Functional Design Requirements for a Core Operating Limit Supervisory System for APR1400

Revision 1

Non-Proprietary

February 2017

REVISION HISTORY

Revision	Date	Page	Description
0	August 2014	All	First Issue
1	February 2017	viii, 1, 7, 105	In response to RAI 356-7881 Question 07-12, correction of some typographical errors

ABSTRACT

Maintaining a nuclear power plant within its Limiting Conditions for Operation (LCO) is a necessary condition for safe operation and acceptable transient consequences. These LCOs are delineated in the Technical Specifications. There are many systems in a nuclear power plant that are used to help the operators maintain the plant within the Limiting Conditions for Operation. One such system is the Core Operating limit Supervisory System (COLSS). COLSS is a digital computer based on-line monitoring system that is designed to assist the operator in implementing the technical specification requirements for monitoring of the following Limiting Conditions for Operations. To do so, COLSS uses measurements of in-core detector signals, CEA positions and plant thermal/hydraulic properties to determine the core power distribution and thermal performance.

This document provides a general description of the scope and methodology of the COLSS algorithm.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd.)

LIST OF TABLES

LIST OF FIGURES

Note: Flow charts are given with each algorithm description.

ACRONYMS AND ABBREVIATIONS

ASI	axial shape index
AOO	anticipated operational occurrence
CEA	control element assembly
COLSS	core operating limit supervisory system
CPC	core protection calculator
CRT	cathode ray tube
DNB	departure from nucleate boiling
DNBR	DNB Ratio
DTL	Detailed Report
FDR	functional design requirements
IPS	Information Processing System
LCO	limiting conditions for operation
LHR	linear heat rate (kW/ft)
PCS	plant computer system
POL	power operating limit
PPS	plant protection system
TST	test report

1. INTRODUCTION

1.1. Purpose

The purpose of this document is to provide a description of the functional design requirements of a Core Operating Limit Supervisory System (COLSS). When implemented with the appropriate data base and addressable constants the Functional Design Requirements described in this document meet the design bases for COLSS given in Section 2.

1.2. Scope

The COLSS is an application program implemented into the Information Processing System (IPS) that aids the operator in maintaining plant operation within selected Limiting Conditions for Operation (LCOs).

This document describes the functional design requirements for:

1. LCO monitoring and supporting algorithms to be implemented in the COLSS application software,

2. Data acquisition, COLSS program scheduling, and interface functions performed by the IPS executive software to assure proper COLSS operation, and

3. Process inputs and process outputs required for COLSS Monitoring.

Figure 1-1 shows a functional block diagram of COLSS algorithms. Values of COLSS constants are not included in this document.

These values will be contained in plant and/or cycle specific database documents.

1.3. Applicability

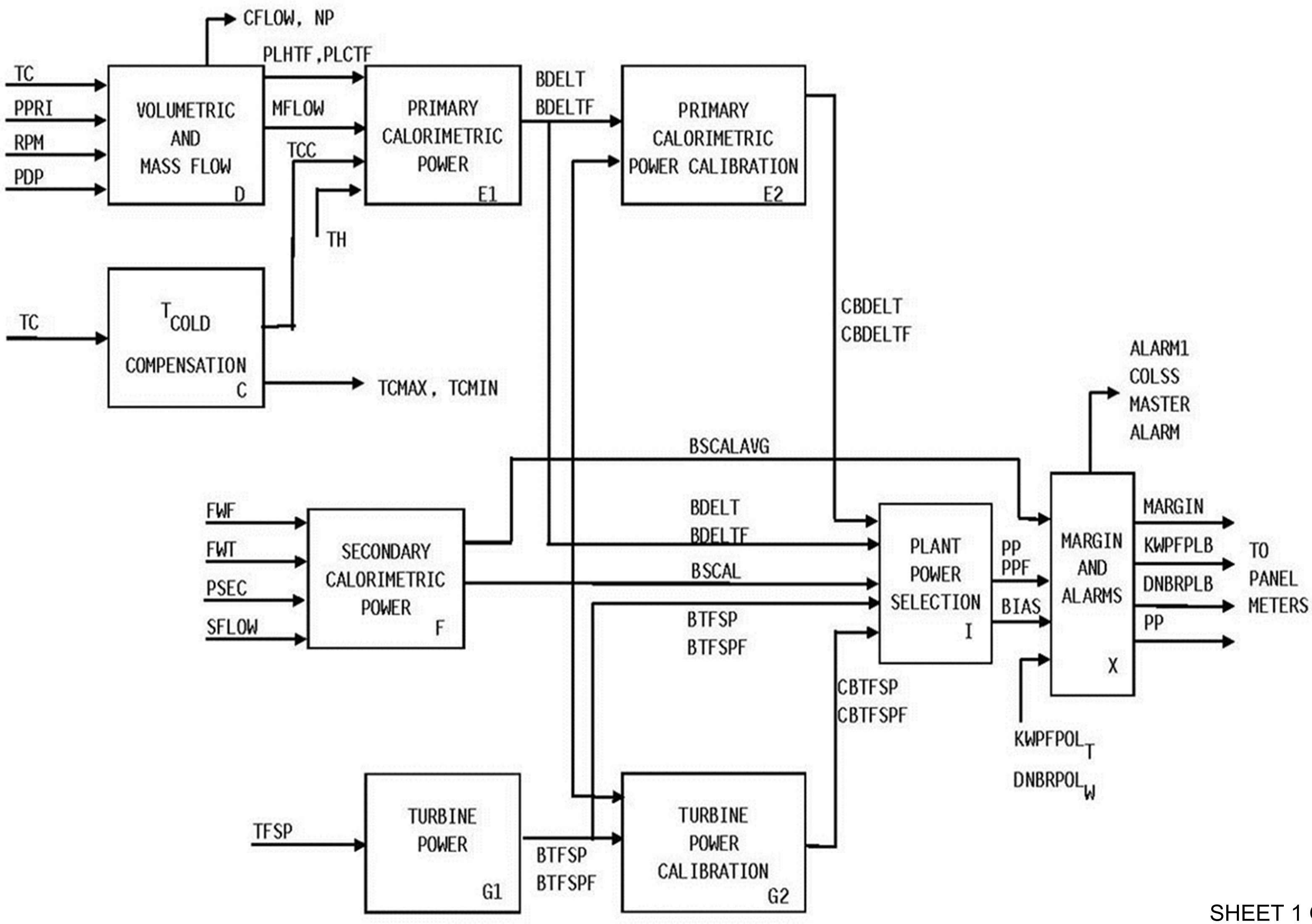
This document is a generic description of COLSS Functional Design Requirements (FDR). It is currently applicable to Advanced Power Reactor 1400 (APR1400).

1.4. Revision History

This document is prepared based on Ref. 1.5.1.

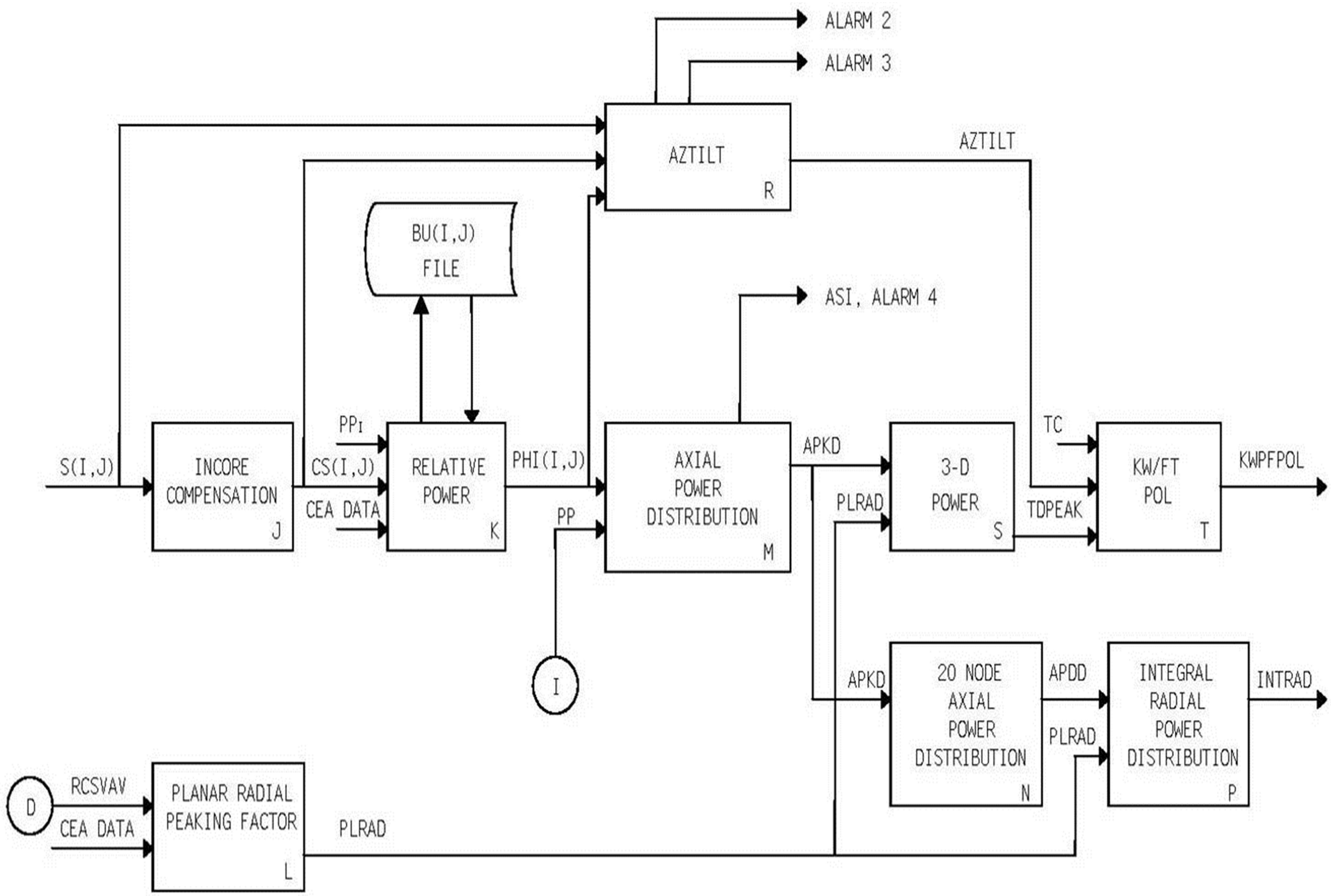
1.5. References

1.5.1 KNF-S34ICD-05005, “Functional Design Requirements for a Core Operating Limit Supervisory System for Shinkori Nuclear Power Plant Units 3&4,” Rev. 1, KNF, May 2013.



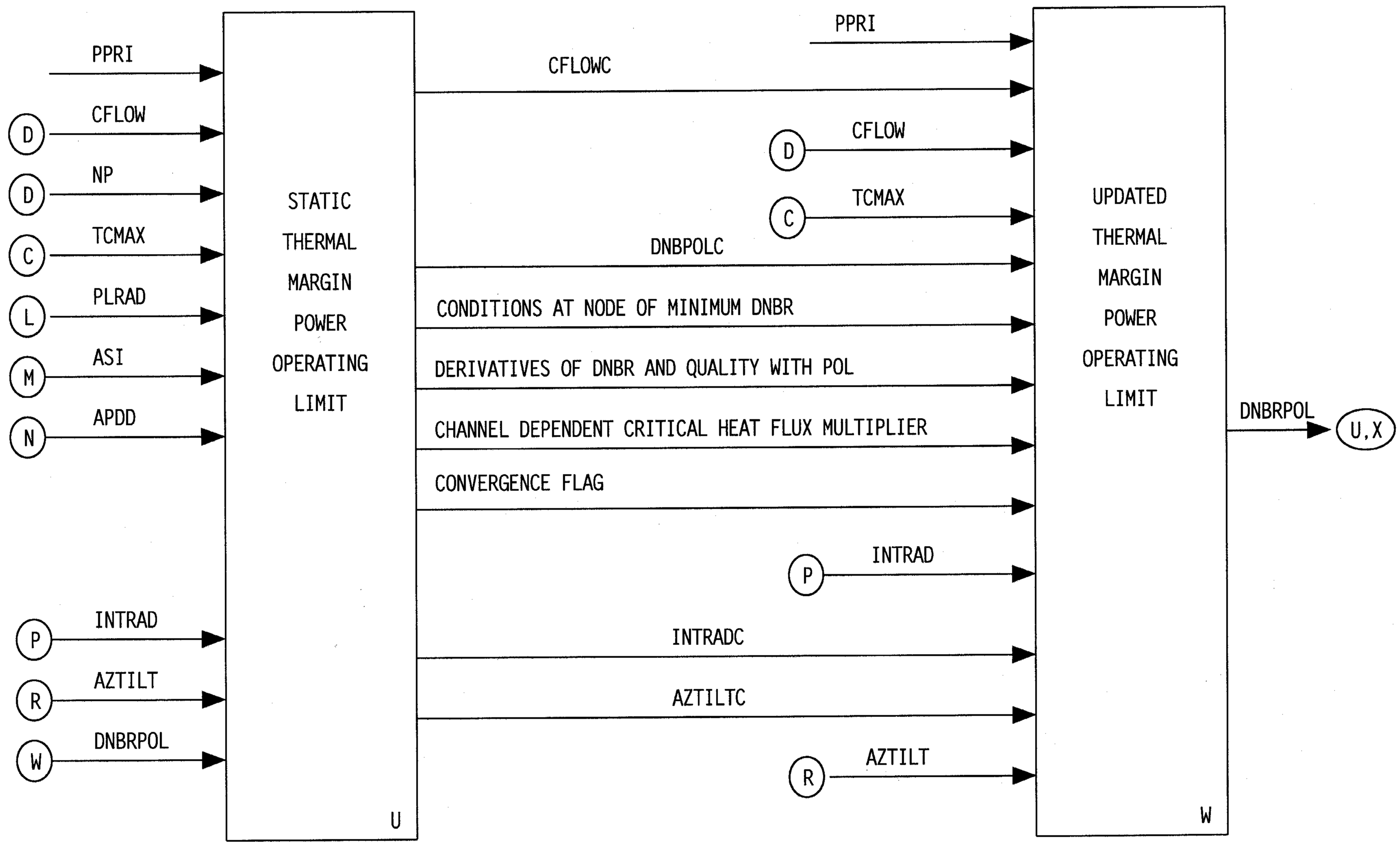
SHEET 1 OF 3

Figure 1-1 FUNCTIONAL DIAGRAM OF A CORE OPERATING LIMIT SUPEVISORY SYSTEM



SHEET 2 OF 3

Figure 1-1 (Cont.) FUNCTIONAL DIAGRAM OF A CORE OPERATING LIMIT SUPEVISORY SYSTEM



SHEET 3 OF 3

Figure 1-1 (Cont.) FUNCTIONAL DIAGRAM OF A CORE OPERATING LIMIT SUPEVISORY SYSTEM

2. COLSS DESIGN BASES

COLSS is designed to assist the operator in implementing sections of the technical specifications requirements for monitoring of the following Limiting Conditions for Operation (LCOs).

1. Departure from Nucleate Boiling Ratio (DNBR) Margin

2. Linear Heat Rate (LHR) Margin

3. Azimuthal Tilt

4. Axial Shape Index (ASI)

COLSS also assists the operator in maintaining core power equal to or below the "steady state" power level requirement imposed by the operating license.

To implement these requirements, COLSS is required to perform the following functions.

1. Compute the DNBR power operating limit from process variable measurements.

2. Compute the peak LHR power operating limit from process variable measurements.

3. Compute the azimuthal tilt and monitor it with respect to the LCO on azimuthal tilt.

4. Compute the axial shape index and monitor it with respect to the LCO on axial shape index.

5. Compute plant power from process variable measurements.

6. Compute the margin to the licensed power and to the peak linear heat rate and DNBR power operating limits.

7. Initiate appropriate alarm sequences and informative messages when any monitored margin or parameter exceeds its LCO.

The power operating limits are calculated such that:

1. No Anticipated Operational Occurrence (AOO) will cause a specified acceptable fuel design limit to be exceeded when initiated from inside the COLSS calculated LCOs, and when proper Plant Protection System (PPS) action occurs.

2. No postulated accident will have consequences more severe than those predicted in the Safety Analysis Report when initiated from inside the COLSS calculated LCOs, and when proper PPS action occurs.

The LCOs are calculated using algorithms that have been designed with adequate time response for the following plant operating conditions:

1. Normal steady state operation at any power between 15 percent and 100 percent of licensed power;

2. Normal, and controlled changes in unit load at any rate up to five percent per minute at any power between 15 percent and 100 percent of licensed power;

3. Step changes in unit load of up to 10 percent initiated at and ending at any power between 15 percent and 100 percent of licensed power.

