity feeding should be available and capable of providing inventory to the RCS because there are redundant flow paths from the BWST and several injection flow paths into the RCS, including the normal DHRS injection line, normal makeup or HPI lines, and the DHRS drop line.

Since gravity feeding takes advantage of the head (elevation) difference between the BWST and the RV, a sufficient RCS vent path must be established to minimize RCS pressurization that would decrease the head difference and prematurely shut off flow from the BWST. Figures IV.J-5 and IV.J-5A provide the differential pressure between the RCS and the RB versus time after shutdown for five selected vent paths. There are a number of other vent paths that could be made in the RCS. The five paths that were evaluated and presented in Figures IV.J-5 and IV.J-5A, the primary manways and hand holes on the SGs and the Pressurizer manway, were the ones mostly likely to be used. The differential pressure data in Figures IV.J-5 and IV.J-5A do not assume any devices, such as filters, or other obstructions are in the flow path. Such resistances would increase the differential pressures from those provided in these figures.

As can be seen from Figures IV.J-5 and IV.J-5A, not only is the size of the RCS vent important, but the location of the RCS vent is also a very important consideration. In choosing a location, the magnitude of the flow path resistance between the core and the vent was evaluated. Because of the significant amount of steam production in the core when high decay heat level exists, a high resistance flow path will result in an increase in RCS pressure above the ambient RB pressure. This increase in RCS pressure will decrease the head difference between the BWST and the RV, decreasing the amount of time the BWST is available for gravity feeding. If the RCS pressure increase is large enough, it may prevent any BWST flow to the RCS.

Increases in RCS pressure may cause other operational problems while attempting to restore DHR. For example, if the Pressurizer manway is used as the RCS vent, then the hot leg and surge line are a resistance in the flow path between the core where steam is being produced and the manway opening. If the steam production in the core is high, RCS inventory in the hot leg and surge line will be displaced via entrainment of liquid by the steam flow into the Pressurizer and cause an increase in RCS pressure. The displaced inventory would then be unavailable for core cooling. The displaced inventory and the pressure drop losses in the surge line due to high steam flow rate may also cause erroneous readings of Pressurizer level, hot leg level, and RV level if the Pressurizer level tap is used for these level indications. Finally, it may cause sufficient increase in RCS pressure to fail the nozzle dams which could cause a loss of additional RCS inventory. For these reasons, the Pressurizer manway (also the code safety valve and PORV) should not be used solely as the RCS vent, at least for the first 40 days after shutdown. As Figure IV.J-5 indicates, after 40 days, the differential pressure is sufficiently low that the Pressurizer manway could be used.

For most situations involving shutdown operations, two SG primary manways provide the most acceptable RCS vent because of the very small RCS to RB differential pressure that occurs (see Figures IV.J-5 and IV.J-5A). One SG primary manway is also an acceptable RCS vent because of the small differential pressure between the RCS and the RB. As indicated in Figure IV.J-5A, there will be a small increase in RCS to RB differential pressure when using one SG manway versus two SG manways early in a shutdown when decay heat levels and steam production in the core would be high. When the SG manways are used as the RCS vent, and especially when only one SG manway is used, this could result in indications which may be confusing as described in the scenario below.

When the RCS is partially drained down but with a water level above the hot leg nozzles such that they are completely full, steam produced in the core will collect under the RV head and displace RC into the hot legs. The result of this displacement is an increase in RCS pressure. The displaced RC will result in an increase in hot leg level indication, which could be interpreted as RCS inventory addition from the BWST. The increase in RCS pressure will decrease the flow rate from the BWST. Decreasing BWST flow rate and increasing hot leg level indication might be conflicting indications which may lead to confusion in determining actions to take. This scenario should not cause a core protection problem because the RCS inventory in the hot legs will drain back to the RV once steam begins to escape through the RCS vent. RCS pressure will then decrease and restore BWST flow.

Gravity feeding from the BWST can be throttled or unthrottled. Unthrottled flow from the BWST may be desired for some period of time because of the status of the plant (e.g., initial refill of the RV if RC inventory is low due to reduced inventory operation for maintenance). However, for the following reasons, it is suggested that flow from the BWST be throttled, if possible.

When BWST flow is throttled to the flow necessary to make up for core boil-off, the time the BWST is available is maximized since BWST inventory is not wasted. This allows more time to restore or establish another cooling method. For example, it may be desired to maintain the RCS subcooled, and unthrottled flow may be sufficient to do so. However, the flow rate required to maintain the RCS subcooled is approximately 6 to 7 times the flow rate required to maintain saturated conditions (i.e., make up for core boil-off only). The extra time gained by throttling flow to that necessary to make up for core boil-off may be crucial in restoring normal DHR or an alternative cooling method before the BWST becomes unavailable for gravity feeding.

Inventory that is being fed from the BWST to the RCS may not actually flow through the core, and therefore core subcooling cannot be maintained even with unthrottled flow. The flow path within the RCS for water from the BWST will depend on the injection point into the RCS and the vent point. For example, if the injection flow path is through the Decay Heat drop line, and the vent is the manway on the SG connected to the same RCS hot leg as the drop line, the injection flow will probably not pass through the core. Thus, any inventory that is being added to the RCS in excess of the rate needed to make up for core boil-off will be wasted because the core cannot be maintained subcooled. The actual time available for unthrottled and throttled BWST flow can be calculated for each plant using Figures IV.J-3, -3A, -4 and -4A, the plant specific BWST volume available for gravity feed, the differential pressure between the RCS and RB using Figures IV.J-5 and -5A due to the RCS vent path that is established, and the actual RB pressure.

Finally, in order maintain the RCS subcooled, the flow rate from the BWST must not only be sufficient to remove core decay heat and also flow through the core, but the available head of the BWST must be sufficient to initially fill the RCS to the point of overflowing the RCS vent (SG manway). For some plants, the available head from the BWST may not be sufficient to fill the RCS. For other plants, the available head of the BWST may be sufficient initially. But the loss of head because of depletion of the BWST inventory due to the gravity feeding will eventually reduce the flow rate such that core subcooling cannot be maintained. Thus, for all these reasons, it is recommended that gravity feed flow from the BWST to the RCS be throttled to that necessary to make up for core boil-off, if possible, rather than be maintained unthrottled.

During gravity feeding, RB pressure must also be controlled in order that the time the BWST is available is maximized. Increases in RB pressure will reduce the available driving head (and available flow rate) of the BWST. Approximately two feet of BWST inventory is unavailable for every one PSIG increase in RB (or RCS) pressure. The combination of RB pressure increase and BWST head decrease as BWST inventory is depleted could eventually result in reaching the shutoff head for the BWST, stopping flow to the RCS while BWST inventory still exists. If the RB Coolers are available, they should be used to control RB pressure. Figure IV.J-6 provides typical RB pressure responses (based on time after the RCS reaches saturation) for three cases: no RB coolers are available; one RB cooler is available when saturated conditions are reached; one RB cooler is available when RB pressure reaches 4 PSIG. These curves should be sufficient for most cases; however, each utility might want to pursue plant-specific RB response data. This may be important on a plant where marginal gravity feed capability exists.

If the RB coolers are not available or are not sufficient to maintain RB pressure near atmospheric conditions, then the RB should be vented to limit RB pressure increases. Figure IV.J-7 provides typical RB pressure responses (based on time after the RCS reaches saturation) with and without venting. Analyses were performed with the goal of maintaining RB pressure in the range of 2 to 5 PSIG. Those analyses yielded the three "with vent" curves with hydraulic resistances, k/(A*A), in the range of 77.1 to 275.2 ft-4, which are presented in Figure IV.J-7. These are equivalent to 3.5 inch to 5 inch diameter vents assuming the form loss coefficient, k, is equal to 1.5 (a sudden expansion or contraction). Each utility can determine possible RB vent paths to use if the hydraulic resistances of those vent paths are known or can be calculated. These curves should be sufficient for most cases; however, each utility might want to pursue plant-specific RB response data. This may be important on a plant where marginal gravity feed capability exists.

3.4 Plant State D: RCS Drained with RV Head Off and Refueling Canal Not Flooded

The major difference between Plant State D and the previous plant states is the RV head has been removed. The alternate cooling/makeup methods for Plant State C that are discussed in Section 3.3.2 should be available for Plant State D. With the RV head off, it is possible to use gravity feed to maintain subcooled conditions in the core. This is possible because the RCS overflow would be at a lower elevation, the RV head versus the SG manway, and because flow through the core can occur with the head off. As inventory is fed from the BWST to the RCS, the loss of head in the BWST may eventually reduce the flow rate such that RCS subcooling cannot be maintained. Therefore, throttling the BWST flow to minimize wasted flow and maximize the time the BWST is available should also be considered.

Additional alternate cooling methods may be available for Plant State D if the refueling canal can be flooded. Although the canal is not flooded by definition for Plant State D, it may be possible to flood it if the seal plate has or can be installed (SFC-5 in Table IV.J-1).

If the refueling canal can be flooded, then the plant is now in Plant State E. The alternate cooling/makeup methods that are available for Plant State E are discussed in Section 3.5.

3.5 Plant State E: RV Head Off and Refueling Canal Flooded

With the refueling canal already flooded, there is an ample supply of water available for removing decay heat. However, it may be desirable to cool the canal, if possible, rather than allow the canal water to heat up and possibly begin to boil. One method would be to maximize the cooling capability of the SF cooling system (SFC-6 in Table IV.J-1). This may establish some circulation (and heat transfer) from the refueling canal to the SF pool.

There are also two possible flow paths that could provide active cooling of the water in the refueling canal. If the DH coolers are available, a SF pump can be lined up to the DH system (SFC-2 in Table IV.J-1). If DH coolers, a DH Pump, SF coolers, and a SF pump are all available, then a flow path from the refueling canal through the SF coolers to the BWST using a SF pump and back to the refueling canal from the BWST through the DH coolers using a DH pump can be established (SFC-4 in Table IV.J-1).

4.0 REACTOR BUILDING (RB) CLOSURE REQUIREMENTS

The NRC Generic Letter 88-17 requires procedures and administrative controls that reasonably assure that Containment (or Reactor Building - RB) closure can be achieved prior to the time at which core uncovery could occur as a result of a loss of DHR coupled with the inability to initiate alternate cooling or to replenish RCS inventory. Each utility's plans for implementing RB closure should include consideration of possible degraded RB environment (e.g., high temperature, humidity, radioactivity levels due to core boiling) prior to closure. RB closure should assure prevention of potential fission product release. Figures IV.J-1 and -2 provide the time to boiling and core uncovery.

These RB closure requirements may interfere with some of the alternative cooling/makeup methods. For example, the time available for gravity feeding from the BWST may be significantly shortened if RB cooling is not available (RB cooling will not prevent RB pressure increase but will minimize it). In this case, RB closure requirements could result in an RB pressure increase that would eventually reach the shutoff head for the BWST, stopping gravity flow to the RCS. If gravity feeding from the BWST is the only core cooling means available, then efforts to minimize RB pressure increase by means in addition to RB cooling (e.g., RB venting) should be attempted. Figures IV.J-6 provides typical RB pressure responses with and without RB coolers available, and Figure IV.J-7 provided typical RB pressure responses with and without RB vents.

5.0 OTHER ISSUES

The purpose of this section is to address other issues of concern that relate to loss of DHRS events; specifically, the use of nozzle dams, boron precipitation, and boron dilution.

5.1 Nozzle Dams

Nozzle dams are being used at the B&WOG plants during certain shutdown operations. While the nozzle dams are being installed, it is important to properly control RCS inventory addition so that RC is not lost out the open flow path through the SG lower manways. The use of nozzle dams also reduces the volume of RC in the RCS available for core cooling; i.e., there is no RC in the SGs. Thus, the amount of time available for restoring core cooling before boiling or core uncovery, ensuring RB closure, etc., is reduced and should be considered when evaluating available core cooling options.

The use of nozzle dams may preclude or may place limitations on some of the core cooling options. For example, due to the fairly low design pressure for the nozzle dams (typically about 30 PSIG), RCS pressure increases need to be minimized when they are in place. Thus, core cooling options which could increase RCS pressure above the design pressure of the nozzle dams should not be used or should be carefully controlled. Each utility should verify which options should not be used or need to be carefully controlled when the nozzle dams are installed.

5.2 Boron Precipitation

Boron precipitation is an issue that needs to be considered during a loss of DHRS event. Boron precipitation can eventually occur if boiling in the core occurs for a long enough period of time. Boron precipitation at the core exit could potentially block RC flow through the core and preclude adequate core cooling. It could also dilute the RC that is boiled off, then condensed and collected, in the RB sump for example, and recirculated to the RCS. If this were to occur, there is the possibility of reactor recriticality unless the dilute is borated (see Section 5.3).

It is expected that boron precipitation will not be a problem for most loss of DHR events. The most likely event for which an extended loss of DHR and prolonged core boiling might occur is a station blackout. In this case, gravity feeding from the BWST is probably the primary alternative cooling/makeup source. Per the Station Blackout Rule, plants have to demonstrate ability to withstand a station blackout for four hours. Per Figure IV.J-8, which provides two curves that illustrate the increase in RCS boron concentration versus time after saturation, assuming the unit has been shut down for at least seventy-two hours and no circulation of water into and out of the core region occurs, boron precipitation will not be a problem in this time range. However, in cases where a loss of DHR extends significantly past four hours, boron precipitation could become a problem unless RCS circulation is established.

Since boron precipitation occurs at a concentration of about 15,000 ppmB for RCS water temperatures of 140°F, circulation of RC in the core region would have to be established within about 12 hours after boiling begins (based on extrapolation of Figure IV.J-8) to prevent boron precipitation. Once decay heat removal has been reestablished, RCS temperature could to be returned to about 140°F without any concern for boron precipitation. Boron precipitation also occurs at a concentration of about 40,000 ppmB at RCS water temperatures of 212°F. Thus, circulation of RC in the core region would have to be established in about 36 hours after boiling begins (based on extrapolation of Figure IV.J-8) to prevent boron precipitation. Once decay heat removal has been reestablished, then the RCS temperature and the RCS boron concentration would have to be monitored and controlled to prevent boron precipitation.

There are several methods for establishing RCS circulation to prevent the concentration of boron and possible precipitation from occurring in the core during an extended loss of decay heat removal capability. Depending on the scenario, some of them may not be available or may not be sufficient to prevent RCS boron concentration from reaching the precipitation limit. One active method is the circulation created by the establishment of the long-term cooling mode, sometimes called "dump-to-sump". This mode establishes a gravity drain flow path from the RCS to the RB sump via the Decay Heat drop line. A second active method involves use of auxiliary pressurizer spray flow to establish circulation by forcing a reverse flow path through the core.

The third method is passive and is the circulation that occurs due to the gap that exists between the RV hot leg nozzles and the core support shield interface. The size of the gap is determined by the temperature difference between the upper core barrel and the RV shell, which is controlled primarily by the saturation temperature and the downcomer liquid temperature. Analyses have been performed for large break LOCAs that indicate the gap flow, by itself, is sufficient to prevent boron precipitation. Similar analyses could be performed for the possible scenarios and conditions that might exist for which this chapter is applicable if credit is taken for gap flow in the prevention of boron precipitation.

Each of these methods should be evaluated for possible use during an extended loss of decay heat removal event. Consistent with recommendations in the past, it is recommended that active methods be available and used in order to ensure boron dilution and thus prevent boron precipitation in the core during an extended loss of decay heat removal event.

5.3 Boron Dilution

Boron dilution may be a problem if demineralized water or low boron concentration water is used for RCS makeup or cooling during an event. Boron dilution should not be a concern when using the alternate cooling methods in Table IV.J-1 that use the BWST as their suction sources because of the required boron concentration in the BWST and because these methods can maintain the RCS subcooled. However, if during an event, makeup to the BWST is used to maintain the BWST as the suction source, then the water sources used for BWST makeup should be monitored to ensure the BWST is not diluted.

For most events, boron dilution should also not be a concern when using the alternate cooling methods Table IV.J-1 that use the RB sump as their suction source. In most cases the RB sump is being used because the BWST has been depleted, and the boron concentration in the RB sump should therefore be close to the BWST concentration. This should be the case unless leakage from a diluted water source (e.g., service water system or auxiliary feedwater system leak) has collected in the RB sump or an extended core boiling event has occurred.

As stated in Section 5.2 above, the RB sump can become diluted as a result of concentrating boron in the core region of the RCS due to extended boiling. For example, if an extended loss of DHRS occurs while the RCS is vented or open (i.e., Plant States C or D), core boil-off will occur. If RCS makeup is being provided by gravity feeding from the BWST, boron is concentrated in the core region of the RCS, and the RB sump will collect the condensed, diluted RCS boil-off. If, following this extended period of core boiling, an alternate cooling method which uses the RB sump as its suction source is made available, then the diluted water in the RB sump would be recirculated to the RCS and could potentially cause core recriticality. Therefore, it is necessary to monitor and control the boron concentration in the RB sump or any other suction source for these alternative cooling methods. Each utility should evaluate all possible sources of demineralized water or low boron concentration water and take appropriate steps to ensure these water sources are not used or only used if they can be adequately borated.

TABLE IV.J-1 - ALTERNATE COOLING/MAKEUP METHODS FOR LOSS OF DHRS OPERATION

		PLANT STATES[1]				
SYSTEM	ALTERNATE COOLING/MAKEUP METHOD	A	B	C	D	E
SG 1	Steam to condenser	C[2]	C[3]			
2	Steam to atmosphere	C	C[3]			
3	Fill and drain	C	C[3]			
4	Boiler-condenser cooling		C			
BWST 1	Gravity feed			M	M	
HPI 1	HPI-overflow to sump, replenish BWST w/RBS pump			O	O	
2	HPI-overflow to sump, recirc. from sump using LPI/HPI pumps			O	O	
3	HPI-only as needed for boil-off		M	M	M	
4	HPI-suction thru dropline, discharge thru MU/HPI lines	C				
5	Conventional HPI cooling, replenish BWST from sump w/RBS pump	O	O	O	O	
SFC 1	Inject from BWST or spent fuel pool	M	M	M	M	
2	Forced cooling thru DH system using SF pump	C	C	C	C	C
3	Inject from BWST using SF pump, RBS pump to BWST	O	O	O	O	
4	Pump to canal from BWST w/DHP, recirc. to BWST w/SF pump					O
5	Flood refueling canal				O	
6	Maximize spent fuel pool cooling					O
LPI 1	LPI-flood sump thru RC opening and recirc. from sump			O	O	
2	Feed and bleed using LPI pump, replenish BWST from sump	O	O	O	O	
3	Flood sump (various sources) and recirc. from sump	O	O	O	O	
CFT 1	Makeup by opening CFT injection valves	M	M	M	M	
Other 1	Inject from BAAS, BWST recirc. pump, canal transfer pump			M	M	
2	Inject from CWRT, CWMT, PWST			M	M	
3	Inject from BWST using RBS pump, use PORV as necessary	O	O	O	O	
4	Makeup from BHUT, RCBT, etc.			M	M	

[1] Plant States:
A = RCS intact and full, SG(s) available
B = RCS intact but not full
C = RCS vented, RV head installed
D = RCS drained, RV head off, fuel transfer canal not flooded
E = RV head off, fuel transfer canal flooded

[2] Cooling Method:
C = Closed cycle
O = Open cycle
M = Makeup

[3] These methods are available provided the RCS can be refilled, in which case, Plant State A is actually established.

FIGURE IV.J-1 Time to Boil after Loss of DHRS, 0-120 Days

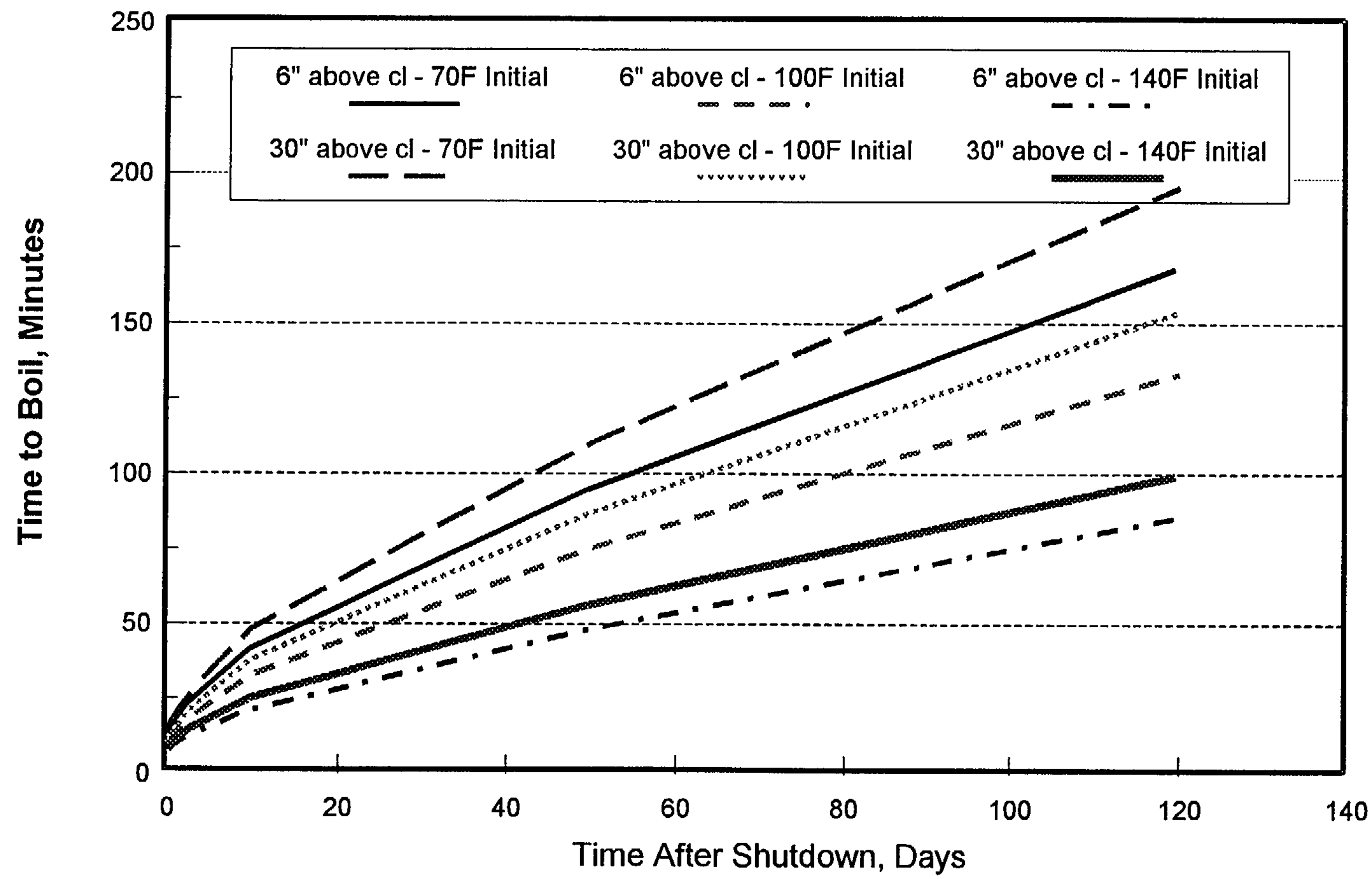


FIGURE IV.J-1A Time to Boil after Loss of DHRS, 0-10 Days

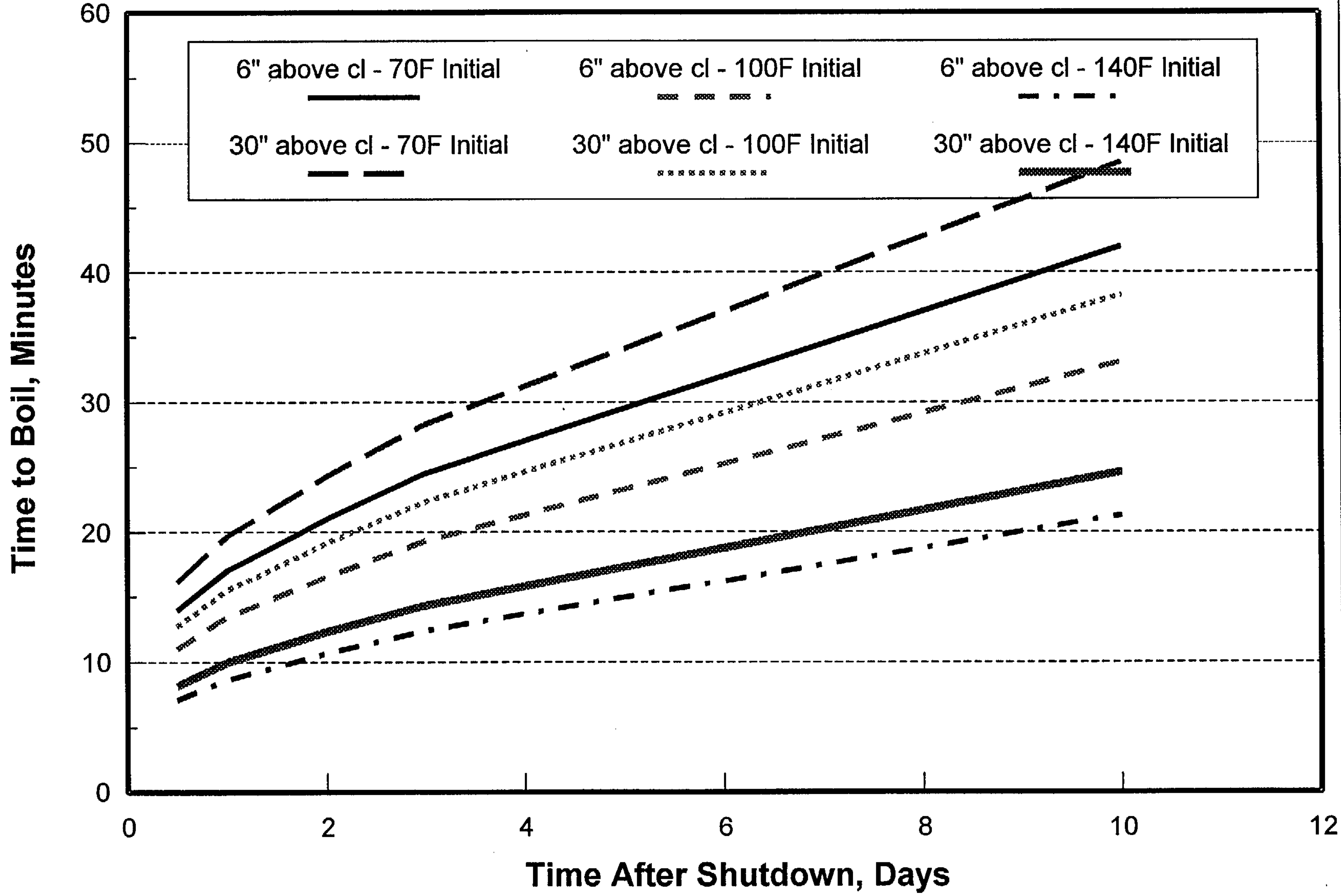


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FIGURE IV.J-2 Time to Uncover after Loss of DHRS, 0-120 Days

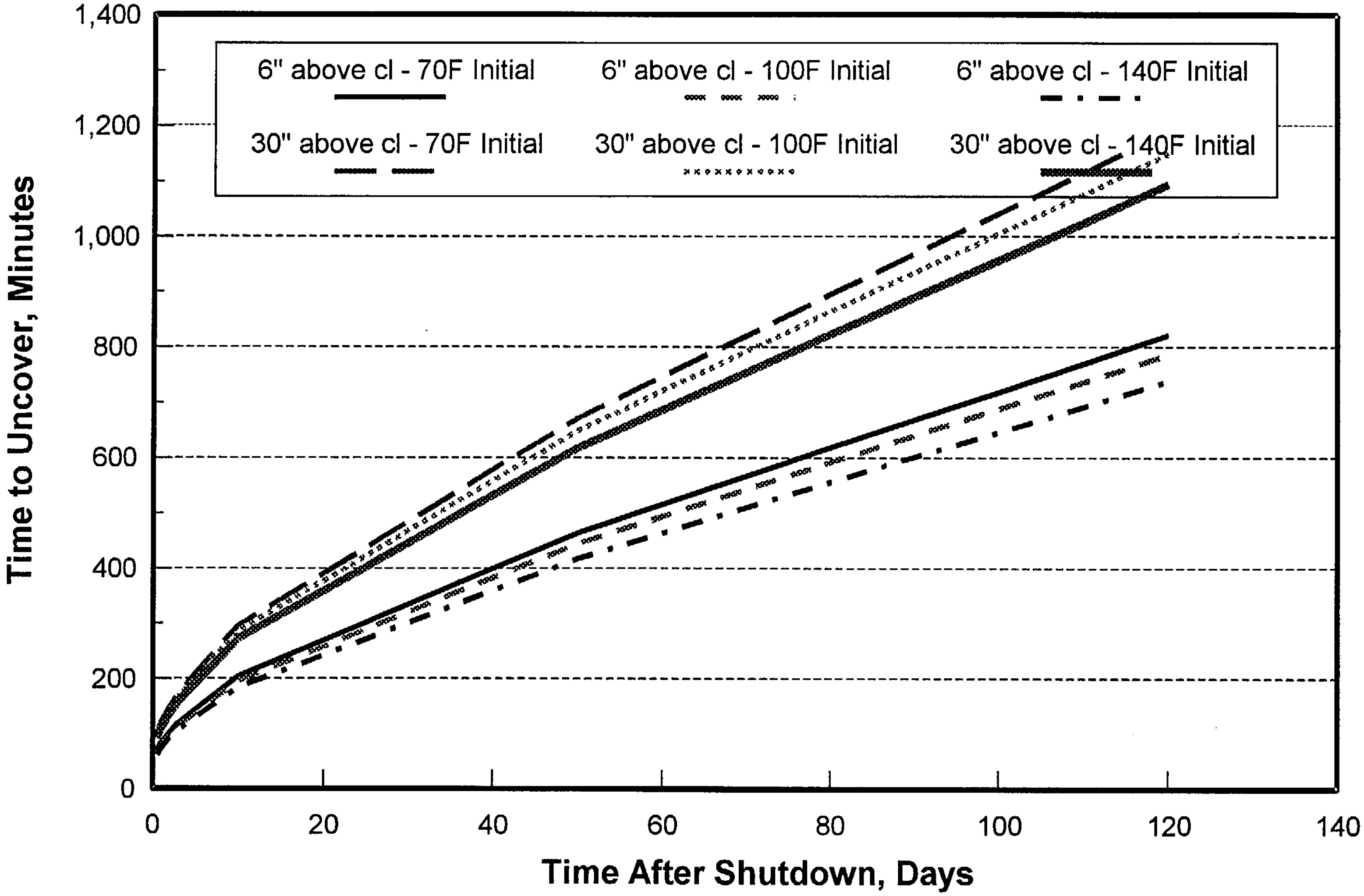

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FIGURE IV.J-2A Time to Uncover after Loss of DHRS, 0-10 Days

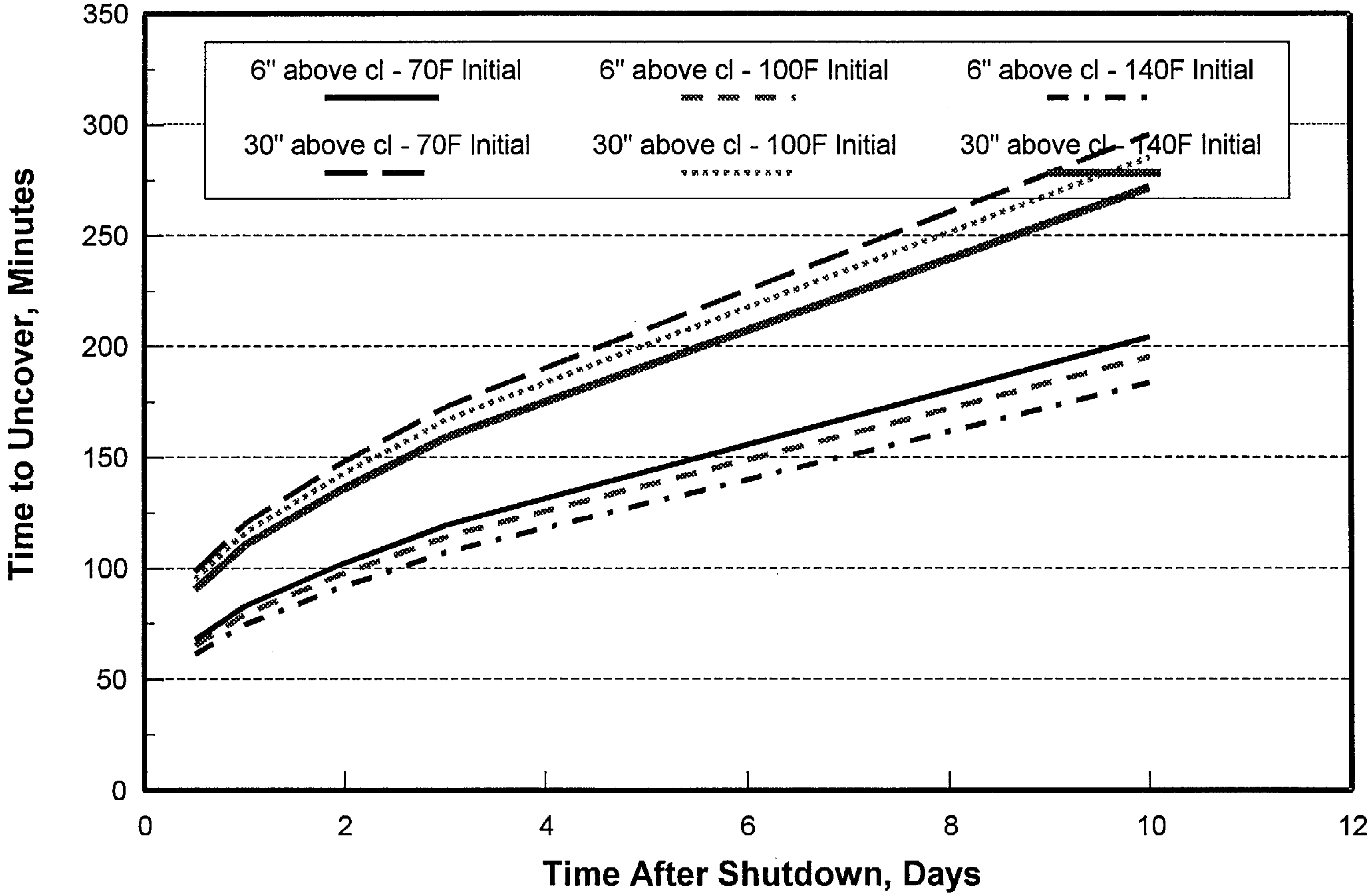

FIGURE IV.J-3 Flow Rates to Maintain Subcooling, 0-120 Days

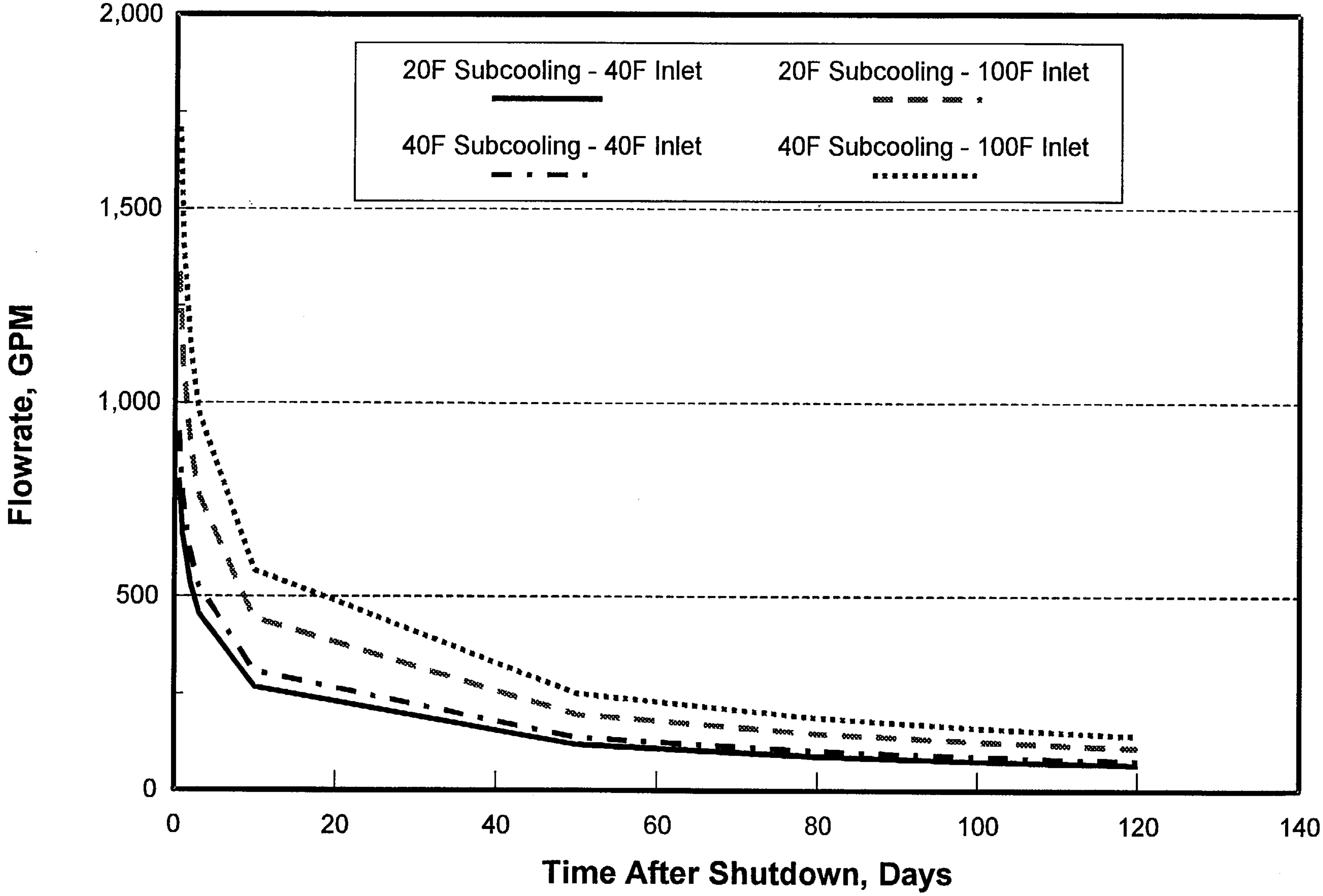

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FIGURE IV.J-3A Flow Rates to Maintain Subcooling, 0-10 Days

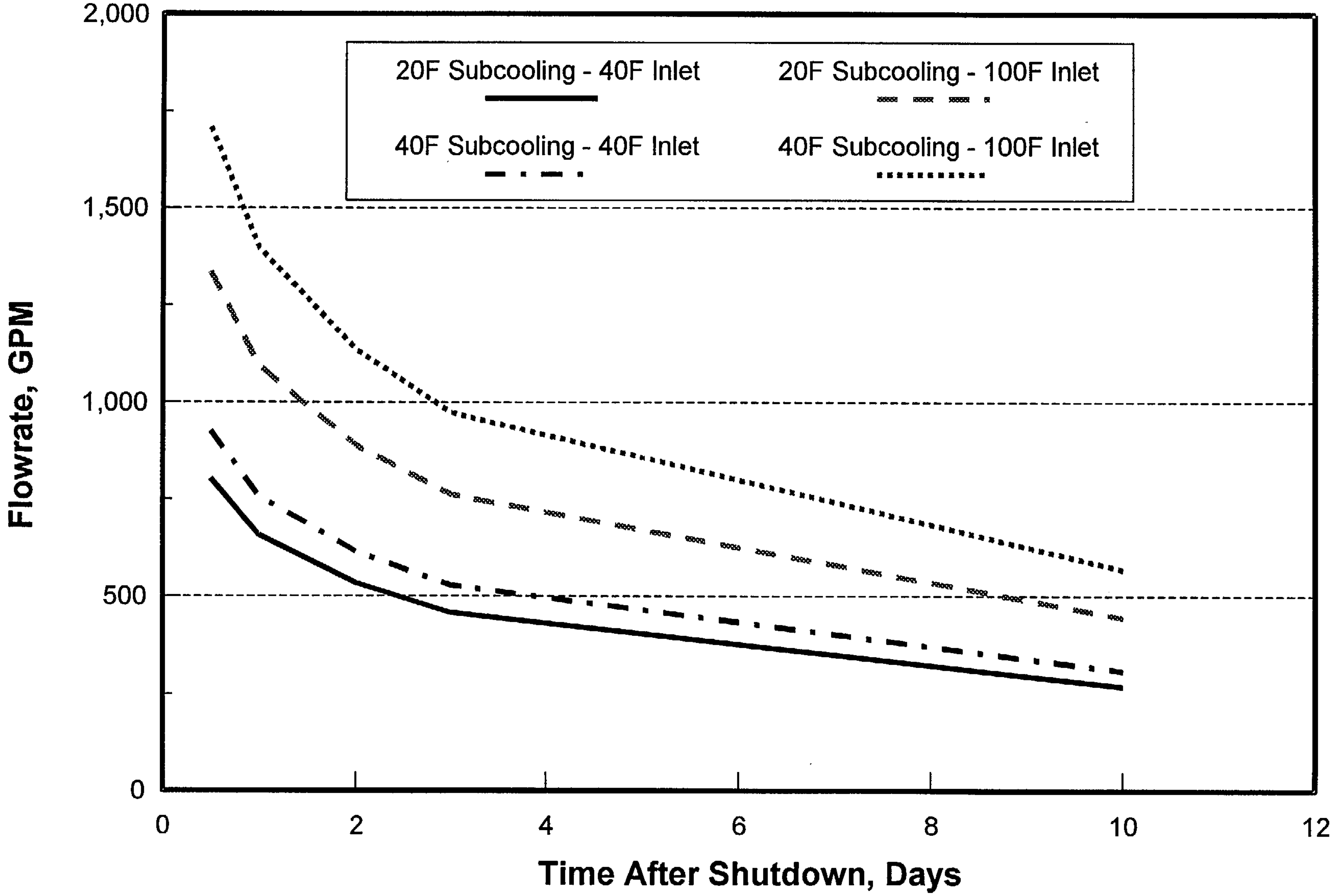

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FIGURE IV.J-4 Minimum Flow Rates for Boiling Makeup, 0-120 Days

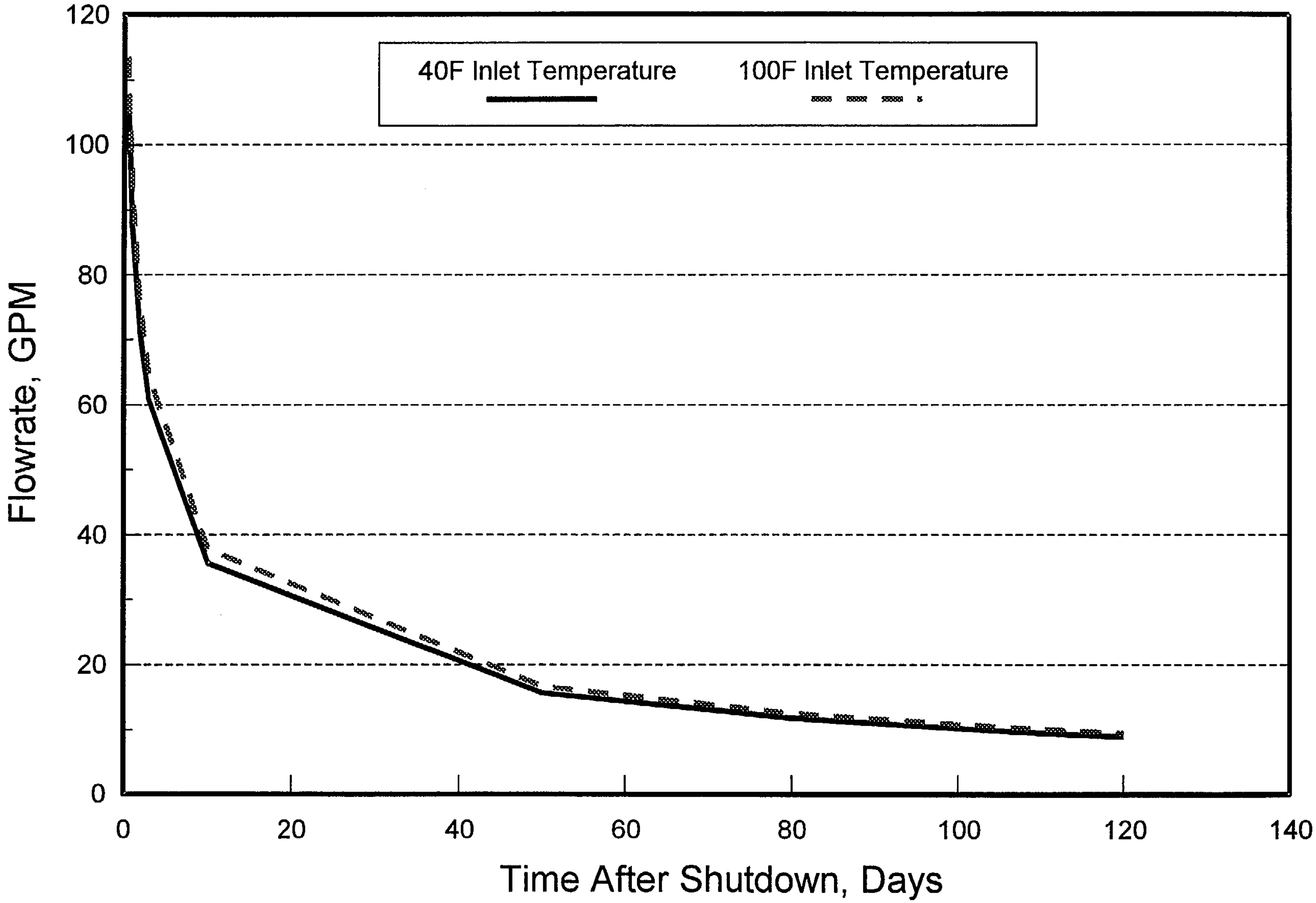


FIGURE IV.J-4A Minimum Flow Rates for Boiling Makeup, 0-10 Days

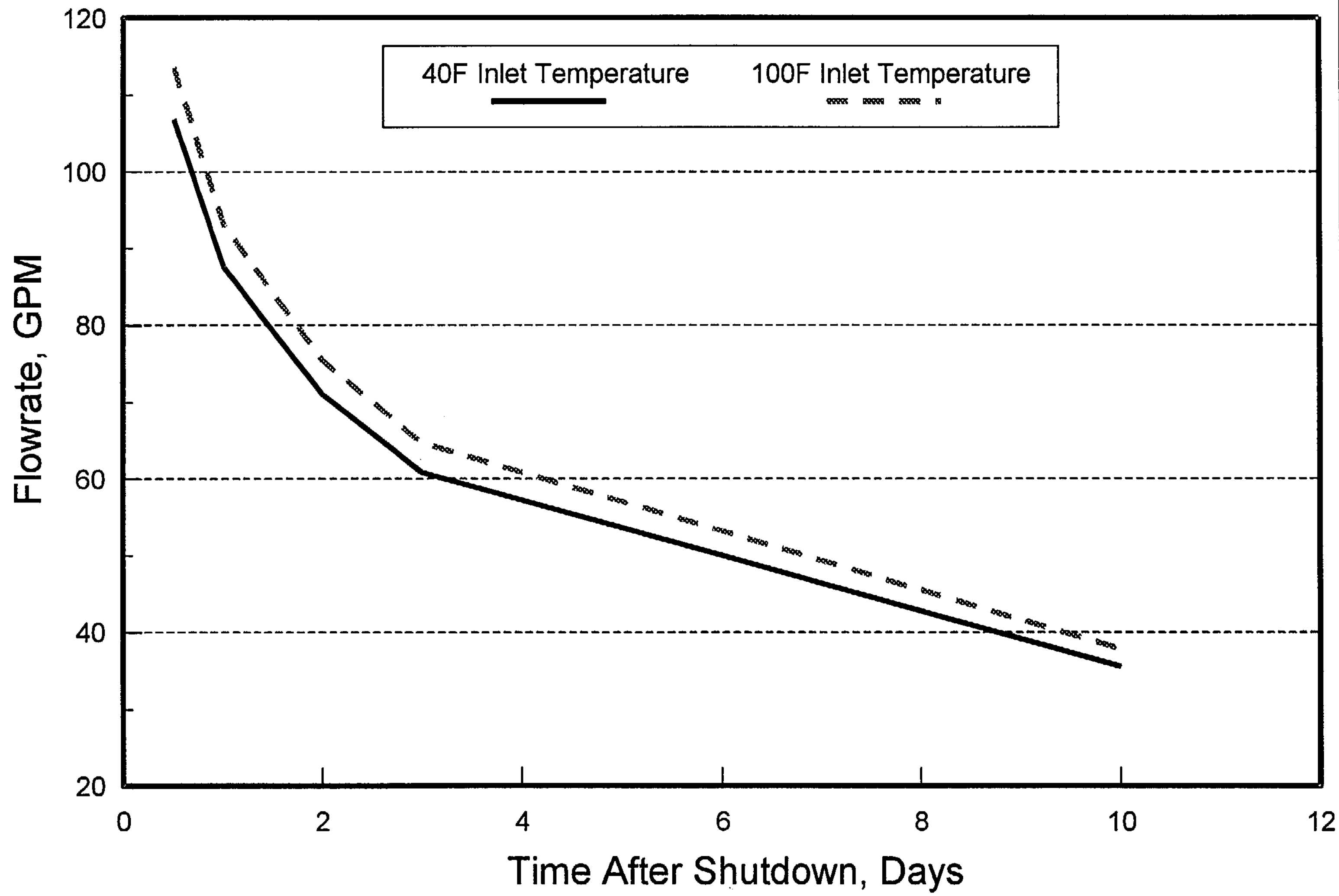


FIGURE IV.J-5 (RCS-RB) Pressure Differential after Loss of DHRS, 0-120 Days

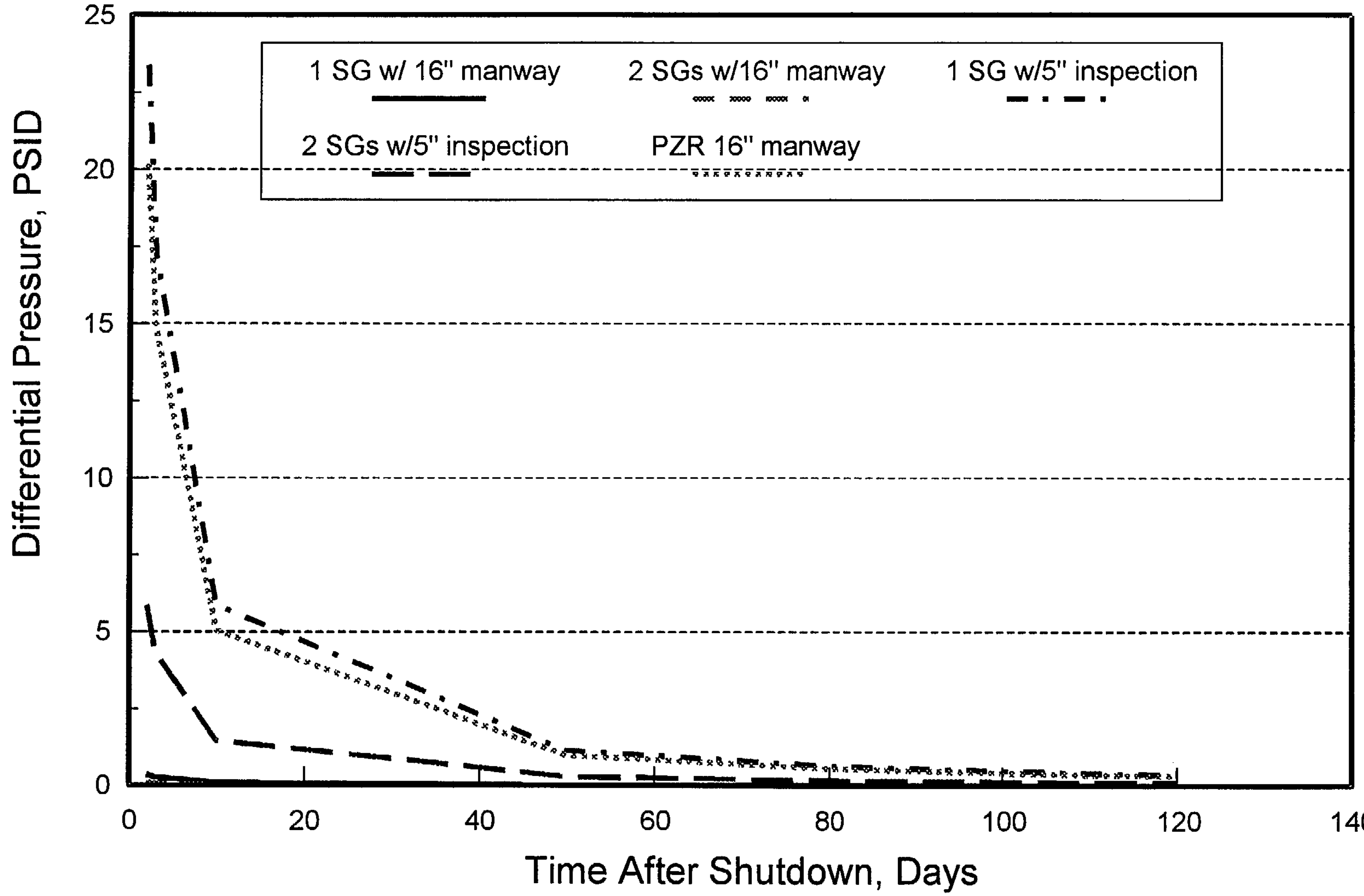


FIGURE IV.J-5A (RCS-RB) Pressure Differential after Loss of DHRS, 0-10 Days

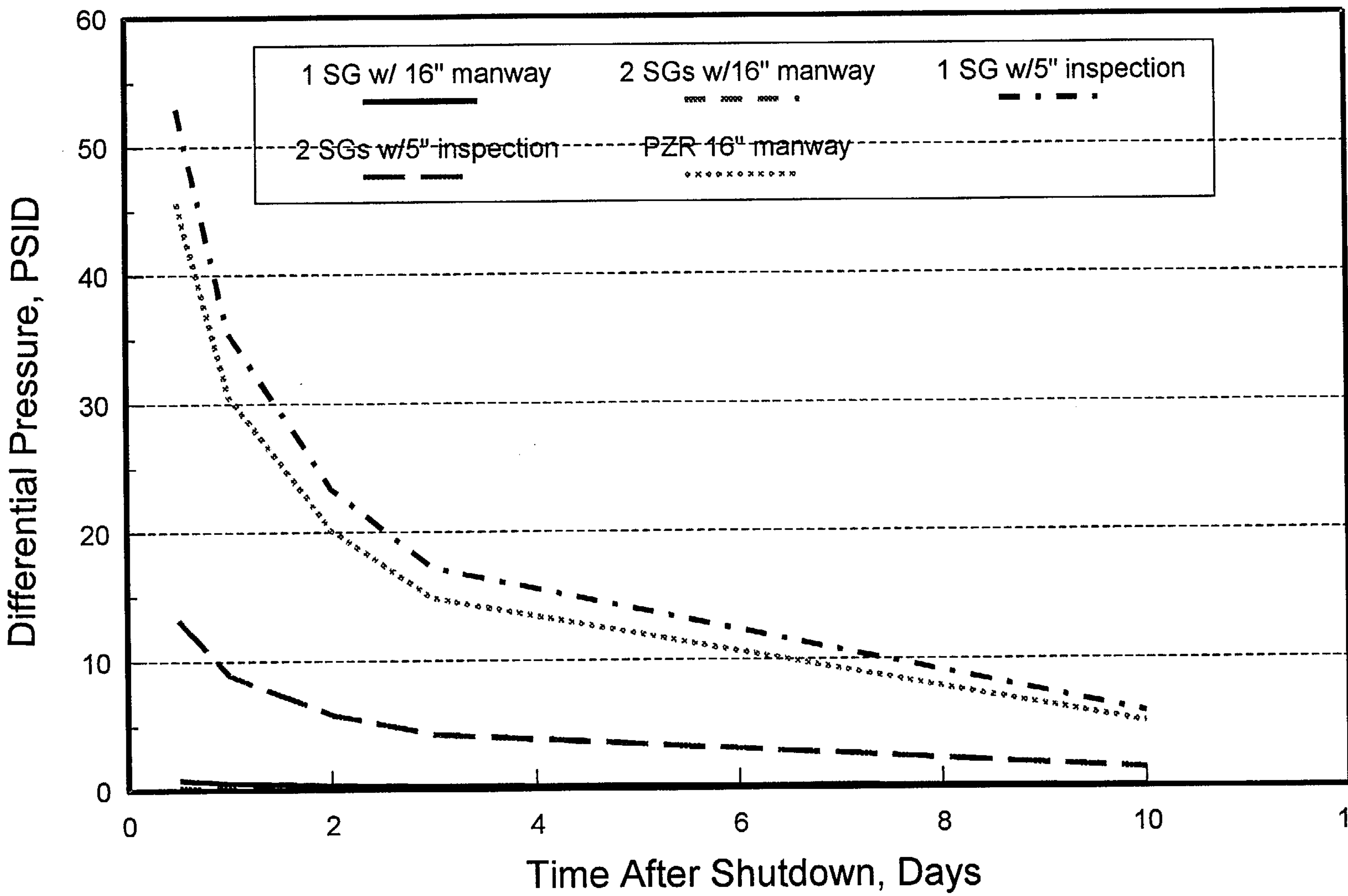


FIGURE IV.J-6 Reactor Building Pressure Response With and Without RB Cooling Units (RCBU)

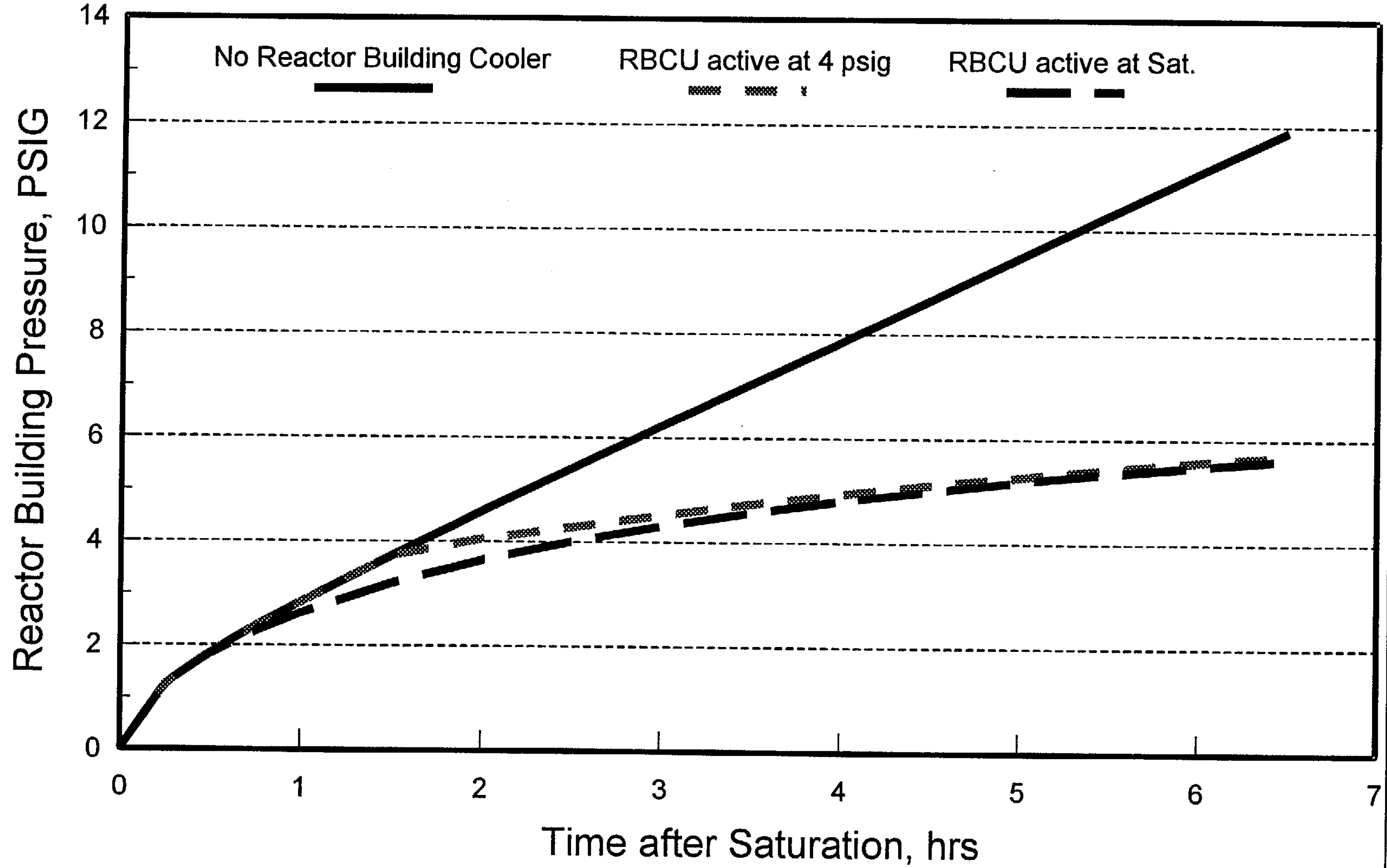


FIGURE IV.J-7 Reactor Building Pressure Response With and Without Venting

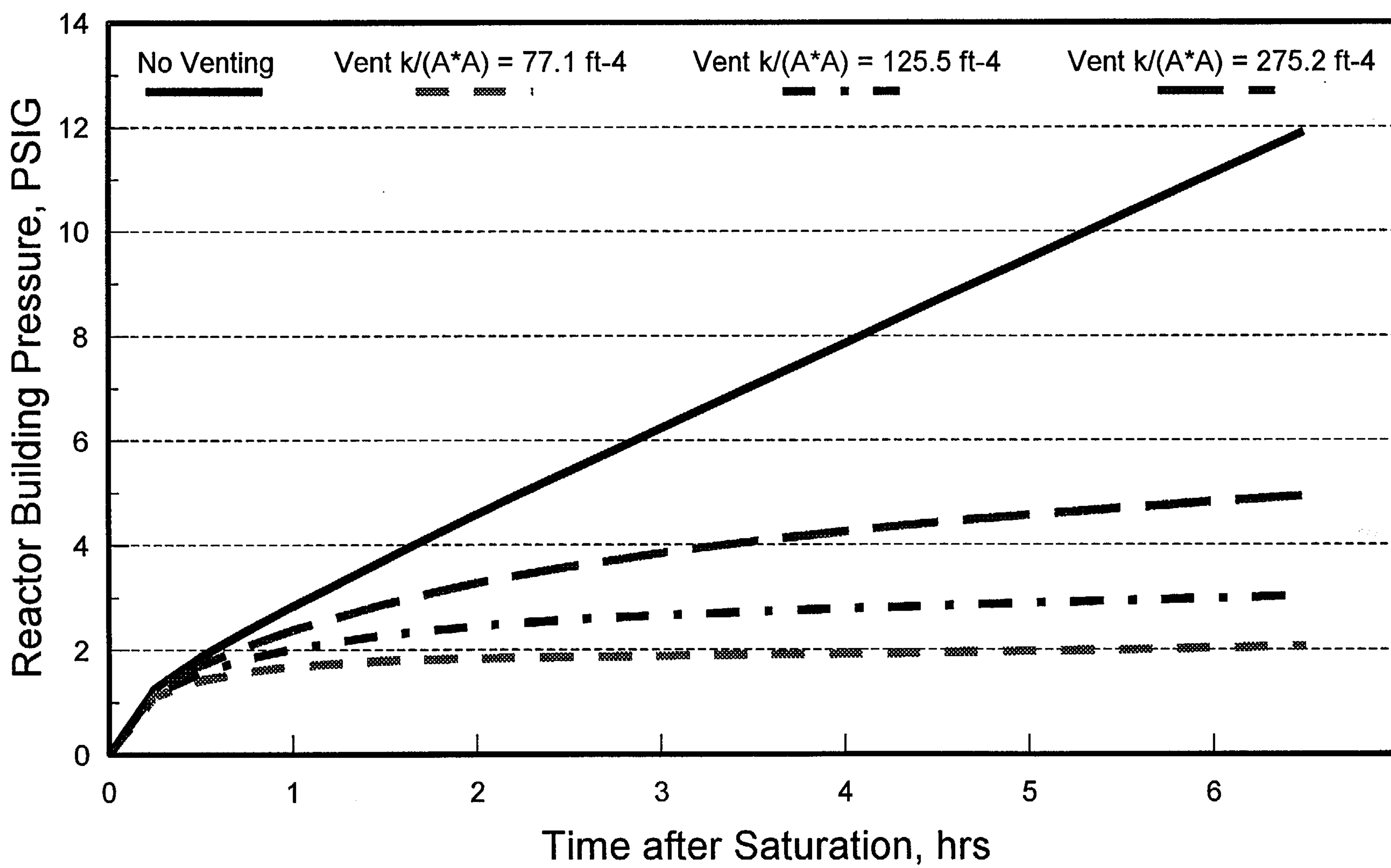
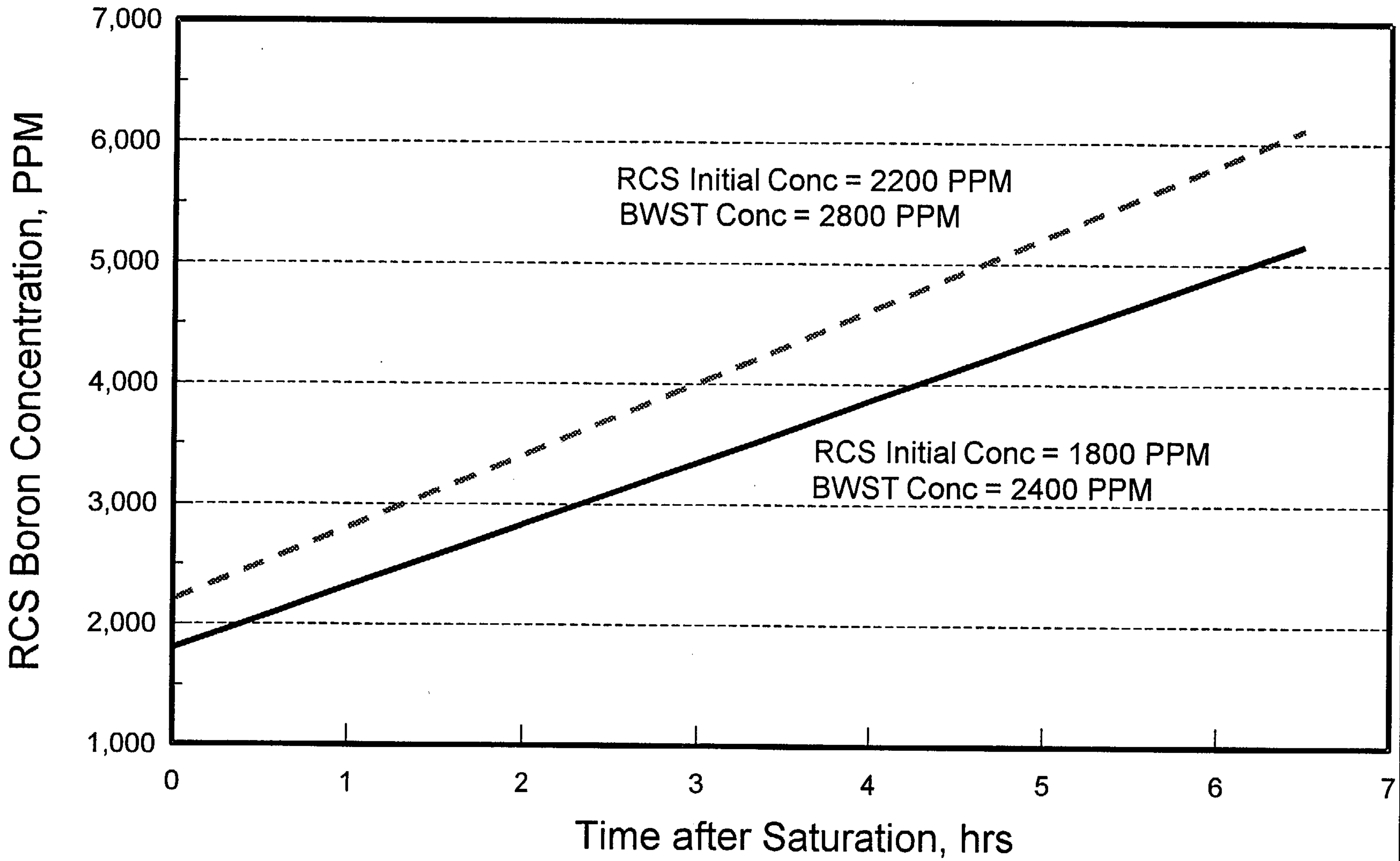


FIGURE IV.J-8 RCS Boron Concentration During Boiloff



Chapter IV.K

Equipment Operation Considerations

1.0 INTRODUCTION

This chapter provides considerations regarding the use of equipment that, while prudent, are secondary to transient mitigation concerns. Therefore, this information is provided here to allow accommodation when possible, but is not included in Volume 1 to preclude interference with transient mitigation and plant stabilization. The considerations covered in this chapter can be implemented during the performance of evolutions within the scope of Volume 1, e.g., during single loop cooldowns, at the user's discretion.

The considerations provided in this chapter are essentially operating guidance to minimize cyclic stresses and cumulative usage factors on equipment. Exceeding this guidance during transient mitigation is possible and accounted for by the post-transient evaluations that are performed to determine long-term usage factor impact. Some of the information, such as feedwater control to dry SGs, is fairly complex to allow as much operating margin as possible. This complexity does not facilitate observance during real-time transient mitigation. In addition, use of guidance in this chapter may be highly dependent on the specific post-transient scenario involved, making it very difficult to prescribe certain actions and sequences in advance. Therefore, to reduce the operator burden during transient mitigation, relatively simple guidance is provided in Volume 1 for observing SG tube-shell ΔT limits, RCP operation, and control of feedwater flow.

The Volume 1 guidance is adequate to achieve transient mitigation with minimal equipment impact. For example, the guidance in Volume 1 for restoring feedwater to a dry SG during mitigation of a loss of heat transfer uses three flowrate limits, depending on RCP status and feed nozzles used. These limits are consistent with the guidance in this chapter if the SG tubes are under an overall compressive load, which is usually the case with a loss of heat transfer. The additional guidance in this chapter provides more detailed, situation-specific information that can be used during relatively stable evolutions where time is available to assess the appropriate curves and tables to optimize control of the RCPs, SGs, and feedwater. This additional guidance is provided for Utility use whenever it is deemed appropriate, but its use should not delay restoration of adequate core cooling. When adequate core cooling does not exist, the Volume 1 guidance should be used. Placing this additional guidance only in Volume 3 makes it available for use (e.g., by Technical Support Center personnel) where the specific plant conditions can be assessed.

The topics covered in this chapter include:

- Determining SG tube-shell ΔT
- RCP operation and alternative actions considering SG tube-shell limits
- RCP restart considering RV head ΔT
- Control of FW sources when recovering a dry SG

2.0 DETERMINING SG TUBE-SHELL ΔT

The SG tube-shell ΔT is an important parameter as it is indicative of the stresses imposed on the tubes due to different expansion or contraction rates between the SG shell and the SG tubes. When the shell is cooler than the tubes (positive ΔT), the tubes are placed under a compressive stress that, if severe enough, can cause the tubes to bow and wear against the support plates. When the shell is hotter than the tubes (negative ΔT), the tubes are placed under a tensile stress that, if severe enough, can propagate existing tube flaws. The normal limits imposed on SG tube-shell ΔT are well below the stress limits where tube damage could occur.

2.1 Limits

Normal limits for SG tube-shell ΔT are:

Tensile (tubes colder):	-100°F
Compressive (tubes hotter):	50°F when RC pressure is < 1800 PSIG <u>and</u> tube temperature is ≥ 500°F 60°F all other conditions

2.2 Determining ΔT

Methods of determining the tube-shell ΔT depend on the RCS and SG status, and in some cases only an approximation can be made. SG shell temperatures are assumed available and are used in all of the methods. The five SG shell thermocouples are roughly uniformly distributed along the length of the shell, thus a straight average of the five thermocouples is reasonable. If, however, any of the thermocouples are not available, then a length-weighted average would be more appropriate. The difference in methods primarily occurs in determining the tube temperature. Suggested methods for the various plant conditions are provided here; all methods assume that the noted indications are available and reliable. Note that use of the incore temperatures is not specified. This is because RTDs are typically more accurate, and incores may not be indicative of actual loop temperature in a stagnant loop. Error corrections are not required in these calculations. Actual measured values are used in any post-transient evaluations, thus actual measured values should be used in determining ΔT.

2.2.a Forced RC Flow

During forced RC flow with SG level, the tube temperature used can be the RC average temperature, or either hot or cold leg temperature. The true tube temperature is actually a weighted average of the tube length above and below the SG level, with most of the tube length normally above the SG level and thus at RCS hot leg temperatures. However, even with high decay heat, the RCS ΔT is only a few degrees, therefore any valid RCS loop temperature could be used. If the forced flow in one loop is reversed, as in a 2-0 or 1-0 RCP combination, then the RCS ΔT in that loop may be a little greater.

A weighted average may be more appropriate if the ΔT limits are approached. Weighted averages are obtained by:

$$T_{tube} = [T_{hot}(53.5-L) + T_{cold}(L + 2.5)]/56$$

where :

L = SG level in feet (indicated)

53.5 = tube length above lower level tap (including upper tubesheet)

2.5 = tube length below lower level tap (including lower tubesheet)

If the EFW nozzles are being used, the true average tube temperature will be impacted during periods of FW flow. Flow through the upper nozzles will elevate the thermal center in the SG, such that most of the heat transfer will occur above the indicated level. However, the elevation at which a given tube transitions to T_{cold} is dependent on its location in the bundle, the decay heat level, and the FW flow rate. The T_{cold} elevation for a single tube or estimation of an effective average elevation for all of the tubes can not be readily determined from available indications; therefore, use of the weighted average based on level should still be used.

If the SG is dry, then the RCS loop temperatures (T_{hot} and T_{cold}) should be equal and any can be used.

2.2.b Natural Circulation

Natural circulation will result in higher loop ΔTs depending on decay heat level. For simplicity, RC average temperature can be used for tube temperature as long as the tube-shell ΔT limits are not approached. If the tube-shell ΔT limits are approached, then the more accurate weighted tube temperature (2.2.a above) should be used. The true average tube temperature will also be affected with FW flow through the upper nozzles, as described in 2.2.a, but will have less of an effect with the higher NC SG levels. If the SG is dry, then natural circulation may not exist, in which case the method described in section 2.2.c applies.

2.2.c Stagnant RC Loop

If no flow exists in the RC loop, then the loop temperature indications may not be directly representative of the tube average temperature. Tube-shell ΔT problems can occur during this condition as the SG shell cools due to ambient losses, while tube temperatures remain fairly constant. In this situation, determining an accurate estimate of the SG tube-shell ΔT becomes more difficult. It is suggested that, as an initial and conservative check of the ΔT, RC hot and cold leg temperatures be used to compare to the compressive and tensile limits, respectively. If a ΔT limit is approached, then the average tube temperature should be calculated as described in this section.