Conditions 1 and 2 accommodate the following load cycle maneuver, for which the NSSS is warranted:

o A 100-50-100 percent load cycle with power maintained initially at 100% rated output for 14 hours, ramping down to 50% over a two hour period, operating for 6 hours at 50% rated output and then ramping up to 100% over the next two hours.

2.1. Limiting Conditions for Operation

LCOs are the limits specified in the Technical Specifications that are used to define ranges of initial conditions for transient and setpoint analysis.

2.2. Anticipated Operational Occurrences

AOOs are defined to be those conditions of normal operation which are expected to occur one or more times within the lifespan of the nuclear power unit.

2.3. Relationship Between Monitoring and Protection Systems

The designs of the monitoring and protection systems are integrated with the plant technical specifications (in which safety limits and limiting conditions for operation are specified) to assure that all safety requirements are satisfied. The monitoring systems, protection systems, and technical specifications thus complement each other. Protection systems provide automatic trip actions to place the plant in a safe condition to prevent abnormal events. The technical specifications set forth the allowable regions and modes of operation of plant systems, components, and parameters. The monitoring systems (meters, displays, and systems such as COLSS) assist the operating personnel in enforcing the technical specifications requirements. Making use of the monitoring systems, protection systems and technical specifications in the manner described above will ensure that all anticipated operational occurrences or postulated accidents will have acceptable consequences if the following conditions are satisfied.

1. The operating personnel maintain all protection systems settings at or within allowable values.

2. The operating personnel maintain actual plant conditions within the appropriate LCOs.

3. Equipment other than that causing an abnormal event, or which have been degraded by such an event, operates as designed.

3. SYSTEM REQUIREMENTS

The system elements and structure required to perform the COLSS monitoring functions are described in this section.

The process inputs, and processing of input signals required to drive the process models in the monitoring programs, are described in Section 3.l.

The output signals, alarms and messages produced by the COLSS monitoring function are described in Section 3.2.

The cathode ray tube (CRT) display reports, detailed print reports, and test execution reports are described in Section 3.3.

The structure of COLSS algorithms, including the sequence and frequency of executions, and conditions which require skipping of an algorithm, is described in Section 3.4.

3.1. COLSS Data Acquisition Procedures

The process input signals required by COLSS are listed in Table 3-1. The origin of these signals is shown in Figures 3-1 and 3-2.

Table 3-1 includes the COLSS symbol, description, units, and scan rate of the COLSS process inputs.

All COLSS procedures described in this document are performed in engineering units. All process inputs must be converted to engineering units prior to use by any of the procedures described herein.

All process inputs except in-core detector signals and control element assembly (CEA) positions are examined to determine their validity for use in the COLSS monitoring procedures. The limits for this validity testing in COLSS may differ from those in the IPS input processing section. The remaining COLSS process inputs are validity checked in COLSS using the sensor validity procedure described in Section 3.1.3 of this specification. The validity procedure selects specific process inputs for use as the process variable signals used by the monitoring procedures described in Section 4.0 of this specification.

The conversion of in-core detector signal to engineering units and the compensation process itself are performed outside of COLSS in the Incore Processing section of the Plant Computer System (PCS). COLSS expects this processing to include detector background and detector sensitivity correction, compensation for rhodium detector dynamics and quality tagging. An algorithm for performing the dynamic compensation process is described in Section 3.1.2.

CEA validity checking and deviation determination is performed outside of COLSS in the Data Acquisition section. The process variables used by COLSS include the height of the lowest CEA in each group and the group deviation, which is the difference in height between the highest and lowest CEAs in each group.

The process variables set by the sensor validity procedure are biased for channel offset or other minor errors. This biasing process is described in Section 3.1.4 of this specification.

3.1.1. NSSS Instrumentation and Description of COLSS Inputs

Figure 3-1 shows a diagram of the COLSS sensor locations indicating the major system components and relative locations of sensors that provide input signals to COLSS.

Table 3-1 provides the COLSS input designations. The following list of variable names describes the COLSS inputs and associated notation.

PPRI - Pressurizer Pressure

TC - Cold Leg Temperature

TH - Hot Leg Temperature

RPM - Reactor Coolant Pump Speed

PDP - Reactor Coolant Pump Differential Pressure

FWF - Feedwater Flow Differential Pressure

FWT - Feedwater Temperature

SFLOW - Secondary Steam Flow Differential Pressure

PSEC - Secondary Steam Pressure

TFSP - Turbine First Stage Pressure

S(I,J) - Rhodium In-Core Detector Signals

CS(I,J) - Compensated rhodium In-Core Detector signals

LSHUT - Height of lowest shutdown CEA in a group

LPSR - Height of lowest part strength CEA in a group

LREG - Height of lowest regulating CEA in a group

DEVS - Shutdown CEA group deviation

DEVP - Part strength CEA group deviation

DEVR - Regulating CEA group deviation

Some parameters are measured in two or more locations. These measurements are indicated by numbers (1, 2 etc.) corresponding to the specific measurements.

Examples:

FWT(1) - Feedwater Temperature for Steam Generator No. 1

RPM(I) - Reactor Coolant Pump speed, where I = 1,2,3,4, designating a specific pump

The in-core detectors are divided into NS strings of ND rhodium detectors. The following designation is used to define the detectors.

Detector strings are identified by the subscript, I

I = 1, 2, 3, … , NS

Detectors within a string are identified by the subscript, J

J = 1, 2, 3, 4, … ,ND

The in-core instrumentation pattern of a core with NS = 61 instrumented channels is shown in Figure 3-2.

Figure 3-3 shows a typical in-core detector string with ND = 5.

The double subscript (I,J) completely identifies a specific detector.

3.1.2. (Block J) In-Core Detector Dynamic Compensation

3.1.2.1.

Dynamic compensation of the in-core detector signals is performed to compensate the corrected detector signal for the beta decay behavior of the rhodium detector element. This compensation is performed outside of COLSS in the in-core processing section of the PCS.

3.1.2.2. Timing

The compensation correction shall be performed for all detectors at ten-second intervals.

3.1.2.3. Inputs

S(I,J) - Corrected in-core detector signal

QS(I,J) - In-core detector signal quality

<u>where</u>

J varies from 1 to 5

I varies from 1 to 61

3.1.2.4. Outputs

CS(I,J) - Compensated rhodium detector signals, to blocks K and R

3.1.2.5. Calculation

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If an in-core detector has a quality tag value of BAD, then it shall be removed from compensation. The in-core detector quality tag values shall be accessible to those algorithms which process in-core detector signals to allow special treatment of failed detectors. It shall be possible to remove a detector from scan at the operator's console. When a detector is removed from scan, its quality shall be set to BAD.

3.1.2.6. Calculation Sequence

Initialization:

When COLSS is restarted, a detector is returned to scan, or its quality tag changes from BAD to GOOD, initialization of the past values of detector input $S_{I,J}$ and the past values of the compensated detector signal $CS_{I,J}$ is required.

The following initialization procedure shall be used.

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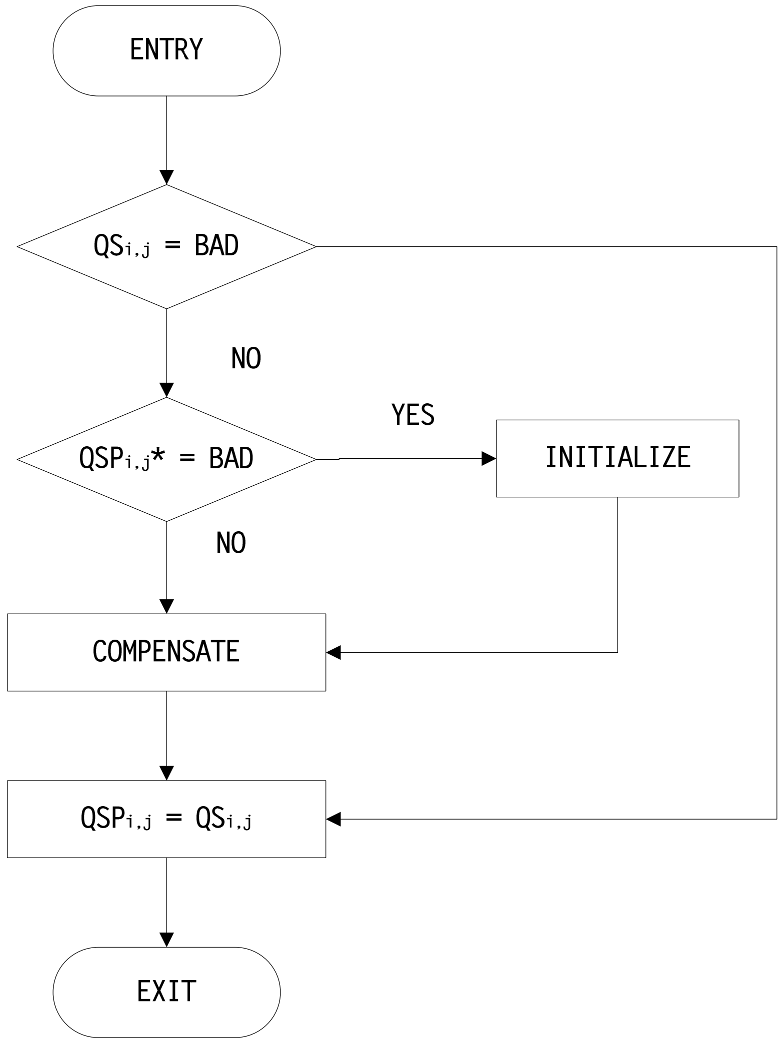
Once initialized the sequence of calculations for each succeeding scan shall be as shown in Figure J-1.



* ALL QSPs INITIALIZED AS BAD FOR FIRST TIME EXECUTION OF BLOCK

QSP : PAST IN-CORE DETECTOR SIGNAL VALIDITY

Figure J-1 SEQUENCE OF CALCULATIONS FOR INCORE SIGNAL DYNAMIC COMPENSATION

3.1.3. (Block A) Sensor Validity Check

3.1.3.1. Description

Sensor validity processing is performed to:

1. Detect process variables that lie outside the COLSS processing range;

2. Detect gross failure of a COLSS process input;

3. Detect deterioration of operation of one sensor of a pair of sensors.

Upon detection of one of these conditions, an informative message is issued, and where possible, corrective action is taken.

The following checks are performed:

1. Out of range sensors (once per scan);

2. Cross check of like sensors (once per scan).

The COLSS program shall be designed so that in the event an invalid sensor is detected, corrective action can be taken either automatically or by the operator from the operator's console. Automatic corrective action consists of the use of alternate sensor inputs for COLSS variables within the limitations noted below. The following options are available for COLSS variables (RPM1, TH1, etc.) in the event of a failed sensor.

1. Automatic replacement of a failed process input by an alternate process input when specified.

2. Automatic algorithm alteration for certain functions when no alternate inputs are available.

3. Substitutions of constants for selected COLSS inputs performed under operator control.

3.1.3.2. Timing

The sensor validity sequence shall be performed immediately after data acquisition processing of each input scan group.

3.1.3.3. Inputs

Table 3-1 gives a complete description of each input, including alternate process inputs. Throughout the body of this specification these inputs are referenced by the symbols shown below.

TC1I, TC2I, TC3I, TC4I	-	Cold leg temperatures
TH1I, TH2I	-	Hot leg temperatures
PPRIA, PPRIB	-	Pressurizer pressure
PSECI(1), PSECI(2)	-	Secondary steam pressures
FWTI(1), FWTI(2)	-	Feedwater temperatures
PDPA(I)	-	RCP DP for pump I, preferred sensor
PDPB(I)	-	RCP DP for pump I, alternate sensor

RPMA(I)	-	RCP speed for pump I, preferred sensor
RPMB(I)	-	RCP speed for pump I, alternate sensor
SFLOW(1)…SFLOW(4)	-	Steam flow DPs
FWFI(1), FWFI(2)	-	Feedwater flow DPs
TFSPA, TFSPB	-	Turbine first stage pressure
S(I, J)	-	In-core detector signals
CS(I, J)	-	Compensated in-core detector signals
LREG(I)	-	Lowest rod position in regulating group I for I = 1,8
LSHUT(I)	-	Lowest rod position in shutdown group I for I = 1, 2
LPSR(I)	-	Lowest rod position in part strength rod group I for I = 1, 2
DEVR(I)	-	Deviation of regulating group I for I = 1,8
DEVS(I)	-	Deviation of shutdown group I for I = 1, 2
DEVP(I)	-	Deviation of part strength group I for I = 1, 2

3.1.3.4. Outputs

TC(1)	-	Cold leg 1A temperature
TC(2)	-	Cold leg 1B temperature
TC(3)	-	Cold leg 2A temperature
TC(4)	-	Cold leg 2B temperature
TH(1)	-	Hot leg 1 temperature
TH(2)	-	Hot leg 2 temperature
PPRI	-	RCS pressure
PSEC(1)	-	S/G 1 steam pressure
PSEC(2)	-	S/G 2 steam pressure
FWT(1)	-	S/G 1 feedwater temperature
FWT(2)	-	S/G 2 feedwater temperature
PDP(1)	-	RCP 1A differential pressure
PDP(2)	-	RCP 1B differential pressure
PDP(3)	-	RCP 2A differential pressure
PDP(4)	-	PDP(4) - RCP 2B differential pressure
RPM(1)	-	RCP 1A speed

RPM(2)	-	RCP 1B speed
RPM(3)	-	RCP 2A speed
RPM(4)	-	RCP 2B speed
SFLOW(1)	-	S/G 1 steam flow differential pressure
SFLOW(2)	-	S/G 2 steam flow differential pressure
FWF(1)	-	S/G 1 feedwater flow differential pressure
FWF(2)	-	S/G 2 feedwater flow differential pressure
TFSP	-	Turbine first stage pressure
S(I, J)	-	In-core detector signals; I = 1 to 61, J = 1 to 5
CS(I, J)	-	Compensated in-core detector signals; I = 1 to 61, J = 1 to 5
LREG(I)	-	Lowest rod position in regulating group I for I = 1,8
LSHUT(I)	-	Lowest rod position in shut down group I for I = 1,2
LPSR(I)	-	Lowest rod position in part strength rod group I for I = 1, 2
DEVR(I)	-	Deviation of regulating group I for I = 1, 8
DEVS(I)	-	Deviation of shutdown group I for I = 1, 2
DEVP(I)	-	Deviation of part strength group I for I = 1, 2

3.1.3.5. Calculations

The sensor validity function is performed in three steps.

1. Process Input Range Check

All COLSS inputs undergo validity checking in Data Acquisition prior to their admission to COLSS. With the exceptions noted below, the COLSS inputs are additionally range-checked in COLSS to determine if their values are within the COLSS processing range.

The followings are not range-checked in COLSS; their validity is determined in Data Acquisition:

- In-core detector signals;
- CEA group positions and deviations;
- Sensors which have failed a Data Acquisition range check.

2. Process Input Cross Check

Certain process input pairs are cross-checked to verify the rationality of process input data.

3. Process Variable Selection

Process variable selection is performed based on the process input validity. Process variable validity is constructed from the process input validity examined in the selection process.

3.1.3.5.1. Process Input Range Check

The process input range check is performed for each process input as follows.

If a process input has been deleted from scan, then that process input shall be treated as being out of range.

If a process input has a value substituted either by console function or by COLSS execution in the TEST mode, then that process input shall be treated as a live process input.

A process input has good validity if that process input lies between its COLSS processing limits, that is: TS

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3.1.3.5.2. Process Input Cross Check

Selected process input pairs are cross-checked to determine the rationality of the input values. This check is intended to detect a gradual deterioration of one sensor of a pair.

Two classes of process inputs are cross-checked:

1. Inputs from two independent channels sensing a process variable;

2. Similar input pairs.

The process inputs are cross-checked as follows.

<u>Four Pump NSSS Operation Check</u>

Similar input pairs are cross-checked only when four reactor coolant pumps are in operation. If each RCP speed input with a validity of GOOD is greater than a constant, then the RCP is considered to be running. If this test is satisfied for each of the four pumps, then similar input cross-checking is performed. That is:

The following tests are performed for each reactor coolant pump (1 through 4)

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On each execution, FORPMP is initialized to TRUE prior to testing the first pump speed pair.

Independent Channel Pair Cross Check

Each independent process input pair is cross-checked to determine the rationality of each sensor of the pair. Because two independent process instrument loops sensing the same physical process condition are available, cross-checking may be performed during NSSS operation in any allowed pump configuration. If either input of the pair has bad validity, then the pair shall not be cross-checked. If the magnitude of difference between two members of the pair exceeds a constant threshold, then the pair is considered unreasonable. That is:

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The process input pairs belonging to this class are shown below.