With a completely stagnant RC loop, the fluid densities in the hot and cold legs must be balanced with those of the fluid inside the SG tubes. An imbalance in densities would cause some loop flow. This balance allows use of the hot and cold leg temperatures in estimating the average tube temperature. There are some assumptions used in this approach to simplify the method while still ensuring a more accurate estimate of the average tube temperature:

- The hot leg temperature in the riser section (RV outlet nozzle to the top of the U-bend) is assumed to be isothermal, and thus represented by the hot leg RTD indication.

- The cold leg temperature is assumed to be isothermal for the region below the RCP spillover elevation to the top of the SG level, for both the cold leg and the SG tubes.

- The cold leg temperature below the SG level is assumed to be the SG saturation temperature.

Based on these assumptions, the average tube temperature for the **lowered-loop plants** can be estimated as:

$T_{tube} = \{T_{hot} (54\text{-}E_{so}) + [T_{cold} (E_{so}\text{-}(L + 0.5))] + T_{sgsat} (L + 2.5)\}/56$

Where:

E_{so} = RCP spillover elevation, in feet above the SG lower tubesheet, upper face (ONS-1, TMI-1: 23.58'; ONS-2,3: 25.75'; CR-3, ANO-1: 24.35')

L = SG level, indicated, in feet

T_{sgsat} = SG saturation temperature for existing SG pressure

56 = total SG tube length, including both tube sheets

2.5 = height of lower SG level tap above lower tube sheet lower face

0.5 = height of lower level tap above lower tube sheet upper face

SG downcomer temperature may be used for T_{sgsat} if the two values are approximately equal. If the downcomer temperature is much colder than the calculated T_{sgsat}, then T_{sgsat} should be used.

The above can be simplified by using a generic approximate value for E_{so} of 25 feet for lowered-loop plants. This changes the estimation to:

$T_{tube} = [T_{hot} (29) + T_{cold} (24.5\text{-}L) + T_{sgsat} (L + 2.5)]/56$

If the SG is dry, then set L = -2.5. This results in the estimation for a dry SG as:

$T_{tube} = [T_{hot} (29) + T_{cold} (27)]/56$

At SG levels at or near the RCP spillover elevation, the T_{cold} term will be near zero. These SG levels are also higher than the cold leg RTDs. With this term near zero, the T_{cold} indication should be compared to T_{sgsat}. Except for possible influences by seal injection, makeup, or HPI flow, they should be approximately equal. If this is the case, then T_{cold} can be used in place of T_{sgsat}; if, however, T_{cold} indicates a much lower temperature, then T_{sgsat} should be used.

If SG level is above the RCP spillover elevation, then the T_{cold} term should be eliminated, i.e., do not use this term if the value is negative. In addition, the T_{hot} term must now be adjusted for level. Thus, at SG levels at or above the RCP spillover elevation, the estimation becomes:

$$T_{tube} = \{T_{hot}\,[54 - (L+0.5)] + T_{sgsat}\,(L + 2.5)\}/56$$

The estimation of tube temperature for the **Davis-Besse** SGs should also use this equation, since any level in the Davis-Besse SGs will be above the RCP spillover elevation.

A summary of the weighted tube temperature calculations is provided in Table IV.K-1.

3.0 RCP OPERATION AND ALTERNATIVE ACTIONS CONSIDERING SG TUBE-SHELL LIMITS

The purpose of this section is to provide guidance for continued RCP operation relative to SG tube-shell ΔT limits. There are plant evolutions, primarily abnormal cooldown modes, where the potential exists for conflict between continued RCP operation and excessive SG tube-shell ΔT limits. RCP operation is desired for virtually all aspects of plant operation covered by the TBD. In addition, actions required to assure transient mitigation and adequate core cooling should not be superceded or unnecessarily complicated by normal operating limits. However, exceeding the SG tube-shell ΔT limits should be constrained to those times during transient mitigation where it may be unavoidable due to higher priority concerns. Once plant conditions are stable, appropriate actions should be taken whenever possible to prevent exceeding the SG tube-shell ΔT limits. This section provides guidance for possible actions in addition to RCP trip to aid observance of the SG tube-shell ΔT limits. Some evolutions, for example HPI cooling with no feedwater source available, may be such that there are no actions available other than tripping the RCPs.

Excessive tube-shell ΔTs should not develop in SGs with controlled heat transfer and normal level for the plant condition (e.g., NC). If one SG is available, RCPs are operating and the RCS cooldown rate can be controlled (including stopped if necessary), then it should be possible to control the idle SG tube-shell ΔT within limits even if the idle SG is dry. This may require cooling the RCS with the active SG to keep up with the idle SG shell cooldown due to ambient losses.

Therefore, potential SG tube-shell ΔT problems with RCPs running should be limited to cases where the cooldown is forced and one or both SGs are idle at low level or dry conditions. Seven plant states were considered where a cooldown is being forced (with one or both SGs idle). Possible actions to reduce tensile and compressive stresses were considered for each of the seven plant states. The suggested actions and relative priorities are depicted in Table IV.K-2 and discussed in the following sections.

In general, the guidance suggests that RCPs should not be tripped for compressive stresses as long as one SG is available for heat transfer. Cooling with the available SG coupled with forced flow should allow restoring the idle SG ΔT to within compressive limits. The guidance also suggests that all other possible actions be attempted before tripping the RCPs for tensile stress. Table IV.K-2 lists six possible actions for tensile stress and five for compressive stress, including RCP trip. The basis for each possible action and suggested priorities for the various plant states are discussed in the following sections.

3.1 Possible Actions to Address Tensile Stresses

Tensile stresses are imposed on the SG tubes primarily due to two factors, tube-shell ΔT and primary-secondary ΔP. Tube temperatures colder than the average SG shell temperature and RCS pressure greater than the SG pressure induce tensile stresses. The ΔT has a proportionally greater effect than the ΔP, i.e., a one-degree change in ΔT results in a larger change in tube stress than the change in tube stress from a one-PSI change in ΔP. However, actions to reduce the tensile tube loading are directed at reducing the tube-shell ΔT and primary-secondary ΔP. The actions to decrease the ΔT include reducing the RCS, and thus SG tube, cooldown rate, restoring at least periodic operation of an idle SG, and slowing thermal communication between the core outlet and the tubes in an idle SG by tripping the RCPs. Under limited conditions the allowable ΔT can be increased. The ΔP can be decreased by reducing RC pressure and by restoring operation of an idle SG. Details of these actions are provided in the following sections.

3.1.1 Reduce RC Pressure

The differential pressure between the RCS and the SG induces tensile stress in the SG tubes. Therefore, minimizing RC pressure as far as practical without violating SCM or RCP NPSH requirements will minimize the ΔP contribution to the overall tensile tube stress. Minimum RC pressure is desirable for other reasons as well, such as to minimize any tube leakage. Therefore, this potential action is listed as first priority in Table IV.K-2 for all of the tensile stress plant states considered.

3.1.2 Reduce Cooldown Rate

If the cooldown is being performed with one SG idle and forced RC flow exists, then reducing the RCS cooldown rate to near the idle SG shell cooldown rate can prevent exceeding the tensile stress limit. This action may not be possible for all plant states, and may not be the most desirable action for some plant states. The idle SG shell cooldown rate may be relatively small, and reducing the RCS cooldown rate that far may be impractical for plant states such as a tube rupture.

3.1.3 Allow Increased Tensile Tube-Shell ΔT

The idle SG tensile tube-shell ΔT limit may be increased to 120-130°F depending on RCS conditions. Figure IV.K-8 shows the allowable RCS pressure-temperature regions for increased tensile tube-shell ΔT limits. The temperature used for this figure should be one that closely corresponds to the SG tube temperature. Methods to determine the tube temperature are provided in section 2.2. The 100°F tensile tube-shell ΔT limit is normally used because it bounds the operating spectrum. The allowable tensile tube-shell ΔT based on tube limits can be greater under a more limited range of conditions.

The intent of this curve is to allow, under restricted conditions, slightly higher tube-shell tensile ΔTs. This may delay or prevent the need for other actions to reduce the tensile ΔT. This option may be relatively low in priority if a tube leak already exists, unless the SG is already isolated, due to the potential for increasing the tube leak rate. This option may also be of limited benefit; for example, use of this action in preference to reducing the cooldown rate (section 3.1.2 above) may only delay the need for a reduced cooldown rate for a short time.

3.1.4 Restore Operation of the Idle SG

This action assumes that the SG was idled intentionally, for example due to a tube leak, and that restoration of feeding and steaming is possible. In these cases, restoring the SG to service may be preferable to other actions because it will allow control of the SG tube-shell ΔT. This action may not be available if the SG was isolated due to a tube rupture or if HPI cooling is in progress due to a total loss of feedwater. This action may also not be available if the SG was isolated and allowed to dry out due to an unisolable steam leak. However, at lower temperatures later in the cooldown, the unisolable steam leak may be sufficiently controllable to restore the SG to service, assuming the leak location is acceptable for steaming.

3.1.5 Periodic Feeding and Steaming

This action involves periodic feeding and steaming of the idle SG per the guidance in Chapter III.G. Periodic feeding and steaming may reduce the ΔT by restoring thermal communication between the SG tubes and the SG shell. This action is not available if the SG was isolated due to a tube rupture or if HPI cooling is in progress due to a total loss of feedwater. This action may be available during HPI cooling if the SG(s) were isolated due to unisolable steam leaks, assuming the leak location is acceptable for steaming.

3.1.6 Trip RCPs

This action will at least slow the tube cooldown in the idle SG. Idle loop circulation could continue and thus tripping the RCPs may not prevent exceeding the tensile limit. This action will also slow the RCS cooldown and depressurization and thus delay transition to DHRS operation in all plant states except one (assuming the condenser is available). HPI cooling will actually reach DHRS operation sooner without an RCP running. HPI cooling is PORV-limited at lower RC pressures and temperatures and the added pump heat can significantly lengthen the time required to attain DHRS conditions. RCP operation is normally desired during HPI cooling to minimize RV stresses, but the added time required to reach DHRS conditions may not be acceptable due to low flow restrictions on the LPI pumps. This action is listed last in priority for all seven plant states in Table IV.K-2, but may have a higher priority during HPI cooling for some plants. If the condenser is not available, tripping the RCPs may decrease the cooldown time by removing a fairly large heat source relative to the ADV capacity.

3.2 Possible Actions to Reduce Compressive Stresses

Compressive stresses are imposed on the SG tubes primarily due to tube-shell ΔT. Tube temperatures hotter than the average SG shell temperature induce compressive stress. Thus actions to reduce the compressive tube loading are directed at reducing the tube-shell ΔT. The actions to decrease the ΔT include increasing the RCS, and thus SG tube, cooldown rate, restoring at least periodic operation of an idle SG, and slowing thermal communication to the tubes in an idle SG by tripping the RCPs. Details of these actions are provided in the following sections.

3.2.1 Increase Cooldown Rate

If the cooldown is being performed with one SG idle and forced RC flow exists, then increasing the RCS cooldown rate will prevent exceeding the SG compressive tube-shell stress limit. The idle SG shell cooldown rate should be less than the allowable RCS cooldown rate, therefore this action, if available, should be sufficient to control the SG compressive tube-shell ΔT within limits. This action is not applicable to the HPI cooling plant state since the cooldown rate during HPI cooling is primarily dictated by RC pressure control. Increasing the cooldown rate during HPI cooling would require additional subcooling or tripping the RCP. While tripping off RCPs may increase the cooldown rate, it is ineffective in controlling tube-shell ΔT in this case and is undesirable due to PTS considerations. Without forced flow, there is little flow through the SG tubes during HPI cooling and thus the tube temperatures will be essentially independent of HPI cooling flow. It is desirable to maintain minimum SCM during HPI cooling (and required if no RCPs are operating, i.e., PTS guidance). Tripping the RCP is addressed in section 3.2.5.

3.2.2 Periodic Feeding and Steaming

This action involves periodic feeding and steaming of the idle SG per the guidance in Chapter III.G. Periodic feeding and steaming may reduce the ΔT by restoring thermal communication between the SG tubes and the SG shell or just by cooling the SG tubes. This action is not available if the SG was isolated due to a SGTR or if HPI cooling is in progress due to a total loss of feedwater. This action may be available during HPI cooling if the SG(s) were isolated due to unisolable steam leaks, assuming the leak location is acceptable for steaming.

3.2.3 Open the PORV

This action only applies to the HPI cooling plant state if the PORV is being allowed to cycle. Opening the PORV will decrease RC pressure which will initially tend to increase the overall compressive loading on the SG tubes. However, maintaining the PORV open will increase the RCS cooldown rate which will increase the tube cooling while an RCP is running. The increased tube cooling (decrease of the compressive tube-shell ΔT) will have a greater effect in reducing the overall compressive loading on the tubes. Opening the PORV may result in a loss of SCM, and thus require tripping of the RCPs. However, tripping the RCPs will slow the thermal communication to the tubes (helps limit compressive loading if the RCS is still heating up) and tripping the RCPs is the only other action available for HPI cooling to limit compressive stresses.

3.2.4 Restore Operation of the Idle SG

This action assumes that the SG was idled intentionally, for example, due to a tube leak, and that restoration of feeding and steaming is possible. In these cases, restoring the SG to service, which will allow control of the SG tube-shell ΔT, may be preferable to other actions. This action is not available if the SG was isolated due to a SGTR or if HPI cooling is in progress due to a total loss of feedwater. This action may also not be available if the SG was isolated and allowed to dry out due to an unisolable steam leak. However, at lower temperatures later in the cooldown, the unisolable steam leak may be sufficiently controllable to restore the SG to service, assuming the leak location is acceptable for steaming.

This action's priority relative to periodic feeding and steaming (in 3.2.2) is reversed from their relative priority for reducing tensile stress. This reversal is based on the relative affects on SG shell cooling and tube cooling. When dealing with tensile stress, the intent of restoring SG heat transfer is to cool the SG shell. Periodic feeding and steaming is not as effective in cooling the shell due to the metal mass involved. Restoring and maintaining SG heat transfer is much more effective for shell cooling. When dealing with compressive stress, the intent of restoring SG heat transfer is to cool the tubes. Tube cooling by periodic feeding and steaming is very effective. Since it is apparent from the plant state that the intent is to isolate the SG(s), it is assumed that periodic feeding and steaming is preferred over restoring operation of the idle SG.

3.2.5 Trip RCPs

This action is only listed on Table IV.K-2 for the HPI cooling plant state. As long as heat transfer exists to one SG, then the idle SG compressive tube loading can be controlled while RCPs are running. Compressive tube-shell ΔTs can develop during two phases of HPI cooling. Initially, a compressive tube-shell ΔT can develop when HPI is insufficient to remove all of the decay heat and thus the RCS continues to heat up. In this case, tripping the RCP will slow the thermal communication to the SG tubes. Later in the HPI cooldown, the RCS cooldown rate becomes PORV-limited and may decrease to below the SG shell ambient loss rate. In this case, tripping the RCP will not help significantly in reducing the compressive tube-shell ΔT, but will allow a faster RCS cooldown rate. If HPI cooling is required until DHRS operation can be established, tripping the RCP will significantly reduce the time required to reach the RCS conditions required for initiation of DHRS operation. An RCP can be restarted after initiation of DHRS operation to help cool the loops and SG tubes.

3.3 Plant States Considered and Relative Action Priorities

This section describes the seven plant states considered where idle SG tube-shell ΔT problems could arise with RCPs running. This section also discusses the recommended priorities between the possible actions as presented in Table IV.K-2. The priorities are only recommendations based on the reasons given; the user should determine the actions and their priorities based on plant-specific capabilities and operating philosophy.

The seven plant states considered do not necessarily bound all possible states. They were chosen because they represented a broad spectrum of the type of plant conditions that could evolve within the scope of guideline coverage. The basic considerations for possible actions and recommended priorities should be applicable for other potential states.

3.3.1 SGTR in Active SG, Idle SG Dry

This plant state (A on Table IV.K-2) could occur when one SG is isolated and dry due to an unisolable steam leak while the active SG has a tube leak. The tube leak forces the cooldown and continued RCP operation is desired to reduce the time required to reach DHRS operation and to allow a minimum primary-to-secondary ΔP.

3.3.1.A Tensile Stress

The first action recommended for all of the tensile stress cases is to ensure that RC pressure is maintained as low as possible above SCM and NPSH limits. This reduces the tensile stress component due to ΔP and is desired anyway for a SGTR to minimize the leak rate.

The second recommended action is to attempt the periodic feeding and steaming actions discussed in Vol. 3, Chapter III.G, section 3.6 for controlling SG tube-shell ΔT. This assumes that the steam leak is in a location that allows periodic steaming without undue risk to personnel or equipment.

The third recommended action is to reduce the cooldown rate using the active SG to more closely match the cooldown rate of the idle SG shell. This action may not be possible or desirable if the idle SG shell cooldown rate is too slow, even with periodic feeding and steaming, to accommodate the tube leak in the active SG.

The fourth recommended action is to allow the idle SG tensile tube-shell ΔT to exceed 100°F if the RCS pressure-temperature relationship can be maintained below the appropriate curves for 120°F and 130°F ΔTs per Figure IV.K-8. The normal 100°F SG tensile tube-shell ΔT limit is used for simplicity since it is valid over the full operating range of pressures and temperatures. In actuality the tubes can be exposed to higher tensile ΔTs under more restricted pressure and temperature ranges as shown in Figure IV.K-8. While higher tensile limits are acceptable within the conditions of Figure IV.K-8, this action is listed fourth for this case since the idle

SG has an unisolable steam leak. The risk of inducing a tube leak in the idle SG should be minimized since the steam leak cannot be isolated, thus reducing the tube stress limit margin by the use of Figure IV.K-8 may be less desirable than the first three actions. In addition, if the cooldown is resulting in an approach to the normal 100°F SG tensile tube-shell limit, then use of the available 20-30°F margin may only provide a temporary solution. However, depending on the event, a little additional time may be all that's needed.

The last recommended action for all tensile stress cases covered by Table IV.K-2 is to trip the RCPs. This will require a longer cooldown time to reach DHRS operation if the condenser is available. In this case, it will require a longer steaming duration on the active SG with a tube rupture. The increase in hot leg temperature will also require additional subcooling, which increases the differential pressure and thus the tube leak flow rate. RC pressure control is more difficult without pressurizer spray, which may also result in slightly more subcooling. If the condenser is not available, the cooldown time may actually decrease since a single-loop cooldown to atmosphere is ultimately limited by the ADV capacity; removal of the RCP heat input will allow the ADV to remove more sensible heat.

One of the listed possible actions in Table IV.K-2 (recovery of the idle SG) is not prioritized for this plant state. Restoring continuous heat transfer to the idle SG is not listed since it is assumed that the steam leak was not controllable thus resulting in this configuration. However, at lower RC pressures and temperatures the steam leak may become controllable thus allowing the use of this action. This could be ascertained during the performance of periodic feeding and steaming (action 2 for this plant state), and assumes that the steam leak is in a location that does not pose undue risk to personnel or equipment. It is also possible that the leak can be subsequently isolated, such as gagging of a stuck-open MSSV, such that restoring heat transfer to the idle SG is possible.

3.3.1.B Compressive Stress

The first recommended action for all plant states where one SG is providing heat transfer is to increase the RCS cooldown rate. This will decrease the tube temperature in the idle SG, since RCPs are running, and thus reduce the compressive stress. It is very improbable that the RCS cooldown rate allowed and achievable would be unable to keep up with the idle SG shell cooldown rate. Thus, except for plant state F where no SGs are available, this action should be sufficient to limit the compressive stress in the idle SG.

The only other action applicable to this plant state is to periodically feed and steam the idle SG to induce additional RCS cooling and/or induce warming of the idle SG shell. This action may be beneficial if the steaming capacity of the active SG is limited.

In addition, as with the actions for tensile stress, the idle SG may become available for continuous heat transfer at lower RC temperatures if it was isolated due to a steam leak.

3.3.2 SGTR in Active SG, Idle SG at Low Levels

This plant state (B on Table IV.K-2) could occur when both SGs have tube leaks and one has been isolated. Low level in this state is relative to other conditions covered where the idle SG is dry or at a high level. Since the level is low enough in the idle SG to result in problems with tube-shell ΔT, the tube leak must be relatively small.

The preferred mitigation strategy when both SGs have tube leaks is to continue steaming both SGs during the cooldown as long as possible. Thus, it would not be expected that one SG could be isolated at a low level. However, this state is included in the event a Utility elects to isolate one SG under these conditions.

3.3.2.A Tensile Stress

As with all tensile cases, the first action is to ensure that minimum RC pressure is being maintained.

The second recommended action for this case is to restore heat transfer to the idle SG. If the isolation of the SG is not required by SGTR considerations, then restoring heat transfer provides the best control of the tube-shell ΔT.

The third recommended action is to attempt the periodic feeding and steaming actions discussed in Vol. 3, Chapter III.G, section 3.6 for controlling the tube-shell ΔT.

The fourth recommended action is to allow a higher tube-shell ΔT as in the previous case (3.3.1).

The fifth recommended action is to reduce the cooldown rate using the active SG to more closely match the cooldown rate of the idle SG shell. This action has a lower priority for this plant state than in the previous case because the idle SG is available for heat transfer and slowing the cooldown to the idle shell cooling rate may not be practical when both SGs have tube leaks.

The last recommended action for all tensile stress cases covered by Table IV.K-2 is to trip the RCPs.

Another possible action for both tensile and compressive stress would be to raise the level in the idle SG. This is not included on the table because restoration of heat transfer to the SG is preferred, and raising the level with FW would require frequent RCS sampling to guard against boron dilution due to back flow.

3.3.2.B Compressive Stress

The actions and priorities for this plant state are the same as plant state A with the addition of restoring heat transfer, since the SG was optionally isolated.

3.3.3 SGTR in Active SG, Idle SG Isolated due to SGTR

This plant state (C on Table IV.K-2) could occur when both SGs have tube leaks and one has been isolated. Since both SGs have tube leaks, it is assumed one would only be isolated due to high level. Since the isolated SG is not available, actions to restore heat transfer or perform periodic feeding and steaming are not applicable. If the SG has been isolated due to a high level, it is very unlikely that a tube-shell ΔT problem will occur. However, tube-shell ΔT problems are not impossible and this plant state is included for breadth of coverage.

3.3.3.A Tensile Stress

As with all tensile cases, the first action is to ensure that minimum RC pressure is being maintained.

The second recommended action is to allow a higher tube-shell ΔT as in the previous cases. The higher priority of this action for this case is due to the unavailability of the isolated SG for heat transfer, and fewer potential complications since the SG is already at a high level.

The third recommended action is to reduce the cooldown rate using the active SG, again a lower priority due to the desire to attain decay heat removal system operation as soon as practical when a tube leak exists.

The last recommended action for all tensile stress cases covered by Table IV.K-2 is to trip the RCPs.

3.3.3.B Compressive Stress

The only action available for this plant state is to increase the cooldown rate with the active SG, since the idle SG is not available. However, as stated previously, this action should be sufficient.

3.3.4 No SGTR in Active SG, Idle SG at Low Levels

This plant state (D on Table IV.K-2) could occur when only one SG has a tube leak and it has been isolated. Low level in this state is relative to the other conditions covered where the SG is dry or at a high level. Since the level is low enough in the idle SG to result in problems with tube-shell ΔT, the tube leak must be relatively small.

3.3.4.A Tensile Stress

As with all tensile cases, the first action is to ensure that minimum RC pressure is being maintained.

The second recommended action is to reduce the cooldown rate using the active SG to more closely match the cooldown rate of the idle SG shell. This action has a higher priority for this case since the active SG does not have a tube leak, and thus delaying the cooldown time to DHRS operation may be better accommodated.

The third and fourth recommended actions are to restore continuous heat transfer or periodic heat transfer to the idle SG. Their relative priorities are the same here as in plant state B (3.3.2) since the isolation of the SG may not be required by SGTR considerations, and restoring heat transfer provides the best control of the tube-shell ΔT.

The fifth recommended action is to allow a higher tensile tube-shell ΔT in the isolated SG, and the last recommended action is again tripping the RCPs.

3.3.4.B Compressive Stress

The possible actions and priorities for this plant state are the same as for plant state B.

3.3.5 No SGTR in Active SG, Idle SG at High Level Due to a SGTR

This plant state (E on Table IV.K-2) could occur when only one SG has a tube leak and has been isolated due to a SGTR. Since the isolated SG is not available, actions to restore heat transfer or perform periodic feeding and steaming are not applicable. If the SG has a high level due to a SGTR, it is very unlikely that a tube-shell ΔT problem will occur. However, tube-shell ΔT problems are not impossible and this plant state is included for breadth of coverage.

3.3.5.A Tensile Stress

As with all tensile cases, the first action is to ensure that minimum RC pressure is being maintained.

This plant state is similar to state C (3.3.3) except that the active SG does not have a tube leak. Therefore, the recommended actions are the same, with the relative priority of actions two and three being reversed for this case. Since the active SG does not have a tube leak, longer cooldown times may be more acceptable, therefore the second recommended action is to reduce the cooldown rate.

3.3.5.B Compressive Stress

Similar to plant state C, the only action available is increasing the RCS cooldown rate to reduce the compressive stress. This action should be sufficient.

3.3.6 HPI Cooling or SBLOCA, No SGs Available

This plant state (F on Table IV.K-2) could occur following an unrecoverable loss of both SGs due to a sustained total loss of feedwater, unisolable steam leaks, or multiple tube ruptures, or due to a SBLOCA where the SGs are also not available. These plant states are not very likely, especially for sustained periods, but these plant states are not impossible and are therefore covered by the guidelines. The available actions are limited for this plant state, and exceeding the normal tensile or compressive tube-shell ΔT limit may be unavoidable.

3.3.6.A Tensile Stress

The first action is again to reduce RC pressure as low as practical. This action is recommended as well for HPI plant states to reduce the thermal stresses imposed on the reactor vessel (required if no RCPs are running, i.e., PTS guidance).

The second recommended action is to allow a higher tensile tube-shell ΔT in accordance with Figure IV.K-8.

If the SGs are not available due to unisolable steam leaks, then it may be possible to periodically feed the SGs to induce some shell cooling. This is shown as the third action, and assumes the steam leak location(s) allows steaming.

The last recommended action is to trip the RCPs. However, tripping the RCPs may be desirable to significantly reduce the cooldown time required to reach DHRS conditions.

As in plant state A (3.3.1), it is possible that controlled, continuous heat transfer could be restored at lower RC temperatures.

3.3.6.B Compressive Stress

Since the RCS cooldown is due to HPI and PORV or break flow, increasing the cooldown rate is not a viable option for this plant state. The RCS cooldown rate will be dictated by the required RC pressure control. If the SGs were isolated due to steam leaks, it may be possible to periodically feed and steam one or both SGs. It may also be possible to restore continuous heat transfer at lower RC temperatures.

If HPI cooling is in progress with an RCP running and the PORV is being allowed to cycle, then opening the PORV and leaving it open may help reduce the compressive stress on the tubes. Opening the PORV will decrease RC pressure which will decrease the tensile tube loading due to the RCS-SG ΔP. This will initially tend to increase the overall compressive loading on the SG tubes. However, maintaining the PORV open will increase the RCS cooldown rate which will increase the tube cooling while an RCP is running. The increased tube cooling (decrease of the compressive tube-shell ΔT) will have a greater affect in reducing the overall compressive loading on the tubes. Opening the PORV may result in a loss of SCM, and thus require tripping of the RCPs. However, tripping the RCPs will slow the thermal communication to the tubes (helps limit compressive loading if the RCS is still heating up).

This is the only plant state addressed where tripping the RCPs should be used for compressive stress, since neither SG is available to control the cooldown rate. Tripping the RCPs may not reduce the compressive stress, and in fact could result in an increase in compressive stress if the loops and tubes cool to ambient at a slower rate than the RCS cooldown with RCPs running. However, tripping the RCPs may decrease the time required to attain DHRS conditions by eliminating the RCP heat load on HPI. An RCP could be restarted after DHRS initiation to help cool the loops and tubes.

3.3.7 Forced Cooldown With One SG Dry

This plant state (G on Table IV.K-2) could occur due to unisolable steam leaks on both SGs, where a controlled but forced cooldown can be maintained on only one SG. The cooldown is forced by the steam leak, but the rate of cooldown is within limits, such that isolation of the remaining SG (and thus HPI cooling) is not required.

3.3.7.A Tensile Stress

In this case, reducing the cooldown rate to near the idle SG shell cooling rate is not possible. The recommended priority for the remaining actions is the same as given in plant state A (3.3.1) for the same basic reasoning.

3.3.7.B Compressive Stress

The possible actions and priorities for this plant state are the same as for plant state A for the same basic reasoning.

4.0 RCP RESTART CONSIDERING RV HEAD ΔT

Starting a RCP with a voided RV head region will produce a flow of relatively cool RC in contact with potentially hotter RV head metal, causing a thermal cycle to the head. This restart event has been conservatively analyzed to establish acceptable conditions for 35 such thermal cycles under Level B Service Condition (Upset condition, ASME Boiler and Pressure Vessel Code), 18 cycles for Oconee.

Figure IV.K-9 shows the acceptable RCS P-T conditions for RCP restart with a voided head. As long as T_{cold} in the associated loop is to the right of the maximum P-T curve of Figure IV.K-9, the RCP can be restarted with a RV head void, and be counted as one of the 35 (18 for ONS) Level B cycles. If the RCP is started with T_{cold} to the left of this curve, then the event is classified as a Level C Service Condition (Emergency condition, ASME Boiler and Pressure Vessel Code) and an analysis will be required to determine the effect of the transient.

This curve assumes that the RV head metal temperature remains at 600°F. If the actual head metal temperature is known, then the curve can be shifted to the left by an amount equal to the amount that the head is cooler than 600°F.

The relationship for the curve is: $P = 3750 - 625(T_1 - T_2)/43$

Where: P = allowable pressure under the RV head (PSIG)
T_1 = RV closure head metal temperature (°F)
T_2 = RC cold leg temperature (°F)

5.0 CONTROL OF FEEDWATER SOURCES WHEN RECOVERING A DRY SG

The guidance provided here for restoring feedwater to a dry SG is intended for stable plant operation where adequate core cooling is already assured through heat removal by the other SG or by HPI cooling. In this case, time exists to allow determination of specific plant conditions and thus specific limits to apply on feedwater flow. Transient situations, where restoration of the SG is necessary to assure adequate core cooling, are addressed in Chapter III.C, Chapter IV.C, and in Volume 1. While time is available to consider the specific plant conditions and limits prior to restoring feed flow to the idle SG, it is important to control the tube-shell ΔT in the idle SG. Guidance for controlling the ΔT in an idle SG is included in Chapter III.G and in section 3.0 of this chapter.

The guidance is divided into basic SG and plant status and available feedwater source. The SG may have an unisolable steam leak or be intact. The RCS may be in forced circulation, single loop natural circulation with a stagnant, full loop, or in single loop natural circulation or HPI cooling with a loop void. The source of feedwater may be relatively cold EFW through the upper nozzles or relatively warm MFW through upper or lower nozzles. EFW (or MFW through the upper nozzles) will initially cool only the tubes wetted by the spray flow, until a pool level is established. MFW through the lower nozzles will cool all of the tubes as a pool is developed, and will provide some cooling of the lower SG shell. The shell area wetted by MFW will cool slower than the tubes due to the larger metal mass; however, the tubes also have a heat source from the RC. These factors, coupled with current RCS pressure, SG pressure, and SG tube-shell ΔT, all affect the cumulative SG stresses and thus the allowable feed flow.

The flow limits provided are for controlled evolutions to minimize unnecessary SG stresses. Transient mitigation actions must first ensure adequate core cooling. The general guidance provided for restoring feed to a dry SG during transient mitigation in Volume 1 is sufficient to limit the SG stresses while accomplishing the objective of establishing adequate core cooling. In addition, post-transient evaluation will quantify the SG stresses. It is recommended that, for all dry SG recovery events, the following parameters should be recorded to aid in the post-transient evaluation: average tube temperature, average shell temperature, RC pressure and temperatures, feed flow rates, and SG pressures.

In most cases where adequate core cooling does not exist, the tube-shell ΔT in a dry SG will be in the compressive loading direction. As can be seen from the guidance in this chapter, compressive tube loads allow more margin for reestablishing feed flow, since adding feedwater will induce a tensile load. For events where tensile tube loads exist, the normal tube-shell ΔT limits can be exceeded during the initiation of feed. This possibility is accounted for in the curves at the end of this chapter for both EFW and MFW initiation.

The flow limits provided in the figures at the end of this chapter are for the initial feed of the dry SG. These allowable feed rates take into consideration the expected initial tube cooling that will result, such that the feed rate can be maintained until heat transfer is restored or the appropriate level setpoint is attained. In all of these curves, there is also a region where no feed flow is allowable. If the no-flow allowed region is being approached, then several options need to be considered. Section 3.0 above provides guidance on possible actions to take to limit the tensile tube loading, including minimizing primary-secondary ΔP, reducing the RC cooldown rate, if possible, and tripping RCPs. In addition, reducing RC pressure can increase the margin to a no-flow allowed region for those figures that have multiple curve limits. If the RC cooldown rate cannot be controlled to prevent exceeding the tube-shell tensile ΔT limit, then feeding the dry SG should be initiated before the applicable limit curve is reached. If feedwater is not available until after the applicable curve limit is reached, then if possible establish conditions within the allowable region of the curve. If that is not possible, and RC cooldown cannot be stopped (i.e., the tensile tube loading will continue to increase), then feeding the SG should be attempted. Monitoring the tube and shell cooldown rates will provide indication of whether the feeding is reducing or increasing the tube-shell ΔT.

Once heat transfer is established, then the feed rate should be controlled as necessary without exceeding the normal SG tube-shell tensile and compressive ΔT limits. Error correction is not required on these curves. These curves are based on not exceeding normal equipment limits that have a cyclic stress component, and any event involving feeding a dry SG will be evaluated for residual impact, if any. The flow limits provided in Volume 1 are error-corrected since they are single limits for a wide-range of possible conditions, and they do not necessarily bound the curves provided here.

All EFW flow limits assumed an EFW temperature of 40°F. All MFW flow limits assumed an MFW temperature of 85°F. If MFW is fed through the upper nozzles, then the EFW flow limits should be used.

5.1 Determining Initial SG Tube-Shell ΔT

Most of the initial feedwater flow limits presented in this chapter are derived based on the existing SG tube-shell ΔT prior to feeding the SG. Once heat transfer has been restored, the feed flows can be controlled based on the observed ΔT. Methods to determine the SG tube-shell ΔT are provided in section 2.0.

5.2 Dry Intact SG With RCPs Running

If forced RC flow exists, then heat transfer to the SG should begin as soon as feed flow is restored. This is true regardless of which feed nozzles are used. If the SG is intact, i.e., no unisolable steam leak paths, then the SG will repressurize and heat removal from the SG can be controlled. Therefore, this situation will result in minimum SG stresses compared to the other plant states, and thus higher feed flowrates can be used. If possible, forced RC flow should normally be established prior to establishing feed flow. The exception is if establishing forced RC flow would result in an excessive compressive ΔT in the dry SG (i.e., core exit temperature is more than 50-60°F hotter than the average SG shell temperature). Forced RC flow also provides greater control over the idle SG tube-shell ΔT and provides a better indication of the SG tube-shell ΔT prior to establishing feed flow.

5.2.1 EFW

The flow limits for reestablishing EFW flow to the dry intact SG, with forced RC flow, are provided in Figure IV.K-1. The flow limit varies depending on initial SG tube-shell ΔT and RC pressure. Reestablishing feed flow will induce an additional tensile load on the wetted tubes as they begin to cool. Thus the allowable initial flow decreases as the tube-shell ΔT becomes more negative (tensile; tubes colder). The curve ends at the upper end at a tube-shell ΔT of +20°F, but the initial flow limit at that point (500 GPM) remains in effect at higher compressive ΔTs. The curve also ends at the lower end at a tube-shell ΔT of -100°F. This is the tensile limit, but does account for the expected initial tube cooling which can result in an initial increase in the tensile ΔT beyond the normal 100°F limit.

Increased RC pressure increases the ΔP across the tubes. This adds a tensile stress component, thus the allowable feed flow rate decreases with increased RC pressure. The SG is assumed to initially be at atmospheric pressure.

The curve shows a maximum initial flow rate of 500 GPM because this was the highest flow rate analyzed. This provides sufficient flow for full decay heat, but also was determined adequate since, again, these limits only apply to the initial refeed. Once heat transfer is restored, flow can be controlled as necessary while monitoring the tube-shell ΔT.

To use Figure IV.K-1, first determine the existing tube-shell ΔT in the idle SG. Compare the tube-shell ΔT to the appropriate RC pressure curve to determine the maximum initial EFW flow, uncorrected for instrument errors. Correction for plant-specific instrument errors will then determine the actual initial flow limit to be used. Once heat transfer has been restored to the idle SG, feed flow can then be controlled based on tube-shell ΔT and RCS cooldown rate.

5.2.2 MFW

MFW will have less of a cooling effect on the tubes, with RCPs running, than EFW. This is due to the higher assumed MFW temperature and due to the absence of the spray depressurization that occurs with EFW. MFW will also pool around all of the tubes, whereas the EFW spray initially affects only the peripheral tubes. MFW also has a greater affect on SG shell cooling than EFW. Thus, the overall increase in tensile tube loading for this case will be less with MFW for equal flows.

The limits for reestablishing MFW flow to the dry intact SG, with forced RC flow, are provided in Figure IV.K-2. The allowable initial flow is ≤ 800,000 lbm/hr for all RC pressure/SG tube-shell ΔT conditions above the curve (also refer to MFW nozzle cycle limitations in section 5.6). Below the curve, any MFW addition and resultant tube cooling could cause the normal allowable tube load (tensile) to be exceeded. Therefore, as discussed in section 5.0, it is preferable to either initiate flow prior to developing conditions below the curve or to restore conditions above the curve.