Independent Process Input Pairs

A Input	B Input	Threshold
RPMA(I)	RPMB(I)	A2
RPMB(I)	PDPB(I)	A3
PPRIA	PPRIB	A6
TFSPA	TFSPB	A11
SFLOWI(1)	SFLOWI(2)	A10
SFLOWI(3)	SFLOWI(4)	A10

Cross-Check of Similar Input Pairs

If the four pump mode flag FORPMP is TRUE, then similar input pairs are cross-checked. The form of the check is used for the independent process input pairs. The similar input pairs and associated thresholds are shown below.

A Sensor	B Sensor	Threshold
TC1I	TC2I	A4
TC3I	TC4I	A4
TH1I	TH2I	A5
FWT(1)	FWT(2)	A7
FWF(1)	FWF(2)	A9
PSEC(1)	PSEC(2)	A8

The intermediate results DMC(I) shall be addressable computed values.

3.1.3.5.3. Process Variables Selection

The use of possible asymmetric NSSS operating conditions and single sensor configuration prevents the use of selection procedures for the following process inputs which are used by the secondary calorimetric power calculation (Block F).

FWF(1)	FWF(2)
FWT(1)	FWT(2)
PSEC(1)	PSEC(2)

Each of the process variables selected for use by the remaining COLSS blocks have both a preferred source and an alternate source. The alternate source is used when the preferred process input has out of range validity. This selection process implements the "automatic replacement" function mentioned earlier.

Three classes of process variables exist for which selection is allowed:

1. RCP speed process variable;

2. Process variables with independent process input channels (excluding RCP speed);

3. Process variables with similar process inputs.

The RCP speed process variable requires special consideration because a stopped pump is a possible case. When a pump is stopped its two speed process inputs may be out of range low. It is possible that a process instrument pair may fail both high or one high and one low. However, these cases are much less probable than the stopped pump. Thus if both speed inputs are out of range, the pump is considered to be stopped.

Process variables with independent process input channels are selected using the general selection procedure.

Process variables with similar process input pairs are selected using the general selection procedure when the four pump test is satisfied. Otherwise, the use of preferred process input is forced.

<u>Reactor Coolant Pump Speed Selection</u>

The reactor coolant pump speed outputs (RPM(I) for I = 1 to 4) and reactor coolant pump speed validity are set using the following rules.

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General Selection Procedure

When the preferred process input has validity GOOD or XCHK, it is used as the process variable and the process variable validity is the validity of the preferred process input.

Otherwise if the alternate process input has validity GOOD, then it is used, and the validity of the process variable is the validity of the process input.

That is:

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The process variable and process input assignments are shown below for independent input pairs.

PROCESS VARIABLE	PREFERRED INPUT	ALTERNATE INPUT
PDP(I)	PDPA(I)	PDPB(I)
PPRI	PPRIA	PPRIB
TFSP	TFSPA	TFSPB
SFLOW(1)	SFLOWI(1)	SFLOWI(2)
SFLOW(2)	SFLOWI(3)	SFLOWI(4)

The process variable and process input assignments are shown below for similar input pairs.

PROCESS VARIABLE	PREFERRED INPUT	ALTERNATE INPUT
TC(1)	TC1I	TC2I
TC(2)	TC2I	TC1I
TC(3)	TC3I	TC4I
TC(4)	TC4I	TC3I
TH(1)	TH1I	TH2I
TH(2)	TH2I	TH1I

Number of Pumps Running Test

After the pump RPM is selected, a check is made for less than two reactor coolant pumps operating. If less than two pumps is running, execution of only blocks A, B, F, G, I, J, K and X shall be continued to accumulate in-core detector burnup and fuel burnup factor data.

This check is made as follows:

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THEN PUMPRUN = PUMPRUN + 1

COLSS Sensor Validity Propagation

In addition to its use in determining sensor selection, the COLSS validation of RNG and XCHK is needed in the Failed Sensor Report (Section 3.3.3) to alert the operators to potential sensor problems. These are not propagated to the remaining COLSS algorithms. Instead, the validity of RNG is treated as BAD, and the validity of XCHK is treated as GOOD.

3.1.3.6. Constants

Symbol	Function
A1	RCP operating speed threshold
A2	RCP speed cross check threshold
A3	RCP DP cross check threshold
A4	TCOLD cross check threshold
A5	THOT cross check threshold
A6	RCS pressure cross check threshold
A7	Feedwater temperature cross check threshold
A8	Steam pressure cross check threshold
A9	Feedwater flow cross check threshold
A10	Steam flow cross check threshold
A11	TFSP cross check threshold
X(I)	Low COLSS processing limit for input(I)
Y(I)	High COLSS processing limit for input(I)

3.1.3.7. Sequence of Calculation

See Figure A-1.

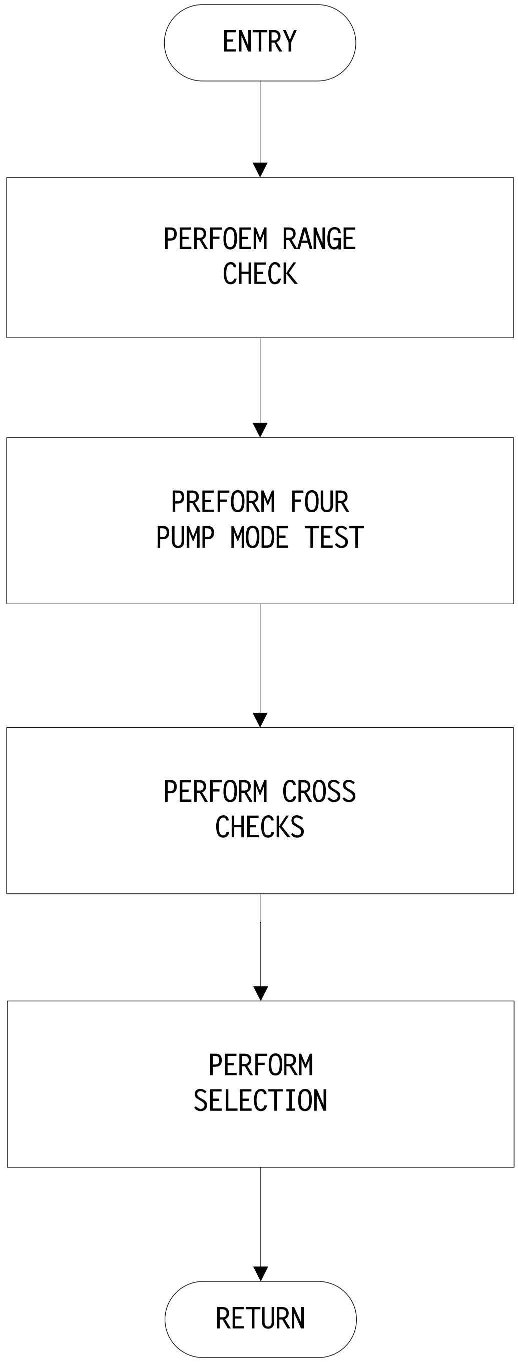

Figure A-1 SENSOR VALIDITY CHECKS SEQUENCE OF CALCULATION

3.1.4. (Block B) Analog Measurement Error Adjustment

3.1.4.1. Description

The purpose of this block is to adjust certain analog inputs for measurement errors after conversion to engineering units. Since the measurement errors are now included in the COLSS overall uncertainty penalty factors, this block is not used any more.

3.1.4.2. Timing

The correction sequence shall be performed immediately after the validity checking of each input scan group.

3.1.4.3. Inputs

PPRI	-	Pressurizer pressure, from block A
TC(I)	-	Cold leg temperatures for I = 1 to 4 from block A
TH(I)	-	Hot leg temperatures for I = 1, 2 from block A
RPM(I)	-	Reactor coolant pump speeds for I = 1, 4 from block A
PDP(I)	-	Reactor coolant pump differential pressures for I = 1, 4 from block A
TFSP	-	Turbine first stage pressure, from block A

3.1.4.4. Outputs

PPRI	-	Pressurizer pressure, to blocks D, E, U
TC(I)	-	Cold leg temperatures, to blocks C, D, E, T
TH(I)	-	Hot leg temperatures, to block E
RPM(I)	-	Reactor coolant pump speeds, to block D
PDP(I)	-	Reactor coolant pump differential pressures, to block D
TFSP	-	Turbine first stage pressure, to block G

3.1.4.5. Calculations

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3.1.4.6. Constants

B01-B16 (See Table B-1.)

Table B-1 LIST OF CONSTANTS FOR ANALOG MEASUREMENT ERROR ADJUSTMENT

Variable	Constant
PPRI	B01
TC(1)	B02
TC(2)	B03
TC(3)	B04
TC(4)	B05
TH(1)	B06
TH(2)	B07
RPM(1)	B08
RPM(2)	B09
RPM(3)	B10
RPM(4)	B11
PDP(1)	B12
PDP(2)	B13
PDP(3)	B14
PDP(4)	B15
TFSP	B16

3.2. COLSS Monitoring Procedures Outputs

The COLSS monitoring procedures calculate the following Power Operating Limits (POL) and plant operating parameters:

1. DNBR POL;

2. Linear heat rate (kW/ft) POL;

3. Azimuthal tilt index;

4. Plant power;

5. Axial shape index.

The monitoring process also calculates:

1. Margin to licensed power,

2. Margin to the DNBR POL, and

3. Margin to the linear heat rate POL.

An alarm (COLSS Master Alarm) is initiated if any of these margins becomes less than an alarm threshold.

This section describes displays and messages associated with those calculations and functions which are directly associated with operation of the power plant.

3.2.1. Alarms

Each of the following COLSS alarms must be provided:

1. COLSS master alarm;

2. COLSS ASI out of limits alarm;

3. Azimuthal tilt index out of technical specification limits alarm;

4. Azimuthal tilt index out of Core Protection Calculator (CPC) limits alarm.

The processing for these COLSS alarms is described in various subsections of Section 4. Typical alarm CRT messages which are displayed in conjunction with these alarms are shown in Figure 3-4.

3.2.1.1. COLSS Master Alarm

The COLSS master alarm is set when:

1. Plant power exceeds the DNBR or linear heat rate POL;

2. Plant power exceeds licensed power;

3. COLSS monitoring is interrupted.

Detailed procedures for setting and clearing this alarm are described in Section 4.

3.2.1.2. ASI Out of Limits Alarm

The ASI out of limits alarm is initiated when the COLSS calculated ASI is outside the limits specified in the Technical Specifications. Detailed procedures for setting and clearing this alarm are presented in Section 4.2.3.

3.2.1.3. Technical Specification Azimuthal Tilt

The Technical Specification azimuthal tilt limit alarm implemented through COLSS is initiated when the COLSS calculated azimuthal tilt exceeds the value specified in the Technical Specifications. Detailed procedures for setting and clearing this alarm are presented in Section 4.2.6.

3.2.1.4. CPC Azimuthal Tilt Allowance

The CPC azimuthal tilt limit alarm is initiated when the COLSS calculated azimuthal tilt exceeds the CPC azimuthal tilt limit. Detailed procedures for setting and clearing this alarm are presented in Section 4.2.6.

3.2.2. Operator Displays

The following displays are provided at the reactor operator's station:

1. Unsmoothed plant power, PP;

2. Unsmoothed DNBR power operating limit, DNBRPLB;

3. Unsmoothed kW/ft power operating limit, KWPFPLB;

4. Core average axial shape index, ASI;

5. High resolution digital display of limiting smoothed margin, MARGIN.

Table 3-2 presents the required range and accuracy of these displays.

3.3. COLSS Output Reports

Additional displays and reports are incorporated in COLSS to assist the operator in monitoring the operation of NSSS and in evaluating COLSS alarms. These reports include:

1. CRT Displays;

2. Detailed Print Report;

3. Axial Power Distribution Plot;

4. Test Mode Report.

In addition, the Failed Sensor Report should include the COLSS sensor validity of RNG and XCHK, as described in Section 3.1.3.5.

3.3.1. CRT Displays

It shall be possible to display the parameters in Table 3-3 with attributes LOG or FAV (Field Adjustable Value) on the interactive display device. Sample reports showing the grouping of related data are found in Figure 3-5. Use of standard report formats where possible is recommended.

3.3.2. Power Distribution Plot

A typical power distribution plot is shown in Figure 3-6. The following information should be included:

1. Report title, customer identification, date, and time;

2. Axial power distribution plot;

3. Part strength CEA group positions;

4. Position of the last six regulating CEA groups in the withdrawal sequence.

This plot is included in the Detailed Print Report. In addition, it may be displayed independently on the CRT.

3.3.3. Failed Sensor Report

The Failed Sensor Report should identify those COLSS sensors that have failed range-checks or cross-checks as described in Section 3.1.3.5.

A typical report is shown in Figure 3-5.

3.3.4. Test Mode Report

This printed report is generated to document the correct operation of the COLSS program. It is generated in the TEST mode of execution and should include:

l. Report title, date, time, and customer identification;

2. All test input data;

3. All block addressable inputs and associated validity;

4. All block addressable outputs and associated validity;

5. All execution control information;

6. All addressable constants;

7. All COLSS meter output variables, alarm and the associated no value validity designator;

8. Those additional items listed in Table 3-3 that are designated for inclusion in the test report (TST).

3.3.5. Detailed Print Report

The detailed print report is designed primarily for COLSS testing or troubleshooting. This report should contain the following information:

1. Date, time, and customer identification;

2. All COLSS process input values and their validity;

3. All block addressable inputs, addressable outputs, and their associated validity;

4. All additional items listed in Table 3-3 that are designated for inclusion in the detailed report (DTL);

5. Power distribution plot.

All items should be from the time frame used as input to the DNBR power operating limit calculations.

3.4. COLSS Control and Structure

3.4.1. Priority and Data Base Access

The COLSS program shall allocate the scheduling priority necessary to meet the system response and timing requirements of Section 3.4.5.

Software control shall be provided to prevent the operator from accidentally altering the basic scan rate of the COLSS sensors from the operator's console.

3.4.2. Modes of Operation

The COLSS program shall have three modes of operation: TEST, SCHEDULED, and UNSCHEDULED.

In the SCHEDULED mode of operation COLSS shall be executed in a dynamically scheduled real time environment performing the functions and calculations specified in this document. Basic scheduled execution of COLSS shall consist of blocks A,B,C,D,E,G,I,J,K and X. When either the validity of primary calorimetric power is BAD or primary calorimetric power is greater than a constant value, STARTF, execution of block F shall be initiated. When the validity of plant power is GOOD and plant power is greater than a constant, STARTL, execution of blocks L,M,N,P,R,S, and T shall be initiated. When the validity of plant power is GOOD and plant power is greater than a constant STARTU, then execution of blocks U, and W shall be initiated.

In the TEST mode COLSS execution shall be performed based on test case input data rather than live sensor inputs. COLSS execution shall start from an uninitialized state. All COLSS processing normally performed in the SCHEDULED mode shall be performed in the TEST mode with the following exceptions, K module 2 and K module 3. This action is intended to protect the burnup data calculated by these modules.

In the TEST mode of execution, the COLSS program blocks should be executed in alphabetical order in a batch fashion rather than in normal sequence at the scheduled interval.

All test data shall be inserted upstream of the validity testing specified in block A to allow testing of the validity function.

In the UNSCHEDULED mode no COLSS blocks shall be executed, and the COLSS master alarm, ALARM1, shall be set.

Table 3-4 shows the allowed COLSS mode transitions.

3.4.3. Sequence of Block Execution

3.4.3.1. One Second Blocks

The one second block of calculations shall be performed in the following sequence; A,B,C,D,E,G,I,W,X.

3.4.3.2. Ten Second Blocks

The ten second block of calculations was designed to allow execution of blocks K,L,M.N,P,R,S and T in alphabetical order. If it is necessary to use multiple overlays to implement the ten second block of calculations, the overlays should preserve the graph structure shown in Figure 3-7. Block J may be performed with the incore data acquisition processing or with the ten second COLSS calculations.

3.4.3.3. Thirty Second Blocks

Blocks F and U shall be executed sequentially. Execution of block F shall be initiated after completion of the one second block of calculations.

3.4.4. Conditions for Skipping Blocks

The algorithm description for each block specifies the conditions under which the block is dropped from service or skipped. These conditions are specified in terms of block input conditions.

3.4.5. System Response and Timing

COLSS is designed to monitor the operation of the nuclear reactor core in real time. To achieve this objective, the monitoring calculations must be performed at frequencies determined by the parameter rate of change during the events which COLSS is designed to accurately monitor. The COLSS calculations are divided into the following groups of tasks:

1. One second data acquisition;

2. One second power calculations;

3. One second power operating limit update;

4. One second monitoring calculations;

5. Ten second data acquisition;

6. Ten second power distribution calculations;

7. Ten second power operating limit calculations;

8. Thirty second secondary calorimetric power calculation;

9. Thirty second power operating limit calculations.

This section will describe the timing requirements for each of these groups of tasks.

3.4.5.1. One Second Data Acquisition

The one second data acquisition processing includes the scanning, analog to digital conversion, and conversion to engineering units for those inputs in Table 3-1 which have a one second scan rate.

The one second data acquisition processing shall be performed at one second intervals. The one second data acquisition processing should complete within 1 second after initiation. Each variable should be scanned and converted at an interval as close to one second as is practicable.

3.4.5.2. One Second Calculations

The one second calculations consist of power calculations, power operating limit update calculations and monitoring calculations (Blocks A,B,C,D,E,G,I,W,X). The one second calculations shall begin immediately following the completion of one second data acquisition processing and shall complete before the next one second interval begins.

All process input data shall be from the one second data acquisition processing just completed, and shall remain unaltered throughout these calculations. If the one second data acquisition must begin before completion of the one second calculations, protection of the process variable data is necessary.

3.4.5.3. Ten Second Data Acquisition

The ten second data acquisition includes the acquisition of CEA position data, the conversion of this data to group height, group deviation, the scanning, analog to digital conversion, conversion to engineering units, validity checking, and compensation of the incore nuclear detector signals.

Other tasks may establish more frequent scan frequency requirements for these process inputs. The values provided for the ten second COLSS calculations shall be acquired concurrently with the acquisition of one second data used by the ten second COLSS calculations.

The CEA inputs used by COLSS need to be transmitted to COLSS only as required for performance of the ten second power distribution calculations.

3.4.5.4. Ten Second Calculations

The ten second COLSS calculations (blocks J,K,L,M,N,P,R,S,T) shall begin immediately following completion of the ten second data acquisition processing and shall complete before the next ten second interval begins.

All ten second data shall be from the completion of ten second data acquisition processing. All one second data and calculated results shall be from one second calculations occurring concurrently with the ten second data acquisition. The data and calculated results used by ten second calculations shall be protected from alteration by more frequently executing tasks.

3.4.5.5. Thirty Second Calorimetric Power Calculations

The calorimetric power calculations (Block F) shall begin at thirty second intervals. The first set of thirty second calculations shall begin immediately following the first set of one second calculations. The secondary calorimetric power calculations shall complete before the next thirty second interval begins.

The validity processing of the Block F input data specified in Block A may be performed as a part of thirty second calculations. All input data shall be protected from alteration by more frequently executing tasks.

3.4.5.6. Thirty Second Power Operating Limit Calculations

The power operating limit calculations (Block U) shall be performed at thirty second intervals. The first thirty second calculation shall be performed after completion of the first set of ten second calculations. These calculations must complete before the next thirty second interval begins.

All input data and calculated results should be from the most recent execution of ten second calculations. All input data and calculated results required by these calculations shall be protected from alteration by more frequently executed tasks.

3.4.5.7. Display Updating

All system meter display outputs and contact closure alarm outputs shall be updated as quickly as practical. However, the display and alarm outputs from all blocks must be updated within one minute of the completion of the group of calculations which determine the values upon which the output is based.

For the one second block of calculations these outputs include:

Plant Power	PP	Block X
Filtered Plant Power	PPF	Block X
Smoothed Margin	MARGIN	Block X
COLSS Master Alarm	ALARM1	Block X
Updated DNBR POL	DNBRPLB	Block X
KW/FT POL	KWPFPLB	Block X

For the ten second block of calculations these outputs include:

Axial Shape Index	ASI	Block M
Axial Shape Inderx Alarm	ALARM4	Block M
CPC Tilt Limit Alarm	ALARM2	Block R
Tech. Spec. Tilt Limit Alarm	ALARM3	Block R

3.4.5.8. Burn Up Factor Update

The daily update of block K burnup factors shall be performed at 24 hour intervals.

3.4.6. COLSS Initialization Requirements

Several COLSS calculations utilize digital filters that require initialization of past values of the input or the calculated result. Table 3-5 summarizes the variables that require initialization and the conditions which require initialization. The detailed procedures for initializing each variable are presented in the block descriptions of Section 4 of this specification. Four conditions require initialization:

l. COLSS was placed in the SCHEDULED mode;

2. COLSS was placed in the TEST mode;

3. COLSS was returned to service following an interruption of COLSS execution;

4. A block is returned to execution following clearing of a condition which caused the block to be skipped.

The DNBR power operating limit assumption and the derivatives of power operating limit with DNBR and quality are also initialized when conditions one through four above occur.

Specific initialization procedures for these parameters are specified in Section 4.3.2.5 of this description.

Table 3-1 COLSS PROCESS INPUTS

COLSS SYMBOL	DESCRIPTION	UNITS	SCAN RATE
RPMA(1)	COLSS RCP SPEED-PUMP 1, PRE	RPM	1 SEC
RPMA(2)	COLSS RCP SPEED-PUMP 2, PRE	RPM	1 SEC
RPMA(3)	COLSS RCP SPEED-PUMP 3, PRE	RPM	1 SEC
RPMA(4)	COLSS RCP SPEED-PUMP 4, PRE	RPM	1 SEC
RPMB(1)	COLSS RCP SPEED-PUMP 1, ALT	RPM	1 SEC
RPMB(2)	COLSS RCP SPEED-PUMP 2, ALT	RPM	1 SEC
RPMB(3)	COLSS RCP SPEED-PUMP 3, ALT	RPM	1 SEC
RPMB(4)	COLSS RCP SPEED-PUMP 4, ALT	RPM	1 SEC
PDPA(1)	COLSS RCP DP-PUMP 1, PRE	PSI	1 SEC
PDPA(2)	COLSS RCP DP-PUMP 2, PRE	PSI	1 SEC
PDPA(3)	COLSS RCP DP-PUMP 3, PRE	PSI	1 SEC
PDPA(4)	COLSS RCP DP-PUMP 4, PRE	PSI	1 SEC
PDPB(1)	COLSS RCP DP-PUMP 1, ALT	PSI	1 SEC
PDPB(2)	COLSS RCP DP-PUMP 2, ALT	PSI	1 SEC
PDPB(3)	COLSS RCP DP-PUMP 3, ALT	PSI	1 SEC
PDPB(4)	COLSS RCP DP-PUMP 4, ALT	PSI	1 SEC
PPRIA	COLSS PRESSURIZER PRESS, PRE	PSIA	1 SEC
PPRIB	COLSS PRESSURIZER PRESS, ALT	PSIA	1 SEC
TFSPA	COLSS TURB 1ST STAGE PRESS, PRE	PSIG	1 SEC
TFSPB	COLSS TURB 1ST STAGE PRESS, ALT	PSIG	1 SEC
SFLOWI(1)	COLSS SG 1 STEAM FLOW DP, PRE	IN H_2O	1 SEC
SFLOWI(2)	COLSS SG 1 STEAM FLOW DP, ALT	IN H_2O	1 SEC
SFLOWI(3)	COLSS SG 2 STEAM FLOW DP, PRE	IN H_2O	1 SEC
SFLOWI(4)	COLSS SG 2 STEAM FLOW DP, ALT	IN H_2O	1 SEC
TC1I	COLSS COLD LEG TEMP-PUMP 1	DEG F	1 SEC
TC2I	COLSS COLD LEG TEMP-PUMP 2	DEG F	1 SEC
TC3I	COLSS COLD LEG TEMP-PUMP 3	DEG F	1 SEC
TC4I	COLSS COLD LEG TEMP-PUMP 4	DEG F	1 SEC
TH1I	COLSS HOT LEG TEMP-LOOP 1	DEG F	1 SEC
TH2I	COLSS HOT LEG TEMP-LOOP 2	DEG F	1 SEC
FWTI(1)	COLSS FW TEMP. SG 1	DEG F	1 SEC

Table 3-1 (Cont.) COLSS PROCESS INPUTS

COLSS SYMBOL	DESCRIPTION	UNITS	SCAN RATE
FWTI(2)	COLSS FW TEMP. SG 2	DEG F	1 SEC
FWFI(1)	COLSS FW FLOW DP. SG 1	IN H_2O	1 SEC
FWFI(2)	COLSS FW FLOW DP. SG 2	IN H_2O	1 SEC
PSECI(1)	COLSS SECONDARY STEAM PR, SG 1	PSIA	1 SEC
PSECI(2)	COLSS SECONDARY STEAM PR, SG 2	PSIA	1 SEC
LREG(1)	CEA REG GRP 1 MINIMUM POS	IN	10 SEC
LREG(2)	CEA REG GRP 2 MINIMUM POS	IN	10 SEC
LREG(3)	CEA REG GRP 3 MINIMUM POS	IN	10 SEC
LREG(4)	CEA REG GRP 4 MINIMUM POS	IN	10 SEC
LREG(5)	CEA REG GRP 5 MINIMUM POS	IN	10 SEC
LREG(6)	CEA REG GRP 6 MINIMUM POS	IN	10 SEC
LREG(7)	CEA REG GRP 7 MINIMUM POS	IN	10 SEC
LREG(8)	CEA REG GRP 8 MINIMUM POS	IN	10 SEC
LPSR(1)	CEA P S GRP 1 MINIMUM POS	IN	10 SEC
LPSR(2)	CEA P S GRP 2 MINIMUM POS	IN	10 SEC
LSHUT(1)	CEA S D GRP 1 MINIMUM POS	IN	10 SEC
LSHUT(2)	CEA S D GRP 2 MINIMUM POS	IN	10 SEC
DEVR(1)	CEA REG GP 1 DEVIATION	IN	10 SEC
DEVR(2)	CEA REG GP 2 DEVIATION	IN	10 SEC
DEVR(3)	CEA REG GP 3 DEVIATION	IN	10 SEC
DEVR(4)	CEA REG GP 4 DEVIATION	IN	10 SEC
DEVR(5)	CEA REG GP 5 DEVIATION	IN	10 SEC
DEVR(6)	CEA REG GP 6 DEVIATION	IN	10 SEC
DEVR(7)	CEA REG GP 7 DEVIATION	IN	10 SEC
DEVR(8)	CEA REG GP 8 DEVIATION	IN	10 SEC
DEVP(1)	CEA P S GP 1 DEVIATION	IN	10 SEC
DEVP(2)	CEA P S GP 2 DEVIATION	IN	10 SEC
DEVS(1)	CEA S D GP 1 DEVIATION	IN	10 SEC
DEVS(2)	CEA S D GP 2 DEVIATION	IN	10 SEC
S(61, 5)	DETECTOR SENSITIVITY COMP FLUX	NV*E14	10 SEC
CS(61, 5)	COMPENSATED DETECTOR FLUX	NV*E14	10 SEC

Table 3-2 OUTPUT REQUIREMENTS

COLSS Output	Definition	Range	Units	Update Frequency	Location	Type
PP	Core average plant power	0 to 125	% Power	1 Sec.	Control Board	Analog
KWPFPLB	Linear heat rate (kW/ft) Power operating limit	0 to 150	% Power	1 Sec.	Control Board	Analog
DNBRPLB	DNBR power operating limit	0 to 125	% Power	1 Sec.	Control Board	Analog
MARGIN	Margin to power operating limits	-50.0 to 125.9	% Power	1 Sec.	Control Board	Digital 4 Digit
ASI	Axial shape index	-0.7 to +0.7	-	10 Sec.	Control Board	Analog
Alarm 1	CCO – Margin alarm	close – open	-	1 Sec.	Annunciator Panel	CCO
Alarm 2	CCO – CPC azimuthal tilt alarm	close – open	-	10 Sec.	Annunciator Panel	CCO
Alarm 3	CCO – Tech. Specification Azimuthal tilt alarm	close – open	-	10 Sec.	Annunciator Panel	CCO
Alarm 4	CCO – Axial Shape Index out of limits alarm	close – open	-	10 Sec.	Annunciator Panel	CCO

Table 3-3 COLSS SYMBOL ATTRIBUTES

	CS	61	5	INCORE DETECTOR COMP FLUX		DTL	TST	
	DEVP	2		PS CEA GROUP DEVIATION	LOG	DTL	TST	
	DEVR	8		REG CEA GROUP DEVIATION	LOG	DTL	TST	
	DEVS	2		S/D CEA GROUP DEVIATION	LOG	DTL	TST	
	FWFI	2		FEEDWATER FLOW DP	LOG	DTL	TST	
	FWTI	2		FEEDWATER TEMPERATURE	LOG	DTL	TST	
	LPSR	2		PS CEA GROUP HEIGHT	LOG	DTL	TST	
	LREG	8		REG CEA GROUP HEIGHT	LOG	DTL	TST	
	LSHUT	2		S/D CEA GROUP HEIGHT	LOG	DTL	TST	
	PDPA	4		RCP PREFERRED DP	LOG	DTL	TST	
	PDPB	4		RCP ALTERNATE DP	LOG	DTL	TST	
	PPRIA			RCS PREFERRED PRESSURE	LOG	DTL	TST	
	PPRIB			RCS ALTERNATE PRESSURE	LOG	DTL	TST	
	PSECI	2		STEAM HEADER PRESSURE	LOG	DTL	TST	
	RPMA	4		RCP PREFERRED SPEED	LOG	DTL	TST	
	RPMB	4		RCP ALTERNATE SPEED	LOG	DTL	TST	
	S	61	5	INCORE DETECTOR RAW FLUX		DTL	TST	
	SFLOW	4		MAIN STEAM FLOW DP	LOG	DTL	TST	
	TC1I			COLD LEG IA TEMPERATURE	LOG	DTL	TST	
	TC2I			COLD LEG IB TEMPERATURE	LOG	DTL	TST	
	TC3I			COLD LEG 2A TEMPERATURE	LOG	DTL	TST	
	TC4I			COLD LEG 2B TEMPERATURE	LOG	DTL	TST	
	TFSPA			TURB FRST STG PRESSURE PREF	LOG	DTL	TST	
	TFSPB			TURB FST STG PRESSURE ALT	LOG	DTL	TST	
	TH1I			LOOP I HOT LEG TEMPERATURE	LOG	DTL	TST	
	TH2I			LOOP 2 HOT LEG TEMPERATURE	LOG	DTL	TST	
A	A01			RCP RUNNING SPEED THRESHOLD			TST	FAV
A	A02			RCP SPEED XCHK THRESHOLD			TST	FAV
A	A03			RCP DP SCHK THRESHOLD			TST	FAV
A	A04			TCOLD SCHK THRESHOLD			TST	FAV
A	A05			THOT XCHK THRESHOLD			TST	FAV

Table 3-3 (Cont.)

A	A06		PZR PRESSURE SCHK THRESHOLD			TST	FAV
A	A07		FW TEMP XCHK THRESHOLD			TST	FAV
A	A08		PSEC XCHK THRESHOLD			TST	FAV
A	A09		FW FLOW DP XCHK THRESHOLD			TST	FAV
A	A10		STM FLW DP CRS CHK THRESHOLD			TST	FAV
A	A11		TURB FRST STG PRS CRS CHK TH			TST	FAV
A	PDP	4	SELECTED RCP DIFF PRES	LOG	DTL	TST	
A	PPRI		SELECTED RCS PRESSURE	LOG	DTL	TST	
A	RPM	4	SELECTED RCS SPEED	LOG	DTL	TST	
A	TC	4	SELECTED COLD LEG TEMP	LOG	DTL	TST	
A	TFSP		SELECTED TURB FRST STG PRES	LOG	DTL	TST	
A	TH	2	SELECTED HOT LEG TEMP	LOG	DTL	TST	
A	FWF	2	SELECTED FEEDWATER FLOW	LOG	DTL	TST	
A	FWT	2	SELECTED FEEDWATER TEMP	LOG	DTL	TST	
A	SFLOW	2	SELECTED STEAM FLOW DP	LOG	DTL	TST	
A	PSEC	2	SELECTED STEAM HDR PRESS	LOG	DTL	TST	
B	B01		RCS PRESSURE BIAS			TST	FAV
B	B02		TC(1) BIAS			TST	FAV
B	B03		TC(2) BIAS			TST	FAV
B	B04		TC(3) BIAS			TST	FAV
B	B05		TC(4) BIAS			TST	FAV
B	B06		TH(1) BIAS			TST	FAV
B	B07		TH(2) BIAS			TST	FAV
B	B08		RPM(1) BIAS			TST	FAV
B	B09		RPM(2) BIAS			TST	FAV
B	B10		RPM(3) BIAS			TST	FAV
B	B11		RPM(4) BIAS			TST	FAV
B	B12		PDP(1) BIAS			TST	FAV
B	B13		PDP(2) BIAS			TST	FAV
B	B14		PDP(3) BIAS			TST	FAV
B	B15		PDP(4) BIAS			TST	FAV
B	B16		TFSP BIAS			TST	FAV

Table 3-3 (Cont.)