To use Figure IV.K-2, first determine the existing tube-shell ΔT in the idle SG. Compare the tube-shell ΔT to the existing RC pressure; if the resulting point lies above the curve, then an initial MFW flow of up to 800,000 lbm/hr (uncorrected for instrument errors) can be used. Any MFW flow for conditions below the curve could result in excessive tensile loading on the tubes. Once heat transfer has been restored to the idle SG, feed flow can then be controlled based on tube-shell ΔT.

5.3 Dry Intact SG With No RCPs

This case differs from section 5.2 in that no RCPs are running. This results in a stagnant RC loop that may have a hot leg void. Thus heat transfer to the SG may not commence as soon as feed is restored. This could result in additional tube cooling before heat transfer is restored and thus will result in lower initial feed flow limits. If the idle loop is full, then natural circulation may begin with the initiation of flow through the upper nozzles. However, to bound these cases without requiring verification of a solid loop, the analyses assumed no primary-secondary heat transfer would occur until after the SG level is raised to the natural circulation setpoint. This also bounds cases with full hot legs and feed through the lower nozzles, where the start of natural circulation flow may not occur until a substantial level has been established.

5.3.1 EFW

The flow limits for reestablishing EFW flow to the dry intact SG, without forced RC flow, are provided in Figure IV.K-3. These initial flow limits are considerably more restrictive than those in Figure IV.K-1 due to the assumption that natural circulation flow will not begin until after the level setpoint is reached. If, in fact, heat transfer and natural circulation flow begin much sooner, then the EFW flow rate can be adjusted as necessary while maintaining the SG tube-shell ΔT within limits.

To use Figure IV.K-3, first determine the existing tube-shell ΔT in the idle SG. Compare the ΔT to the appropriate RC pressure curve to determine the maximum initial EFW flow, uncorrected for instrument errors. Correction for plant-specific instrument errors will then determine the actual initial flow limit to be used. Once heat transfer has been restored to the idle SG, feed flow can then be controlled based on tube-shell ΔT.

Once feedwater has been restored, the SG should begin to repressurize even without natural circulation flow. If NC flow is not established, the SG tubes will cool and the resulting SG pressure will be considerably less than saturation pressure for the existing hot leg temperature. The analysis supports continued feeding, at the initial rate, up to the natural circulation level setpoint and assumes NC flow does not start. Therefore, the flowrate can be maintained at the initial value all the way to the NC level setpoint, without initiating NC flow, and still be within the bounds of the analysis. However, the rate can be reduced if desired to further limit the tube cooling rate. If NC flow is not established, it may be preferable to terminate feed flow at a level below the NC level setpoint while other actions to initiate NC flow can be performed. The SG level will allow some thermal communication between the tubes and shell while the high point vent is used to eliminate a loop void. Subsequent refeeding of the SG may initiate NC if sufficient loop refill has occurred. Once NC flow, and heat transfer, have been restored, then further SG feeding can be controlled by normal limits.

5.3.2 MFW

The flow limits for reestablishing MFW flow to the dry intact SG, without forced RC flow, are provided in Figure IV.K-4. The concept for these limits is the same as the limits presented in Figure IV.K-2 (forced flow) except the limit above the curve is 400,000 lbm/hr without primary flow. Also refer to MFW nozzle cycle limitations in section 5.6.

To use Figure IV.K-4, first determine the existing tube-shell ΔT in the idle SG. Compare the ΔT to the existing RC pressure; if the resulting point lies above the curve, then an initial MFW flow of up to 400,000 lbm/hr (uncorrected for instrument errors) can be used. Any MFW flow for conditions below the curve could result in excessive tensile loading on the tubes. Once heat transfer has been restored to the idle SG, feed flow can then be controlled based on tube-shell ΔT.

As in the EFW analysis, this case assumed continued feeding to the NC level setpoint without inducing any NC flow. In the case of MFW (through the lower nozzles), NC flow would not initiate, even without a loop void, until an appreciable level has been established. Therefore, if it is not known that a loop void exists, the MFW flow should continue to the NC level setpoint. The level will help establish thermal communication between the tubes and shell. Plants that use MFW through the upper (EFW) nozzles should use the guidance in section 5.3.1 and Figure IV.K-3.

5.4 Trickle Feed of SGs with Unisolable Steam Leaks

This case differs from the previous cases in that the SG cannot fully repressurize due to an unisolable steam leak. Thus a constant SG level may not be achievable and the cooldown rate, as well as the tube-shell limits, may have to be controlled by feed flow.

Trickle feed, to be effective, requires primary to secondary heat transfer when feed flow is initiated. For this reason, MFW flow through the lower nozzles should only be attempted if an RCP is running. Similarly, flow through the upper nozzles will not be effective if the hot leg is voided sufficiently to prevent establishing NC flow, but insufficiently to allow BCC.

The decision to feed an SG with an unisolable steam leak should consider the leak location relative to personnel and key equipment.

5.4.1 EFW

The initial flow limits for establishing EFW trickle feed flow to an SG with an unisolable steam leak are provided in Figures IV.K-5 and IV.K-7. Figure IV.K-5 provides limits for the case where an RCP is running; Figure IV.K-7 provides limits for the case where no RCP is running, but the loop is full such that NC flow should be established when feed flow is established. The allowable flowrates, for a given initial ΔT, are higher than the allowable flowrates for the intact SG cases shown in Figures IV.K-1 and IV.K-3. This resulted from additional conservative assumptions in the intact SG cases and, in the case of Figure IV.K-3, natural circulation was not assumed to start in order to bound cases involving hot leg voids; in Figure IV.K-7, natural circulation was assumed, which allows higher initial flowrates.

To use Figures IV.K-5 and IV.K-7, first determine the existing tube-shell ΔT in the idle SG. Compare the ΔT to the appropriate RC pressure curve to determine the maximum initial EFW flow, uncorrected for instrument errors. Correction for plant-specific instrument errors will then determine the actual initial flow limit to be used.

These curves provide the initial flow limits; flow rate should be adjusted after heat transfer is restored to control both the RCS cooldown rate and the SG tube-shell ΔT. The ΔT will also depend on the shell cooling rate, which in turn will depend on the size of the steam leak, ability to establish any SG level, ambient heat loss rate, etc.. It is possible that the SG shell will cool slowly (e.g., less than 10°F/HR) even with the flow of relatively low temperature steam, in which case the RCS cooldown rate will have to be similarly limited to prevent exceeding the SG tube-shell ΔT limits.

The natural circulation limits are more restrictive to account for the slower loop transport time. The SG tubes will initially cool farther for the same EFW flow during the initial loop transport.

5.4.2 MFW

Guidance to determine the initial flow for establishing MFW trickle feed flow to an SG with an unisolable steam leak is provided in Figure IV.K-6. These curves are for the case of an RCP running; without an RCP running and the ability to establish appreciable level in the SG, MFW trickle feed should not be attempted. Some plants may have the capability to provide MFW flow to the upper (EFW) nozzles; in this case the appropriate EFW flow limits should be used per section 5.4.1. The assumed EFW temperatures bound the MFW temperatures. Also refer to MFW nozzle cycle limitations in section 5.6.

Figure IV.K-6 shows the expected initial RCS cooldown rates vs. MFW flow rate for two cases of time after shutdown from full power history (15 minutes and two hours after shutdown) and two initial SG tube temperatures (400°F and 600°F). Lower decay heat levels and initial tube temperatures will require less flow for the same cooldown rate. The curves on Figure IV.K-6 are not limits, but rather guides from which to estimate the potential cooldown rates due to the MFW flow. MFW flow should be adjusted once heat transfer has been restored to control both the RCS cooldown rate and the SG tube-shell ΔT. Since only the very lower portions of the tubes are wetted in this mode, the tube cooldown rate will be essentially equal to the RCS cooldown rate. Thus the MFW flow and the cooldown rate can be controlled by the observed tube-shell ΔT and curves like those in Figure IV.K-5 are not necessary.

5.5 Restoring Feed to a Dry SG with CBPs

There may be instances when the MFW pumps are not available, but the remainder of the condensate and feed system is available. In these instances the condensate booster pumps can be used to restore feed flow to a dry SG under certain conditions.

If the RCS temperature is less than the saturation temperature corresponding to the CBP shutoff head, then the CBPs can be used with the MFW flow limits/guidance provided in this chapter and normal SG level control should be possible. If, however, the SGs could repressurize above the CBP shutoff head, then other considerations should be made.

A primary concern when using condensate booster pumps is the possibility of thermal cycles on the MFW nozzles (see section 5.6). Use of the MFW nozzles should result in a constant flowrate above a minimum value to limit cyclic stresses on the nozzles. In using a CBP at RC temperatures near or above the saturation temperature corresponding to the CBP shutoff head, care must be taken to maintain SG pressure low enough to allow continued minimum flow from the CBP. This can be accomplished by use of the TBVs or ADVs to essentially create a steam leak and use of the CBP to provide trickle feed flow.

The intent is to provide a steam relief path of sufficient capacity to remove decay heat and allow some RCS cooldown while maintaining SG pressure below the CBP shutoff head. Once the steam relief path is established and SG pressure is less than the CBP shutoff head, then MFW flow can be initiated with the CBP. The initial flow rate should be less than the capacity of the TBV or ADV for the desired pressure, but more than the minimum flow for the MFW nozzles (see section 5.6).

Once flow is established, then the cooldown rate can be controlled by throttling MFW flow and/or the steam relief path. When adjusting the feed and steam flow rates, exercise caution to prevent reducing MFW flow below the minimum flow for the MFW nozzles (section 5.6). Depending on decay heat, initial RC temperature, etc., it may not be possible to initially establish SG level without causing excessive RCS cooldown. This may lead to approaching the SG tube-shell tensile ΔT limit since the SG shell cooling will be at a lower rate than normal. The RCS only needs to be cooled to approximately 425°F or less to prevent SG pressures greater than the CBP shutoff head. Therefore, depending on initial conditions, it is possible that this intentional trickle feed cooldown method can attain RC temperatures that will permit normal feeding, steaming, and SG level control before SG tube-shell limits are reached. However, if exceeding the SG limits cannot be prevented, then this method should be terminated until RC temperature is sufficiently reduced by other means. In addition, since SG level can not be initially established at the natural circulation setpoint at RC temperatures greater than approximately 425°F, this method should not be attempted if no RCPs are running unless RC temperature can be maintained less than approximately 425°F. When RC temperature is sufficiently reduced by other means, to prevent SG pressurization above the CBP shutoff head, then this method can be attempted without RCPs.

5.6 MFW Nozzle Cycles

The MFW flow rate must be greater than 160,000 lbm/hr to ensure the nozzles remain full (no water/steam interface inside the nozzle). The nozzles have been analyzed for a lifetime usage of 50 cycles where a cycle is defined as going from 0 lbm/hr to greater than 160,000 lbm/hr and back to 0 lbm/hr. Thus, one transient involving on-off MFW flow control, such as use of the CBP without preventing SG pressures greater than the CBP shutoff head, could use up a significant number of the allowable cycles.

Ideally, for MFW nozzle cyclic stress considerations, MFW flow should be maintained greater than 160,000 lbm/hr. However, this flow rate may be excessive depending on plant conditions. Sustained flow rates less than 160,000 lbm/hr, where the nozzles are partially filled with steam, have not been analyzed. However, a sustained flow rate less than 160,000 lbm/hr should have less cyclic stress impact on the nozzles than on-off MFW flow control.

Therefore, anytime the MFW nozzles are used, the preferred control is to provide sustained flow greater than 160,000 lbm/hr. If this flow is excessive for plant conditions, then the next best alternative is to provide sustained flow at the rate required by plant conditions. In this case, MFW flow rates and temperatures should be recorded for post-event stress evaluation. MFW on-off flow control should be avoided if at all possible. If on-off flow control does occur, even inadvertently, then MFW flow rates and temperatures should be recorded for post-event stress evaluation.

Table IV.K-1
Weighted Tube Temperature Calculations

Plant Condition	Calculation Method
Forced Flow	$T_{tube} = [T_{hot}(53.5\text{-}L) + T_{cold}(L + 2.5)]/56$
Natural Circulation Flow	$T_{tube} = [T_{hot}(53.5\text{-}L) + T_{cold}(L + 2.5)]/56$
Stagnant Loop, Dry SG (except DB)	$T_{tube} = [T_{hot}(29) + T_{cold}(27)]/56$
Stagnant Loop, SG Level < RCP Spillover (except DB)	$T_{tube} = \{T_{hot}(54\text{-}E_{so}) + [T_{cold}(E_{so}\text{-}(L + 0.5))] + T_{sgsat}(L + 2.5)\}/56$
Stagnant Loop, SG Level ≥ RCP Spillover and Davis Besse	$T_{tube} = \{T_{hot}[54\text{-} (L+0.5)] + T_{sgsat}(L + 2.5)\}/56$

Where:

E_{so} = RCP spillover elevation, in feet above the SG lower tubesheet, upper face (ONS-1, TMI-1: 23.58'; ONS-2,3: 25.75'; CR-3, ANO-1: 24.35')

L = SG level, indicated, in feet

T_{sgsat} = SG saturation temperature for existing SG pressure

56 = total SG tube length, including both tube sheets

2.5 = height of lower SG level tap above lower tube sheet lower face

0.5 = height of lower level tap above lower tube sheet upper face

Table IV.K-2
Suggested Prioritized Actions to Reduce SG Tube Stresses

Plant States

Possible Actions for Tensile Stress (Negative Tube-Shell ΔT)	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Ensure RC pressure low as practical	1	1	1	1	1	1	1
Reduce cooldown rate on active SG	3	5	3	2	2	N	N
Allow higher ΔT per Figure IV.K-8	4	4	2	5	3	2	3
Restore heat transfer to idle SG	*	2	N	3	N	*	*
Periodic feed/steam idle SG per III.G	2	3	N	4	N	3	2
Trip RCP(s)	5	6	4	6	4	4	4
Possible Actions for Compressive Stress (Positive T-S ΔT)	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Increase cooldown rate on active SG	1	1	1	1	1	N	1
Periodic feed/steam idle SG per III.G	2	2	N	2	N	1	2
Open PORV if intentionally cycling	N	N	N	N	N	2	N
Restore idle SG heat transfer	*	3	N	3	N	N	*
Trip RCP(s)	N	N	N	N	N	3	N

Plant states:
- A SGTR in active SG, idle SG dry (unisolable steam leak)
- B SGTR in active SG, idle SG low level
- C SGTR in active SG, idle SG at a high level due to SGTR
- D No SGTR in active SG, idle SG low level
- E No SGTR in active SG, idle SG at a high level due to SGTR
- F HPI cooling or SBLOCA, no SGs available
- G Forced cooldown with other SG dry (steam leaks on both SGs)

(RCP(s) are operating in each of the seven plant states)

Notes:
- N Not applicable
- * Idle SG with steam leak may become controllable at lower pressures and temperatures such that heat transfer could be restored (via trickle feed).

General:
1. Do <u>not</u> trip RCP for compressive stress as long as one SG is available for heat transfer.
2. RCP trip should be the <u>last</u> of possible actions for tensile stress.

Figure IV.K-1

Allowable Initial EFW Flowrates to Dry Intact SG vs. Delta T and RC Pressure (PSIG), RCP On

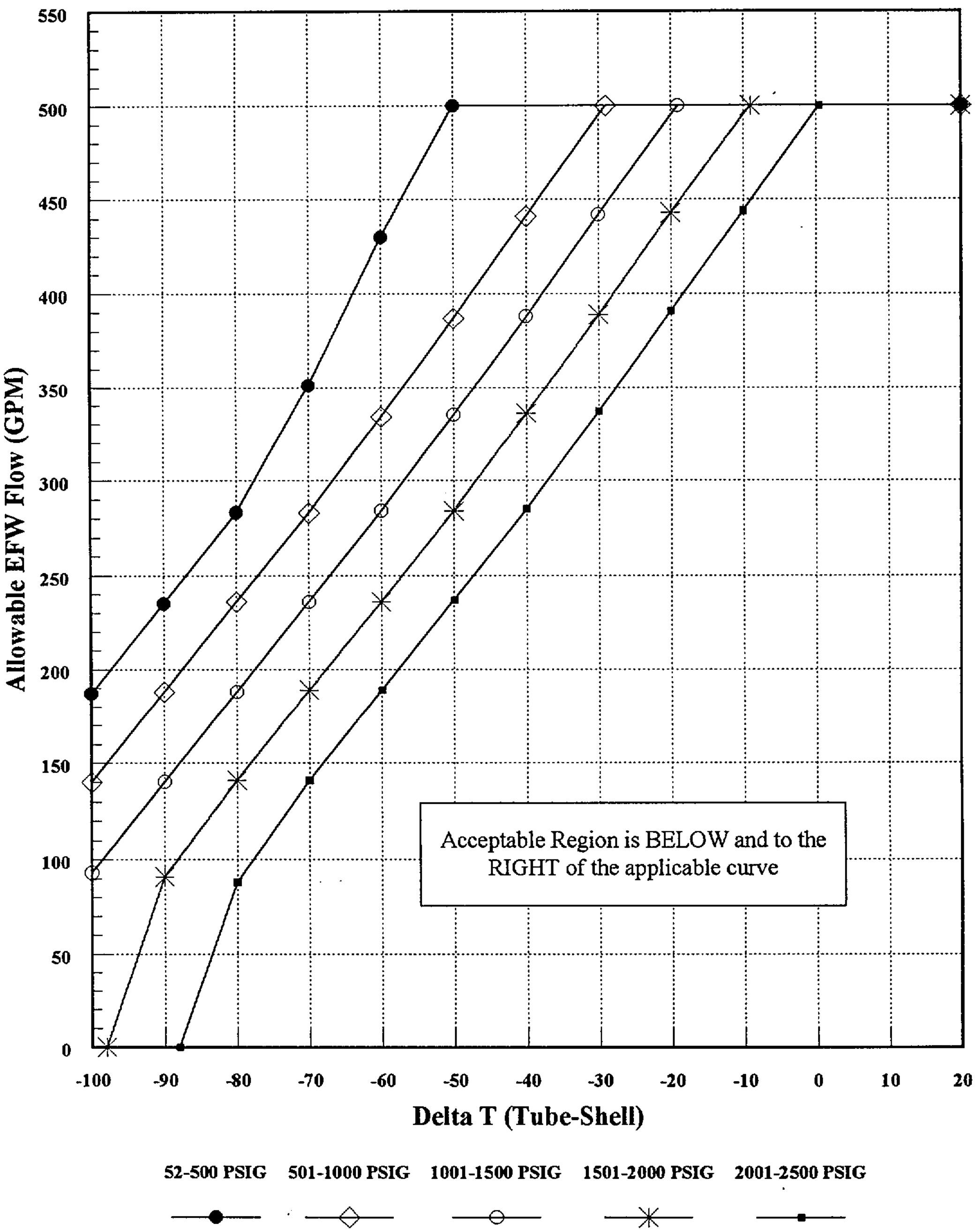
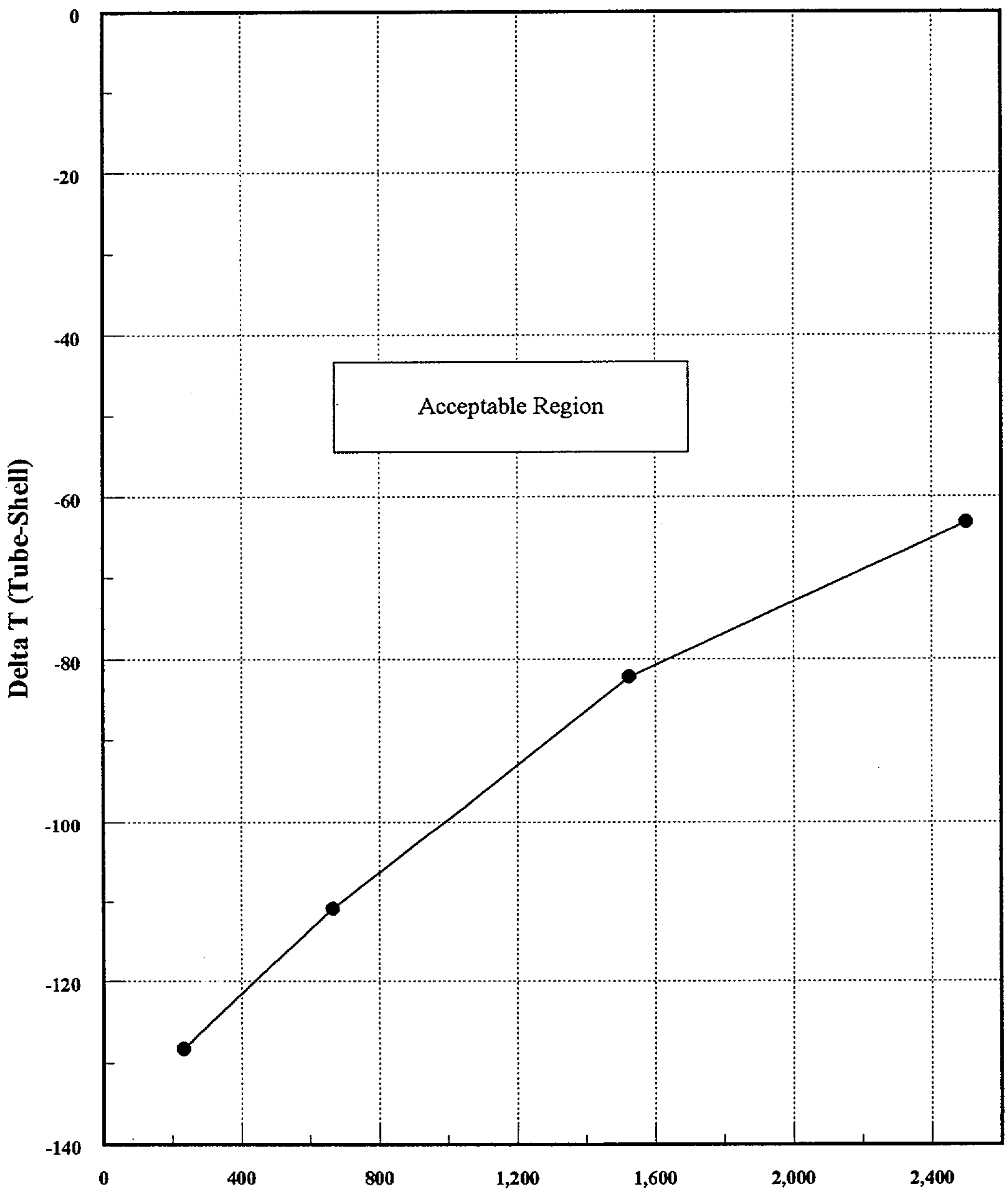


Figure IV.K-2

Allowable Initial MFW Flowrates to Dry Intact SG vs. Delta T and RCS Pressure, RCP On



Above curve limit flow to 800,000 lbm/hr; do not feed with MFW below curve.

Figure IV.K-3

Allowable Initial EFW Flowrates to Dry Intact SG vs. Delta T and RCS Pressure, No Primary Flow

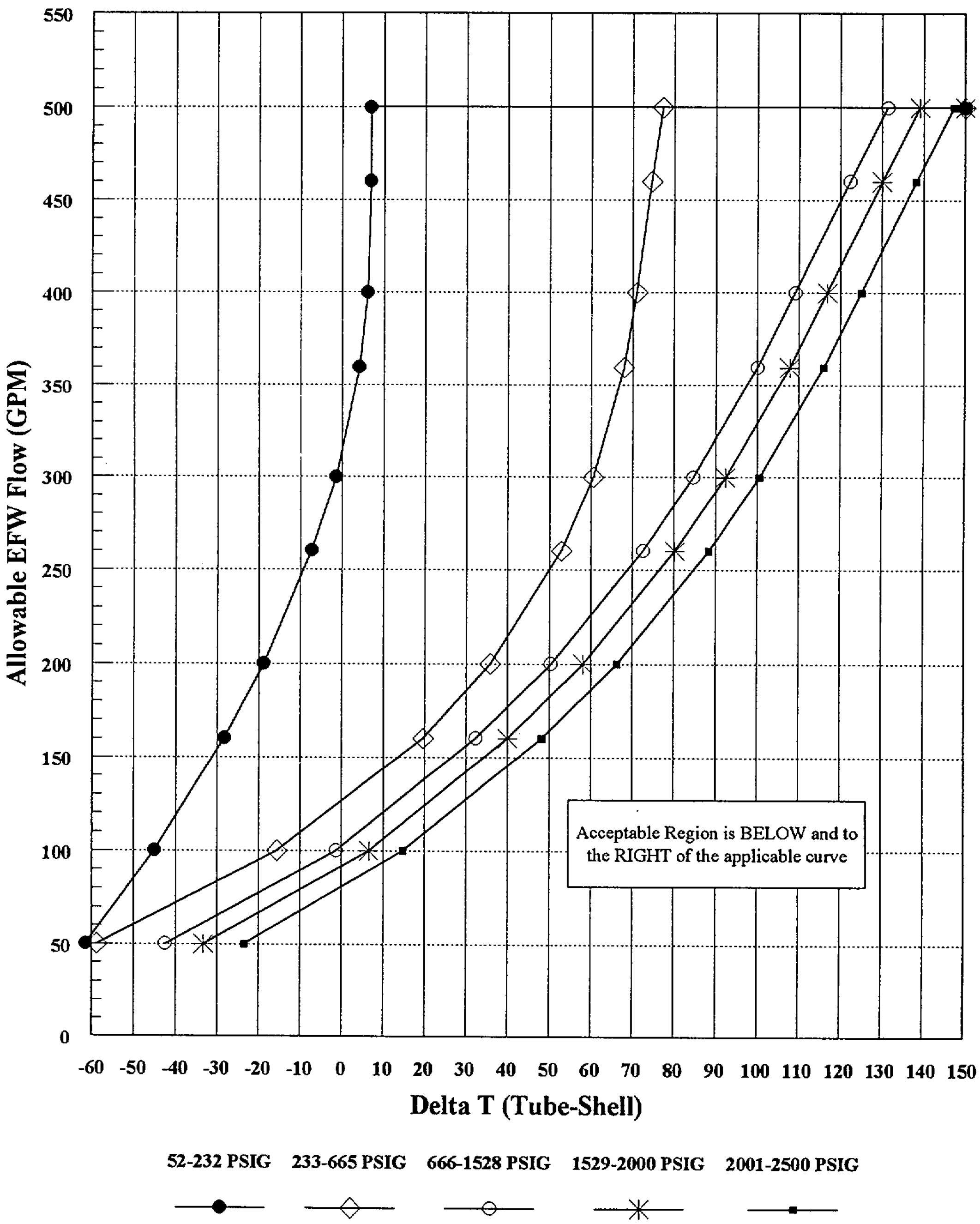
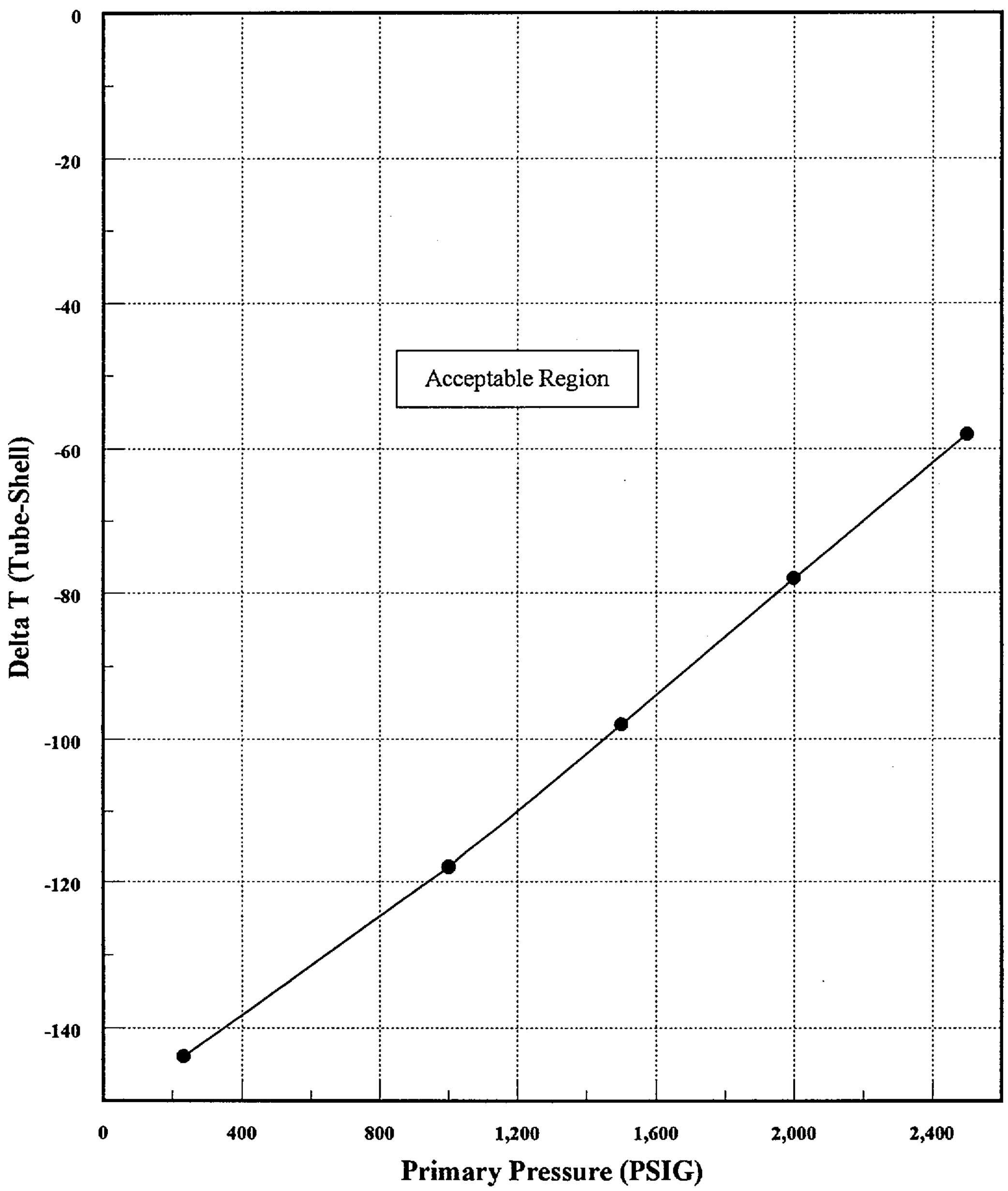


Figure IV.K-4

Allowable Initial MFW Flowrates to Dry Intact SG
vs. Delta T and RCS Pressure, No Primary Flow



Curve is based on feeding to the NC level setpoint.

Above curve, limit flow to 400,000 lbm/hr; do not feed with MFW below curve.

Figure IV.K-5

Allowable Initial Trickle Feed EFW Flowrates to Dry SG vs. Delta T and RCS Pressure, RCP on

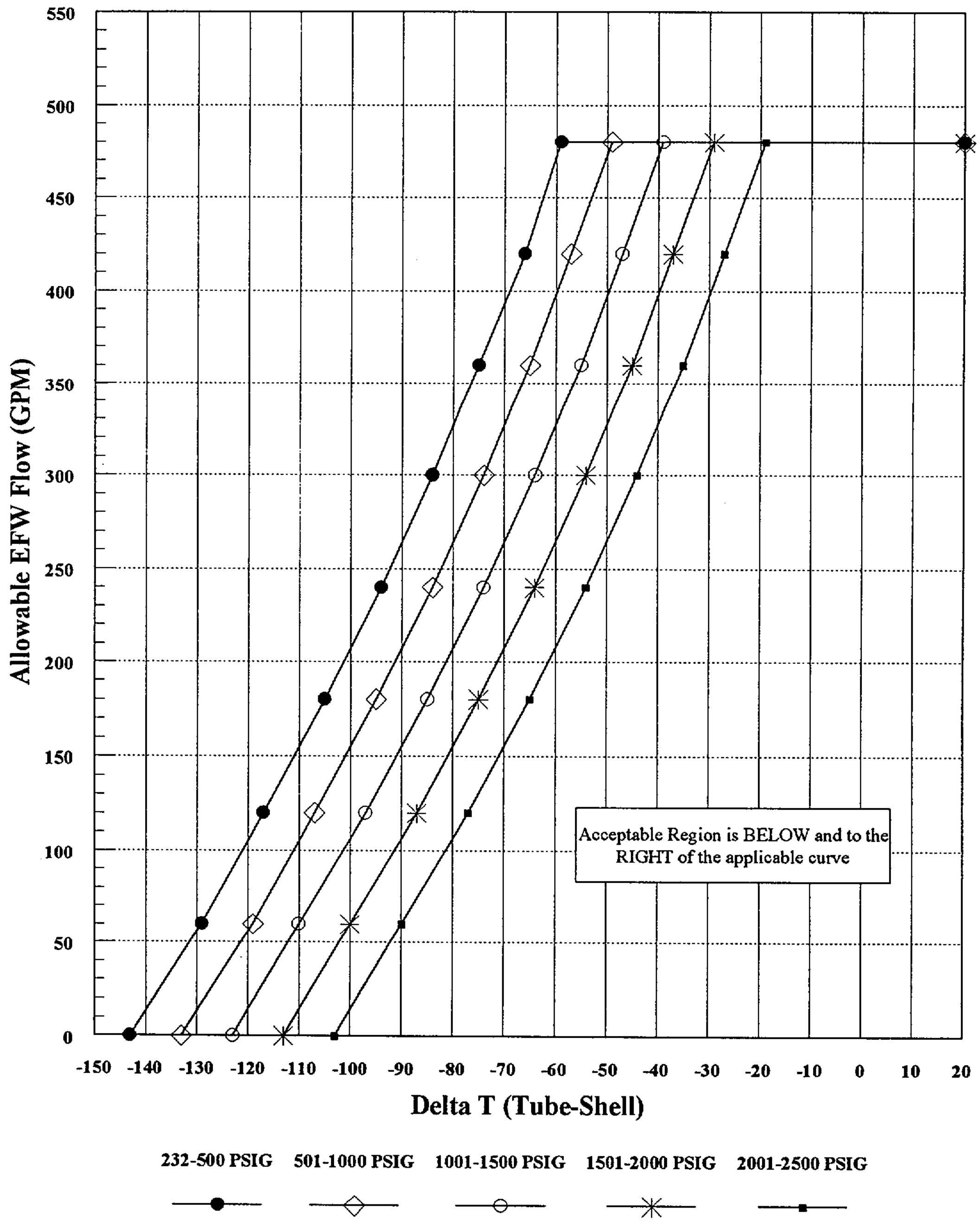
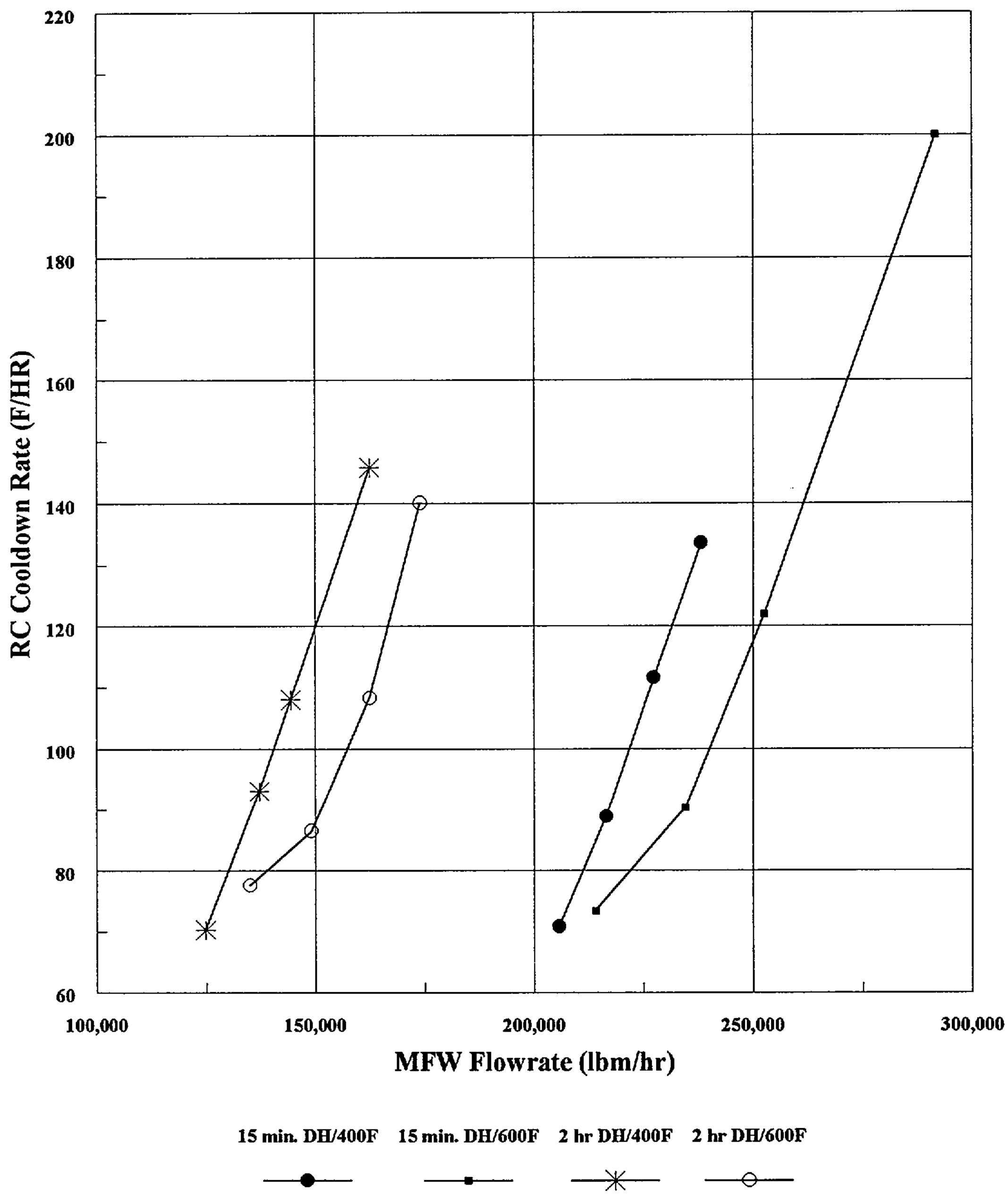