C	TCC	4	COMPENSATED COLD LEG TEMP	LOG	DTL	TST	
C	TCMAX		CORE INLET TEMP FOR DNBRPOL	LOG	DTL	TST	
C	TCCPI	4	TCCP TEST MODE INITIALIZATION VALUE			TST	FAV
C	TCPI	4	TCP TEST MODE INITIALIZATION VALUE			TST	FAV
D	CFLOW		REACTOR VESSEL VOL FLOW RATE	LOG	DTL	TST	
D	D20	4	POSITIVE FLOW PUMP GAIN			TST	FAV
D	D21	4	POSITIVE FLOW PUMP BAIS			TST	FAV
D	D27	4	NEGATIVE FLOW PUMP GAIN			TST	FAV
D	D28	4	NEGATIVE FLOW BIAS			TST	FAV
D	D29		TOTAL FLOW GAIN			TST	FAV
D	D30		TOTAL FLOW BIAS			TST	FAV
D	D31		NORMALIZED REFERENCE FLOW				FAV
D	GPM	4	COLD LEG VOLUMETRIC FLOW	LOG	DTL	TST	
D	HEAD	4	RCP HEAD	LOG	DTL	TST	
D	MFLOW	4	COLD LEG MASS FLOW RATE	LOG	DTL	TST	
D	NP		PUMP CONFIGURATION INDEX			TST	
D	PCFLOW		NORM REACTOR VESSEL VOL FLOW	LOG	DTL	TST	
D	PLCTF		PT LOOP COLD LEG FACTOR			TST	
D	PLHTF		PT LOOP HOT LEG FACTOR			TST	
D	RCSV	4	COLD LEG COOLANT SP VOL			TST	
D	TMFLOW		REACTOR VESSEL MASS FLOW	LOG	DTL	TST	
D	TRMFLO		TREND. REL VESSEL MASS FLOW RATE	LOG		TST	
D	RMFLOW		RELATIVE MASS FLOW RATE	LOG		TST	
D	RCSVAV		INLET MODERATOR AVG. SPECIFIC VOLUME	LOG	DTL	TST	
E	BDELT		UNFILTERED PRIM. CALOR POWER	LOG	DTL	TST	
E	BDELTF		FILTERED PRIMARY CALOR POWER	LOG	DTL	TST	
E	BDYN		DYNAMIC PRIMARY CAL POWER	LOG	DTL	TST	
E	BSTAT		STATIC PRIMARY CAL POWER	LOG	DTL	TST	
E	CBDELT		CALIB UNFILT PRI CAL POWER	LOG	DTL	TST	
E	CBDELTF		CALIB FILT PRI CAL POWER	LOG	DTL	TST	
E	CDP		UNFILT PRI CAL POWER CALIB PAST VALUE		DTL	TST	

Table 3-3 (Cont.)

E	CDFP		FILT PRI CAL POWER CALIB PAST VALUE				
E	E04		DYNAMIC POWER LIMIT			TST	FAV
E	E05		DYNAMIC POWER GAIN			TST	FAV
E	E06		PRI CAL POWER BIAS			TST	FAV
E	E07		PRI CAL POWER GAIN			TST	FAV
E	HIN	4	COLD LEG COOLANT ENTHALPY			TST	
E	HOUT	2	HOT LEG COOLANT ENTHALPY			TST	
E	THMPI		THMP TEST MODE INITIALIZATION VALUE			TST	FAV
E	BDYNPI		BDYNP TEST MODE INITIALIZATION VALUE			TST	FAV
E	CDPI		CDP TEST MODE OR DEMAND INITIALIZATION VALUE			TST	FAV
E	CDFPI		CDFP TEST MODE OR DEMAND INITIALIZATION VALUE			TST	FAV
F	BMF	2	BLOWDOWN MASS FLOW RATE			TST	FAV
F	BSCAL		SECONDARY CAL POWER	LOG	DTL	TST	
F	BSCRAW		RAW SEC CAL POWER	LOG	DTL	TST	
F	BSCALAVG		AVERAGED SECONDARY CALORIMETRIC POWER	LOG	DTL	TST	
F	ECP		ENERGY ADDED TO RCS BY RCPS			TST	FAV
F	EG	2	S/G ENERGY REMOVAL RATE	LOG	DTL	TST	
F	ENS		NSSS ENERGY LOSSES			TST	FAV
F	EPHT		PZR HEATER POWER			TST	FAV
F	F01	2	S/G STATIC FWP CORRECTION			TST	FAV
F	F02	2	S/G FLOW FWP CORRECTION			TST	FAV
F	F03	2	C			TST	FAV
F	F04	2	S/G PRESSURE STATIC CORRECT			TST	FAV
F	F05	2	S/G PRESSURE FLOW CORRECT			TST	FAV
F	F35		RATED THERMAL POWER				FAV
F	XF	2	STEAM QUALITY			TST	FAV

Table 3-3 (Cont.)

F	XBF	2	BLOWDOWN QUALITY			TST	FAV
F	F09	2	S/G VENTURI TEMP CONST			TST	FAV
F	LDMF		LETDOWN MASS FLOW RATE			TST	FAV
F	LDH		LETDOWN ENTHALPY			TST	FAV
F	SELMF		SEAL MASS FLOW RATE			TST	FAV
F	SELH		SEAL FLOW ENTHALPY			TST	FAV
F	CWMF		COOLING WATER MASS FLOW RATE			TST	FAV
F	CWH		COOLING WATER ENTHALPY RISE			TST	FAV
F	PCMF		OTHER PRIMARY COOLANT FLOW			TST	FAV
F	PCH		OTHER PRIM COOLANT ENTHALPY			TST	FAV
F	EPRL		PRESSURIZER HEAT LOSS			TST	FAV
F	EPIPL		PIPING HEAT LOSS			TST	FAV
F	ESG		STEAM GENERATOR HEAT LOSSES			TST	FAV
F	CGMF		CHARGING MASS FLOW RATE			TST	FAV
F	CGH		CHARGING ENTHALPY			TST	FAV
F	ELECT		OTHER ELECT EQPT HEAT INPUTS			TST	FAV
F	EMIS		OTHER MISC HEAT INPUTS			TST	FAV
F	FWMF	2	S/G FEEDWATER MASS FLOW RATE	LOG	DTL	TST	
F	FWP	2	FEEDWATER PRESSURE	LOG		TST	
F	PSG	2	STEAM GENERATOR PRESSURE	LOG		TST	
F	SMFLOW	2	S/G STEAM MASS FLOW RATE	LOG	DTL	TST	
F	STARTF		POWER AT WHICH BSCAL STARTS		DTL	TST	FAV
G	BTFSP		UNFILTERED TURBINE POWER	LOG	DTL	TST	
G	BTFSPF		FILTERED TURBINE POWER	LOG	DTL	TST	
G	CBTFSP		CALIBRATED BTFSP	LOG	DTL	TST	
G	CBTFSPF		CALIBRATED BTFSPF	LOG	DTL	TST	
G	CTP		BTFSP CALIB PAST VALUE		DTL	TST	
G	CTFP		BTFSPF CALIB PAST VALUE		DTL	TST	
G	CTPI		CTP TEST MODE OR DEMAND INITIALIZATION VALUE			TST	FAV
G	CTFPI		CTFP TEST MODE OR DEMAND INITIALIZATION VALUE			TST	FAV

Table 3-3 (Cont.)

G	G1			TURBINE POWER CORREL COFF			TST	FAV
G	G2			TURBINE POWER CORREL COFF			TST	FAV
G	G3			TURBINE POWER CORREL COFF			TST	FAV
G	G4			TURBINE POWER CORREL COFF			TST	FAV
I	BIAS			POWER OPERATING LIMIT BIAS	LOG	DTL	TST	
I	PP			PLANT POWER	LOG	DTL	TST	
I	PPF			FILTERED PLANT POWER	LOG	DTL	TST	
I	PPB			BIASED PP FOR PDIL			TST	
K	BUP	61	5	FUEL REGION BURNUPS		DTL	TST	
K	PHI	61	5	ASSEMBLY FLUX POWER		DTL	TST	
K	TPHI	61	5	INTEGRATED FLUX PWR			TST	
L	PF			CEA POSITION PENALTY FACTOR		DTL	TST	
L	PF1			CEA SEQUENCE PENALTY FACTOR	LOG	DTL	TST	
L	PF2			CEA DEVIATION PENALTY FACTOR	LOG	DTL	TST	
L	PF3			PENALTY FACTOR ADJUST	LOG	DTL	TST	
L	PLARD	20		PLANAR RADIAL PEAKING FACTOR		DTL	TST	
L	AB1	15		UNPENALIZED RADIAL PEAK FACTOR			TST	FAV
L	VADJUST			SPECIFIC VOLUME NOMINAL COND.		DTL	TST	
L	STARTL			POWER AT WHICH BLOCK L STARTS		DTL	TST	FAV
M	ALARM4			ASI OUT OF LIMIT ALARM	LOG	DTL	TST	
M	APKD	40		40 NODE AXIAL PD FOR POL	LOG	DTL	TST	
M	ASI			CORE AVG AXIAL SHAPE INDEX	LOG	DTL	TST	
M	ASILL			ASI LOW LIMIT			TST	FAV
M	ASIHL			ASI HIGH LIMIT			TST	FAV
M	TIME4			EVENT DURATION ASI LIMIT EX	LOG	DTL	TST	
M	TIME4A			ANNUAL DURATION ASI LIM EX	LOG	DTL	TST	
N	APDD	20		CORE AVG AXIAL PD FOR DNBR		DTL	TST	
P	ASIHC			HOT CHANNEL ASI	LOG	DTL	TST	
P	INTRAD			INTEGRAL RADIAL FACTOR		DTL	TST	
R	ALARM2			AZTILT > CPC TILT ALLOWANCE	LOG	DTL	TST	
R	ALARM3			AZTILT > CORE TILT LIMIT	LOG	DTL	TST	
R	AZTILT			CORE AVG AXIMUTHAL TILT	LOG	DTL	TST	

Table 3-3 (Cont.)

R	GVTILT			PLANAR VECTOR AVG TILT		DTL	TST	
R	ATILT			ARITHMETIC AVG TILT		DTL	TST	
R	TL2			POWER DEPENDENT TILT LIMIT	LOG	DTL	TST	
R	TR			CPC TILT ALLOWANCE	LOG	DTL	TST	
R	TL3			TECH SPEC TILT LIMIT			TST	FAV
R	TAZIM	9	5	RAW AZIMUTHAL TILTS	LOG	DTL	TST	
R	TIME2			EVENT DURATION AZTILT > CPC	LOG	DTL	TST	
R	TIME2A			CUM DURATION AZTILT > CPC	LOG	DTL	TST	
R	TIME3			EVENT DURATION AZTILT > CORE	LOG	DTL	TST	
R	TIME3A			CUM DURATION AZTILT > CORE	LOG	DTL	TST	
S	TDPEAK	40		HOT CHNL AXIAL PD FOR KW/FT	LOG	DTL	TST	
S	MAX3DPK			MAX THREE-D PEAK FACTOR	LOG	DTL	TST	
T	KLIM			KW/FT LIMIT	LOG	DTL	TST	
T	KWPFPOL			RAW LINEAR HEAT RATE POL	LOG	DTL	TST	
T	KWFT	40		LINEAR HEAT RATE	LOG	DTL	TST	
T	UNCERT			ADJUSTMENT FOR MODEL UNCER.		DTL		FAV
U	STARTU			POWER AT WHICH BLOCK U STARTS		DTL	TST	FAV
U	DN3			DNBR CONVERGENCE TOLERANCE		DTL	TST	FAV
U	HIN			COOLANT INLET ENTHALPY		DTL	TST	
U	VIN			COOLANT INLET SPECIFIC VOLUME		DTL	TST	
U	INITU			FLAG: INITIALIZE U		DTL	TST	
U	ASIUFF			ASI AFTER CORRECTION		DTL	TST	
U	GIN			UFF CORRECTED MASS VEL		DTL	TST	
U	FSPLIT			FLOW CORRECTION FACTOR		DTL	TST	
U	POLGC			POL 1ST GUESS @ LIMITING UFF		DTL	TST	
U	FZHC(I)	20		RENORMALIZED HOT CHANNEL AXIAL POWER DISTRIBUTION		DTL	TST	
U	ITERNO			BLOCK U ITERATION			TST	
U	DNBRMIN			MINIMUM DNB RATIO			TST	
U	QULMIN			QUALITY AT DNBRMIN			TST	
U	DENTHM			ENTHALPY RISE TO MINIMUM DNBR			TST	
U	FCMIN			F-CORRECTION FACTOR AT MINIMUM DNBR			TST	

Table 3-3 (Cont.)

U	GDNBM	MASS VELOCITY AT MINIMUM DNBR			TST	
U	QDNBM	CRITICAL HEAT FLUX AT MINIMUM DNBR			TST	
U	CHNMULM	CHANNEL MULTIPLIER			TST	
U	POLGF(1)	CONVERGED POL @ UFF.LT.1.0	LOG	DTL	TST	
U	POLGH(2)	CONVERGED POL @ UFF.EQ.1.0	LOG	DTL	TST	
U	DPOLUC	MARGIN ALLOW. @ PP, ASI&UFF	LOG	DTL	TST	
U	EPOL1	UNC. FACTOR, UFF.LT.1.0		DTL	TST	FAV
U	EPOL2	UNC. FACTOR, UFF.LT.1.0		DTL	TST	FAV
U	EPOL3	UNC. FACTOR, UFF.EQ.1.0		DTL	TST	FAV
U	EPOL4	UNC. FACTOR, UFF.EQ.1.0		DTL	TST	FAV
U	IAUCT	POL AUCTIONEERING FLAG		DTL	TST	FAV
U	DNBPL1	POL AT UFF.LT.1.0		DTL	TST	
U	DNBPL2	POL AT UFF.EQ.1.0		DTL	TST	
U	IFLAG	CONVERGENCE FLAG	LOG	DTL	TST	
U	IFLAGD	CONVERGENCE CONDITION D	LOG	DTL	TST	
U	DNBRC	MINIMUM DNBR AT POL		DTL	TST	
U	QLDNBC	QUALITY AT DNBRC		DTL	TST	
U	DENTHC	ENTHALPY RISE AT DNBRC		DTL	TST	
U	CFLOWC	VOLUMETRIC FLOW RATE		DTL	TST	
U	DNBDEV	DNBR DERIVATIVE	LOG	DTL	TST	
U	QULDEV	QUALITY DERIVATIVE	LOG	DTL	TST	
U	FDNBC	F-CORRECTION AT DNBRC		DTL	TST	
U	GDNBC	MASS VELOCITY AT DNBRC		DTL	TST	
U	QDNBC	CRITICAL HEAT FLUX AT DNBRC		DTL	TST	
U	DNBPOLC	STATIC DNBR POL	LOG	DTL	TST	
W	DNBRPOL	UPDATED DNBR POL	LOG	DTL	TST	
W	DFRMAX	MAXIMUM F RATIO	LOG	DTL	TST	
W	SLOPE	QUALITY CORRECTION FACTOR		DTL	TST	
W	GCORR	FLOW CORRECTION FACTOR		DTL	TST	
W	QLDNB	QUALITY AT DNBR NODE		DTL	TST	
W	DNBR	DNBR AT MINIMUM		DTL	TST	
W	DNBRP1	INITIAL VALUE OF DNBRPOL	LOG	DTL	TST	

Table 3-3 (Cont.)

X	ALARM1	COLSS MASTER ANNUNCIATOR ALM	LOG	DTL	TST	
X	ALARM1A	BSCALAVG > LICENSED POWER	LOG	DTL	TST	
X	ALARM1B	PPS > DNBR POL	LOG	DTL	TST	
X	ALARM1C	PPS > LINEAR HEAT RATE POL	LOG	DTL	TST	
X	ALARM1D	PP > DNBR POL	LOG	DTL	TST	
X	DPOL	DNBR MARGIN ALLOWANCE		DTL	TST	
X	ALARM1E	PP > LINEAR HEAT RATE POL	LOG	DTL	TST	
X	ALARM1L	BSCAL > INSTANTANEOUS LICENSED POWER LIMIT	LOG	DTL	TST	
X	DNBRPLB	BIASED UPDATED DNBR POL	LOG	DTL	TST	
X	DNBRS	SMOOTHED DNBR POL	LOG	DTL	TST	
X	KWPFPLB	BIASED LINEAR HEAT RATE POL	LOG	DTL	TST	
X	KWPFS	SMOOTHED LINEAR HEAT RATE PL	LOG	DTL	TST	
X	MARGIN	SMOOTHED MARGIN	LOG	DTL	TST	
X	PPS	SMOOTHED PLANT POWER	LOG	DTL	TST	
X	PPFS	SMOOTHED FILTERED PLANT POWER	LOG	DTL	TST	
X	TIME1A	EVENT DURATION PPFS > LIC PL	LOG	DTL	TST	
X	TIME1AA	ANNUAL DURATION PPFS > LIC PL	LOG	DTL	TST	
X	TIME1B	EVENT DURATION PPS > DNBRPL	LOG	DTL	TST	
X	TIME1BA	ANNUAL DURATION PPS > DNBRPL	LOG	DTL	TST	
X	TIME1C	EVENT DURATION PPS > LHR POL	LOG	DTL	TST	
X	TIME1CA	ANNUAL DURATION PPS > LHR PL	LOG	DTL	TST	
X	LPL	LICENSED POWER LIMIT				FAV
X	LPLB	INSTANTANEOUS LICENSED POWER LIMIT				FAV

Table 3-4 ALLOWED COLSS MODE TRANSITIONS

		FINAL MODE		
		SCHEDULED	UNSCHEDULED	TEST
INITIAL MODE	SCHEDULED	N/A	ALLOWED	NOT ALLOWED
	UNSCHEDULED	ALLOWED	N/A	ALLOWED
	TEST	NOT ALLOWED	ALLOWED	N/A

N/A - NOT APPLICABLE

Table 3-5 COLSS INITIALIZATION SUMMARY

Variable	Block	Conditions Requiring Initialization		
		COLSS Startup	Computer Restart	Block Skipped
TCP	C	Yes	Yes	Yes
TCCP	C	Yes	Yes	Yes
TRMFLO	D	Yes	Yes	Yes
THMP	E	Yes	Yes	Yes
BDYNP	E	Yes	Yes	Yes
CDP	E	Yes	Yes	Yes
CDFP	E	Yes	Yes	Yes
BSCAL	F	Yes	Yes	Yes
CTP	G	Yes	Yes	Yes
CTFP	G	Yes	Yes	Yes
SP	J	No*	Yes	No
CSP	J	No*	Yes	No
BUP	K	Yes	Yes	No
TPHI	K	Yes	Yes	No
PPS	X	Yes	Yes	No
PPFS	X	Yes	Yes	No
DNBRS	X	Yes	Yes	No
KWPFS	X	Yes	Yes	No

* Assumes Block J has been appropriately initialized outside of COLSS.

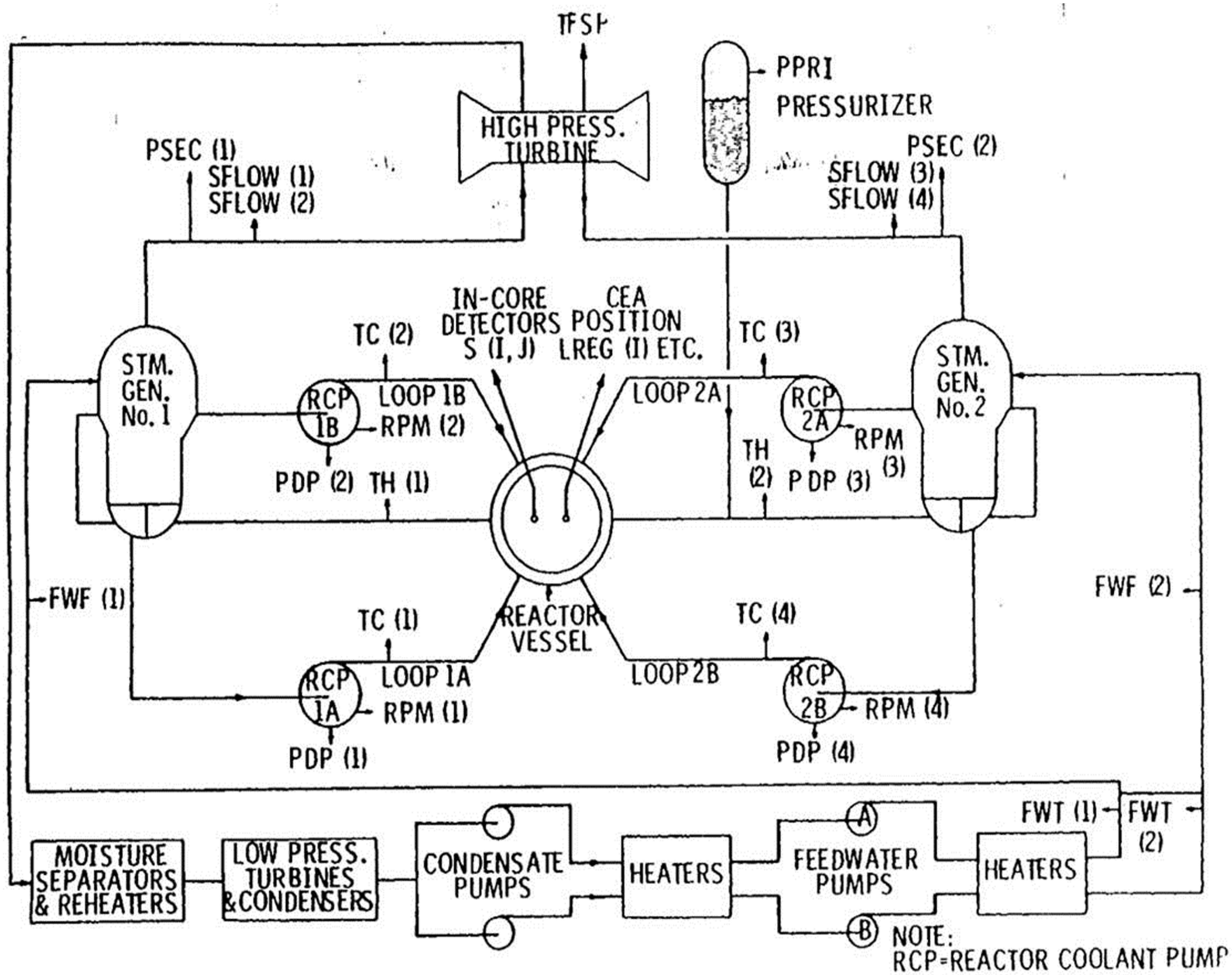


Figure 3-1 TYPICAL COLSS SENSOR LOCATIONS

180°

90° (left) / 270° (right)

					1	2	3	4	5	6	7 1					
			8 2	9	10	11 3	12	13	14 4	15	16	17	18			
		19	20	21	22 5	23	24 6	25	26	27 7	28	29 8	30	31 9		
	32	33 10	34	35 11	36	37	38	39 12	40	41	42	43	44	45	46	
	47	48	49	50	51 13	52	53 14	54	55	56 15	57	58 16	59	60	61	
62	63 17	64	65 18	66	67	68	69	70	71	72	73	74	75	76 19	77	78
79	80	81 20	82	83	84 21	85	86	87 22	88	89 23	90	91	92 24	93	94	95 25
96	97	98	99 26	100	101	102 27	103	104	105	106	107 28	108	109	110	111	112
113	114 29	115	116	117	118	119	120 30	121 31	122	123	124	125 32	126	127 33	128	129 34
130	131	132	133	134	135 36	136	137	138	139 37	140	141	142	143 38	144	145	146
147	148	149	150 39	151	152	153	154	155	156	157	158 40	159	160	161 41	162	163
164	165	166 42	167	168	169 43	170	171	172 44	173	174	175	176	177 45	178	179 46	180
	181 47	182	183	184	185	186 48	187	188	189 49	190	191 50	192	193	194	195	
	196	197	198 51	199	200	201	202	203	204	205	206	207 52	208	209 53	210	
		211	212	213 54	214	215 55	216	217	218 56	219	220 57	221	222	223		
			224	225	226	227	228 58	229	230	231 59	232	233	234 60			
					235 61	236	237	238	239	240	241					

0°

NNN : Full Core Box Number
MM : ICI Number

Figure 3-2 TYPICAL IN-CORE INSTRUMENTATION PATTERN

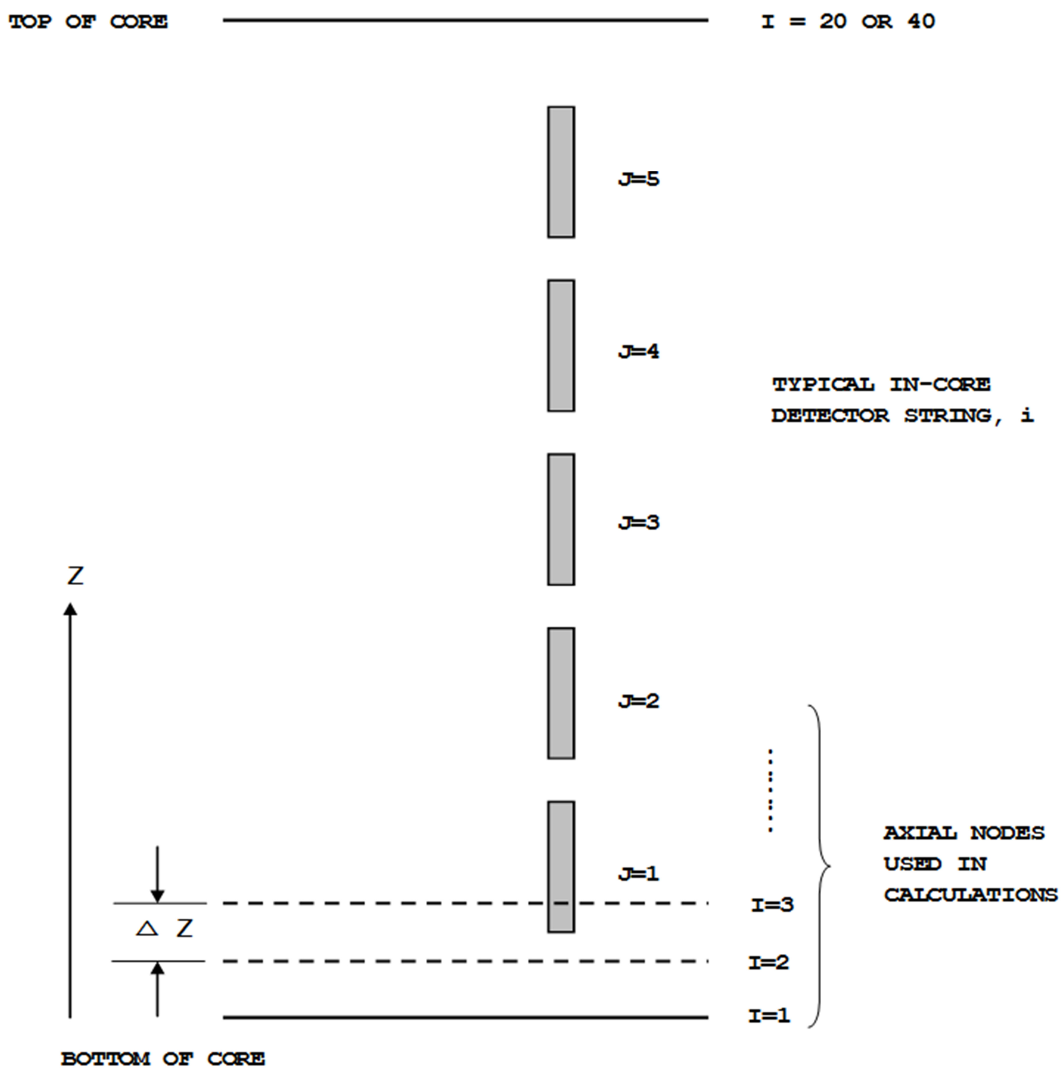


Figure 3-3 TYPICAL IN-CORE DETECTOR STRING

Alarm 1 Messages

(TIME)			
XX:XX:XX	ALARM	COLSS	DNBR POWER LIMIT EXCEEDED (MSG1B)
XX:XX:XX	ALARM	COLSS	KW/FT POWER LIMIT EXCEEDED (MSG1C)
XX:XX:XX	ALARM	COLSS	LICENSED POWER LIMIT EXCEEDED (MSG1A)
XX:XX:XX	ALARM	COLSS	INSTANTANEOUS DNBR POWER LIMIT EXCEEDED (MSG1D)
XX:XX:XX	ALARM	COLSS	INSTANTANEOUS KW/FT POWER LIMIT EXCEEDED (MSG1E)
XX:XX:XX	ALARM	COLSS	INSTANTANEOUS POWER LIMIT EXCEEDED (MSG1L)
XX:XX:XX	ALARM	COLSS	LPL ALARM DURATION EXCEEDED (TIME1A)
XX:XX:XX	ALARM	COLSS	DNBR ALARM DURATION EXCEEDED (TIME1B)
XX:XX:XX	ALARM	COLSS	KW/FT ALARM DURATION EXCEEDED (TIME1C)
XX:XX:XX	ALARM	COLSS	ANNUAL LPL VIOLATION (TIME1AA)
XX:XX:XX	ALARM	COLSS	ANNUAL DNBR VIOLATION (TIME1BA)
XX:XX:XX	ALARM	COLSS	ANNUAL KW/FT VIOLATION (TIME1CA)

Alarm 2 and Alarm3 Messages

XX:XX:XX	ALARM	COLSS	CPC TILT LIMIT EXCEEDED (MSG2A)
XX:XX:XX	ALARM	COLSS	TECH SPEC TILT LIMIT EXCEEDED (MSG2B)
XX:XX:XX	ALARM	COLSS	CPC TILT ALARM DURATION EXCEEDED (TIME2)
XX:XX:XX	ALARM	COLSS	TECH SPEC TILT ALARM DURATION EXCEEDED
(TIME2)			
XX:XX:XX	ALARM	COLSS	CPC TILT ALARM ANNUAL DURATION EXCEEDED
(TIME2A)			
XX:XX:XX	ALARM	COLSS	TECH SPEC TILT ALARM ANNUAL DURATION EXCEEDED (TIME3A)

Figure 3-4 TYPICAL ALARM CRT MESSAGES

Alarm 4 Messages

XX:XX:XX	ALARM	COLSS	ASI OUT OF LIMITS (MSG4)
XX:XX:XX	ALARM	COLSS	ASI ALARM DURATION EXCEEDED (TIME4)
XX:XX:XX	ALARM	COLSS	ASI ANNUAL DURATION EXCEEDED (TIME4A)

General Alarms

XX:XX:XX	ALARM	COLSS REMOVED FROM SERVICE
XX:XX:XX	ALARM	HOT LEG DEVIATION EXCEEDED
	ETC.	

When the alarm condition clears, the word CLEAR shall be substituted for the word ALARM above.

Alarm Printer Messages

The alarm printer shall include the messages shown above.

Alarm Criteria

The criteria for generating message 1 are given in BLOCK X.

The criteria for generating messages 2 and 3 are given in BLOCK R.

The criteria for generating message 4 are given in BLOCK M.

Figure 3-4 (Cont.)

COLSS POWER AND OPERATING LIMITS

DATE: 07/04/02
TIME: 16:14:58
CPU#: 1

POINT ID	DESCRIPTION	VALUE	UNITS
CIJXPPFS	FILTERED PLANT POWER - SMOOTHE	99.83	PCT
CIJXPPF	FILTERED PLANT POWER - UNSMOOTHE	99.97	PCT
CIJXPPS	PLANT POWER - SMOOTHED	100.02	PCT
CIJXPP	PLANT POWER - UNSMOOTHED	100.15	PCT
CIJXMARG	MARGIN TO POWER OPERATING LIMIT	0.13	PCT
CIJXDELT	DELTA T POWER - CALIBRATED	100.15	PCT
CIJXBDLT	DELTA T POWER - UNCALIBRATED	99.91	PCT
CIJXCBTF	TURBINE POWER - CALIBRATED	99.79	PCT
CIJXBTFS	TURBINE POWER - UNCALIBRATED	99.70	PCT
CIJXBSCL	SECONDARY CALORIMETRIC POWER	99.86	PCT
CIJXEG1	STEAM GENERATOR POWER OUTPUT 1	.12161E+10	KCAL/HR
CIJXEG2	STEAM GENERATOR POWER OUTPUT 2	.12177E+10	KCAL/HR
CIJXDNBS	DNBR PWR OPER LIMIT- SMOOTHED	104.33	PCT
CIJXDNBB	DNBR PWR OPER LIMIT- UNSMOOTHED	104.44	PCT
CIJXKWPS	KW/FT PWR OPER LIMIT- SMOOTHED	123.99	PCT
CIJXKWPF	KW/FT PWR OPER LIMIT- UNSMOOTHED	124.03	PCT
CIYXAZT	AZIMUTHAL TILT	0.3218E-01	NO UNIT
CIYKTL3	AZIMUTHAL TILT W/ TECH SPEC	0.1E+00	NO UNIT
CIYKTL2	AZIMUTHAL TILT W/ CPC LIMITS	0.2E-01	NO UNIT
CIYXASI	AXIAL SHAPE INDEX	-.1439E-01	NO UNIT
CIYKASIL	AXIAL SHAPE INDEX W/ LO LIMIT	-0.27E+00	NO UNIT
CIYKASIH	AXIAL SHAPE INDEX W/ HI LIMIT	0.25E+00	NO UNIT
CIKTM1A	LICENSED PWR LIMIT - EVENT TIME	0.0E+00	MIN
CIKTM1AA	LICENSED PWR LIMIT - ANNUAL TIME	.12457E+04	MIN
CIKTM1B	DNBR POWER LIMIT - EVENT TIME	0.0E+00	MIN
CIKTM1BA	DNBR POWER LIMIT - ANNUAL TIME	0.0E+00	MIN
CIKTM1C	KW/FT POWER LIMIT - EVENT TIME	0.0E+00	MIN
CIKTM1CA	KW/FT POWER LIMIT - ANNUAL TIME	0.0E+00	MIN