Figure IV.K-6

RC Cooldown Rate vs. Trickle Feed MFW Flowrate to Dry SG
Based on Initial Decay Heat Level /RC Temperature (RCP(s) On)



Assumed MFW temp. of 85F

Figure IV.K-7

Allowable Initial Trickle Feed EFW Flowrates to Dry SG vs. Delta T and RCS Pressure, Natural Circulation

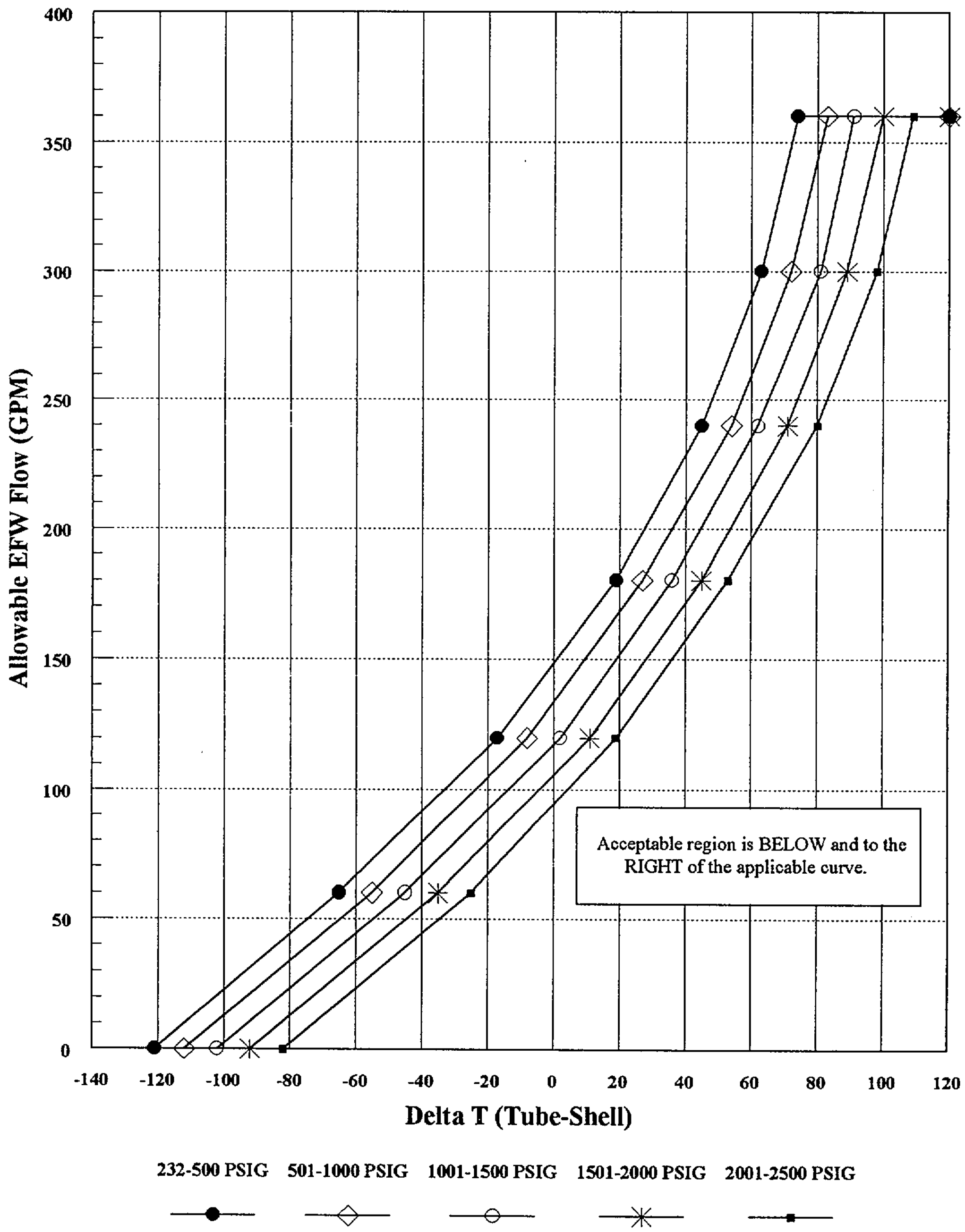
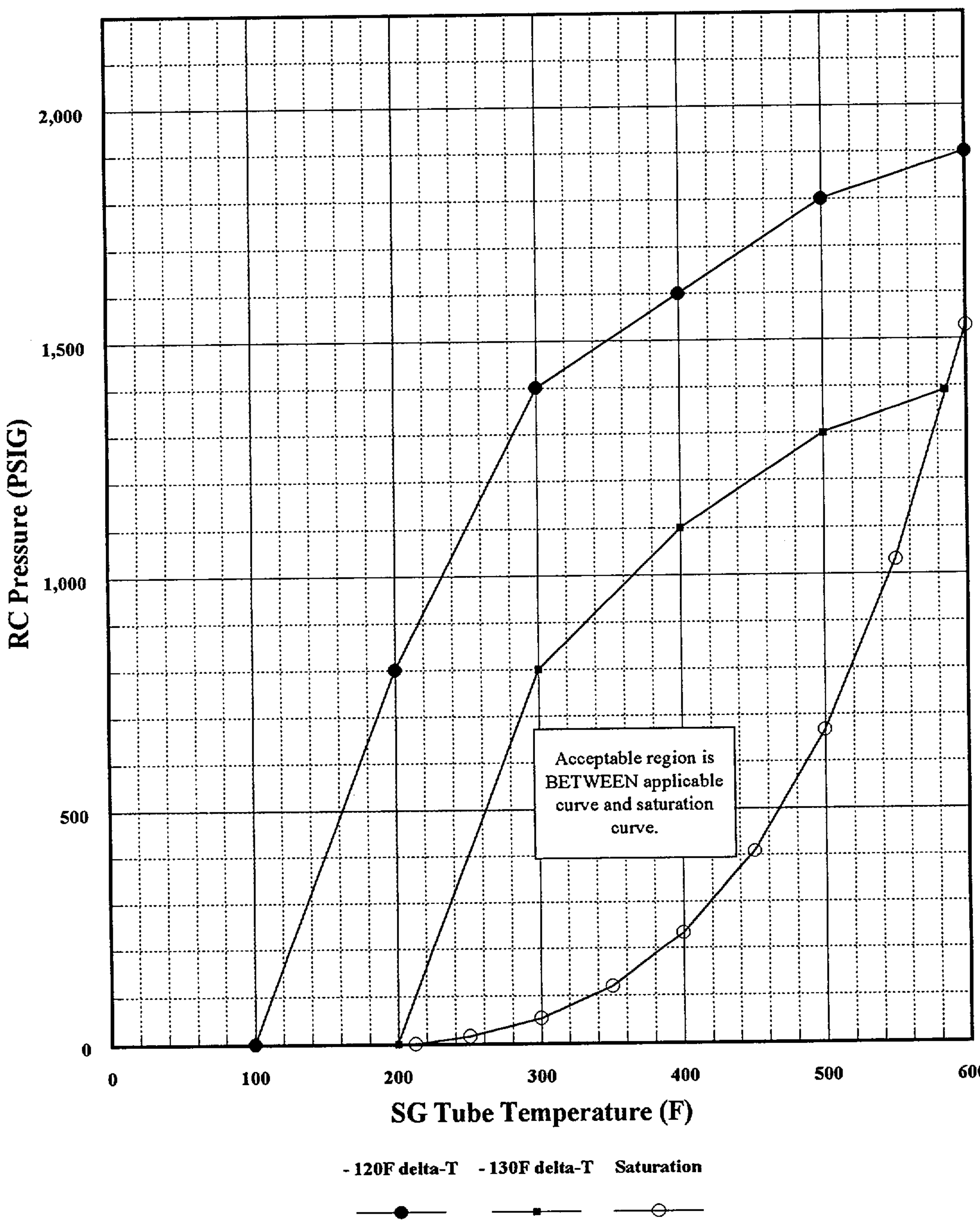


Figure IV.K-8

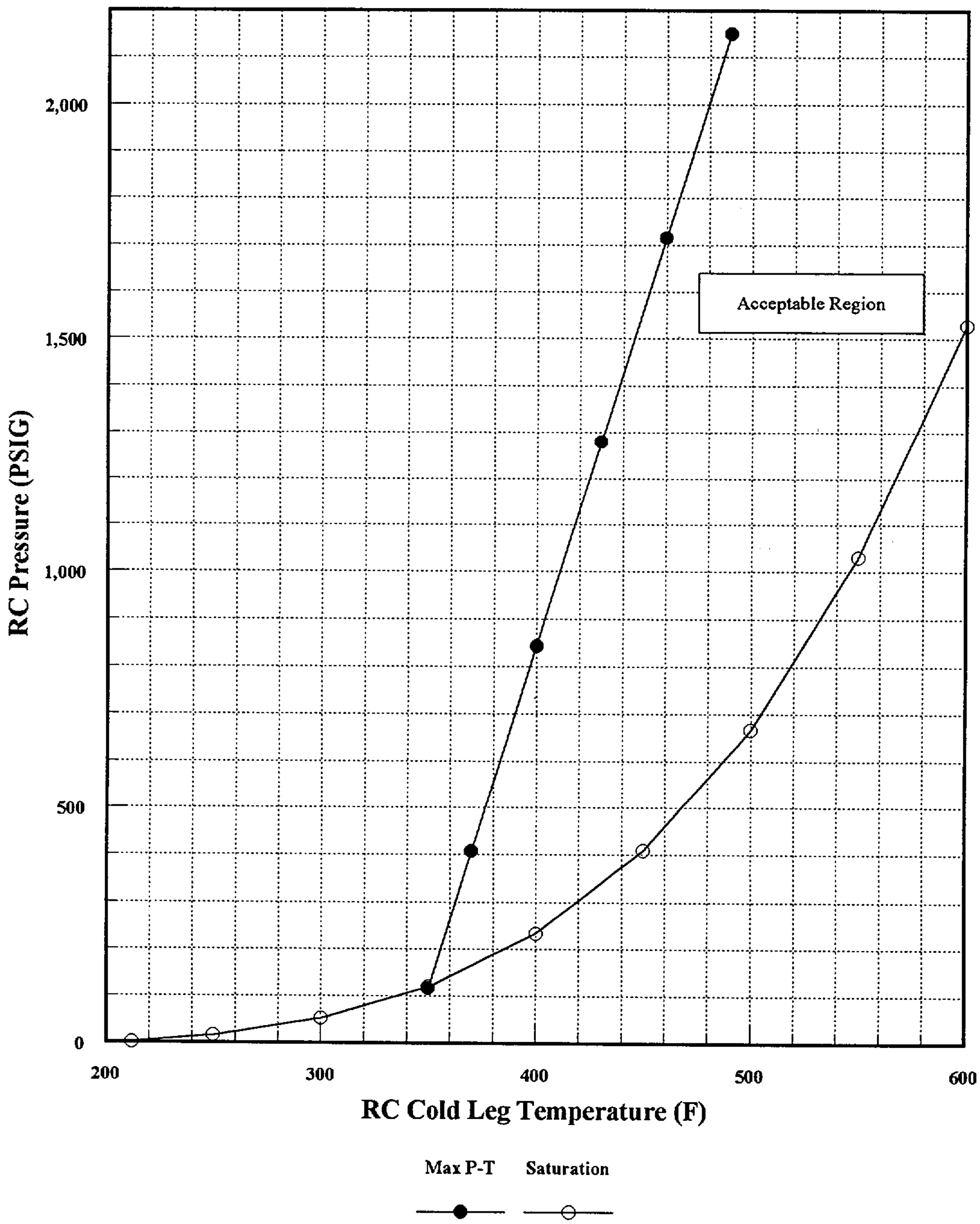
Allowable RCS P-T vs. Extended Tube-Shell Tensile (Negative) Delta T



These curves assume SG at atmospheric pressure and therefore applicable at any SG pressure

Figure IV.K-9

Allowable RCS P-T for RCP Restart with Voided RV Head



This curve assumes RV head at 600F
P-T is RV head pressure-Cold leg temperature

Part V

RULES

1.0 Loss of SCM Rule

Whenever SCM is lost, perform the following:

1.1 Trip all RCPs immediately.[1]

1.2 Initiate full flow[2] from at least two HPI pumps.

1.3 Initiate and control EFW flow per Rule 4.0.

1.4 Ensure full flow from two LPI pumps when RCS pressure permits.

NOTES

1. If RCPs not tripped within two minutes after a loss of SCM, then RCP operation (one RCP in each loop preferred) must be maintained until SCM restored or until LPI flow is established. If a RCP trips, the other RCP in that loop must be started immediately.

   If SCM is lost immediately following RCP restart, then the RCPs do not need to be tripped immediately but must be tripped if SCM is not restored within two minutes.

2. Full HPI flow may require flow balancing or isolation of a broken HPI line accomplished by plant specific methods. The intent is to ensure minimum flows required for LOCA are met.

2.0 HPI Throttling/Termination Rule

2.1 HPI flow <u>may not</u> be throttled unless SCM exists.[1]

2.2 HPI flow <u>must</u> be throttled to prevent violating the RV P-T limit.

2.3 HPI flow <u>may not</u> be terminated if <u>any</u> of the following conditions exist:

a. The core outlet temperature is superheated.

b. The core outlet temperature is saturated <u>and</u> LPI flow is less than [minimum flow rate].[5]

c. The core outlet temperature is subcooled <u>and</u> RCS injection required is greater than the makeup system capacity <u>and</u> LPI flow does not exist.

2.4 HPI flow <u>may</u> be terminated if <u>any</u> of the following conditions exist:

a. The core outlet temperature is subcooled <u>and</u> RCS injection required (makeup and contraction) is within the capacity of normal makeup.

b. The core outlet temperature is subcooled <u>and</u> LPI flow exists <u>and</u> HPI has been throttled to [minimum allowable pump flow] <u>and</u> the RCS P-T is <u>not</u> increasing.[3]

c. The core outlet temperature is saturated <u>and</u> LPI flow >[minimum flow rate] exists.[3,4,5]

2.5 HPI flow <u>must</u> be throttled to prevent exceeding [pump runout].[2]

2.6 HPI flow <u>must</u> be maintained greater than [minimum allowable pump flow].

Notes

1. HPI may not be throttled, even with SCM, if HPI cooling is in progress until core exit thermocouple temperatures are decreasing, except to prevent violating the RV P-T limit.

2. When reducing flow to prevent pump runout, care should be taken to not reduce flow more than necessary to prevent exceeding the limit.

3. In these cases, HPI should not be terminated until switchover to RB sump suction is required.

4. When the core outlet temperature is saturated and LPI flow exists, the PORV may be opened in an attempt to increase LPI flow to >[minimum flow rate].

5. LPI minimum flow rates, not including instrument error, are:

177FA Plants except ANO-1	1000 GPM in each line
ANO-1 (2 LPI pumps)	2630 GPM per pump
ANO-1 (1 LPI pump)	3020 GPM for pump

3.0 Pressurized Thermal Shock (PTS) Rule

3.1 The PTS guidance must be invoked whenever one of the following criteria are met:

a. RC pump on or natural circulation with HPI off:
Whenever T_{cold} is less than 338°F[1] and the rate of cooldown exceeds the allowed RCS Technical Specification cooldown rate.

b. RC pumps off and HPI on:[2]
Whenever all RC pumps are off and HPI is on.

3.2 If PTS guidance is invoked, then maintain core outlet temperature and pressure near the SCM limit.

NOTES

1. Temperature values must be adjusted for plant specific instrument and process errors.

2. HPI on is defined as one or more HPI pumps on while taking suction from the BWST and injecting through one or more of the HPI lines. For Davis Besse, this also means one or more MU pumps on while taking suction from the BWST during MU/HPI cooling.

4.0 Feedwater/SG Control Rule

4.1 Whenever SCM is lost, SG level(s) must be raised the [loss of SCM setpoint] using EFW or MFW as follows:

a. EFW <u>must</u> be provided continuously at ≥ the [minimum fill rate (EFIC)] or at ≥ the [minimum total flow rate] until the [loss of SCM setpoint] is reached. EFW should not be throttled unless necessary[1].

	Loss SCM Setpoint[2]	Minimum Total EFW Flow Rate[2]	<u>Minimum Fill Rate(EFIC)</u>
Davis Besse	100 inches SUR	N/A[3]	N/A
ANO-1 and CR-3	73% OR	400 GPM	2 inches/minute
ON-1,2 and 3	79% OR	400 GPM	N/A
TMI-1	70% OR	400 GPM[4]	N/A

b. MFW using EFW nozzles <u>must</u> be provided at a total MFW flow rate > 600[2] GPM until the [loss of SCM setpoint] is achieved[5].

c. MFW using MFW nozzles <u>must</u> be provided to achieve the [loss of SCM setpoint] within 25 minutes of loss of SCM[6].

4.2 EFW pump flow <u>must</u> be maintained less than [pump runout].

4.3 Establish and control at the appropriate SG level setpoint ([low level limit setpoint], [NC setpoint], or [loss of SCM setpoint]).

4.4 When manually restoring feed flow to a dry SG (intact or trickle feed[7]) limit the flow rate as follows:

EFW nozzles, RCP on	:	≤ 450 GPM
EFW nozzles, RCPs off	:	≤ 200 GPM
MFW nozzles	:	≤ 200,000 lbm

Once heat transfer has been restored in the SG, feed rates can be adjusted as necessary to control the cooldown and SG tube-shell ΔT.

If the minimum flow rate required by 4.1 applies and conflicts with these values, then the criteria of 4.1 supercede the criteria of 4.4.

NOTES

1. EFW manual flow control should only occur if either the automatic EFW control system is not functioning properly or if the SG becomes uncoupled (loss of heat transfer). Even under manual control, throttling should not be performed unless necessary. For level rate control systems, if the system does not initially feed due to a level error (actual level higher than target level), this is considered as not functioning properly for the purpose of this rule. Also, for the purpose of this rule, a SG becoming uncoupled is defined as EFW flow greater than the total minimum EFW flow causing the SG pressure to decrease substantially below RCS pressure.

2. These values do not include instrument errors.

3. Davis Besse need only feed to 100 inches SUR level to achieve the loss of SCM setpoint. Because of this relatively low level, there is little time or need to throttle EFW before reaching the setpoint. For this reason, there is no minimum total EFW flow rate limit for Davis Besse and Davis Besse should not throttle EFW flow.

4. TMI-1 should not throttle EFW flow if only one motor-driven EFW pump is available.

5. EFW nozzle flow rates, while using MFW, could be substantially greater than those associated with EFW. For this reason, a total MFW flow rate approximately equivalent to normal full decay heat EFW flow rate (e.g., ~ 800 GPM) should be used. Throttling below this flow rate should not be performed unless necessary, e.g., MFW flow rate is causing the SG pressure to decrease substantially below RCS pressure. In any case, total MFW flow rate through the EFW nozzles must remain ≥ the prescribed limit until the [loss of SCM setpoint] is achieved.

6. When using MFW through the MFW nozzles, condensation heat transfer area sufficient to remove decay heat is not be available until the [loss of SCM setpoint] is achieved. Achieving this level by 25 minutes after loss of SCM assures that PCTs remain within acceptable limits.

7. Trickle feed (feeding a SG with an unisolable steam leak) should not be attempted unless the steam leak is known to be in a location that is not detrimental to personnel or key equipment or no other method of core cooling is available. Trickle feed using MFW nozzles should not be attempted unless RCP(s) running.

5.0 Reactivity Control Rule

Whenever[1] an unexpected increase in neutron flux is observed with rods inserted, perform the following:

5.1 Stop any dilution activities in progress.

5.2 Initiate emergency boration until adequate SDM is established.

5.3 Stabilize RCS temperature.

NOTES

1. One exception is the case where a rapid cooldown is being performed due to a loss of SCM with HPI unavailable. In this case, the cooldown and depressurization of the RCS is more important, and a significant return to power should not occur.

Part VI

REFERENCES

References

1.0 General Plant Comparisons

1.1 Document No. 51-1123827-00, "Comparison of DB-1 and ANO-1 for ATOG,"P. R. Boylan, M. E. Newlin, 2/25/81. Function: Comparison of select plant parameters significant to ATOG between ANO-1 and DB-1. Facilitated modifying the ANO-1 FOAK ATOG document to reflect the DB-1 plant. Technical bases for comparison provided by list of references contained in this document.

1.2 Document No. 51-1121907-00, "ATOG Comparison Between ANO-1 and CR-3 Nuclear Stations," E. A. Hiltunen, R. B. Brownell, 11/25/80. Function: Same as Reference 1.1 above except comparison between ANO-1 and Crystal River-3 plants.

1.3 Document No. 32-1121199-00, "ATOG ANO-1/TMI-1 Systems Comparison,"P. R. Boylan, L. J. Rudy, 12/10/80. Function: Same as Reference 1.1 above except comparison is between ANO-1 and TMI-1 plants.

1.4 Document No. 32-1120675-00, "Comparison of ANO-1 and ONS-III for ATOG,"M. E. Newlin, K. J. Vavrek, C. W. Tally, 8/22/80. Function: Similar to Reference 1.1 above except applies to Oconee 1, 2, and 3 plants.

1.5 Document No. 32-1106885-00,01, "ATOG ANO-1, Rancho Seco Systems Comparison," L. Rudy, D. Newton, 11/18/83. Function: Similar to Reference 1.1 above except applies to Rancho Seco plants.

1.6 Document No. 12-1153713-00, "Comparison of DB-1 and ONS-3," B. L. Brooks, R. L. Black, 3/27/85. Function: Comparison of DB-1 ATOG Part 1 to the ONS-3 ATOG Part 1 to help DB-1 reference the ONS-3 ATOG in their Procedures Generation Package because the NRC SER on B&W plants was written on the ONS-3 ATOG.

1.7 Document No. 86-1118380-00, "ATOG-TED Analytical Data," K. J. Vavrek, M. E. Newlin, 3/21/80. Function: Specifies analytical input data for DB-1 for use and reference in the ATOG program.

1.8 Document No. 12-1155531-00, "Comparison of Rancho Seco to ONS-Unit 3," B. L. Brooks, R. L. Black, 3/26/85. Function: Same as Reference 1.6 above except that comparison is between Rancho Seco and ONS-3.

1.9 Document No. 12-1156769-00, "Comparison of Crystal River Unit 3 to Oconee Nuclear Station Unit 3," D. G. Newton, B. L. Brooks, 3/27/85. Function: Same as Reference 1.6 above except that comparison is between CR-3 and ONS-3.

PART VI
REFERENCES

The following list of references represents information (Calculational Packages, Reports, Transient Information Documents, Analytical Input Summaries etc.) created or used by FTI during the development of the Abnormal Transient Operating Guidelines (ATOG) and the Technical Bases Document (TBD). Each reference provides information on specific topics but a one-for-one correlation between the information contained in the Technical Bases Document and the references by themselves cannot always be made. Engineering judgement was used in making the transition between the strict, detailed analyses (often from several sources) and the guidance provided in ATOG and the Technical Bases Document. Furthermore, material in some of the documents is of more theoretical than of practical interest for various reasons (e.g., overly conservative assumptions, subsequent design changes, etc.).

References

1.0 General Plant Comparisons

1.1 Document No. 51-1123827-00, "Comparison of DB-1 and ANO-1 for ATOG,"P. R. Boylan, M. E. Newlin, 2/25/81. Function: Comparison of select plant parameters significant to ATOG between ANO-1 and DB-1. Facilitated modifying the ANO-1 FOAK ATOG document to reflect the DB-1 plant. Technical bases for comparison provided by list of references contained in this document.

1.2 Document No. 51-1121907-00, "ATOG Comparison Between ANO-1 and CR-3 Nuclear Stations," E. A. Hiltunen, R. B. Brownell, 11/25/80. Function: Same as Reference 1.1 above except comparison between ANO-1 and Crystal River-3 plants.

1.3 Document No. 32-1121199-00, "ATOG ANO-1/TMI-1 Systems Comparison,"P. R. Boylan, L. J. Rudy, 12/10/80. Function: Same as Reference 1.1 above except comparison is between ANO-1 and TMI-1 plants.

1.4 Document No. 32-1120675-00, "Comparison of ANO-1 and ONS-III for ATOG,"M. E. Newlin, K. J. Vavrek, C. W. Tally, 8/22/80. Function: Similar to Reference 1.1 above except applies to Oconee 1, 2, and 3 plants.

1.5 Document No. 32-1106885-00,01, "ATOG ANO-1, Rancho Seco Systems Comparison," L. Rudy, D. Newton, 11/18/83. Function: Similar to Reference 1.1 above except applies to Rancho Seco plants.

1.6 Document No. 12-1153713-00, "Comparison of DB-1 and ONS-3," B. L. Brooks, R. L. Black, 3/27/85. Function: Comparison of DB-1 ATOG Part 1 to the ONS-3 ATOG Part 1 to help DB-1 reference the ONS-3 ATOG in their Procedures Generation Package because the NRC SER on B&W plants was written on the ONS-3 ATOG.

1.7 Document No. 86-1118380-00, "ATOG-TED Analytical Data," K. J. Vavrek, M. E. Newlin, 3/21/80. Function: Specifies analytical input data for DB-1 for use and reference in the ATOG program.

1.8 Document No. 12-1155531-00, "Comparison of Rancho Seco to ONS-Unit 3," B. L. Brooks, R. L. Black, 3/26/85. Function: Same as Reference 1.6 above except that comparison is between Rancho Seco and ONS-3.

1.9 Document No. 12-1156769-00, "Comparison of Crystal River Unit 3 to Oconee Nuclear Station Unit 3," D. G. Newton, B. L. Brooks, 3/27/85. Function: Same as Reference 1.6 above except that comparison is between CR-3 and ONS-3.

2.0 Lack of Adequate Subcooling Margin

2.1 Topical Report BAW-10102, Rev. 2, "ECCS Evaluation of B&W's 205 FA NSS," R. J. Lowe, G. E. Anderson Jr., B. M. Dunn, December 1975. Function: Extensive Large Break LOCA and limited Small Break LOCA Analyses of 205 FA B&W Plants. Provided system response data for various LOCA situations.

2.2 Document No. 74-1122501-02,03, "Operator Guidelines for Small Breaks for Oconee 1, 2, and 3; Three Mile Island 1 and 2; Rancho Seco; and Arkansas 1," M. M. Horne, R. G. McAndrew, 4/6/83. Function: Generic small break LOCA guidelines for the plants listed. These guidelines deal with SBLOCA recognition and mitigation. Guidelines were updated and adopted as necessary to reflect ATOG philosophy.

2.3 B&W Dwg. No. 1132194-01, "TVA Small Break LOCA Event Tree (Dwg. #1132194)," G. E. Anderson, L. R. Cartin, J. J. Kelly, 4/7/83, Contract No. 600-5250/620-0015. Function: Provided logical evaluation and confirmation of detections and mitigation techniques for a range of small break LOCAs on 205 FA (TVA) plants.

2.4 B&W Dwg. No. 1134962-01, "Supply System Small Break LOCA Event Tree (Dwg. #1134962)," G. E. Anderson, L. R. Cartin, J. J. Kelly, 6/30/82. Function: Similar to Reference 2.3 above; applicable to WNP-1 and -4 plants.

2.5 Document No. 86-1148388-00, "Letter, J. H. Taylor (B&W) to S. A. Varga (NRC), dated 7/18/78," J. C. Seals, J. R. Paljug, 1/16/84. Function: Summarizes results of design basis analyses of a series of intermediate size SBLOCAs on the B&W 177 FA plants. Also defines the approximate largest break size within HPI capacity to keep core covered and smallest break size which will not result in saturated RCS repressurization. Results generically applicable to all B&W plants.

2.6 Document No. 86-1126621-00, "LOCA: RCS Fluid Discharge to Interconnected Systems," G. E. Anderson. Function: Similar to Reference 2.3 above; specifically, confirms effectiveness of RCS and RB isolation systems during LOCA situations. Applicability: specifically to WNP-1 and -4; generically to all B&W plants.

2.7 Document No. 86-1126056-00, "Analytical Basis to be Used in the Development of Operator Guidelines for the High Point Vents During Small Break Transients," R. C. Jones, J. A. Randazzo, 6/11/81. Function: Prescribes guidelines for use of RCS high point vents to remove residual voids after subcooling has been restored to a saturated RCS. Generically applicable to all B&W plants.

2.8 Document No. 32-1124757-00,01, "205 FA HPI Line Break with 36-Foot AFW Level and No Cavitating Venturis," D. Doss, W. Bloomfield, 9/3/81. Function: Establishes emergency secondary level at 36 feet for the B&W 205 FA plants.

2.26 Document No. 32-1102045-00, "Loss of Main Feedwater Coupled with a Stuck Open EMOV Valve in Pressurizer," N. K. Savani, W. Bloomfield, 9/27/79. Function: Analyze a loss of MFW transient coupled with a stuck open EMOV in the pressurizer for B&W 177 FA lower loop plants.

2.27 Document No. 32-1134227-00,01 "Cold Shutdown LOCA Analysis," M. A. Rinckel, R. H. Smith, W. L. Bloomfield, 9/13/83. Function: Investigate RCS repressurization following a LOCA during cold shutdown.

2.28 Document No. 32-1138230-00, "Evaluation of Effects of 1500 Plugged SG Tubes on TMI-1 Post LOCA Core Safety," G. E. Anderson, K. C. Shieh, 11/15/82. Function: Assess the impact of plugging 1500 SG tubes on existing LOCA analyses applicable to the TMI-1 plant.

2.29 Document No. 32-1141304-00, "Boiler/Condenser Effectiveness Study for TMI-1, Generic 177 FA LL, and Davis-Besse 1 Plants," L. K. Nicholson, J. R. Paljug, 3/31/83. Function: Show the relationship between the boiler-condenser mode of heat removal and HPI cooling. Applicable to the TMI-1 and DB-1 plants and generically to the B&W 177 FA plants.

2.30 Document No. 32-1148283-00 thru 02, "RCP Trip Criteria During a SBLOCA (Realistic Analysis)," M. A. Haghi, E. P. Menard, J. R. Paljug, 5/8/84. Function: Similar to that of Reference 2.16.

2.31 Document No. 32-1156623-00, "TVA CFT Line Break with a Double Ended PZR Spray Line Rupture," J. C. Seals, J. R. Paljug, 3/19/85. Function: Perform a SBLOCA analysis in which one of the core flood lines is broken coincident with a double ended pressurizer spray line rupture. Applicable to the B&W 205 FA plants.

2.32 Document No. 51-1155610-00, "Maximum Allowable SG Tube Plugging at TMI-1," G. E. Anderson, K. C. Shieh, 12/12/84. Function: Similar to that of Reference 2.28 above. Applicable to the TMI-1 plant.

2.33 Document No. 86-1102225-00, "ECCS Analysis of Small Breaks in Conjunction with Emergency Feedwater Flow Failure," W. Bloomfield, N. H. Shah, 4/24/79. Function: Analyze SBLOCA with a single failure in the EFW system. Applicable to the ONS-1, 2, 3 plants.

2.34 Document No. 86-1117679-00, "Response to Item 2B of 8/20/80 Ross Letter," S. A. Kellogg, R. C. Jones, 2/12/80. Function: Summarizes the results of Reference 2.12 above. Generically applicable to B&W 177 FA LL plants.

2.35 Document No. 86-1134226-00,01, "Cold Shutdown LOCA Analysis," R. H. Smith, W. L. Bloomfield, 9/23/83. Function: Similar to that of Reference 2.27 above.

2.16 Document No. 32-1153310-00, "Extension of RC Pump Trip Manual Action Time," E. P. Menard, J. R. Paljug, 11/15/84. Function: Confirmed: 1) need for RC pump trip early in some SBLOCA transients, 2) the existence of a reasonable amount of time (10 minutes) available for operator action to trip RC pumps, based on realistic analytical assumptions. Applicable to all B&W plants.

2.17 Document No. 86-1131176-00, "Phase III of RCP Trip Program," J. C. Seals, W. Bloomfield, 2/8/82. Function: Analytical confirmation of the need for early RC pump trip, during certain sizes of SBLOCA, on the B&W 205 FA plants.

2.18 Document No. 51-1132119-03,04, "Guidance for Post-LOCA Tripping of Reactor Coolant Pumps," G. E. Anderson, L. R. Cartin, 8/2/82, 1/11/83. Function: Provides analytical confirmation that automatic RC pump trip criteria for B&W's 205 FA plants will ensure 10CRR50.46 conformance for SBLOCA situations.

2.19 Document No. 86-1149090-00, "Task 3: Part 1 RC Pump Restart with Solid System," M. A. Rinkel, C. W. Tally, 12/22/83. Function: Portion of analytical basis for solid RCS cooldown guidance; basis for warning statement concerning possibility of pressure spikes if RC pumps restarted with a water-solid RCS. Applicable to all B&W plants.

2.20 Document No. 86-1149318-00, "Task 3: Part 2 ATOG RC Pump Restart with RV Head Void," M. A. Rinkel, C. W. Tally, 1/5/84. Function: Portion of analytical basis for cooldown procedures with RCS voids and for RC pump restart guidelines. A basis for warning statement concerning sudden RCS pressure decreases following RC pump restart with voids present. Applicable to all B&W plants.

2.21 Document No. 32-1149087-00, "Task 4: Depressurization," M. A. Rinkel, B. L. Boman, 12/13/83. Function: Part of analytical basis for guidance on plant depressurization following reactor trip. Applicable to all B&W plants.

2.22 This reference DELETED.

2.23 Document No. 32-1146797-00, "RCP Restart with RV Head Void," B. L. Boman, M. A. Rinckel, 8/17/84. Function: Calculational file for Reference 2.20 above. Generically applicable to all B&W plants.

2.24 Document No. 86-1117415-01, "Steam Generator Level Adequacy in Reflux Mode," P. Wong, G. E. Anderson, 1/29/81. Function: Summarizes the results of Reference 2.9 above. Generically applicable to B&W 177 FA plants.

2.25 Document No. 86-1149088-00, "Task 4: Depressurization," M. A. Rinckel, C. W. Tally, 12/19/83. Function: Summarizes the results of Reference 2.21 above. Generically applicable to all B&W plants.

2.26 Document No. 32-1102045-00, "Loss of Main Feedwater Coupled with a Stuck Open EMOV Valve in Pressurizer," N. K. Savani, W. Bloomfield, 9/27/79. Function: Analyze a loss of MFW transient coupled with a stuck open EMOV in the pressurizer for B&W 177 FA lower loop plants.

2.27 Document No. 32-1134227-00,01 "Cold Shutdown LOCA Analysis," M. A. Rinckel, R. H. Smith, W. L. Bloomfield, 9/13/83. Function: Investigate RCS repressurization following a LOCA during cold shutdown.

2.28 Document No. 32-1138230-00, "Evaluation of Effects of 1500 Plugged SG Tubes on TMI-1 Post LOCA Core Safety," G. E. Anderson, K. C. Shieh, 11/15/82. Function: Assess the impact of plugging 1500 SG tubes on existing LOCA analyses applicable to the TMI-1 plant.

2.29 Document No. 32-1141304-00, "Boiler/Condenser Effectiveness Study for TMI-1, Generic 177 FA LL, and Davis-Besse 1 Plants," L. K. Nicholson, J. R. Paljug, 3/31/83. Function: Show the relationship between the boiler-condenser mode of heat removal and HPI cooling. Applicable to the TMI-1 and DB-1 plants and generically to the B&W 177 FA plants.

2.30 Document No. 32-1148283-00 thru 02, "RCP Trip Criteria During a SBLOCA (Realistic Analysis)," M. A. Haghi, E. P. Menard, J. R. Paljug, 5/8/84. Function: Similar to that of Reference 2.16.

2.31 Document No. 32-1156623-00, "TVA CFT Line Break with a Double Ended PZR Spray Line Rupture," J. C. Seals, J. R. Paljug, 3/19/85. Function: Perform a SBLOCA analysis in which one of the core flood lines is broken coincident with a double ended pressurizer spray line rupture. Applicable to the B&W 205 FA plants.

2.32 Document No. 51-1155610-00, "Maximum Allowable SG Tube Plugging at TMI-1," G. E. Anderson, K. C. Shieh, 12/12/84. Function: Similar to that of Reference 2.28 above. Applicable to the TMI-1 plant.

2.33 Document No. 86-1102225-00, "ECCS Analysis of Small Breaks in Conjunction with Emergency Feedwater Flow Failure," W. Bloomfield, N. H. Shah, 4/24/79. Function: Analyze SBLOCA with a single failure in the EFW system. Applicable to the ONS-1, 2, 3 plants.

2.34 Document No. 86-1117679-00, "Response to Item 2B of 8/20/80 Ross Letter," S. A. Kellogg, R. C. Jones, 2/12/80. Function: Summarizes the results of Reference 2.12 above. Generically applicable to B&W 177 FA LL plants.

2.35 Document No. 86-1134226-00,01, "Cold Shutdown LOCA Analysis," R. H. Smith, W. L. Bloomfield, 9/23/83. Function: Similar to that of Reference 2.27 above.

2.36 Document No. 86-1139812-00, "PSC 8-81 Boron Depletion Effect Study," Y. F. Hsu, R. J. Schomaker, 1/17/83. Function: Evaluate boron depletion effects during RCS natural circulation and forced circulation phases following the boiler-condenser cooling period of a SBLOCA.

2.37 Document No. 86-1148294-00,01 "RCP Operation During SBLOCA (Best Est. Anal.)," M. A. Haghi, J. R. Paljug, 3/29/84. Function: Summarizes the results of Reference 2.30 above.

2.38 Document No. 86-1153311-00, "Extension of RC Pump Trip Manual Action Time," E. P. Menard, J. R. Paljug, 11/15/84. Function: Summarizes the results of Reference 2.16 above.

2.39 Document No. 86-1156750-00, "TVA CFT Line Break with a Double Ended PZR Spray Line Rupture," J. C. Seals, J. R. Paljug, 3/12/85. Function: Summarizes the results of Reference 2.31 above. Generically applicable to the B&W 205 FA plants.

2.40 Document No. 51-1164527-00, "DB SBLOCA Analyses Assumptions Evaluation," J. R. Paljug, B. M. Dunn, 9/12/86. Function: Evaluate the assumptions made in SBLOCA analyses for DB-1. Applicable to the DB-1 plant.

2.41 Document No. 32-1131175-00, "Phase III of the RC Pump Trip Program," J. C. Seals, W. L. Bloomfield, 2/8/82. Function: Calculational file for Reference 2.17 above.

2.42 Document No. 32-1151200-00, "Phase III of the 205-FA Plant SBLOCA Methods Program," J. C. Seals, J. R. Paljug, 8/7/84. Function: Demonstrate, via benchmark with previous models, changes to the predictions of system trends following SBLOCAs occurring as a result of the models incorporated into the revised SBLOCA evaluation model. Applicable to the 205-FA plants.

2.43 Letter number OG-92-1124, John Link (GPUN) to David Deatherage (DPCO), "IST Observations,", dated December 18, 1992. Function: Provides recommendation to revise TBD to clarify that normal cooldown limits do not apply when the RCS is saturated, and that the unaffected (or least affected) SG should be maintained as a heat sink during a cooldown with a tube rupture.

2.44 Document No. 51-1266321-01, "AIS for LOCA", G.J. Wissinger, J.C. Seals, 3/29/99. Function: Identify and control key parameters and inputs that are to be used for performing the Mark-B10K large and small break LOCA analyses for DB-1.

2.45 Document No. 86-1266216-02, "Oconee R5/M2 Mk-B9B10F LOCA Summary", D. R. Page, K. S. Pacheco, 5/20/98. Function: Summarizes the results of the RELAP5-based EM analyses of the Oconee units. These large and small break LOCA analyses were performed to support increased tube plugging of 20% with a maximum steam SG tube plugging of 25%.

3.19 Document No. 86-1123962-01, "DB-1 ATOG Transient Information Document for LOFW," P. R. Boylan, M. E. Newlin, 3/26/81. Function: Similar to Reference 3.1 above except for DB-1 plant.

3.20 Document No. 32-1146244-00, "Supply System LOFW/LOOP (Loss of Feedwater/Loss of Offsite Power) ATOG Analysis," L. J. Rudy, D. L. Smith, 7/25/83. Function: Similar to Reference 3.1 above except for Supply System Plants WNP-1 and WNP-4. Also applicable to portions of ATOG dealing with loss of offsite power events.

3.21 Document No. 86-1146245-00, "SS LOFW/LOOP ATOG Transient Information Document," L. J. Rudy, D. L. Smith, 7/29/83. Function: Same as Reference 3.20 above.

3.22 Document No. 86-1125515-00, "CR-3 (Crystal River-3) Loss of Feedwater Transient Information Document," R. B. Brownell, P. R. Boylan, 5/14/81. Function: Similar to Reference 3.1 above except applicable to CR-3 plant.

3.23 Document No. 86-1117655-00,01 "ATOG LOFW - Main Success Path," J. A. Weimer, C. W. Tally, 1/7/85. Function: Similar to Reference 3.1 above except generically applicable to B&W's 177 FA Lowered Loop Plants.

3.24 Document No. 32-1123291-00, "ATOG Analysis for TMI-1 LOFW Event, TBS Failed Open," R. B. Brownell, M. E. Newlin, 11/5/81. Function: Similar to Reference 3.1 above except applicable to TMI-1 plant.

3.25 Document No. 79-1100937-03, "ANO LOMFW Event Tree," J. M. Knoll, J. J. Kelly, B. L. Brooks, 2/20/85. Function: Provides logical evaluation and confirmation of detection and mitigation techniques for a loss of feedwater event in the ANO-1 plant. Serves as a basis for the ATOG Part I guidelines and for the ATOG Part II discussions dealing with loss of feedwater events.

3.26 Document No. 79-1121380-02, "SMUD - LOMFW Event Tree," P. R. Boylan, D.G. Newton, 3/23/84. Function: Similar to Reference 3.25 above except applicable to the Rancho Seco plant.

3.27 Document No. 79-1126191-00, "TVA - LOMFW Event Tree," R. L. Bright, P. R. Boylan, 9/25/81. Function: Similar to Reference 3.25 above except applicable to the TVA Bellefonte 1 and 2 plants.

3.28 Document No. 79-1120030-01, "Oconee - LOMFW Event Tree," P. R. Boylan, J. J. Kelly, 3/31/81. Function: Similar to Reference 3.25 above except applicable to the Oconee 1, 2, and 3 plants.

3.8 Document No. 32-1130818-00, "TVA ATOG Total Loss of Feedwater Analysis," R. L. Bright, P. R. Boylan, 3/16/82. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.9 Document No. 32-1131486-00, "TVA ATOG LOFW Excessive AFW," R. L. Bright, P. R. Boylan, 5/12/82. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.10 Document No. 86-1131779-00,01, "TVA ATOG Total LOFW Path," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.11 Document No. 86-1131930-00,01, "TVA ATOG LOFW with Excessive AFW (Transient Information Document) TID," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.12 Document No. 51-1151135-00, "TVA ATOG Analysis; LOFW; Delete (Reactor Trip) RT on MFW Pump Trip," R. W. Moore, L. J. Rudy, 4/27/84. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.13 Document No. 86-1134278-00,01, "TVA ATOG LOFW w/Loss of Primary Inventory Control (Low)," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.14 Document No. 86-1132897-00,01, "TVA ATOG Loss of Main Feedwater w/Low Secondary Pressure," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.15 Document No. 86-1130793-00,01, "TVA ATOG LOFW Main Success Path," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.16 Document No. 86-1134279-00, "TVA ATOG LOFW with Loss of Offsite Power," R. L. Bright, P. R. Boylan, 5/27/82. Function: Similar to Reference 3.1 above except for TVA Bellefonte 1 and 2 plants.

3.17 Document No. 86-1131527-00, "Midland-2 LOFW (Transient Information Document) TID," B. L. Bowman, R. S. Talley, 3/3/82. Function: Similar to Reference 3.1 above except for Midland Units 1 and 2.

3.18 Document No. 32-1123961-00, "ATOG (Davis Besse) DB-1 LOFW and Failure of AFW TRAP Analysis," P. R. Boylan, M. E. Newlin, 3/27/81. Function: Similar to Reference 3.1 above except for Davis Besse (DB) -1 plant.

3.19 Document No. 86-1123962-01, "DB-1 ATOG Transient Information Document for LOFW," P. R. Boylan, M. E. Newlin, 3/26/81. Function: Similar to Reference 3.1 above except for DB-1 plant.

3.20 Document No. 32-1146244-00, "Supply System LOFW/LOOP (Loss of Feedwater/Loss of Offsite Power) ATOG Analysis," L. J. Rudy, D. L. Smith, 7/25/83. Function: Similar to Reference 3.1 above except for Supply System Plants WNP-1 and WNP-4. Also applicable to portions of ATOG dealing with loss of offsite power events.

3.21 Document No. 86-1146245-00, "SS LOFW/LOOP ATOG Transient Information Document," L. J. Rudy, D. L. Smith, 7/29/83. Function: Same as Reference 3.20 above.

3.22 Document No. 86-1125515-00, "CR-3 (Crystal River-3) Loss of Feedwater Transient Information Document," R. B. Brownell, P. R. Boylan, 5/14/81. Function: Similar to Reference 3.1 above except applicable to CR-3 plant.

3.23 Document No. 86-1117655-00,01 "ATOG LOFW - Main Success Path," J. A. Weimer, C. W. Tally, 1/7/85. Function: Similar to Reference 3.1 above except generically applicable to B&W's 177 FA Lowered Loop Plants.

3.24 Document No. 32-1123291-00, "ATOG Analysis for TMI-1 LOFW Event, TBS Failed Open," R. B. Brownell, M. E. Newlin, 11/5/81. Function: Similar to Reference 3.1 above except applicable to TMI-1 plant.

3.25 Document No. 79-1100937-03, "ANO LOMFW Event Tree," J. M. Knoll, J. J. Kelly, B. L. Brooks, 2/20/85. Function: Provides logical evaluation and confirmation of detection and mitigation techniques for a loss of feedwater event in the ANO-1 plant. Serves as a basis for the ATOG Part I guidelines and for the ATOG Part II discussions dealing with loss of feedwater events.

3.26 Document No. 79-1121380-02, "SMUD - LOMFW Event Tree," P. R. Boylan, D.G. Newton, 3/23/84. Function: Similar to Reference 3.25 above except applicable to the Rancho Seco plant.

3.27 Document No. 79-1126191-00, "TVA - LOMFW Event Tree," R. L. Bright, P. R. Boylan, 9/25/81. Function: Similar to Reference 3.25 above except applicable to the TVA Bellefonte 1 and 2 plants.

3.28 Document No. 79-1120030-01, "Oconee - LOMFW Event Tree," P. R. Boylan, J. J. Kelly, 3/31/81. Function: Similar to Reference 3.25 above except applicable to the Oconee 1, 2, and 3 plants.

3.29 Document No. 79-1121281-01, "Davis Besse - LOMFW Event Tree," P. R. Boylan, C. W. Tally, J. J. Kelly, 1/22/81. Function: Similar to Reference 3.25 above except applicable to the Davis Besse-1 plant.

3.30 Document No. 79-1121345-01, "Crystal River - LOFW Event Tree," R. B. Brownell, J. J. Kelly, 7/1/81. Function: Similar to Reference 3.25 above except applicable to the Crystal River-3 plant.

3.31 B&W Drawing No. 1120125F-01, "Three Mile Island Unit One (TMI-1) Loss of Main Feedwater Event Tree," P. R. Boylan, R. B. Brownell, 4/8/81. Function: Similar to Reference 3.25 above except applicable to the TMI-1 plant.

3.32 B&W Drawing No. 79-1128211-01, "Midland Plant Units 1 and 2 Loss of Feedwater Event Tree," R. S. Talley, R. B. Brownell, 6/7/82. Function: Similar to Reference 3.26 above except applicable to Midland Units 1 and 2.

3.33 Document No. 86-1118379-02, "EFW Reliability for ANO-1," R. S. Enzinna, W. Weaver, 3/12/80. Function: Discusses design detail and overall reliability of EFW system.

3.34 Document Nos. 2-1094589-00 thru 2-1094594-01, "Loss of Feedwater Safety Sequence Diagrams," supplied for customer by EDS Nuclear, 3/5/80. Contents: Customer supplied information relating to sequence of equipment operation and plant response following a loss of feedwater event. Applicable to ANO-1 plant.

3.35 Document Nos. 2-1094638 through 2-1094642-00, "Loss of Feedwater Safety Sequence Diagrams," supplied for customer by EDS Nuclear, 4/25/80. Contents: Similar to Reference 3.34 above. Applicable to Oconee 1, 2, and 3 plants.

3.36 Document No. 2-1094712-00, "Emergency FW System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 3.34 above. Applicable to Oconee 1, 2, and 3 plants.

3.37 Document No. 2-1094679-00, "Emergency Feedwater System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 3.34 above. Applicable to TMI-1 plant.

3.38 Document Nos. 2-1094687 through 2-1094691-00, "Loss of Normal Feedwater Safety Sequence Diagram," supplied for customer by EDS Nuclear, 6/5/80. Applicable to TMI-1 plant. Contents: Similar to Reference 3.34 above.

3.39 Document Nos. 2-1094720 through 2-1094723-00, "Loss of Feedwater Safety Sequence Diagram," supplied for customer by EDS Nuclear, 8/19/80. Applicable to Davis Besse-1 plant. Contents: Similar to Reference 3.34 above.

3.61 Document No. 32-1121734-00,01, "Two Stuck Open Safety Valves," D. A. Doss, W. L. Bloomfield, 7/29/81. Function: Similar to that of Reference 3.1 above.

3.62 Document No. 51-1131546-00,01, "Loss of Feedwater Accident," K. C. Shieh, W. L. Bloomfield, 3/4/82. Function: Similar to that of Reference 3.1 above.

3.63 Document No. 86-1103585-00,01, "Loss of Feedwater Accident," J. C. Seals, W. L. Bloomfield, 1/12/82. Function: Summarizes the results of Reference 3.50 above. Applicable to the 177FA LL plants.

3.64 Document No. 86-1121763-00,01, "Two Stuck Open Safety Valves," D. A. Doss, W. L. Bloomfield, 6/23/81. Function: Summarizes the results of Reference 3.61 above.

3.65 Document No. 86-1126460-00, "Complete Loss of Feedwater Transient," M. A. Haghi, W. L. Bloomfield, 7/8/81. Function: Summarize all loss of FW transients at DB-1 post TMI-2 to June 1981. Applicable to the DB-1 plant.

3.66 Document No. 86-1127514-00 thru 02, "Davis-Besse 1 Loss of All Feedwater Transient, Task 140, Part 2," M. A. Haghi, B. M. Dunn, 9/28/82. T. E. Geer. Function: Summarizes the results of Reference 3.51 above. Applicable to the DB-1 plant.

3.67 Document No. 2-1094702-01, "Emergency Feedwater System Auxiliary Diagram," D. G. Newton, B. L. Brooks, 2/20/85. Function: Identify the auxiliary systems essential to the operation of emergency feedwater system and instrumentation requirements. Applicable to the ANO-1 plant.

3.68 Document No. 86-1167601-00, "Task AS-4, Operator Actions/Natural Circulation," J. C. Seals, 2/20/87. Function: Summarizes the results of Analysis Specification AS-4 that examined the effect of certain operator actions to reestablish natural circulation following a SBLOCA. Results are generically applicable to all B&W 177 FA plants.

3.69 Document No. 32-1159004-00,01 "Task AS-4 Evaluation of Operator Actions to Reestablish Natural Circulation," C. L. Ritchey, M. V. Parece, 7/27/87. Function: Calculation package for 3.68 above.

3.70 Document No. 86-1173989-01, "HPI Cooling (Task AS-5) Transient Information Document," M. V. Parece, R. H. Ellison, 2/27/89. Function: Summarizes the results of the analyses of reference 3.71. Applicable to all 177FA.

3.71 Document No. 32-1159743-00, "AS-5 HPI Cooling Analysis," M. V. Parece, J. C. Seals, 2/23/89. Function: Contains HPI cooling analyses for generic 177-FA plant. Applicable to 177FA.

3.50 Document No. 32-1103583-00,01, "Loss of Feedwater Accident," J. C. Seals, D. R. Ennis, W. L. Bloomfield, 1/12/82. Function: Similar to Reference 3.1 above. Specifically, provides verification that HPI flow will provide adequate core cooling (prevent core uncovering) during a total loss of feedwater if HPI or AFW is actuated within 20 minutes after the event starts.

3.51 Document No. 32-1127513-00 thru 03, "Davis Besse-1 Loss of All Feedwater Transient with Start-up Feedwater Pump," M. A. Haghi, B.M. Dunn, 9/28/82. Function: Similar to Reference 3.1 above; specifically, relates to operator actions and start-up feedwater pump performance during a total loss of feedwater event. Applicable to the Davis Besse-1 plant.

3.52 Document No. 32-1100479-00 thru 02, "TMI-2 LOFW - CADDS Evaluation," C. S. Banwarth, R. O. Vosburgh, 10/12/79. Function: Deals with benchmarking of CADDS code against data from 3/28/79 TMI-2 transient.

3.53 This reference deleted.

3.54 Document No. 32-1106360-00, "ANO-1 ATOG/Loss of MFW Transient Main Success Path," J. M. Knoll, C. W. Tally, 9/15/80. Function: Similar to Reference 3.1 above. Applicable to the ANO-1 plant.

3.55 Document No. 86-1118183-00, "ANO-ATOG Loss of Main FW/Failure of EFW," P. R. Boylan, C. W. Tally, 3/24/80. Function: Summarizes the results of Reference 3.3 above. Applicable to the ANO-1 plant.

3.56 Document No. 86-1118694-00," ANO-ATOG LOFW Path 6 (Excessive EFW)," P. R. Boylan, C. W. Tally, 4/22/80. Function: Summarizes the results of Reference 3.2 above. Applicable to the ANO-1 plant.

3.57 Document No. 86-1119248-00, "ANO-1 LOFW-ATOG - Main Steam Safety Valve Fails to Reseat," J. M. Knoll, C. W. Tally, 5/16/80. Function: Summarizes the results of Reference 3.4 above. Applicable to the ANO-1 plant.

3.58 Document No. 86-1119379-00, "ANO-1 LOFW-ATOG Turbine Bypass System Fails Open," J. M. Knoll, C. W. Tally, 5/22/80. Function: Summarizes the results of Reference 3.1 above. Applicable to the ANO-1 plant.

3.59 Document No. 86-1125051-00, "TMI-1 Loss of MFW Transient Information Document," M. E. Newlin, R. B. Brownell, 4/14/81. Function: Similar to that of Reference 3.1 above.

3.60 Document No. 32-1120268-00, "Resolution of PSC 49-79 - Potential RCS Pressure Buildup for Loss of all Feedwater Evaluation," M. G. Gharakhani, R. M. Hiatt, 7/8/80. Function: Analysis of RCS pressure buildup for a loss of all FW event to resolve PSC 49-79.

3.61 Document No. 32-1121734-00,01, "Two Stuck Open Safety Valves," D. A. Doss, W. L. Bloomfield, 7/29/81. Function: Similar to that of Reference 3.1 above.

3.62 Document No. 51-1131546-00,01, "Loss of Feedwater Accident," K. C. Shieh, W. L. Bloomfield, 3/4/82. Function: Similar to that of Reference 3.1 above.

3.63 Document No. 86-1103585-00,01, "Loss of Feedwater Accident," J. C. Seals, W. L. Bloomfield, 1/12/82. Function: Summarizes the results of Reference 3.50 above. Applicable to the 177FA LL plants.

3.64 Document No. 86-1121763-00,01, "Two Stuck Open Safety Valves," D. A. Doss, W. L. Bloomfield, 6/23/81. Function: Summarizes the results of Reference 3.61 above.

3.65 Document No. 86-1126460-00, "Complete Loss of Feedwater Transient," M. A. Haghi, W. L. Bloomfield, 7/8/81. Function: Summarize all loss of FW transients at DB-1 post TMI-2 to June 1981. Applicable to the DB-1 plant.

3.66 Document No. 86-1127514-00 thru 02, "Davis-Besse 1 Loss of All Feedwater Transient, Task 140, Part 2," M. A. Haghi, B. M. Dunn, 9/28/82. T. E. Geer. Function: Summarizes the results of Reference 3.51 above. Applicable to the DB-1 plant.

3.67 Document No. 2-1094702-01, "Emergency Feedwater System Auxiliary Diagram," D. G. Newton, B. L. Brooks, 2/20/85. Function: Identify the auxiliary systems essential to the operation of emergency feedwater system and instrumentation requirements. Applicable to the ANO-1 plant.

3.68 Document No. 86-1167601-00, "Task AS-4, Operator Actions/Natural Circulation," J. C. Seals, 2/20/87. Function: Summarizes the results of Analysis Specification AS-4 that examined the effect of certain operator actions to reestablish natural circulation following a SBLOCA. Results are generically applicable to all B&W 177 FA plants.

3.69 Document No. 32-1159004-00,01 "Task AS-4 Evaluation of Operator Actions to Reestablish Natural Circulation," C. L. Ritchey, M. V. Parece, 7/27/87. Function: Calculation package for 3.68 above.

3.70 Document No. 86-1173989-01, "HPI Cooling (Task AS-5) Transient Information Document," M. V. Parece, R. H. Ellison, 2/27/89. Function: Summarizes the results of the analyses of reference 3.71. Applicable to all 177FA.

3.71 Document No. 32-1159743-00, "AS-5 HPI Cooling Analysis," M. V. Parece, J. C. Seals, 2/23/89. Function: Contains HPI cooling analyses for generic 177-FA plant. Applicable to 177FA.

3.72 Document No. 51-1159699-00, "RELAP5 Analyses of Makeup/HPI Cooling for DavisBesse Unit 1," M. A. Rinkel, R. H. Ellison, 5/13/87. Function: Evaluates success paths to adequate core cooling following a complete loss of all feedwater to both steam generators. Applicable to DB-1 only.

3.73 Document No. 32-1168039-00, "LOFW F&B Cooling with Modified MU System for TED", J. A. Weimer, M. A. Rinckel, 5/4/87. Function: Analyze MU/HPI Cooling with modified Davis Besse MU system which includes two MU flow paths and MU/LPI piggyback capability.

4.0 Excessive Primary to Secondary Heat Transfer

4.1 Document No. 32-1106880-00, "Excessive FW - Success Path with ESAS – ANO Path 5," K. J. Vavrek, C. W. Tally, 6/16/80. Function: Supporting document for ATOG Part I guidance and Part II discussions dealing with detection and mitigation of an excessive FW event on the ANO-1 plant.

4.2 Document No. 86-1117945-00, "Excessive FW - Event Description and Analytical Output to ANO - Main Success Path with ESAS," K. J. Vavrek, C. W. Tally 3/26/80. Function: Similar to that of Reference 4.1 above.

4.3 Document No. 86-1118690-00,01, "ANO - Excessive FW - Main Success Path -Path 1," J. A. Weimer, C. W. Tally, 1/3/85. Function: Similar to that of Reference 4.1 above.

4.4 Document No. 32-1106881-00, "Excessive FW - Success Path without ESAS – Path 1 ANO," K. J. Vavrek, C. W. Tally, 6/16/80. Function: Similar to that of Reference 4.1 above.

4.5 Document No. 86-1119078-00, "ANO - Excessive MFW with MSSV Failed Open," P. R. Boylan, C. W. Tally, 5/9/80. Function: Similar to that of Reference 4.1 above.

4.6 Document No. 86-1119443-00, "ATOG/ANO Excessive Main Feedwater with No Emergency FW," K. J. Vavrek, C. W. Tally, 6/24/80. Function: Similar to that of Reference 4.1 above.

4.7 Document No. 86-1119075-00, "ATOG/ANO Excessive Main Feedwater with Excessive Emergency FW," K. J. Vavrek, C. W. Tally, 6/24/80. Function: Similar to that of Reference 4.1 above.

4.8 Document No. 86-1119073-00, "Excessive FW with Turbine Bypass Failure," K. J. Vavrek, C. W. Tally, 6/24/80. Function: Similar to that of Reference 4.1 above.

4.31 Document No. 32-1119324-00, "ANO ATOG Test for TRAP Steam Pressure Response," P. R. Boylan, C. W. Tally, 5/21/80. Function: Similar to Reference 4.1 above.

4.32 Document No. 86-1125714-00, "OTSG Level Curves for DB-1 Excessive Main Feedwater, L. J. Rudy, M. E. Newlin, 5/11/81." Function: Similar to Reference 4.1 above except for Davis Besse-1 Plant.

4.33 Document No. 32-1106466-00,01, "SSLB-Event Description of Success Path #1," R. J. Schomaker, L. B. Wimmer, 5/7/80. Function: Supporting document for ATOG Part I guidelines and Part II discussions related to detection and mitigation of a small steam line break. Applicable to the ANO-1 plant.

4.34 Document No. 86-1117538-00,01, "SSLB-Event Description for Success Path #1," R. J. Schomaker, L. B. Wimmer, 5/7/80. Function: Similar to Reference 4.33 above. Applicable to ANO-1 plant.

4.35 Document No. 86-1118050-00, "DYSID vs. TRAP Comparison for ATOG SSLB Success Path 1," M. S. Kai, R. J. Schomaker, 3/31/80. Function: Similar to Reference 4.33 above. Applicable to ANO-1 plant.

4.36 Document No. 86-1106760-00, "Power Train Analysis of Steam Line Break," J. M. Knoll, C. W. Tally, 12/7/79. Function: Similar to Reference 4.33 above. Applicable to ANO-1 plant.

4.37 Document No. 86-1123200-00, "Transient Information Document for Small Steam Line Break Events at ONS-III," R. H. Ellison, R. J. Schomaker, 4/1/81. Function: Similar to Reference 4.33 above. Applicable to Oconee 1, 2, and 3 plants.

4.38 Document No. 86-1123784-00, "TMI-1 ATOG Transient Information Document for SSLB," J. S. Schwenn, R. J. Schomaker, 4/24/81. Function: Similar to Reference 4.33 above. Applicable to TMI-1 plant.

4.39 Document No. 51-1120507-00, "Crystal River III ATOG Data Base," M. Lockey, R. J. Schomaker, 10/14/80. Function: Compilation of available information for the ATOG Data Base - Crystal River III.

4.40 Document No. 86-1125293-00, "CR-3 Small Steam Line Break Event Transient Information Document," J. S. Schwenn, R. J. Schomaker, 7/30/81. Function: Similar to Reference 4.33 above. Applicable to Crystal River-3 plant.

4.41 Document No. 86-1127102-00,01, "ATOG SMUD SSLB Transient Information Document," L. J. Rudy, D. G. Newton, 11/22/83. Function: Similar to Reference 4.33 above. Applicable to Rancho Seco plant.

4.20 Document No. 79-1120034-01, "Oconee - EMFW Event Tree," K. J. Vavrek, M. E. Newlin, 2/20/81. Function: Same as for Reference 4.18 above except for Oconee plant.

4.21 Document No. 79-1121312-01, "Davis Besse - EMFW Event Trees," K. J. Vavrek, J. J. Kelly, 6/4/81. Function: Same as Reference 4.18 above except for Davis Besse-1 Plant.

4.22 Document No. 79-1121415-02, "Crystal River - EMFW Event Tree," L. J. Rudy, J. J. Kelly, 11/24/80. Function: Same as for Reference 4.18 above except for Crystal River-3 plant.

4.23 Document (B&W Dwg) No. 1121221F-01, "TMI-1 Excess Main Feedwater Event Tree," L. J. Rudy, M. E. Newlin, 10/6/80. Function: Same as for Reference 4.18 above except for TMI-1 plant.

4.24 Document No. 79-1128213-01, "Excess MFW Event Tree - Midland Unit 2," R. S. Talley, C. W. Tally, 6/7/82. Function: Same as for Reference 4.18 above except for Midland Units 1 and 2.

4.25 Document Nos. 2-1094608 through 2-1094613-01, "Excessive Feedwater Safety Sequence Diagram," supplied for customer (ANO-1) by EDS Nuclear, 3/5/80. Contents: Customer supplied information relating to sequences of equipment operation and plant response following an excessive feedwater event. Applicable to ANO-1 plant.

4.26 Document Nos. 2-1094615 through 2-1094619-00, "Excessive Feedwater Safety Sequence Diagram," supplied for customer (ONS) by EDS Nuclear, 4/25/80. Contents: Similar to Reference 4.25 above except applicable to Oconee Nuclear Station.

4.27 Document Nos. 2-1094666 through 2-1094670-00, "Excessive Feedwater Safety Sequence Diagram," supplied for customer (TMI-1) by EDS Nuclear 6/5/80. Contents: Same as Reference 4.25 above except applicable to TMI-1 plant.

4.28 Document Nos. 2-1094736 through 2-1094739-00, "Excessive Feedwater Safety Sequence Diagram," supplied for customer (DB-1) by EDS Nuclear, 8/19/80. Contents: Same as Reference 4.25 above except applicable to Davis Besse-1 Nuclear Station.

4.29 Document Nos. 2-1094859 through 2-1094863-00, "Excessive Feedwater Safety Sequence Diagram," supplied for customer (CR-3) by EDS Nuclear, 9/23/80. Contents: Same as Reference 4.25 above except applicable to Crystal River-3 Nuclear Plant.

4.30 Document No. 2-1094964B-00, "SMUD Rancho Seco Unit 1 Control Logic Diagram Feedwater Isolation Logic B, Rancho Seco, 2/1/77." Contents: Logic diagram for feedwater isolation. Applicable to Rancho Seco Nuclear Plant.

4.31 Document No. 32-1119324-00, "ANO ATOG Test for TRAP Steam Pressure Response," P. R. Boylan, C. W. Tally, 5/21/80. Function: Similar to Reference 4.1 above.

4.32 Document No. 86-1125714-00, "OTSG Level Curves for DB-1 Excessive Main Feedwater, L. J. Rudy, M. E. Newlin, 5/11/81." Function: Similar to Reference 4.1 above except for Davis Besse-1 Plant.

4.33 Document No. 32-1106466-00,01, "SSLB-Event Description of Success Path #1," R. J. Schomaker, L. B. Wimmer, 5/7/80. Function: Supporting document for ATOG Part I guidelines and Part II discussions related to detection and mitigation of a small steam line break. Applicable to the ANO-1 plant.

4.34 Document No. 86-1117538-00,01, "SSLB-Event Description for Success Path #1," R. J. Schomaker, L. B. Wimmer, 5/7/80. Function: Similar to Reference 4.33 above. Applicable to ANO-1 plant.

4.35 Document No. 86-1118050-00, "DYSID vs. TRAP Comparison for ATOG SSLB Success Path 1," M. S. Kai, R. J. Schomaker, 3/31/80. Function: Similar to Reference 4.33 above. Applicable to ANO-1 plant.

4.36 Document No. 86-1106760-00, "Power Train Analysis of Steam Line Break," J. M. Knoll, C. W. Tally, 12/7/79. Function: Similar to Reference 4.33 above. Applicable to ANO-1 plant.

4.37 Document No. 86-1123200-00, "Transient Information Document for Small Steam Line Break Events at ONS-III," R. H. Ellison, R. J. Schomaker, 4/1/81. Function: Similar to Reference 4.33 above. Applicable to Oconee 1, 2, and 3 plants.

4.38 Document No. 86-1123784-00, "TMI-1 ATOG Transient Information Document for SSLB," J. S. Schwenn, R. J. Schomaker, 4/24/81. Function: Similar to Reference 4.33 above. Applicable to TMI-1 plant.

4.39 Document No. 51-1120507-00, "Crystal River III ATOG Data Base," M. Lockey, R. J. Schomaker, 10/14/80. Function: Compilation of available information for the ATOG Data Base - Crystal River III.

4.40 Document No. 86-1125293-00, "CR-3 Small Steam Line Break Event Transient Information Document," J. S. Schwenn, R. J. Schomaker, 7/30/81. Function: Similar to Reference 4.33 above. Applicable to Crystal River-3 plant.

4.41 Document No. 86-1127102-00,01, "ATOG SMUD SSLB Transient Information Document," L. J. Rudy, D. G. Newton, 11/22/83. Function: Similar to Reference 4.33 above. Applicable to Rancho Seco plant.

4.42 Document No. 86-1125543-00, "DB-1 ATOG SSLB TID," R. H. Ellison, M. Liebermann, 5/21/81. Function: Similar to Reference 4.33 above. Applicable to Davis- Besse-1 plant.

4.43 Document Nos. 32-1137021-00 through -02, "CPC SLB DNB Analyses," M. V. Parece, S. Skidmore, 8/4/83. Function: Similar to Reference 4.33 above. Applicable to Midland 1 and 2 plants.

4.44 Document No. 32-1118994-00, "ANO-1 ATOG SSLB Inside Containment," R. J. Schomaker, L. B. Wimmer, 9/22/80. Function: Similar to Reference 4.33 above. Applicable to ANO-1 plant.

4.45 Document No. 32-1131202-00, "ATOG TVA Small Steam Line Break - Stuck Open MSSV," B. L. Bowman, P. R. Boylan, 3/10/82. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.46 Document No. 32-1131766-00,01, "ATOG TVA Small Steam Line Break - 2.5 ft^2 Unisolable Leak," B. L. Bowman, P. R. Boylan, 2/14/83. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.47 Document No. 86-1131200-00,01, "ATOG TVA Small Steam Line Break – Main Success Path," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.48 Document No. 86-1131201-00,01, "ATOG TVA Small Steam Line Break – Stuck Open MSSV," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.49 Document No. 86-1131767-00 thru 02, "ATOG TVA Small Steam Line Break," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.50 Document No. 86-1132572-00,01, "ATOG TVA Small Steam Line Break - Loss of Primary Inventory (Low)," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.51 Document No. 86-1132573-00 thru 02, "ATOG TVA Small Steam Line Break – Loss of Offsite Power (LOOP)," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.52 Document No. 86-1132574-00,01, "ATOG TVA Small Steam Line Break - Loss of Secondary Inventory Control," L. J. Rudy, D. G. Newton, 5/16/84. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.53 Document No. 32-1130515-00,01, "ATOG TVA Small Steam Line Break – Main Success Path," J. S. Muransky, B. L. Boman, 3/14/83. Function: Similar to Reference 4.33 above. Applicable to Bellefonte 1 and 2 plants.

4.54 Document Nos. 02-1094987-00, 1150804E-00, 02-1094989-00, 02-1094990-00, 02-1094991-00, 02-1094992-01, "SMUD - Small Steam Line Break Safety Sequence Diagram," supplied for customer by EDS Nuclear, 6/15/81. Contents: Customer supplied information relating to sequence of equipment failure and plant responses following a small steam line break. Applicable to Rancho Seco plant.

4.55 Document Nos. 2-1094583 through 2-1094588-01, "Small Steam Line Break Safety Sequence Diagram," supplied for customer by EDS Nuclear, 3/5/80. Contents: Similar to Reference 4.54 above. Applicable to the ANO-1 plant.

4.56 Document Nos. 2-1094620 through 2-1094625-00, "Small Steam Line Break - Safety Sequence Diagram," supplied for customer by EDS Nuclear, 4/25/80. Contents: Similar to Reference 4.54 above. Applicable to the Oconee 1, 2 and 3 plants.

4.57 Document Nos. 2-1094671 through 2-1094676-00, "Small Steam Line Break Safety Sequence Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 4.54 above. Applicable to TMI-1 plant.

4.58 Document Nos. 2-1094740 through 2-1094744-00, "Small Steam Line Break Safety Sequence Diagram," supplied for customer by EDS Nuclear, 8/19/80. Contents: Similar to Reference 4.54 above. Applicable to Davis Besse-1 plant.

4.59 Document Nos. 2-1094864 through 2-1094870-00, "Small Steam Line Break Safety Sequence Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 4.54 above. Applicable to Crystal River-3 plant.

4.60 Document No. 79-1121462-02, "SMUD Small Steam Line Break Event Tree," J. S. Schwenn, R. J. Schomaker, 11/20/80. Function: Provides logical evaluation and confirmation of detection and mitigation techniques for a small steam line break; serves as a basis for guidance and discussions on this type of event. Applicable to Rancho Seco plant.

4.61 Document No. 79-1126281-01, "TVA Small Steam Line Break Event Tree,." P. R. Boylan, J. J. Kelly, 9/30/81. Function: Similar to Reference 4.60 above. Applicable to Bellefonte 1 and 2 plants.

4.62 Document No. 79-1100954-02, "ANO - Small Steam Line Break Event Tree," R. J. Schomaker, J. J. Kelly, 10/26/79. Function: Similar to Reference 4.60 above. Applicable to ANO-1 plants.

4.63 Document No. 79-1121381-01, "Davis-Besse Small Steam Line Break Event Tree," R. H. Ellison, J. J. Kelly, 10/22/80. Function: Similar to Reference 4.60 above. Applicable to Davis Besse-1 plant.

4.64 Document No. 79-1121454-01, "Small Steam Line Break Event Tree," R. H. Ellison, R. J. Schomaker, 12/2/80. Function: Similar to Reference 4.60 above. Applicable to Crystal River-3 plant.

4.65 B&W Drawing No. 1120031F-01, "Oconee III Small Steam Line Break Event Tree," R. H. Ellison, J. J. Kelly, 3/27/81. Function: Similar to Reference 4.60 above. Applicable to Oconee 1, 2 and 3 plants.

4.66 B&W Drawing No. 1120141F-00, "TMI-1 Small Steam Line Break Event Tree," J. S. Schwenn, R. J. Schomaker, 9/29/80. Function: Similar to Reference 4.60 above. Applicable to TMI-1 plant.

4.67 Document No. 79-1127643-01, "CPCo SSLB Event Tree for ATOG," J. S. Schwenn, J. J. Kelly, 10/12/81. Function: Similar to Reference 4.60 above. Applicable to Midland 1 and 2 plants.

4.68 Document No. 86-1131368-00, "CPCo Small Steam Line Break Event Transient Information Document," J. S. Schwenn, R. J. Schomaker, 3/29/82. Function: Similar to Reference 4.33 above. Applicable to Midland 1 and 2 plants.

4.69 Document No. 32-1139576-00 , "WPPSS ATOG Small Steam Line Break - 1 Ft^2 Break," M. V. Parece, S. L. Johnson, 3/30/83. Function: Similar to Reference 4.33 above. Applicable to WNP 1 and 4 plants.

4.70 Document No. 32-1106879-00, "Power Train Runs for Excessive Feedwater," K. J. Vavrek, C. W. Tally, 2/22/80. Function: Similar to that of Reference 4.1 above.

4.71 Document No. 32-1106883-00, "Excess MFW with MSSV Failed Open - ANO Path 3B," P. R. Boylan, C. W. Tally, 5/16/80. Function: Similar to that of Reference 4.1 above. Applicable to the ANO-1 plant.

4.72 Document No. 86-1119307-00, "ANO-ATOG Excessive FW with Failed Open MSSV (no ESAS)," P. R. Boylan, C. W. Tally, 5/13/80. Function: Summarizes the results of Reference 4.5 above. Applicable to the ANO-1 plant.

4.73 Document No. 32-1117857-00, "DYSID vs. TRAP Comparison for ATOG,"M. S. Kai, R. J. Schomaker, 3/31/80. Function: Similar to that of Reference 4.33 above.