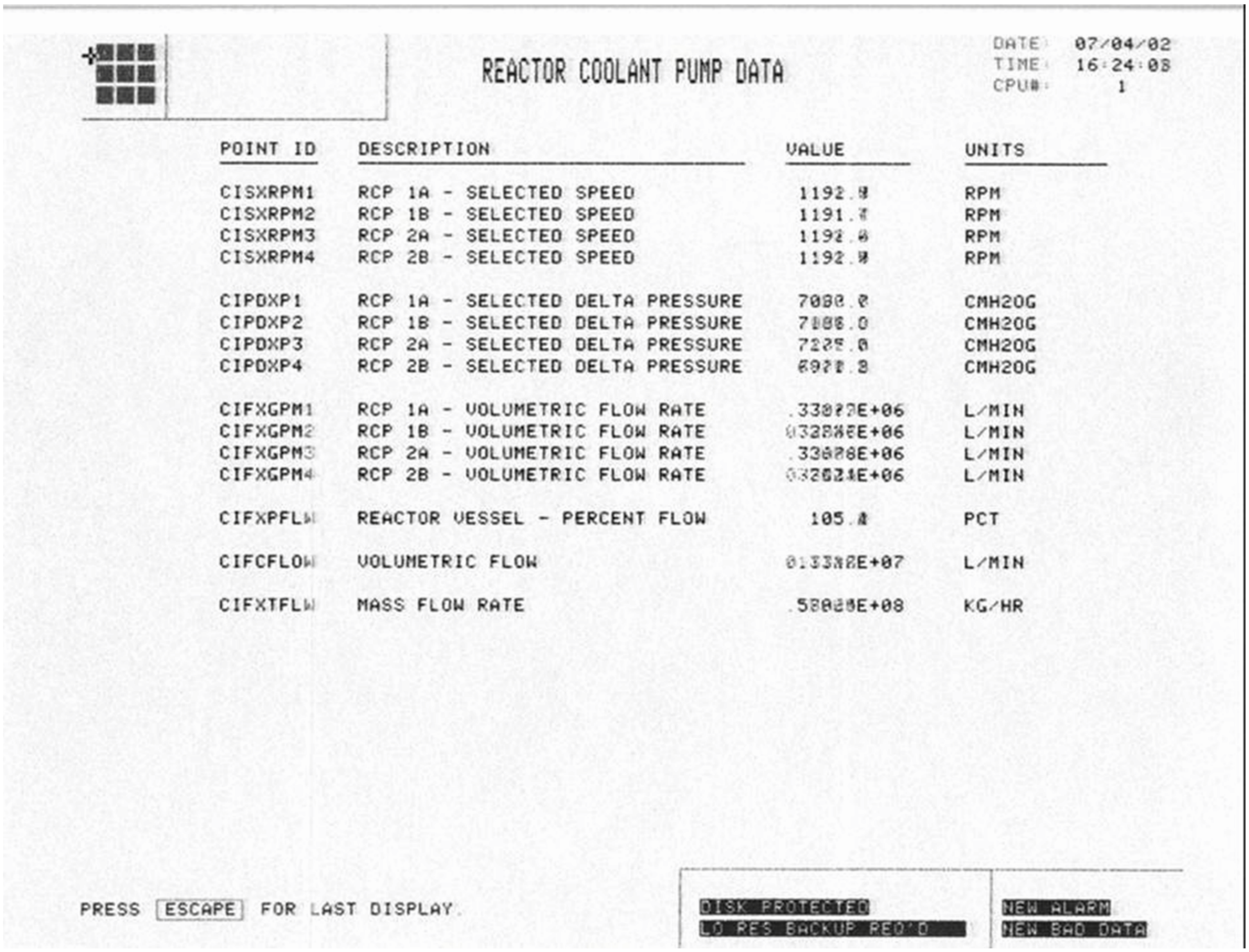
PRESS [ESCAPE] FOR LAST DISPLAY.

DISK PROTECTED
LO RES BACKUP REQ'D

NEW ALARM
NEW BAD DATA

* Display can be converted to British units, if required. Typical values provided in this table are from YGN Unit 5 COLSS.

Figure 3-5 TYPICAL CRT DISPLAY*



REACTOR COOLANT PUMP DATA

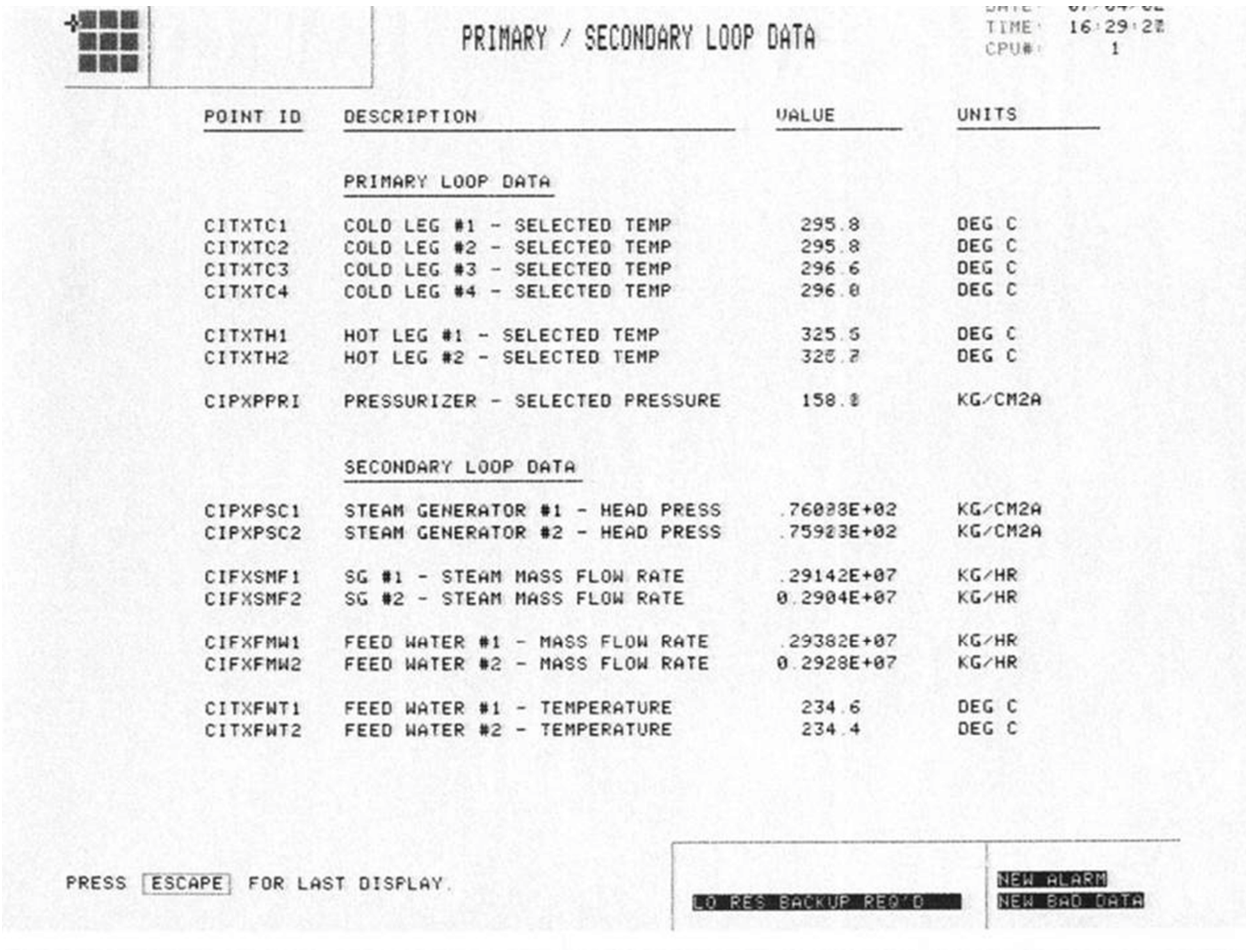
DATE: 07/04/02
TIME: 16:24:08
CPU#: 1

POINT ID	DESCRIPTION	VALUE	UNITS
CISXRPM1	RCP 1A - SELECTED SPEED	1192.9	RPM
CISXRPM2	RCP 1B - SELECTED SPEED	1191.7	RPM
CISXRPM3	RCP 2A - SELECTED SPEED	1192.6	RPM
CISXRPM4	RCP 2B - SELECTED SPEED	1192.9	RPM
CIPDXP1	RCP 1A - SELECTED DELTA PRESSURE	7080.0	CMH2OG
CIPDXP2	RCP 1B - SELECTED DELTA PRESSURE	7186.0	CMH2OG
CIPDXP3	RCP 2A - SELECTED DELTA PRESSURE	7225.0	CMH2OG
CIPDXP4	RCP 2B - SELECTED DELTA PRESSURE	6972.3	CMH2OG
CIFXGPM1	RCP 1A - VOLUMETRIC FLOW RATE	.33077E+06	L/MIN
CIFXGPM2	RCP 1B - VOLUMETRIC FLOW RATE	.32886E+06	L/MIN
CIFXGPM3	RCP 2A - VOLUMETRIC FLOW RATE	.33028E+06	L/MIN
CIFXGPM4	RCP 2B - VOLUMETRIC FLOW RATE	.32624E+06	L/MIN
CIFXPFLW	REACTOR VESSEL - PERCENT FLOW	105.4	PCT
CIFCFLOW	VOLUMETRIC FLOW	.13388E+07	L/MIN
CIFXTFLW	MASS FLOW RATE	.58028E+08	KG/HR

PRESS [ESCAPE] FOR LAST DISPLAY.

DISK PROTECTED
LO RES BACKUP REQ'D
NEW ALARM
NEW BAD DATA

Figure 3-5 (Cont.)



PRIMARY / SECONDARY LOOP DATA

TIME: 16:29:2[illegible]
CPU#: 1

POINT ID	DESCRIPTION	VALUE	UNITS
	PRIMARY LOOP DATA		
CITXTC1	COLD LEG #1 - SELECTED TEMP	295.8	DEG C
CITXTC2	COLD LEG #2 - SELECTED TEMP	295.8	DEG C
CITXTC3	COLD LEG #3 - SELECTED TEMP	296.6	DEG C
CITXTC4	COLD LEG #4 - SELECTED TEMP	296.0	DEG C
CITXTH1	HOT LEG #1 - SELECTED TEMP	325.5	DEG C
CITXTH2	HOT LEG #2 - SELECTED TEMP	325.7	DEG C
CIPXPPRI	PRESSURIZER - SELECTED PRESSURE	158.1	KG/CM2A
	SECONDARY LOOP DATA		
CIPXPSC1	STEAM GENERATOR #1 - HEAD PRESS	.76038E+02	KG/CM2A
CIPXPSC2	STEAM GENERATOR #2 - HEAD PRESS	.75923E+02	KG/CM2A
CIFXSMF1	SG #1 - STEAM MASS FLOW RATE	.29142E+07	KG/HR
CIFXSMF2	SG #2 - STEAM MASS FLOW RATE	0.2904E+07	KG/HR
CIFXFMW1	FEED WATER #1 - MASS FLOW RATE	.29382E+07	KG/HR
CIFXFMW2	FEED WATER #2 - MASS FLOW RATE	0.2928E+07	KG/HR
CITXFWT1	FEED WATER #1 - TEMPERATURE	234.6	DEG C
CITXFWT2	FEED WATER #2 - TEMPERATURE	234.4	DEG C

PRESS ESCAPE FOR LAST DISPLAY.

LO RES BACKUP REQ'D

NEW ALARM
NEW BAD DATA

Figure 3-5 (Cont.)

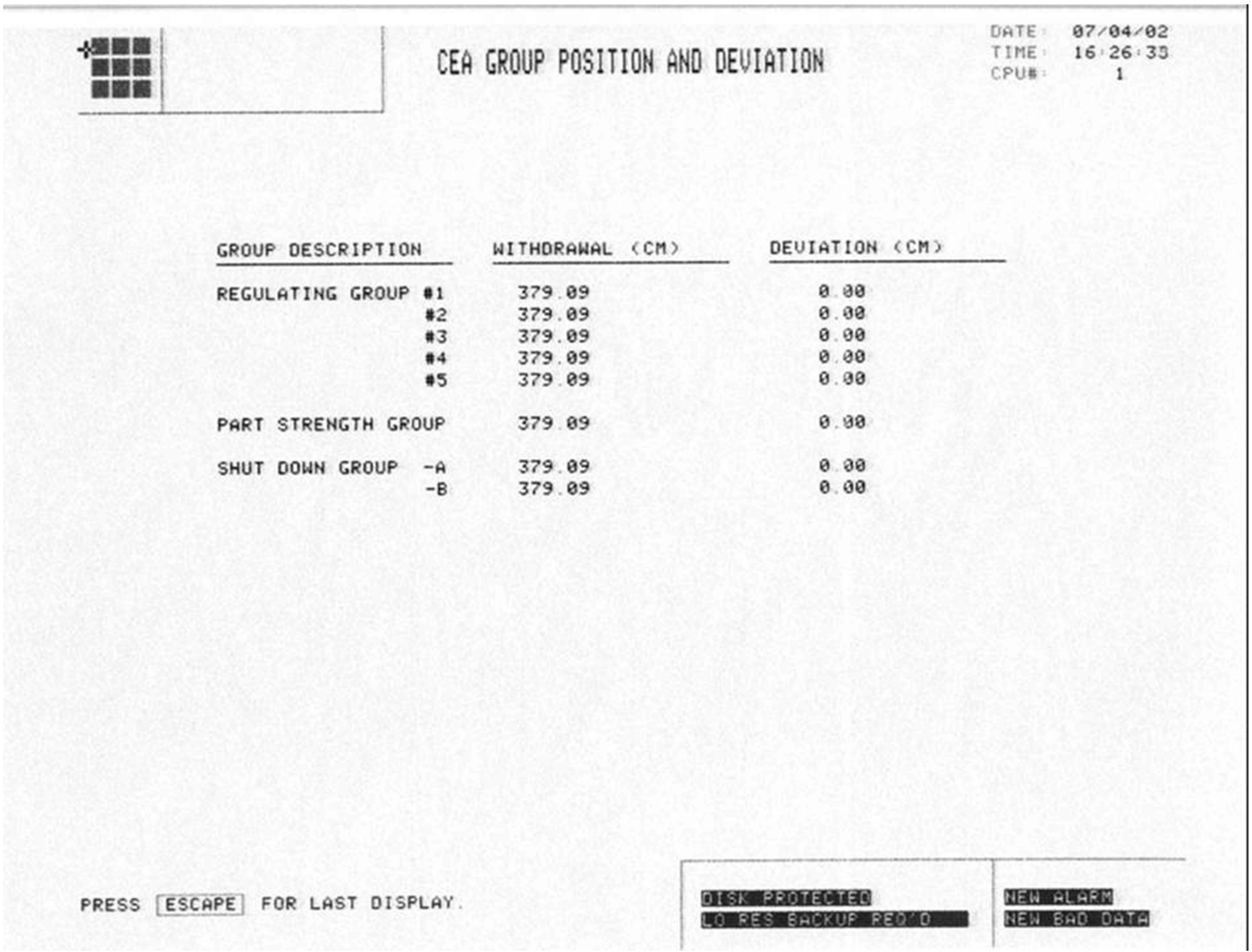


Figure 3-5 (Cont.)