4.74 Document No. 32-1123198-00, "ATOG-ONS-3 TBS Failure Analysis," R. H. Ellison, R. J. Schomaker, 2/27/81. Function: Calculational file for Reference 4.37 above. Applicable to the ONS-3 plant.

4.75 Document No. 32-1124013-00, "DB-1 ATOG SSLB Analysis," R. H. Ellison, R. J. Schomaker, 5/22/81. Function: Similar to Reference 4.33 above. Applicable to the DB-1 plant.

4.76 Document No. 86-1119507-00, "ANO-1 ATOG SSLB - Inside Containment," R. J. Schomaker, L. B. Wimmer, 8/22/80. Function: Summarizes the results of Reference 4.44 above. Applicable to the ANO-1 plant.

4.77 Document No. 86-1125292-00, "Revisions to ANO-1 ATOG Figures for the TMI-1 SSLB," J. S. Schwenn, R. J. Schomaker, 4/14/81. Function: Similar to that of Reference 4.33 above. Applicable to the TMI-1 plant.

4.78 Document Nos. 02-1094982-00, 02-1094983-00, 1150803-00, 1150807-00, 02-1094986-01, "Excessive Feedwater Safety Sequence Diagram," supplied for the customer by EDS Nuclear, 6/15/81. Contents: Similar to that of Reference 4.25 above. Applicable to the Rancho Seco plant.

4.79 Document No. 32-1106759-00, "Power Train Analysis of Steamline Break," J. M. Knoll, C. W. Tally, 12/7/79. Function: Calculational File for Reference 4.36 above.

4.80 NUREG 1195, "Loss of Integrated Control System Power and Overcooling Transient at Rancho Seco on December 26, 1985," US NRC, 12/31/85. Function: Results of the NRC review of the December 26, 1985 Rancho Seco event.

5.0 Steam Generator Tube Rupture Event

5.1 Document No. 32-1107031-00: "ANO-1 OTSG Tube Rupture Transient Analysis (ATOG)," M. Liebmann, M. V. Costello, 3/17/80. Function: Analysis of ANO-1 plant response to SGTR using a digital thermal hydraulics code. Generally applicable to all B&W plants.

5.2 Document No. 86-1118041-00: "ANO-1 OTSG Tube Rupture Transient Analysis (ATOG)," M. Liebmann, M. V. Costello, 3/17/80. Function: Summary document for Reference 5.1 above.

5.3 Document No. 32-1118044-00: "ANO-1 OTSG Tube Rupture w/LOOP Analysis (ATOG)," M. Liebmann, M. V. Costello, 4/30/80. Function: Identical to Reference 5.1 except with loss-of-offsite power coincident with rupture. Applicable to all B&W plants.

5.4 Document No. 51-1148397-00: "SGTR Mitigation in 177 FA Plants," M. V. Parece, R. H. Ellison, 6/26/84. Function: Engineering evaluation document providing guidance and discussions concerning the detection and mitigation of SGTR. Generically applicable to all 177 plants.

5.5 Document No. 32-1148117-00: "177 FA SGTR Best Estimate Analysis," M. A. Haghi, M. V. Parece, 1/31/84. Function: Computer analysis of SGTR on ANO-1 plant design to show that operator actions as per ATOG preclude loss-of-subcooling margin. Generically applicable to all B&W 177-FA lowered loop plants.

5.6 Document No. 86-1148118-00: "177 FA SGTR Best Estimate Analysis," M. V. Parece, R. H. Ellison, 1/31/84. Function: Summary document for Reference 5.5 above.

5.7 Document No. 32-1150650-00,01: "Davis-Besse REDBL5 SGTR Analysis," D. W. Throckmorton, M. V. Parece, 10/21/85. Function: Identical to Reference 5.5 above but applicable to TED's Davis-Besse plant only.

5.8 This reference deleted.

5.9 Document No. 51-1146263-00: "Tube Rupture and Solid Plant Operation Simulator Runs," B. L. Bowman, H. A. Bailey, 8/2/83. Function: Document typical plant response to SGTR and solid plant using OFR simulator. Generically applicable to all B&W plants.

5.10 This reference deleted.

5.11 Document No. 12-1148447-00: "Analysis of Plant Response and Environmental Consequences During SGTR at the Ginna Power Plant." Function: Westinghouse analysis of Ginna SGTR event. General system response and "lessons learned" are applicable to all B&W plants.

5.12 Document No. 32-9857-00: "Safety Assessment of SG Tube Leakage at the Oconee Nuclear Power Station," M. V. Bonaca, R. J. Schomaker, 3/28/79. Function: Similar to Reference 5.11 above, except performed for Oconee SGTR event. Applicable to all B&W plants.

5.13 Document No. 77-1147486-02: "Assessment of Single Tube Rupture in 1 OTSG w/small Tube Leak in Other," M. V. Parece, R. H. Ellison, 4/17/84. Function: Similar to Reference 5.4 above. Generically applicable to the B&W 205 FA plants.

5.14 Document No. 77-1147487-01: "An Evaluation of Plant control During MSGTR in Both OTSGs," M. V. Parece, R. H. Ellison, 4/10/84. Function: Similar to Reference 5.4 above. Generically applicable to the B&W 205 FA plants.

5.15 Document No. 79-1100960-02: "ANO - SGTR Event Tree," M. Liebmann, J. J.Kelly, 10/26/79. Function: Provides logical evaluation and confirmation of detection and mitigation techniques for a SG tube rupture event; serves as a basis for guidance and discussions on this type of event. Applicable to ANO-1 plant.

5.16 Document No. 79-1122865-01: "SMUD - SGTR Event Tree," T. A. Daniels, E.W. Swanson, 1/16/81. Function: Similar to Reference 5.15 above. Applicable to Rancho Seco plant.

5.17 Document No. 79-1126268-00: "TVA - SGTR Event Tree," R. J. Schomaker, J. J. Kelly, 9/10/81. Function: Similar to Reference 5.15 above. Applicable to Bellefonte 1 and 2 plants.

5.18 Document No. 79-1128179-00: "Consumers - SGTR Event Tree," R. S. Enzinna, J. J. Kelly, 10/22/81. Function: Similar to Reference 5.15 above. Applicable to Midland 1 and 2 plants.

5.19 Document No. 79-1120056-01: "Oconee - SGTR Event Tree," T. A. Daniels, E. W. Swanson, 9/9/80. Function: Similar to Reference 5.15 above. Applicable to Oconee 1, 2, and 3 plants.

5.20 Document No. 79-1121390-00: "Davis-Besse - SGTR Event Tree," T. A. Daniels, E. W. Swanson, 11/18/80. Function: Similar to Reference 5.15 above. Applicable to Davis-Besse plant.

5.21 Document No. 79-1121366-00: "Crystal River - SGTR Event Tree," L. B. Wimmer, E. W. Swanson, 11/11/80. Function: Similar to Reference 5.15 above. Applicable to Crystal River-3 plant.

5.22 Document No. 79-1120137-01: "Steam Generator Tube Rupture Event Tree," L. R. Carter, E. W. Swanson, 9/9/80. Function: Similar to Reference 5.15 above. Applicable to TMI-1 plant.

5.23 Document Nos. 02-1094595-00, 02-1094596099, 02-1094597-01, 02-1094598-01, 02-1024599-01, 02-1094600-00, 02-1094601-01: "SG Tube Rupture Safety Sequence Diagram," supplied for customers by EDS Nuclear and B&W, 3/5/80. Contents: Customer-supplied information relating to sequence of equipment failure and plant responses following a SG tube rupture. Applicable to the ANO-1 plant.

5.24 Document Nos. 02-1094626 through 02-1094631-00: "SG tube Rupture Safety Sequence Diagram," supplied for customers by EDS Nuclear, 4/25/80. Contents: Similar to Reference 5.23 above. Applicable to Oconee 1, 2, and 3 plants.

5.25 Document Nos. 02-1094660 through 02-1094665-00: "SG Tube Rupture Safety Sequence Diagram," supplied for customers by EDS Nuclear, 6/5/80. Contents: Similar to Reference 5.23 above. Applicable to TMI-1 plant.

5.26 Document Nos. 02-1094730 through 02-1094735-00: "SG tube Rupture Safety Sequence Diagram," supplied for customer by EDS Nuclear, 8/19/80. Contents: Similar to Reference 5.23 above. Applicable to Davis-Besse Unit 1.

5.27 Document Nos. 02-1094852 through 02-1094858-00: "SG tube rupture Safety Sequence Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 5.23 above. Applicable to Crystal River-3 plant.

5.28 Document No. 32-1119841-00: "TVA ATOG Steam Generator Tube Rupture IEOTSG Overfill Analysis," T. A. Daniels, L. S. LeBeam, 8/10/82. Function: RELAP5 digital computer code analysis of IEOTSG secondary fill rates vs. subcooling margin during SGTR. Applicable to 205-FA plants.

5.29 Document No. 32-1153343-00: "SGTR Dose Calcs for TRACC Limits," M. V. Parece, S. Skidmore, 5/6/85. Function: Thyroid and whole-body radiation dose calculations are performed to show that off-site radiation doses are acceptable during SGTR. Applicable to all B&W 177-FA plants.

5.30 Document No. 86-1153344-00: "SGTR Dose Calcs for TRACC Limits,: M. V. Parece, S. Skidmore, 5/6/85. Function: Summary document for Reference 5.29 above.

5.31 Document Nos. 02-1094976-00, 02-1150805-00, 02-1148673-00, 02-1094979-00, 02-1094980-00,02-1094981-01: "SG tube Rupture Safety Sequence Diagram," supplied for customer by EDS Nuclear and B&W, 6/15/81. Contents: Similar to Reference 5.23 above. Applicable to Rancho Seco plant.

5.32 Document No. 51-1148397-00, Attachment pages 34 through 43, United States NRC, Office of Inspection and Enforcement, "Steam Generator Tube Ruptures at Two PWR Plants," I. E. Information Notice No. 79-27, No. 16, 1979. Function: Supporting document for Reference 5.4 above. Included in Ref. 5.4 above.

5.33 Document No. 51-1148397-00, Attachment pages 45 through 49, "Steam Generator Tube Rupture at R. E. Ginna Nuclear Power Plant," Nuclear Safety , Vol. 24, No. 1, Jan.-Feb. 1983. Function: Supporting document for Reference 5.4 above. Included in Ref. 5.4 above.

5.34 Document No. 51-1148397-00, Attachment pages 46 through 64, INPO Significant Operation Experience Report, No. 83-2, "Steam Generator Tube Ruptures," May 3, 1983. Function: Supporting document for Reference 5.4 above. Included in Ref. 5.4 above.

5.35 Document 51-1148397-00, Attachment pages 66 through 77, "Steam Generator Tube Rupture Transient for Pressurized Water Reactors," D. Dobranich, R. J. Henniger, and N. S. DeMuth, Los Alamos National Laboratory, LA-UR-82-2498. Function: Supporting document for Reference 5.4 above. Included in Ref. 5.4 above.

5.36 Document 51-1148397-00, Attachment pages 173 through 216, L. O. Mayer, Northern States Power Company, Minneapolis, Minnesota to J. G. Keppler, U. S. NRC, Glen Ellyn, Illinois, "Prairie Island Unit 1 Steam Generator Tube Break Licensee Event Report," October 16, 1979, Docket No. 50-282, License No. DPR-42, LER 79-27. Function: Supporting document for Reference 5.4 above. Included in Ref. 5.4 above.

5.37 Document No. 86-1118045-00, "ANO-1 OTSG Tube Rupture w/LOOP Analysis (ATOG)," M. Liebmann, M. V. Costello, 4/29/80. Function: Summarizes the results of Reference 5.3 above. Applicable to the ANO-1 plant.

5.38 Document No. 86-1120490-00, "OTSG Tube Rupture Alternate Paths (ANO-1, ATOG)," M. Liebmann, R. J. Schomaker, 8/22/80. Function: Similar to that of Reference 5.1 above. Applicable to the ANO-1 plant.

5.39 Document No. 47-1164369-00, "Response to NRC Questions on the Steam Generator Tube Rupture Chapter of the B&W Owners Group Emergency Operating Procedures Technical Bases Document," R. L. Black, B. L. Brooks, 7/10/86. Function: A summary of responses to the NRC relating primarily to questions on the SGTR chapter of the TBD.

5.40 Document No. 32-1206318-00,-01, "Activity Releases for AS-1," M. V. Parece, T. H. Ramin, 10/9/91, 12/17/91. Function: Provides calculation results for input to CRAC2 analyses for determining off-site doses during tube ruptures. Applicable to all 177FA plants.

5.41 Document No. 86-1206319-00, "Activity Releases for AS-1," M. V. Parece, T. H. Ramin, 10/9/91. Function: Summary file for Reference 5.40. Applicable to all 177FA plants.

5.42 Document No. 77-1206359-00, "Final AS-1 Report," M. V. Parece, T. H. Ramin, to be released. Function: Provides final results of CRAC2 analyses for determining off- site doses during tube ruptures. Applicable to all 177FA plants.

5.43 Document No. 51-1203209-00, "FR in Comp Review," D. B. Mitchell, J. T. Willse, 6/6/91. Function: Provides justification to remove the fuel rod in compression curves as limits on plant operations. Specifically applicable to Davis Besse, but generally applicable to all 177FA plants with MK-B fuel.

5.44 Document No. 18-1173987-01, "RCS Functional Specifications for ANO-1," R. W. Moore, 5/31/89. Function: Provides general functional requirements for the design and operation of the Reactor Coolant System (RCS) components. Applicable to ANO-1.

5.45 Document No. 18-1005812-02, "RCS Functional Specifications for CR-3," D. L. Smith, 8/5/83. Function: Provides general functional requirements for the design and operation of the Reactor Coolant System (RCS) components. Applicable to CR-3.

5.46 Document No. 18-1149327-00, "RCS Functional Specifications for DB-1," J. R. Burris, 5/1/84. Function: Provides general functional requirements for the design and operation of the Reactor Coolant System (RCS) components. Applicable to DB-1.

5.47 Document No. 18-1130828-03, "RCS Functional Specifications for OC-1, 2, & 3," R. W. Moore, 6/9/89. Function: Provides general functional requirements for the design and operation of the Reactor Coolant System (RCS) components. Applicable to OC-1, 2, & 3.

5.48 Document No. 18-1173549-01, "RCS Functional Specifications for TMI-1," R. W. Moore, 5/26/89. Function: Provides general functional requirements for the design and operation of the Reactor Coolant System (RCS) components. Applicable to TMI-1.

5.49 Document No. 18-1092000015-09, "RCS Functional Specifications for BLN-1 & 2," J. R. Burris, 2/28/86. Function: Provides general functional requirements for the design and operation of the Reactor Coolant System (RCS) components. Applicable to BLN-1 & 2.

6.0 Inadequate Core Cooling

6.1 Document No. 32-1105235-00, "Correlation of Clad Temperature to Core Exit Fluid Temperature on Different Power Shapes," J. A. Randazzo, R. L. Lowe, 11/6/79. Function: Determination of relationship between exit fluid temperature and fuel cladding for 177 FA plants. Relationship is utilized in the discussion of recognition and mitigation of the stages of ICC.

6.2 Document No. 32-1126993-00, "Incore Thermocouple Utilization of 205 FA Plants," J. A. Randazzo, W. L. Bloomfield, 9/2/81. Function: Same as Reference 6.1 above except for 205 FA plants.

6.3 Document No. 51-1155643-00, "The Basis for Inadequate Core Cooling Operating Guidelines for 205 FA Plants," D. Menard, J. R. Paljug, 1/7/85. Function: Discussion and explanation of prescribed actions for recognizing and responding to core uncovering conditions. Applicability: specifically to Bellefonte 1 and 2; generically to all B&W plants.

6.4 Document No. 79-1143529-00, "205 FA ICC ATOG Event Tree," D. Mulvihill, J. R. Paljug, 2/28/84. Function: Provided logical evaluation and verification of detection and mitigation techniques for dealing with and recovering from inadequate core cooling conditions. A basis for the ICC discussion for the 205 FA plants. Generically applicable to all B&W plants.

6.5 Document No. 32-1132603-00, "Correlation of Cladding Temperature Vs. Core Exit Fluid Temperature," Y. F. Hsu, W. L. Bloomfield, 5/5/82. Function: Provides correlation at 2200°F T_{clad} for thermocouple qualification purposes. Generically applicable to B&W 177 FA plants.

6.6 Document No. 69-1224353-01,02, Generic Severe Accident Guideline (GSAG) and Generic Severe Accident Guideline Technical Bases Document (GSAGTBD), T. L. Book, B. L. Brooks, 3/11/94, 3/31/2000. Function: The GSAGTBD provides the utilities with a severe accident mitigation basis. The GSAG provides utilities with a suggested method of severe accident mitigation.

7.0 Cooldown Methods

7.1 Topical Report BAW-1801: "Single Loop Natural Circulation Cooldown," C. W. Tally, J. D. Carlton, 8/82. Function: Digital computer code analysis of single loop natural circulation cooldown on lowered loop 177 FA plant. Generically applicable to all B&W lowered loop 177-FA.

7.2 Document No. 86-1132874-00, "TMI-1 SBLOCA Analysis for Thermal Shock Evaluations," Y. F. Hsu, L. R. Cartin, 5/6/82. Function: Part of analytical basis for defining RV pressure-temperature thermal stress limits. Applicable to TMI-1 plant.

7.3 Document No. 77-1152846-00, "Stress Analysis of the Reactor Vessel Closure Region for a Natural Circulation Cooldown Transient," R. L. Black, R. J. Schomaker, 8/7/84. Function: Similar to Reference 7.2 above. Generically applicable to all B&W 177 FA plants.

7.4 Document No. 32-1128155-00,01, "Thermal Shock Duke," M. A. Haghi, W. Bloomfield, 1/25/82, Contract No. 582-7218. Function: Provided additional technical bases for existing thermal shock analyses. Confirmed the need for operator action to prevent thermal shock, as prescribed by guidelines for HPI flow control and actions with RC pumps.

7.5 Topical Report BAW-1648, "Thermal Mechanical Report - Effect of HPI on Vessel Integrity for Small Break LOCA Event with Extended Loss of Feedwater," November 1980. Function: Discussed potential for and possible conditions leading to RV thermal stress. Explained need for, and nature of, operator actions needed to prevent RV brittle fracture. Provides a basis for discussions and guidance on HPI flow control, RC pump operation, and cooldown limits, particularly during LOFW conditions.

7.6 Document No. 2-1095001-00, "SMUD - Turbine Bypass and Atmospheric Dump," supplied for the customer by EDS Nuclear, 6/8/81. Contents: Part of analytical basis for evaluation of methods and effectiveness of operation for equipment vital to maintenance, during transients, of control over the five fundamental functions of:

1. Reactivity Control
2. RCS Pressure Control
3. RCS Inventory Control
4. Secondary Pressure Control
5. Secondary Inventory Control

7.7 Document No. 2-1095002-00, "SMUD - Reactor Coolant Pressure Control System Auxiliary Diagram," supplied for the customer by EDS Nuclear, 6/8/81. Contents: Similar to Reference 7.6 above.

7.8 Document No. 2-1095000-00, "SMUD - Turbine Control System Auxiliary Diagram," supplied for the customer by EDS Nuclear, 6/8/81. Contents: Similar to Reference 7.6 above.

7.9 Document No. 2-1094684-00, "Turbine Control (EHC) System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 7.6 above. Applicable to TMI-1.

7.10 Document No. 2-1094685-00, "Turbine Bypass and Atmospheric Dump System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 7.6 above. Applicable to TMI-1.

7.11 Document No. 2-1094686-00, "RC Pressure Control System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 7.6 above.

7.12 Document No. 2-1094707-00, "Electro Hydraulic Control System Auxiliary Diagram," supplied for customer by EDS Nuclear, 3/5/80. Contents: Similar to Reference 7.6 above. Applicable to ANO-1.

7.13 Document No. 2-1094708-01, "Turbine Bypass System Auxiliary Diagram," D G. Newton, B. L. Brooks, 2/20/85. Contents: Similar to Reference 7.6 above. Applicable to ANO-1.

7.14 Document No. 2-1094709-00, "RC Pressure Control System Auxiliary Diagram," supplied for customer by EDS Nuclear, 3/31/80. Contents: Similar to Reference 7.6 above. Applicable to ANO-1.

7.15 Document No. 2-1094717-00, "Turbine Control System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 7.6 above. Applicable to Oconee 1, 2, and 3.

7.16 Document No. 2-1094718-00, "Turbine Bypass and Atmospheric Dump System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 7.6 above. Applicable to Oconee 1, 2, and 3.

7.17 Document No. 2-1094719-00, "RC Pressure Control System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 7.6 above. Applicable to Oconee 1, 2, and 3.

7.18 Document No. 2-1094826-00, "Turbine Control (EHC) System Auxiliary Diagram," supplied for customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 7.6 above. Applicable to Davis-Besse plant.

7.19 Document No. 2-1094827-00, "Turbine Bypass System Auxiliary Diagram," supplied for customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 7.6 above. Applicable to Davis-Besse plant.

7.20 Document No. 2-1094828-00, "RC Pressure Control System, PZR HTR & Spray System Auxiliary Diagram," supplied for customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 7.6 above. Applicable to Davis-Besse plant.

7.21 Document No. 2-1094838-00, "Turbine Control System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/26/80. Contents: Similar to Reference 7.6 above. Applicable to Crystal River-3.

7.22 Document No. 2-1094839-00, "Turbine Bypass and Atmospheric Dumps System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/26/80. Contents: Similar to Reference 7.6 above. Applicable to Crystal River-3.

7.23 Document No. 2-1094878-00, "RC Pressure Control System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 7.6 above. Applicable to Crystal River-3.

7.24 Topical Report BAW-1742, Rev. 1, "Response to NRC Letter 81-21 (Natural Circulation Cooldown Task 3A)," August 1983. Function: Demonstrates that the 205 plants can be controlled and cooled down by natural circulation without forming a void in the reactor vessel (RV) upper head. Shows that if a void does form in RV upper head, it can be detected and mitigated so that cooldown can be continued. Provides bases for operator guidelines for natural circulation cooldown. Generically applicable to B&W 205 FA plants.

7.25 Document No. 32-1151155-00, "Stress Analysis of the Reactor Vessel Closure Region for a Natural Circulation Cooldown Transient," A. D. Nana, W. L. Redd, 6/21/84. Function: To demonstrate that the stresses induced in the RV closure head, studs and upper shell region due to a natural circulation cooldown transient meet the requirements of the ASME Code Section III for Class 1 components. Generically applicable to B&W 177 FA plants.

7.26 Document No. 32-1150499-00, "Reactor Vessel Head Stress Analysis Inputs," B. L. Boman, C. W. Tally, 3/22/84. Function: Provide analysis inputs to Reference 7.25 above. Generically applicable to B&W 177 FA plants.

7.27 Document No. 86-1132885-00, "205 FA Natural Circulation Cooldown Rate Information Document," M. Benac, B. L. Boman, 8/6/82. Function: Document RV head cooldown rates for B&W 205 FA plants in natural circulation. Generically applicable to B&W 205 FA plants.

7.28 Document No. 77-1156347-00, "Impact of B&W Site Instruction 65-018-00 on Natural Circulation Cooldown," J. F. Walters, R. G. McAndrew, 2/11/85. Function: Provides guidance and instructions for recognizing and mitigating a transient which could result in a violation of the PTS limits. Generically applicable to B&W 177 FA plants.

7.29 Document No. 32-1120426-00, "Analysis of OTSG Fill Using Either MFW or EFW," R. W. Winks, C. W. Tally, 8/12/80. Function: Provides analysis of plant response to OTSG fill with MFW or EFW to the 50% level on operate range in anticipation of tripping all RC pumps under non-emergency operating conditions. Applicable to the TMI-1 plant.

7.30 Document No. 86-1120427-01,02, "Analysis of the Steam Generator Anticipatory Fill Prior to Shutting Down All RC Pumps," R. W. Winks, J. J. Kelly, 2/23/81. Function: Summarizes the results of Reference 7.29 above. Applicable to the TMI-1 plant.

7.31 Document No. 32-1132845-00, "TMI-1 SBLOCA Analysis for Thermal Shock Evaluations," Y. F. Hsu, L. R. Cartin, 5/5/82. Function: Calculational file for Reference 7.2 above. Applicable to the TMI-1 plant.

7.32 Document No. 32-1152915-00, "RV Head Fluid Temperature Response During Natural Circulation (NC) Cooldowns," B. L. Boman, M. A. Rinckel, 8/23/84. Function: Determine RV head fluid temperature response during NC Cooldowns. Generically applicable to the B&W 177 FA plants.

7.33 Document No. 32-1152916-00, "RV Head Void Expansion," B. L. Boman, R. R. Lange, 7/26/84. Function: Determine the required subcooling margin for continued primary depressurization (with a head void) without interrupting natural circulation.

7.34 Document No. 32-1171124-00, "Owner's Group Task AS-3: Re-establishment of Natural Circulation from Asymmetric Hot Leg Voids," N. Vasudevan, J. A. Weimer, July 1988. Function: Confirm parameters for identification of loop voids and analyze effectiveness of various mitigation actions. Applicable to all B&W 177FA plants.

7.35 Document No. 86-1172257-00, "Transient Information Document - Owners Group Task AS-3 Results - Bases for ATOG and Recommendations Based on Task AS-3 Analyses," N. Vasudevan, Martin V. Parece, August 1988. Function: Summarizes results of Reference 7.34. Applicable to all B&W 177FA plants.

7.36 Document No. 32-1219212-00, "Loss of DHRS Calculations," B. L. Boman, J. A. Weimer, June 1993. Function: Provides bases for loss of DHRS guidance by providing calculations for minimum core flow rates to maintain subcooling and boil-off makeup, times to boiling and core uncover, RCS-to-RB differential pressure vs. time during boil-off and RCS boron concentration vs. time during boil-off. Applicable to all B&WOG 177FA plants.

7.37 NRC NUREG/CR-5855, "Thermal-Hydraulic Processes During Reduced Inventory Operation with Loss of Residual Heat Removal," April 1992.

8.0 Equipment Operation

8.1 Document No. 86-1125426-00, "Makeup Line and HPI flow Rates vs. Pressure for NSS-11 - ATOG Prog.," J. W. Merchant, T. A. Mong, 5/6/81. Function: Part of analytical basis for evaluation of methods and effectiveness of operation for equipment vital to maintenance, during transients, of control over the five fundamental functions of:

1. Reactivity Control

2. RCS Pressure Control

3. RCS Inventory Control

4. Secondary Pressure Control

5. Secondary Inventory Control Applicable to Rancho Seco plant.

8.2 Document No. 2-1094997-00, "SMUD - Low Pressure Injection System Auxiliary Diagram," supplied for the customer by EDS Nuclear, 6/8/81. Contents: Identify the auxiliary systems essential to the operation of safety systems and instrumentation requirements for the auxiliary systems. Applicable to RS-1.

8.3 Document No. 2-1094819-00, "HPI System Auxiliary Diagram," supplied for the customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 8.2 above. Applicable to the Davis Besse plant.

8.4 Document No. 2-1094681-00, "Low Pressure Injection System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 8.2 above. Applicable to TMI-1.

8.5 Document No. 2-1094677-00, "High Pressure Injection System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 8.2 above, plus provides a basis for recommended operator actions in the event of an HPI line break. Applicable to TMI-1.

8.6 Document No. 2-1094700-00, "HPI System Auxiliary Diagram," supplied for customer by EDS Nuclear, 3/31/80. Contents: Similar to Reference 8.2 above. Applicable to ANO-1.

8.7 Document No. 2-1094704-00, "Low Pressure Injection System Auxiliary Diagram," supplied for customer by EDS Nuclear, 3/31/80. Contents: Similar to Reference 8.2 above. Applicable to ANO-1.

8.8 Document No. 2-1094710-00, "HPI System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 8.2 above. Applicable to Oconee 1, 2, and 3.

8.9 Document No. 2-1094714-00, "Low Pressure Injection System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 8.2 above. Applicable to Oconee 1, 2, and 3.

8.10 Document No. 2-1094823-00, "Low Pressure Injection System Auxiliary Diagram," supplied for customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 8.2 above. Applicable to Davis-Besse plant.

8.11 Document No. 2-1094871-00, "High Pressure Injection System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 8.2 above. Applicable to Crystal River-3.

8.12 Document No. 2-1094875-00, "Low Pressure Injection System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 8.2. Applicable to Crystal River-3.

8.13 Document No. 32-1106961-01, "Calculations of OTSG Levels for ATOG," M. E. Newlin, R. B. Brownell, 2/20/81. Function: Code for converting OTSG inventory to OTSG level. Generically applicable to all B&W 177 FA plants.

8.14 Document No. 32-1150199-00, "Minimum AFW Flowrates/SG Level Requirements for SBLOCA," D. Mulvihill, J. R. Paljug, 3/23/84. Function: Provides SG level and AFW flow requirements to ensure adequate core cooling for SBLOCA (0.005-0.02 ft2) which utilize the boiler condenser mode of cooling. Generically applicable to all B&W plants. Specifies SG emergency level requirements (e.g., 95% level for 177 FA Lowered Loop plants) during possible LOCA situations.

8.15 This reference deleted.

8.16 Document No. 12-1134300-00, "Non-Condensible Gas Source Model," R. H. Smith, N. K. Savani, 6/18/82. Function: Pertinent to high point vent operation and recommended operator actions during cyclic boiler-condenser conditions. Generically applicable to all B&W plants.

8.17 Document No. 32-1117950-00,01, "ANO-1 ATOG RB Pressure Calc. .," G. S. Shukla, R. J. Schomaker, 5/7/80. Function: Defines containment pressure and temperature response for high energy discharges (various rates) within containment. Verifies adequacy of safety system actuation setpoints in accident mitigation. Applicability: specifically to ANO-1; generically to all B&W plants.

8.18 Document No. 86-1118047-00, "ANO-1 ATOG RB Pressure Calc.," G. S. Shukla, R. J. Schomaker, 3/28/80. Function: Supplements the analysis contained in Reference 8.17 above.

8.19 Document No. 86-1118911-00, "ANO-1 ATOG RB Pressure Calc. Additional Analysis," G. S. Shukla, R. J. Schomaker, 5/6/80. Function: Supplements the analysis contained in Reference 8.17 above.

8.20 Document No. 86-1125975-00, "RB Spray Setpoint in TVA FSAR," M. A. Haghi, W. L. Bloomfield, 5/22/81. Function: Verified adequacy of RB cooling/spray system to maintain conditions within design limits during LOCA conditions with 4 psig high pressure actuation setpoint. Applicable to Bellefonte 1 and 2 plants.

8.21 Document No. 86-1103119-00,01, "Containment Response to a Small Break LOCA," K. C. Shieh, J. A. Randazzo, 12/4/79. Function: Analytical basis for defining pressure and temperature transient responses to high energy discharges within containment. Specifically applicable to Midland plants; generically applicable to all B&W plants.

8.22 Topical Report 43-BAW-10103A, Rev. 3, "ECCS Analysis of B&W's 177 FA Lowered Loop NSS," R. C. Jones, J. R. Biller, B. M. Dunn, 7/77. Function: Description of plant and RB response to a spectrum of LOCAs. Similar to Reference 2.1 but applicable to B&W's 177 FA Lowered Loop plants.

8.23 Topical Report 43-BAW-10105, "ECCS Evaluation of B&W's 177 FA Raised Loop NSS," W. Bloomfield, L. R. Cartin, J. M. Hill, 6/75. Function: Similar to Reference 8.22 above; applicable to the Davis- Besse-1 plant.

8.24 Document No. 2-1094994-00, "SMUD - Reactor BLDG Spray System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/81. Contents: Technical information essential to defining containment transient responses (pressure, temperature, radiation, gas level increases), equipment operation (e.g., automatic isolation, cooler and spray operation), and mitigation actions (e.g., manual equipment operation, purging, sampling). Applicable to Rancho Seco plant.

8.25 Document No. 2-1094999-00, "SMUD - Containment Isolation System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/4/81. Contents: Similar to Reference 8.24 above. Applicable to Rancho Seco plant.

8.26 Document No. 2-1094678-00, "RB Spray System Auxiliary Diagram," supplied to customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 8.24 above. Applicable to TMI-1 plant.

8.27 Document No. 2-1094682-00, "RB Emergency Cooling System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 8.24 above. Applicable to TMI-1 plant.

8.28 Document No. 2-1094701-00, "RB Spray System Auxiliary Diagram," supplied for customer by EDS Nuclear 3/31/80. Contents: Similar to Reference 8.24 above. Applicable to ANO-1 plant.

8.29 Document No. 2-1094705-00, "RB Emergency Cooling System Auxiliary Diagram," supplied for customer by EDS Nuclear, 3/31/80. Contents: Similar to Reference 8.24 above. Applicable to ANO-1 plant.

8.30 Document No. 2-1094706-00, "RB Isolation System Auxiliary Diagram," supplied for customer by EDS Nuclear, 3/31/80. Contents: Similar to Reference 8.24 above. Applicable to ANO-1 plant.

8.31 Document No. 2-1094711-00, "RB Spray System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 8.24 above. Applicable to Oconee 1, 2, and 3 plants.

8.32 Document No. 2-1094715-00, "RB Emergency Cooling System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 8.24 above. Applicable to Oconee 1, 2, and 3 plants.

8.33 Document No. 2-1094716-00, "RB Isolation System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 8.24 above. Applicable to Oconee 1, 2, and 3 plants.

8.34 Document No. 2-1094820-00, "Containment Spray System Auxiliary Diagram," supplied for customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 8.24 above. Applicable to Davis Besse plant.

8.35 Document No. 2-1094824-00, "Containment Air Cooling System Auxiliary Diagram," supplied for customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 8.24 above. Applicable to Davis Besse plant.

8.36 Document No. 2-1094825-00, "Containment Vessel Isolation System Auxiliary Diagram," supplied for Customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 8.24 above. Applicable to Davis Besse plant.

8.37 Document No. 2-1094872-00, "Reactor Building Spray System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 8.24 above. Applicable to Crystal River-3 plant.

8.38 Document No. 2-1094876-00, "RB Emergency Cooling System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 8.24 above. Applicable to Crystal River-3 plant.

8.39 Document Nos. 2-1094877 and 2-1094879-00, "RB Isolation System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 8.24 above. Applicable to Crystal River-3 plant.

8.40 Document No. 70-1150827-00, "TVA Containment Event Tree," N. Goulding, B. L. Brooks, 4/19/84. Function: Provides logical evaluation and confirmation of detection and mitigation techniques for transients and/or equipment failures within the containment. Applicable to the Bellefonte 1 and 2 plants.

8.41 Document No. 2-1094998-00, "SMUD - Containment Coolers (System Auxiliary Diagram)," supplied for customer by EDS Nuclear, 6/5/81. Contents: Similar to Reference 8.24 above. Applicable to Rancho Seco plant.

8.42 Document No. 2-1094683-00, "RB Isolation System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Similar to Reference 8.24 above. Applicable to TMI-1 plant.

8.43 Document No. 86-1117978-00, "ANO-1 ATOG Reactor Building Pressure Calc," G. S. Shukla, M. V. Costello, 3/7/80. Function: Summarizes the results of Reference 8.17 above. Applicable to ANO-1 plant.

8.44 Document No. 32-1106901-00, "MU Line and HPI Flow Rates Vs. RC Pressure -ATOG," J. W. Merchent, T. A. Mong, 5/14/81. Function: Similar to that of Reference 8.1 above. Applicable to the B&W 177 FA plants.

8.45 Document No. 32-1146598-00, "RCP Restart - A Relap 4 Analysis," B. L. Boman, R. W. Moore, 9/26/83. Function: Investigate plant response to restarting RCP with loop voids present in the system.

8.46 Document No. 86-1106932-00, "MU Line and HPI Flowrates Vs. RC Pressure for NSS-8," J. W. Merchent, T. A. Mong, 12/13/79. Function: Similar to that of Reference 8.1 above. Applicable to ANO-1 plant.

8.47 Document No. 86-1118922-00, "Makeup Line and HPI Flow Rates Vs. RC Pressure for NSS-14," J. W. Merchent, T. A. Mong, 4/29/80. Function: Similar to that of Reference 8.1 above. Applicable to the DB-1 plant.

8.48 Document No. 86-1121912-00, "Makeup Line and HPI Flow Rates Vs. RC Pressure for NSS-5," J. W. Merchent, T. A. Mong, 10/27/80. Function: Similar to that of Reference 8.1 above. Applicable to the TMI-1 plant.

8.49 Document No. 86-1123092-00, "Makeup Line and HPI Flow Rates Vs. RC Pressure for NSS-7," J. W. Merchent, T. A. Mong, 1/21/81. Function: Similar to that of Reference 8.1 above. Applicable to the CR-3 plant.

8.50 Document No. 32-1159751-01, "ECCS HPI Flow Reduction Justification," J. C. Seals, J. R. Paljug, 9/12/86. Function: Evaluate a 10% flow reduction in the HPI system. Applicable to the DB-1 plant.

8.51 Document No. 32-1165523-00, "Time to Drain the BWST During Total Station Blackout," J. C. Seals, C. W. Tally 8/25/86. Function: Determine the amount of time it takes to drain the BWST during total station blackout.

8.52 Document No. 32-1165529-00,01, "Justification of Balancing HPI at 20 Minutes Following HPI Line Break," J. C. Seals, S. L. Harrison, 10/13/86. Function: Verify that operator action at 20 minutes to isolate the broken HPI line will not result in core uncovery.

8.53 Document No. 51-1153316-00, "ANO-1 Use of HPV and RVHV to Limit PORV Cycling," E. P. Menard, J. R. Paljug, 11/28/84. Function: Evaluate effectiveness of HPV and RVHV to limit PORV cycling during a LOFW event. Applicable to the ANO-1 plant.

8.54 Document No. 51-1159553-00,01, "ECCS Flows", J. R. Paljug, J. C. Seals, 10/2/86. Function: List the injection flows used in best estimate "feed and bleed" cooling analyses for DB-1. Applicable to the DB-1 plant.

8.55 Document No. 51-1164182-01,02, "HPI Flow Acceptance Criteria - ECCS Analysis," J. R. Paljug, J. C. Seals, 10/2/86. Function: Provide information on HPI flow rates used in existing ECCS analyses, verifies these flow rates, and discusses throttling assumptions and instructions. Applicable to the DB-1 plant.

8.56 Document No. 2-1094993-00, "High Pressure Injection System Auxiliary Diagram," supplied for the customer by EDS Nuclear, 6/4/81. Function: Similar to that of Reference 8.1 above. Applicable to the Rancho Seco plant.

8.57 Document No. 32-1159707-00, "Justification of Minimum EFIC Fill Rate," J. R. Paljug, J. C. Seals, January 7, 1987. Function: Evaluate the adequacy of the minimum EFIC fill rate to provide SG heat removal for SBLOCAs analyzed. Applicable to ANO-1, CR-3, and Rancho Seco.

8.58 Document No. 86-1165886-00, "Justification of Minimum EFIC Fill Rate" J. R. Paljug, J. C. Seals, January 6, 1987. Function: Summary document for Reference 8.57 above. Applicable to ANO-1, CR-3, and Rancho Seco.

8.59 Document No. 86-1150200-00, "Minimum AFW Flow Rates/SG Level Requirements for SBLOCA," D. Mulvihill, J. R. Paljug, May 31, 1984. Function: Provide minimum AFW flow and minimum SG level requirements to ensure adequate core cooling for certain SBLOCAs (0.005 to 0.02 ft2). This summarizes the results of Reference 8.14. Applicable to all B&W 177 FA Lowered Loop plants.

8.60 Document No. 32-1171652-00,01, "DB-1 SBLOCA Min AFW Flow and Min SG Level Requirement," D. G. Newton, M. A. Rinckel, June 5, 1989. Function: Provide minimum AFW flow and minimum SG level requirements to ensure adequate core cooling for certain SBLOCAs (0.005 to 0.02 ft2). Applicable to Davis-Besse.

8.61 Document No. 51-1173630-00, "Re-evaluation of EFIC Fillrate," A. W. Maass, J. C. Seals, 2/3/89. Function: Re-evaluate EFIC fill rates using a more realistic assumption of post-trip secondary steam pressure. Applicable to ANO-1, CR-3, and Rancho Seco.

8.62 Document No. 32-1150199-00, "Minimum AFW Flow Rates/SG Level Requirements for SBLOCA," D. Mullvihill, J. R. Paljug, 3/23/84. Function: Provide minimum SG level and EFW flow requirements to ensure adequate core cooling for SBLOCA using boiler condenser cooling.

8.63 Document No. 32-1141304-00, "Boiler/Condenser Effectiveness Study for TMI-1, Generic 177-FA LL and Davis-Besse-1 Plants," L. K. Nicholson, J. R. Paljug, 3/31/83. Function: Show the relationship between the boiler-condenser mode of heat removal and HPI cooling.

8.64 Document No. 12-1132555-00, "Benchmark for AFW (EFW) Models," K. C. Heck, R. A. Turner, 4/14/82. Function: Provides a summary of key information pertaining to AFW spray models.

8.65 Document No. 32-9444-00, "Analysis of Small Break Spectrum at Pump Discharge," 177FA LL, M. A. Haghi, N. H. Shah, 10/31/78. Function: Analyze a spectrum of small breaks at the RCP discharge.

8.66 Document No. 77-1165715-00, "SBLOCA for B&W 1777 LL Plants in Response to NUREG 0737 Item II.K.3.31 September 1986," G. E. Anderson, J. R. Paljug, 10/23/86. Function: Describes SBLOCA transient behavior, compares revised engineering model results with previous results and determines the applicable conservatism of previous SBLOCA spectrum analyses.

8.67 Document No. 77-1165793-00, "SBLOCA for B&W 177RL Plants in Response to NUREG 0737 Item II.K.3.31 October 1986," G. E. Anderson, J. R. Paljug, 11/11/86. Function: Describes SBLOCA transient behavior, compares revised engineering model results with previous results and determines the applicable conservatism of previous SBLOCA spectrum analyses.

8.68 Document No. 32-1176035-00, "PTS Guidance Curve Development," Ashok Nana, K. K. Yoon, 9/18/89, B&W Proprietary. Function: Develop relaxed PTS limit.

8.69 Document No. 47-1159091-00, "Design Requirements for DSS (Diverse Scram System) and AMSAC (ATWS Mitigation System Actuation Circuitry)", R. W. Dorman, R. J. Schomaker, 06/16/86. Provides the generic design bases for ATWS modifications required of B&W 177FA and 205FA plants by 10CFR50.62.

8.70 Document No. 32-1179831-00, "AS-6 RCP Operation, RV Closure Head Region Stress Analysis", Allen Miller, John Shepard, 1/10/91. Function: Determine structural acceptability of the RV closure head region during RCP start with a RV Head void.

8.71 Document No. 51-1202041-00, "AS-6: RC Pump Restart with RCS Voids", G. E. Anderson, R. H. Ellison, 9/6/91. Function: Determine RCS response during RCP starts with RCS voids.

8.72 B&W Doc. I.D. 32-1177256-00, "Technical Basis for Reactor Vessel Level Indication System (RVLIS) Action Statement," R. S. Enzinna, S. H. Levinson, 03/16/90. Provides a description and limitations for RVL & HLL and a technical basis for B&WOG plants that demonstrates that the incremental risk of core damage resulting from RVLIS inoperability is small and does not warrant reactor shutdown.

8.73 Document No. 51-1203209-00, "FP in Compression Review," D. B. Mitchell, B. T. Friend, 2/3/92. Function: Justification for removal of the fuel rod in compression criteria. Applicable to all 177-FA plants with Mark-B Fuel.

8.74 Document No. 32-1202178-00, "PTS Interim Guidance Downcomer Temperatures," B. L. Bowman, J. R. Smotrel, 6/18/91. Function: Predicts downcomer fluid temperatures during SBLOCA transients in which HPI is not throttled at 100oF SCM.

8.75 Document No. 32-1203267-00,01, "Interim PTS Guidance Fracture Mechanics Analysis," A. D. Nana, K. K. Yoon, 6/24/91, BWNS Proprietary. Function: Provides fracture mechanics analysis and develops an interim PTS guidance curve for B&WOG 177-FA plants. Applicable to all B&W 177-FA plants.

8.76 Document No. 51-1203495-00, "PTS Interim Curve Development," D. G. Newton, A. D. Nana, 7/3/91, BWNS Proprietary. Function: Provides the PTS relaxed interim guidance and its bases. Applicable to all B&W 177-FA plants.

8.77 Document No. 32-1213343-00, "PTS Task 3 SBLOCA Low Decay Heat", G. Anderson, 1/5/93, BWNS Proprietary. Function: Documents the RELAP5/MOD2 SBLOCA analyses which generated the thermal-hydraulic data used for Reference 8.78. Applicable to all B&W 177-FA plants.

8.78 Document No.32-1212194-00, "PTS Thermal Mixing DC Temperature", B.L. Bowman, 5/26/92, BWNS Proprietary. Function: Calculates downcomer fluid temperatures during SBLOCA transients in which RCS flow is interrupted and core cooling is provided by HPI. Applicable to all B&W 177-FA plants.

8.79 Document No. 32-1219219-00, "PTS Task 3 Overcooling T-H", G.E. Anderson, 12-30-92, BWNS Proprietary. Function: Develops a set of transient temperature conditions for a composite overcooling event, for use in PTS analyses. Applicable to all B&W 177-FA plants.

8.80 Document No. 86-1219309-00, "PTS Task 3 Overcooling T-H", G.E. Anderson, 12-30-92, BWNS Proprietary. Function: Describes a set of transient temperature conditions for a composite overcooling event, for use in PTS analyses. Applicable to all B&W 177-FA plants.

8.81 Document No. 32-1177154-00, "CRAFT2/RELAP5 SBLOCA Comparison", C. Ritchey, 5/31/90, BWNS Proprietary. Function: Documents the benchmark of the RELAP5/MOD2 computer code to a CRAFT2 code prediction of a .04 ft2 cold leg pump discharge break. Applicable to all B&W 177-FA plants.

8.82 Document No. 32-1212280-00, "PTS Parametric Study of Overcooling Events", A. D. Nana, 3/31/92, BWNS Proprietary. Function: Performs a parametric study of overcooling events to determine the minimum acceptable overcooling temperature which can be experienced provided current Tech. Spec. P/T limits are maintained following the event. Applicable to all B&W 177-FA plants.

8.83 Document No. 32-1219277-00, "PTS Composite Overcooling Transient - FM Analyses", A. D. Nana, 3/2/93, BWNS Proprietary. Function: Provides FM analysis of a composite and modified composite overcooling event and compares critical pressures from the transient to the B&WOG bounding Tech. Spec. basis P/T limit curve. Applicable to all B&W 177-FA plants.

8.84 Document No. 32-1218142-00, "Long Term High Decay Heat SBLOCA FM Analyses", J.W. Moore, 5/12/93, BWNS Proprietary. Function: Provides FM analysis of four cases of high decay heat SBLOCA transients. Applicable to all B&W 177-FA plants.

8.85 Document No. 32-1219120-00, "Long Term Low Decay Heat SBLOCA FM Analyses", A. D. Nana, 5/24/93,BWNS Proprietary. Function: Provides FM analysis for six cases of low decay heat SBLOCA transients. Applicable to all B&W 177-FA plants.

8.86 Document No. 86-1219922-00, "Long Term PTS Guidance Summary - FM Section", A. D. Nana, 5/24/93, BWNS Proprietary. Function: Summarizes all LEFM analysis that have been performed for the development of the long term PTS guidance for B&WOG plants. Applicable to all B&W 177-FA plants.

8.87 Document No. 32-1223359-00, "PTS Downcomer Temperatures - Low Decay Heat", B.L. Bowman, 4/23/93, BWNS Proprietary. Function: Calculation of mixed fluid downcomer temperatures and film heat transfer coefficients during SBLOCA events in which decay heat was zero or small. Applicable to all B&W 177-FA plants.

8.88 Document No. 51-1224403-00, "Modified PTS Guidance Developed via PTS Working Group," D.G. Newton, 6/18/93, BWNS Proprietary. Function: provides relaxed PTS guidance for B&WOG 177-FA plants. Applicable to all B&W 177-FA plants.

8.89 Document No. 51-1201147-00, "Guidelines for Terminating HPI Flow," D. G. Newton, J. C. Seals, 10/31/90. Function: Improves the guidance for terminating HPI flow, primarily to provide guidance when the break size is too small to provide specified LPI flow rates. Applicable to all 177-FA plants.

8.90 Document No. 51-1266113-00, "Post-LOCA Boron Concentration Management", J.A. Klingenfus, K. S. Pacheco, 4/11/97, FTI Proprietary. Function: summarizes results of the formal, safety-grade core boron concentration calculations and evaluations supporting operation of all B&W-designed plants. Applicable to all B&W 177-FA plants.

8.91 Document No. 86-1266272-02, "Post-LOCA Boron Concentration Management for CR-3", G. J. Wissinger, 5/4/98. Function: summarizes boron concentration control methods and calculations needed for the CR-3 plant to meet NRC requirements for post-LOCA boron concentration control. Applicable to the CR-3 plant.

8.92 Document No. 32-1245087-00, -01, -02, -03, Boron Concentration Transients with RCP Start, J. R. Gloudemans, B. M. Dunn, 10/96, 3/97, 4/97, 2/00. Function: provide guidelines for RCP starts following specific deboration events.

8.93 Document No. 32-1178846-00, "Allowable AFW Flow for OTSG," J. A. Burgess and D. E. Costa, 12/6/91, BWNS Proprietary. Function: Determine the maximum allowable AFW flow to a dry, depressurized but intact SG with forced primary flow. Applicable to all B&W 177FA plants.

8.94 Document No. 32-1201289-00, "Allowable MFW Flow, Dry SG Refill," A. M. Miller and A. T. Fisher, 1/23/91, BWNS Proprietary. Function: Determine the maximum allowable MFW flow to a dry, depressurized but intact SG with forced primary flow. Applicable to all B&W 177FA plants.

8.95 Document No. 32-1218893-00, "Allowable Tube ΔT, Dry SG, Phase 2," A. M. Miller and F. S. Pajaro, 6/15/93, BWNS Proprietary. Function: Determine the maximum allowable AFW and MFW flow to a dry, depressurized but intact SG without forced primary flow and the maximum allowable AFW flow to a dry, depressurized SG with an unisolable steam leak, with and without forced primary flow. Applicable to all B&W 177FA plants.

8.96 Document No. 32-1159251-01, "OTSG Tube Allowables (ΔT vs. ΔP)," D. E. Costa, G. L. Weatherly, 8/7/87. Function: Determine equations for tube load calculations and the relationship of allowable ΔT and ΔP. Applicable to all B&W 177FA plants.

8.97 Document No. 32-1176220-00, -01, "AFW Refill of Dry Depressurized OTSG," R. G. Sanderson and R. H. Ellison (Rev. 00, 2/23/90), D. J. Skulina and M. V. Parece (Rev. 01, 11/30/90. Function: Determine thermal-hydraulic response of feeding a dry, depressurized but intact SG with AFW with forced primary flow for input to the stress analyses of Reference 8.89. Applicable to all B&W 177FA plants.

8.98 Document No. 32-1177135-01, "MFW Refill of Dry Depressurized OTSG," D. J. Skulina and M. V. Parece, 11/9/90. Function: Same as Reference 8.93, for input to Reference 8.90. Applicable to all B&W 177FA plants.

8.99 Document No. 32-1212196-00, "AFW Refill of a Depressurized SG With No Primary Flow," B. Vindy Singh and D. J. Skulina, 5/25/93, BWNS Proprietary. Function: Same as Reference 8.93, for input to Reference 8.91. Applicable to all B&W 177FA plants.

8.100 Document No. 32-1212190-00, "Phase 2 Dry OTSG Refill with MFW," D. J. Skulina and B. Vindy Singh, 12/2/92, BWNS Proprietary. Function: Same as Reference 8.93, for input to Reference 8.91. Applicable to all B&W 177FA plants.

8.101 Document No. 32-1212204-00, "AFW Refill of a SG Unable to Repressurize," B. Vindy Singh and D. J. Skulina, 3/26/93, BWNS Proprietary. Function: Same as Reference 8.93, for input to Reference 8.91. Applicable to all B&W 177FA plants.

8.102 Document No. 32-1219339-00, -01, "MFW Nozzle, Dry SG Refill Analysis," A. M. Miller and T. P. Waylett, 1/12/94, BWNS Proprietary. Function: Determine the stresses in the MFW nozzle closures during the refill of a dry, depressurized SG. Applicable to all B&W 177FA plants.

8.103 Document No. 32-1212233-00, "MFW Trickle Feed of a Dry Depressurized OTSG," D. J. Skulina and B. Vindy Singh, 1/11/93, BWNS Proprietary. Function: Determine cooling rates of MFW flow to an SG with an unisolable steam leak. Applicable to all B&W plants.

8.104 Document No. 32-1212234-00, "Refill of a Dry Depressurized OTSG with MFW Using CBPs," D. J. Skulina and B. Vingy Singh, 5/20/93, BWNS Proprietary. Function: Evaluate the ability to control a cooldown using the condensate booster pumps. Applicable to all B&W 177FA plants.

8.105 Document No. 51-1224886-02, "OTSG Refill Summary Report," D. J. Skulina and D. E. Costa, 9/29/94. Function: Summarizes the analyses performed in References 8.89-8.100. Applicable to all B&W 177FA plants.

8.106 FTI Letter INS-96-7086, "OTSG Tube to Shell Delta Temperature," L. M. Lesniak (FTI) to L. J. Sexton (FPC), dated 9/13/96. Function: Summarizes work performed and calculation methods used to determine SG tube temperatures during a 9/5/96 event involving compressive tube loads. Calculation methods generally applicable to all B&W 177FA plants.

9.0 Transient Recognition, Mitigation Control

9.1 Document No. 32-1106955-01, "ATOG - PZR Pressure Response During LOOP (Loss of Offsite Power)/Main Success Path," M. E. Newlin, L. J. Rudy, 9/10/80. Function: Supporting document for ATOG Part I guidance and Part II discussions related to detection and mitigation of a loss of offsite power event. Applicable to the ANO-1 plant.

9.2 Document No. 32-1106954-00, "Loss of Offsite Power/Excessive AFW - ATOG," M. E. Newlin, C. W. Tally, 6/16/80. Function: Similar to Reference 9.1 above. Applicable to the ANO-1 plant.

9.3 Document No. 32-1106953-00, "Loss of Offsite/Onsite Power - No EFW -ATOG," M. E. Newlin, C. W. Tally, 4/22/80. Function: Similar to Reference 9.1 above. Applicable to the ANO-1 plant.

9.4 Document No. 32-1106949-00, "Main Success Path, Loss of Offsite Power," M. E. Newlin, C. W. Tally, 6/4/80. Function: Similar to Reference 9.1 above. Applicable to the ANO-1 plant.

9.5 Document No. 86-1119369-00, "ATOG Excessive AFW/LOOP," M. E. Newlin, C. W. Tally, 6/2/80. Function: Similar to Reference 9.1 above. Applicable to the ANO-1 plant.

9.6 Document No. 86-1119367-00, "ATOG Loss of Off-site Power Exc. Makeup with EFW,: M. E. Newlin, C. W. Tally, 6/23/80. Function: Similar to Reference 9.1 above. Applicable to the ANO-1 plant.

9.7 Document No. 86-1119255-00,01, "Main Success Path: Loss of Offsite Power -ATOG," J. A. Weimer, C. W. Tally, 1/7/85. Function: Similar to Reference 9.1 above. Applicable to ANO-1 plant.

9.8 Document No. 86-1119582-00, "ATOG LOOP/NO DGS (Diesel Generator)," M. E. Newlin, C. W. Tally, 6/23/80. Function: Similar to Reference 9.1 above. Applicable to ANO-1 plant.

9.9 Document No. 86-1118159-01, "ANO Loss of Onsite/Offsite Power - No EFW: ATOG," M. E. Newlin, C. W. Tally, 6/2/80. Function: Similar to Reference 9.1 above. Applicable to ANO-1 plant.

9.10 Document No. 86-1131520-00, "CPCo Midland 2 LOOP Transient Information Document," R. S. Talley, D. L. Smith, 3/1/82. Function: Similar to Reference 9.1 above. Applicable to Midland Units 1 and 2.

9.11 Document No. 86-1125976-00,01, "CR-III ATOG LOOP TID," E. A. Hiltunen, R.B. Brownell, 8/11/81. Function: Similar to Reference 9.1 above. Applicable to Crystal River-3 plant.

9.12 Document No. 32-1120510-00, "TMI-1 Loss of Offsite/Onsite PWR: 1 MSSV Failed Open on S/G-B," E. A. Hiltunen, M. E. Newlin, 4/7/81. Function: Similar to Reference 9.1 above. Applicable to TMI-1 plant.

9.13 Document No. 86-1123921-00, "ATOG TID: Loss of Offsite/Onsite Power, TMI-1," E. A. Hiltunen, M. E. Newlin, 5/21/81. Function: Similar to Reference 9.1 above. Applicable to TMI-1 plant.

9.14 Document No. 86-1122497-00, "ATOG TID/Loss of Offsite Power," M. E. Newlin, P. R. Boylin, 12/12/80. Function: Similar to Reference 9.1 above. Applicable to Oconee 1, 2 and 3 plants.

9.15 Document No. 86-1125435-00, "Analytical Results for TMI-1 Loss of Offsite/Onsite Power," E. A. Hiltunen, P. R. Boylin, 4/24/81. Function: Similar to Reference 9.1 above. Applicable to TMI-1 plant.

9.16 Memo, M. E. Newlin to Distribution, "Analytical Input Summary for Loss of Offsite/Onsite Power at Rancho Seco," M. E. Newlin, E. A. Hiltunen, 10/27/80, File No. NSS-11/T3.4. Function: Discusses LOOP and comparison of plant responses between ANO-1 and Rancho Seco. Concludes that ANO-1 and Rancho Seco systems are similar and that no specific LOOP analyses are required for Rancho Seco. See Reference 9.1 above.

9.17 Document No. 86-1124178-00, "ATOG Loss of Offsite Power Transient Information Document," M. E. Newlin, L. J. Rudy, 3/26/81. Function: Similar to Reference 9.1 above. Applicable to Davis-Besse 1 plant.

9.18 Document No. 79-1100949-03, "ANO-LOOP Event Tree," D. G. Newton, B. L.Brooks, 2/20/85. Function: Provides logical evaluation and confirmation of detection and mitigation techniques for a loss of offsite power event at the ANO-1 plant. Serves as a basis for the ATOG Part I guidance and Part II discussions dealing with loss of offsite power.

9.19 Document No. 79-1121480-02, "SMUD - LOOP Event Tree," M. E. Newlin, D. G. Newton, 3/16/84. Function: Similar to Reference 9.18 above except applicable to Rancho Seco plant.

9.20 Document No. 79-1120026-01, "Oconee - LOOP Event Tree," M. E. Newlin, J. J. Kelly, 8/27/80. Function: Similar to Reference 9.18 above except applicable to Oconee 1, 2 and 3 plants.

9.21 Document No. 79-1120153-01, "ATOG/LOOP/Event Tree," E. A. Hiltunen, C. W. Tally, 10/3/80. Function: Similar to Reference 9.18 above except applicable to TMI-1 plant.

9.22 Document No. 79-1121253-01, "Davis-Besse - LOOP Event Tree," M. E. Newlin, P. R. Boylin, 5/12/81. Function: Similar to Reference 9.18 above except applicable to Davis-Besse 1 plant.

9.23 Document No. 79-1121357-01, "Crystal River - LOOP Event Tree," E. A. Hiltunen, M. E. Newlin, 11/19/80. Function: Similar to Reference 9.18 above except applicable to Crystal River-3 plant.

9.24 Document No. 79-1128212-01, "Midland Plant Units 1 and 2, Loss of Offsite Power Event Tree," R. S. Talley, C. W. Tally, 10/2/81. Function: Similar to Reference 9.18 above except applicable to Midland 1 and 2 plants.

9.25 Document Nos. 02-1094602-00, 02-1094603-01, 02-1094604-01, 02-1094605-01, 02-1094605-01, 02-1094606-00, 02-1094605-01, "Loss of Offsite A/C Power Safety Sequence Diagram," supplied for customer by EDS Nuclear, 3/5/80. Contents: Customer supplied information relating to sequence of equipment failure and plant response following a loss of offsite power event. Applicable to ANO-1 plant

9.26 Document Nos. 2-1094724 through 2-1094729-00, "Loss of Offsite AC Power Safety Sequence Diagram," supplied for customer by EDS Nuclear, 8/19/80. Contents: Similar to Reference 9.25 above. Applicable to Davis-Besse 1 plant.

9.27 Document Nos. 2-1094846 through 2-1094851-00, "Loss of Offsite AC Power Safety Sequence Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 9.25 above. Applicable to Crystal River-3 plant.

9.28 Document No. 02-1094970-00, 02-1094971-00, 02-1094972-00, 02-1094973-00, 02-1094974-01, 02-1094975-01, "SMUD - LOOP SSD," supplied for customer by EDS Nuclear, 6/15/81. Contents: Similar to Reference 9.25 above. Applicable to Rancho Seco plant.

9.29 Document No. 86-1126639-00,01, "Rancho Seco ATOG LOOP TID," L. Rudy, D.G. Newton, 11/22/83. Function: Similar to Reference 9.1 above. Applicable to Rancho Seco plant.

9.30 Document No. 86-1137718-00, "B&W Plant Transient Prediction," J. C. Seals, N. K. Savani, 11/2/82, Contract No. 582-7198. Function: Benchmarking of LOCA analysis code against ANO-1 plant loss of offsite power event, 6/24/80. Indicated that code could accurately predict phenomena of LOOP event. Increased confidence in LOCA-associated trends predicted by code and in the use of code results as a basis for ATOG.

9.31 Document No. 86-1125356-00, "P-T Plots - TMI-1 ATOG - ANO-1 LOOP Data Plotted per TMI-1 Format," E. A. Hiltunen, P. R. Boylan, 4/23/81. Function: Loss of Offsite Power plant response data plotted on a simulated P-T display; illustrated the plant response to a LOOP event as it would be displayed in the control room. A basis for the P-T diagram in the LOOP discussion. Applicable to ANO-1 and TMI-1 plants.

9.32 Document No. 86-2496-01, "Std 205 Hydraulic Report," J. M. Knoll, R. B. Park, 7/20/79. Function: System flow distributions for 1-, 2-, 3- and 4-pump operation. Used throughout ATOG for defining transient systems responses and consequences of operator action during partial pump operation conditions. Primarily for 205 FA plants; results and trends can be extrapolated to 177 FA plants.

9.33 Document No. 32-1132533-00, "Two-Phase Flow Pump Model Evaluation," M. Bostoni, N. K. Savani, 4/9/82. Function: Evaluation of performance of upgraded two-phase flow pump model in B&W accident evaluation codes. Benchmarked well with test data. Used to define expected RCP behavior during two-phase flow situations; this information was used as a basis for pump-related guidance and discussion for all B&W plants.

9.34 Document No. 32-1128018-00, "Non-Equilibrium Pressurizer Evaluation," M. Bostoni, J. R. Paljug, 10/13/81. Function: Confirmed accuracy of pressurizer models used in transient analysis codes. Code predictions about transient pressurizer responses are a basis for related discussion in guidelines.

9.35 Document No. 32-1127045-00, "Evaluation of PORV and PSV's Fluid Inlet Conditions," D. A. Doss, W. L. Bloomfield, 8/18/81. Function: Determined the capacity and effectiveness of pressure relief valves in the pressurizer (the PORV and safety valves) in relieving sufficient mass and energy to limit RCS pressure increases. Pressure limits assumed in previous analyses of SBLOCAs, LOFW and other events, were valid based on relief capacities of valves as confirmed by these analyses.

9.36 Document No. 86-1125060-00, "TMI-1 P-T Diagrams for ATOG," L. J. Rudy, P. R. Boylan, 3/30/81. Function: Overcooling event plotted on a simulated P-T display; illustrates plant response as it would be displayed in the control room. A basis for the P-T diagrams in the overcooling (excess MFW) and other sections. Applicable to the TMI-1 plant.

9.37 Document No. 86-1125130-00, "TMI-1 P-T Plots and Tabular Data for ATOG," R. B. Brownell, P. R. Boylan, 4/24/81. Function: Illustrates the ability of the ATOG P-T display to visually communicate to the operator present conditions and trends. A basis for the P-T diagrams used to illustrate various events.

9.38 Document No. 32-1128016-00,01, "RCS Liquid Volume versus Liquid Level," J. R. Paljug, J. Cudlin, 12/14/83. Function: Similar to Reference 9.40 below; specifically serves as analytical basis for guidance for RV and hot leg level measurement systems during LOCA (saturated RCS) and ICC conditions in the Bellefonte 1 and 2 plants.

9.39 Document No. 2-1094680-00, "Chemical Addition System Auxiliary Diagram," supplied for customer by EDS Nuclear, 6/5/80. Contents: Part of analytical basis for evaluation of methods and effectiveness of operation for equipment vital to maintenance, during transients, of control over the five fundamental functions of: 1. Reactivity Control 2. RCS Pressure Control 3. RCS Inventory Control 4. Secondary Pressure Control 5. Secondary Inventory Control as well as corrosion control. Applicable to the TMI-1 plant.

9.40 Document No. 2-1094703-00, "Chemical Addition System Auxiliary Diagram," supplied for customer by EDS Nuclear, 3/31/80. Contents: Similar to Reference 9.39 above. Applicable to ANO-1.

9.41 Document No. 2-1094713-00, "Chemical Add System Auxiliary Diagram," supplied for customer by EDS Nuclear, 4/29/80. Contents: Similar to Reference 9.39 above. Applicable to Oconee 1, 2, and 3.

9.42 Document No. 2-1094822-00, "Chemical Addition System Auxiliary Diagram," supplied for customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 9.39 above. Applicable to Davis Besse plant.

9.43 Document No. 2-1094874-00, "Chemical Add. System Auxiliary Diagram," supplied for customer by EDS Nuclear, 9/23/80. Contents: Similar to Reference 9.39 above. Applicable to Crystal River-3.

9.44 Document No. 51-1140889-00, "PS&C Suggested TRAP Base Deck for TVA ATOG," P. R. Boylan, R. B. Brownell, 2/16/83. Function: Documentation of base computer code deck to be used in analyses of ATOG transients. Applicable to Bellefonte 1 and 2 plants.

9.45 Document No. 67-1002386-00, "Limits and Precautions," K. L. Barclay, R. L. Pittman, 2/10/78. Function: Defines limits of normal and transient operation, e.g., cooldown ratio, SG tube to shell differential temperatures, RC pump operating requirements. Applicable to Crystal River-3.

9.46 Document No. 67-1003781-04, "Limits and Precautions," R. B. Park, D. A. Downtain, 8/22/85. Function: Similar to Reference 9.45; applicable to Bellefonte 1 and 2 plants.

9.47 Document No. 67-1005821-01, "Limits and Precautions," R. A. Pendergraft, D. A. Downtain, 1/28/83. Function: Similar to Reference 9.45; applicable to Midland 1 and 2.

9.48 Document No. 67-1118131-00, "Limits and Precautions," R. B. Park, D. A. Downtain, 3/2/84. Function: Similar to Reference 9.45; applicable to WNP 1 and 4.

9.49 Document No. DP-1101-01, "Plant Operating Limits and Precautions for Duke Power Company Oconee Unit I," K. R. Ellison, D. W. Berger, 10/6/69. Function: Similar to Reference 9.45; applicable to Oconee I.

9.50 Document No. DP-1101-01, "Plant Operating Limits and Precautions for Duke Power Company Oconee Unit II," R. L. Pittman, J. P. Ittner, 10/5/72. Function: Similar to Reference 9.45; applicable to Oconee II.

9.51 Document No. DP-1101-01, "Limits and Precautions for Duke Power Company Oconee Unit III," E. H. Davis, J. P. Ittner, 10/31/73. Function: Similar to Reference 9.45; applicable to Oconee III.

9.52 Document No. DP-1101-01, "Metropolitan Edison Company Three Mile Island Unit One Plant Limits and Precautions," M. P. Horrell, G. K. Stair, 6/15/73. Function: Similar to Reference 9.45; applicable to TMI-1.

9.53 Document No. DP-1101-02, "Plant Set Points for Arkansas Power and Light Nuclear One," 6/14/73. Function: Similar to Reference 9.45; applicable to ANO-1.

9.54 Document No. DP-1101-01, "Sacramento Municipal Utility District Rancho Seco Unit 1 Plant Limits and Precautions," 1/31/74. Function: Similar to Reference 9.45; applicable to Rancho Seco.

9.55 Document No. DP-1101-01, "Limits and Precautions for Toledo Edison Company Davis Besse 1," 5/25/73. Function: Similar to Reference 9.45; applicable to Davis- Besse 1.

9.56 Document No. DP-1101-01, "Arkansas Nuclear 1 Unit 1 Plant Limits and Precautions," G. J. Heinen, R. K. Cothren, 4/21/72. Function: Similar to Reference 9.45; applicable to ANO-1.

9.57 Document No. 32-1123714-00, "Davis-Besse ATOG LOOP/ Excessive AFW," M. E. Newlin, L. J. Rudy, 4/15/81. Function: Similar to Reference 9.1 above. Applicable to DB-1 plant.

9.58 Document No. 86-1125982-00, "PORV Actuation on LOOP," M. E. Newlin, E. A. Hiltunen, 5/28/81. Function: Compare plant data and analytical results for ATOG LOOP and determine specifically if PORV will lift upon LOOP for DB-1 and TMI-1. Applicable to the DB-1 and TMI-1 plants.

9.59 Document No. 32-1118539-00, "ATOG - DYSID Vs. TRAP for Pressurizer Pressure," J. M. Sims, L. J. Rudy, 4/22/80. Function: Confirm RC pressure response to transients using DYSID code compared with TRAP code results. Applicable to the ANO-1 plant.

9.60 Document No. 32-1120418-00, "PZR Spray Vs. RCP Combination," C. W. Tally, J. M. Knoll, 7/16/80. Function: To summarize spray flow as a function of running RCP combination.

9.61 Document No. 32-1151245-00, "177 RV Head Fluid Temperature Response During Venting," B. L. Boman, J. A. Weimer, 8/24/84. Function: Develop method to determine RV head fluid temperature response during liquid venting (no head void). Generically applicable to the B&W 177 FA plants.

9.62 Document No. 32-1153044-00,01, "RV Head Bubble/Pump Restart," M. A. Rinckel, R. R. Lange, 8/8/84. Function: To determine the P-T transient within the upper head region (assumed o be initially full of steam) following pump restart.

9.63 Document No. 86-1120419-00, "PZR Spray vs. RCP Combination," C. W. Tally, J. M. Knoll, 7/16/80. Function: Similar to that of Reference 9.60 above.

9.64 Document No. 51-1159882-00,01, "SBLOCA Temperature Data," J. R. Paljug, J. C. Seals, 10/2/86. Function: List temperature data for determination of temperature compensation of Level Measurement System at ANO-1. Applicable to the ANO-1 plant.

9.65 Document Nos. 2-1094632 through 2-1094637-01, "Loss of Offsite AC Power Safety Sequence Diagram," supplied for the customer by EDS Nuclear, 8/22/80. Contents: Similar to Reference 9.25 above. Applicable to the ONS-1, 2, 3 plants.

9.66 Document No. 2-1094996-00, "Chemical Addition System Auxiliary Diagram," supplied for the customer by EDS Nuclear, 6/8/81. Contents: Similar to that of Reference 9.39 above. Applicable to the Rancho Seco plant.

9.67 Document Nos. 2-1094654 through 2-1094659-00, "Loss of Offsite AC Power Safety Sequence Diagram," supplied for the customer by EDS Nuclear, 6/5/80. Contents: Similar to that of Reference 9.25 above. Applicable to the TMI-1 plant.

9.68 Document Nos. 74-1123297-00, 76-1123298-00, "Oconee Unit 3 Abnormal Transient Operating Guidelines," J. J. Kelly, E. F. Dowling, 5/13/82. Function: Provide operating guidelines for detection and mitigation of abnormal transients using a symptomatic approach. Applicable to Oconee Units 1, 2, and 3.

9.69 Document No. 74-1124158-00, "Three Mile Island Unit 1 ATOG," B. L. Brooks, E. F. Dowling, 3/12/85. Function: Similar to that of Reference 9.68 above. Applicable to the TMI-1 plant.

9.70 Document No. 74-1126473-00, "Crystal River Unit 3 ATOG," J. J. Kelly, D. A. Napior, 1/5/83. Function: Similar to that of Reference 9.68 above. Applicable to the CR-3 plant.

9.71 Document No. 74-1122058-00,01,02, "Arkansas Nuclear One Unit 1 ATOG," D. G. Newton, W. F. Jones, 9/11/86. Function: Similar to that of Reference 9.68 above. Applicable to the ANO-1 plant.

9.72 Document No. 74-1127469-01, "Rancho Seco ATOG," B. L. Brooks, R. L. Black, 3/13/85. Function: Similar to that of Reference 9.68 above. Applicable to the Rancho Seco plant.

9.73 Document No. 74-1125531-00, "Davis-Besse Unit 1 ATOG," J. J. Kelly, D. A. Napior, 10/22/82. Function: Similar to that of Reference 9.68 above. Applicable to the DB-1 plant.

9.74 Document No. 74-1135402-06, " Bellefonte Nuclear Plant Units 1 and 2 ATOG," B. L. Brooks, J. W. Tunstill, 8/19/85. Function: Similar to that of Reference 9.68 above. Applicable to the Bellefonte Units 1 and 2.

9.75 Document No. 51-1178252-00, "AS-2 Evaluation Report", G.E. Anderson, R. H. Ellison, 11/90. Function: Analytical results for a loss of HPI with a loss of all FW and for a loss of HPI during a small break LOCA.

9.76 Document No. 32-1175337-00, "SBO Coping Analysis", M. V. Parece, W. J. Wollscheild, 12/89. Function: Best estimate simulation of a station blackout.

9.77 Document No. 86-1177138-00,01, "Station Blackout TID", M. V. Parece, R. H. Ellison, 6/1/90. Function: Summary results of Document No. 32-1175337-00, "SBO Coping Analysis".

9.78 Document No. 51-1212183-00, "Justification of SBO Guidance in EOP TBD," M. V. Parece, B. L. Brooks, 2/13/92. Function: Provides summary of engineering assessment performed to justify SBO guidance. Applicable to all 177-FA plants.

10.0 Reactor Building

10.1 NRC Regulatory Guide 1.7 Rev 2, "Control of Combustible Gas Concentrations in Containment following a Loss-of-Coolant Accident," 1978

10.2 Document No. BAW 10105, Section 9, "ECCS Analysis of B&W's 177FA Raised-Loop NSS," June 1975

10.3 NRC NUREG/CR-3468, "Hydrogen: Air: Steam Flammability limits and Combustion Characteristics in the FITS Vessel," December 1976

10.4 NRC NUREG/CR-4763, "Safety-Related Equipment Survival in Hydrogen Burns in Large Dry PWR Containment Buildings," March 1988

10.5 Document No. 77-1125866-00, "Operator Training-Degraded Core Recognition and Mitigation," June 1981

10.6 NRC NUREG 0737, "Clarification of TMI Action Plan Requirements," Item IIE.4.2.,November 1980

10.7 NRC NUREG 1037, "Containment Performance Working Group Report (Draft)," May 1985

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10.10 Document No. BAW 10020, "An Evaluation of Purging as a Means of Controlling Post-Accident Reactor Building Hydrogen Concentration," April 1969

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