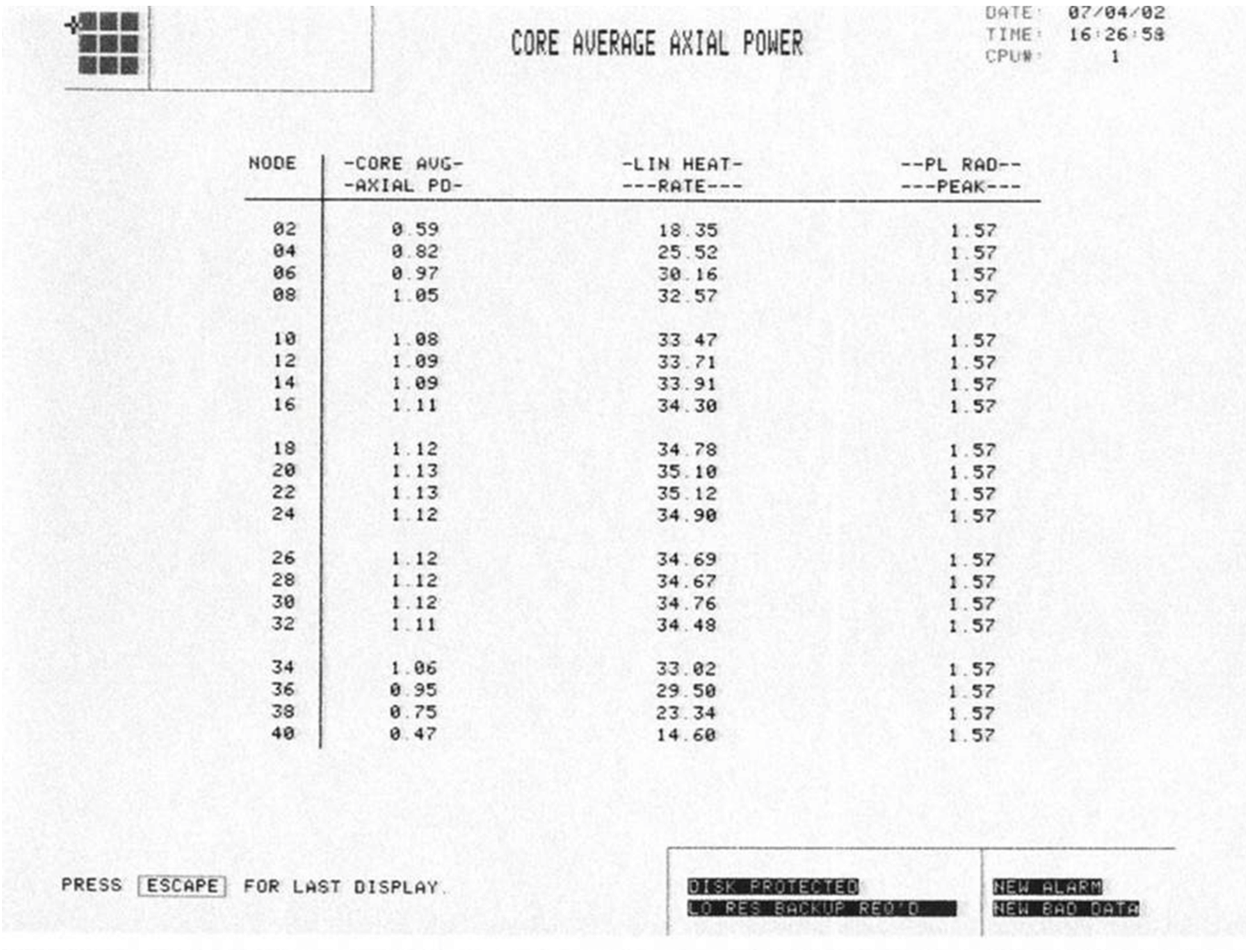


Figure 3-5 (Cont.)

05/29/99 14:35:53 - YGN 5 - COLSS FAILED SENSOR REPORT

POINT ID	CODE	DESCRIPTION	VALUE	UNITS
RCT111Y	XCHK	COLD LEG 1A TEMP CONTROL	293.887	DEG C
RCT115	XCHK	COLD LEG 1B TEMP WIDE RNG	297.2	DEG C
RCT125	XCHK	COLD LEG 2A TEMP WIDE RNG	297.762	DEG C
RCT121Y	XCHK	COLD LEG 2B TEMP CONTROL	294.438	DEG C

END OF COLSS FAILED SENSOR REPORT

Figure 3-5 (Cont.)

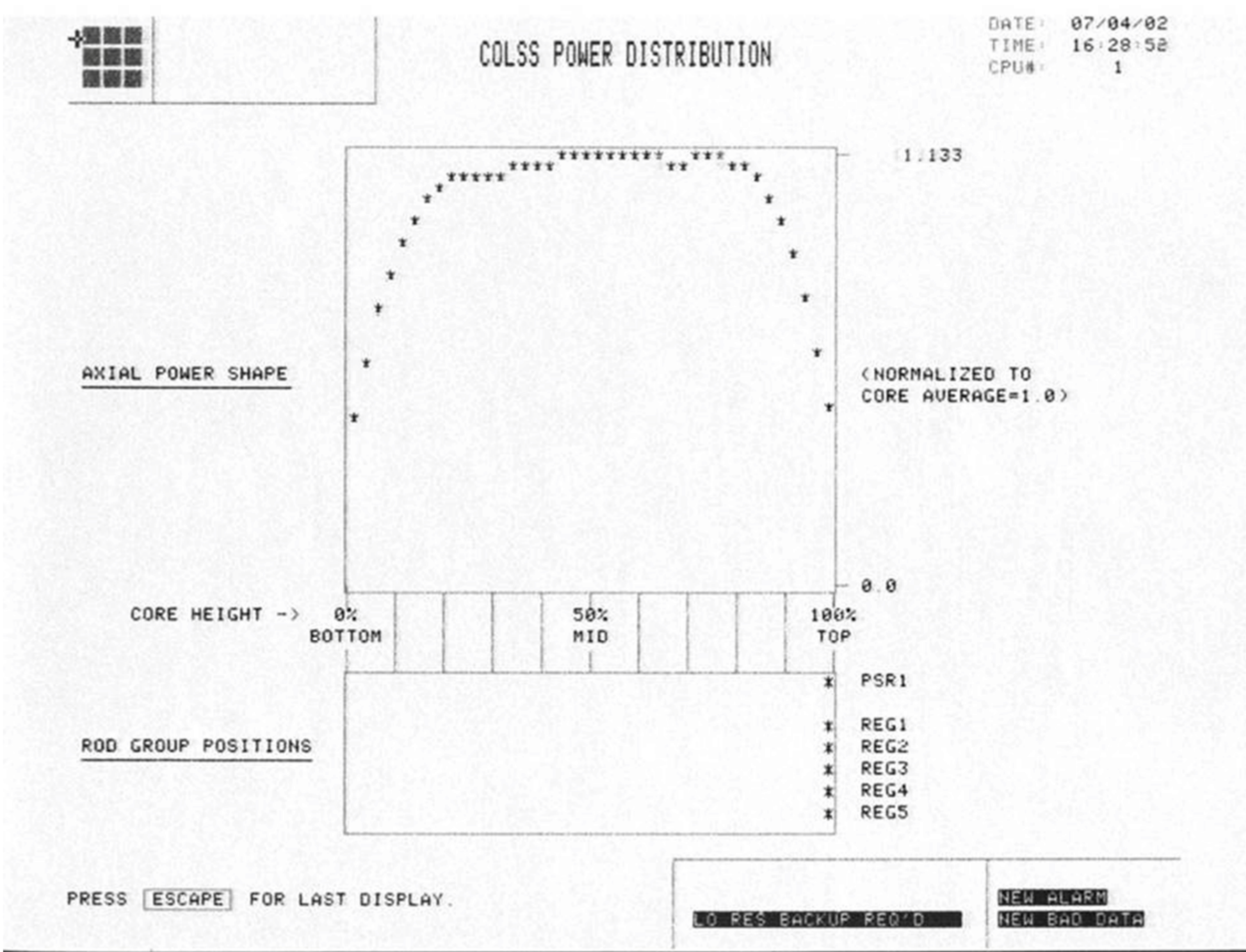


Figure 3-6 TYPICAL COLSS POWER DISTRIBUTION

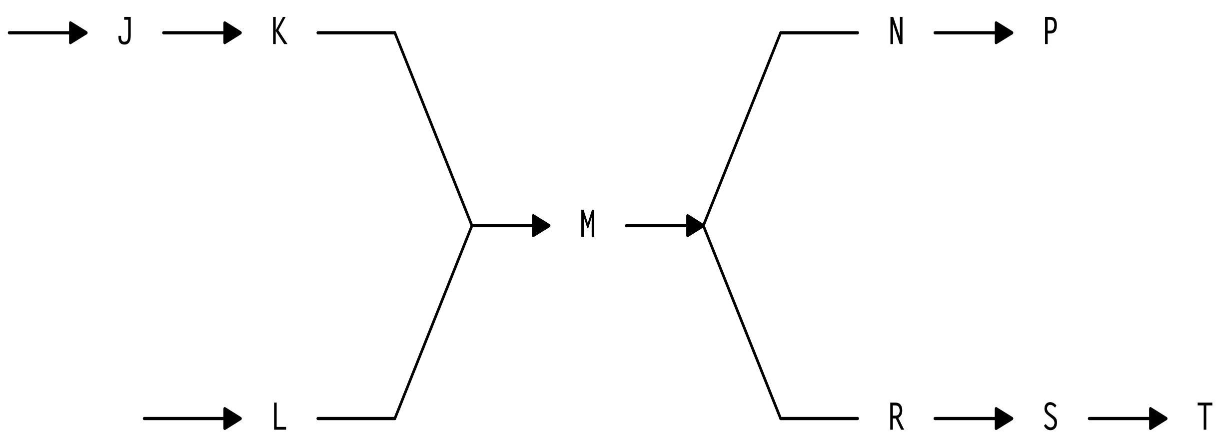


Figure 3-7 SEQUENCE OF EXECUTION OF 10 SECOND BLOCKS

4. ALGORITHM DESCRIPTION

The COLSS monitoring procedure algorithms are divided into four groups by function:

l. Plant Power Calculations;

2. Power Distribution Calculations;

3. Power Operating Limit Calculations;

4. Limiting Conditions for Operation Monitoring.

Detailed algorithms are described for performing all required processing. Where iterative algorithms are used, all necessary convergence criteria, next estimate calculations, and loop structures are fully described.

4.1. Plant Power Calculations

This block of calculations calculates the plant power level, which is used by the operator as a reactor power indication and is monitored by COLSS for comparison with licensed power and COLSS calculated DNBR and linear heat rate power operating limits. Included in the power calculations are the following major functions:

1. Compensation of cold leg temperatures for sensor and transport dynamics;

2. Calculation of vessel volumetric flow;

3. Calculation of cold leg and vessel mass flow;

4. Calculation of primary calorimetric power;

5. Calibration of primary calorimetric power with respect to secondary calorimetric power;

6. Calculation of turbine power from turbine first stage pressure;

7. Calibration of turbine power with respect to secondary calorimetric power;

8. Calculation of secondary calorimetric power;

9. Plant power selection and power operating limit bias calculation.

4.1.1. (Block C) Tcold Dynamic Compensation

4.1.1.1. Description

Block C performs the Tcold compensation required to correct the measured cold leg temperatures for sensor dynamics and inlet plenum mixing delays.

4.1.1.2. Timing

The calculations of block C are performed as a part of the one second group of calculations.

4.1.1.3. Inputs

TC(I)	-	Cold leg temperature for I = 1 to 4 from block B

4.1.1.4. Outputs

TCC(I)	-	Compensated cold leg temperature for I = 1 to 4
TCMAX	-	Maximum compensated cold leg temperature
TCMIN	-	Minimum compensated cold leg temperature

4.1.1.5. Calculations

The calculations of block C shall be skipped and the output validity set to BAD if any TC(I) has validity BAD.

The four values of cold leg temperature must be compensated for sensor and plenum mixing time constants. This compensation is performed as follows.

TS

Initialization

Initialization of the Tcold compensation is required when COLSS is placed in service, in response to a computer restart, and when restarting the block after a BAD input validity has changed to GOOD.

The Tcold compensation is initialized by setting the output, the past value of output, and the past value of input to the current value of input.

TS

4.1.1.6. Constants

C1, C2

4.1.1.7. Sequence of Calculations

See Figure C-1.

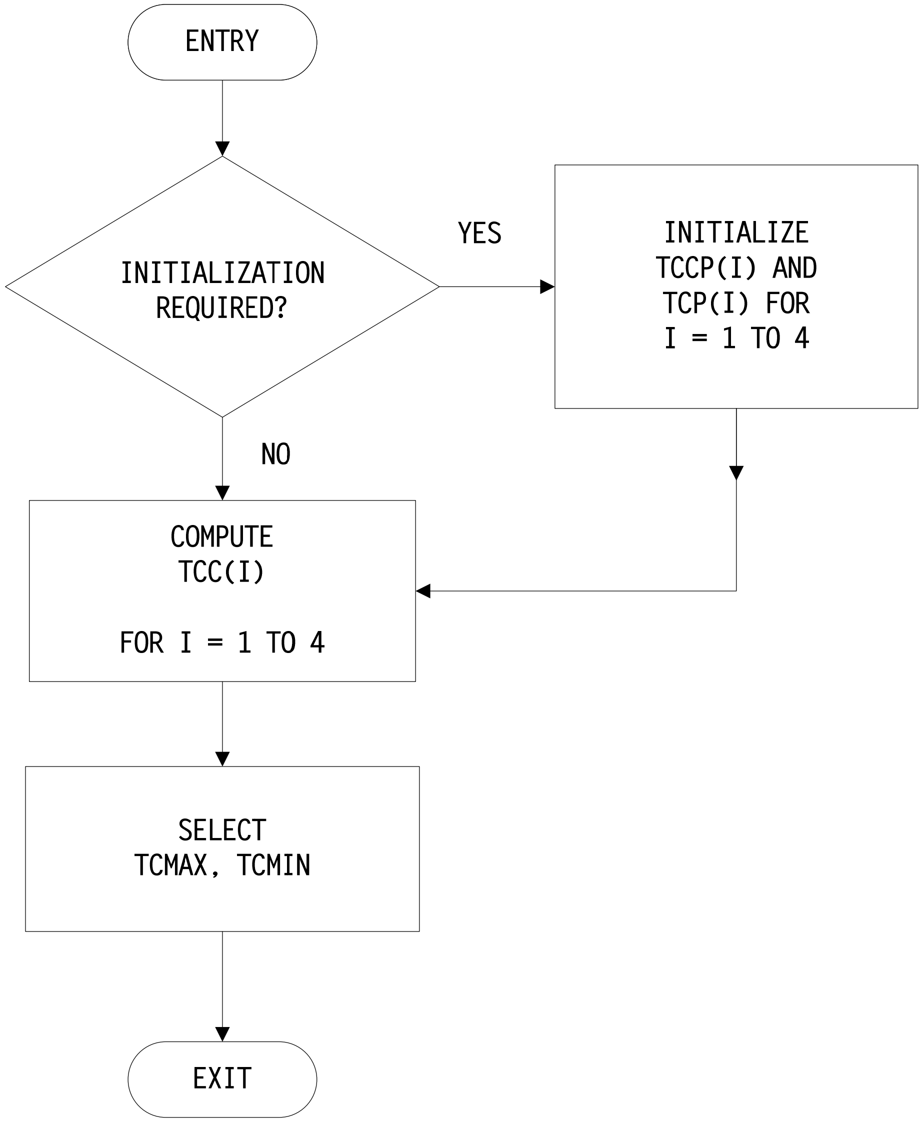


Figure C-1 SEQUENCE OF CALCULATIONS

4.1.2. (Block D) Reactor Coolant Volumetric Flow and Mass Flow

4.1.2.1. Description

Block D performs three functions:

1. Pump dependent constant selection;

2. Reactor coolant pump volumetric flow calculation;

3. Volumetric flow to mass flow conversion.

Pump dependent constants are selected for use in the primary calorimetric power calculation.

Reactor coolant pump volumetric flow is computed from pump speed and differential pressure. Volumetric flow is converted to mass flow for use in the primary calorimetric power calculation. Volumetric flow is also used in the DNBR power operating limit calculation.

4.1.2.2. Timing

The calculations of block D are performed as a part of the one second group of calculations.

4.1.2.3. Inputs

Module One: Pump Dependent Constants.

RPM(I)	-	Reactor coolant pump speed for I = 1 to 4 from block B

Module Two: Volumetric Flow and Mass Flow Calculation.

RPM(I)	-	Reactor coolant pump speed for I = 1 to 4 from block B
PDP(I)	-	Reactor coolant pump differential pressure for I = 1 to 4 from block B
TC(I)	-	Cold leg temperature for I = 1 to 4 from block B
PPRI	-	Primary system pressure from block B

4.1.2.4. Outputs

Module One: Pump Dependent Constants.

NP	-	Pump configuration index
PLCTF	-	Cold leg flow factor
PLHTF	-	Hot leg flow factor

Module Two: Volumetric Flow and Mass Flow.

GPM(I)	-	Pump volumetric flow rate for I = 1 to 4
MFLOW(I)	-	Pump mass flow rate for I = 1 to 4
TMFLOW	-	Total mass flow rate

CFLOW	-	Total volumetric flow
PCFLOW	-	Normalized volumetric flow
RMFLOW	-	Vessel mass flow relative to the CPC design mass flow rate to printer reports
TRMFLO	-	Trended relative vessel mass flow rate to printer reports
RCSVAV	-	Inlet moderator average specific volume in cubic feet per pound mass, to block L

4.1.2.5. Calculations

The calculations of block D are divided into two modules:

1. Pump dependent constant selection;

2. Volumetric flow and mass flow calculation.

The calculations of block D shall be skipped, and the output validity is set to BAD if any input has validity BAD.

Module One: Pump Dependent Constants

Selection of flow factors:

The reactor coolant pump configuration (NP) is determined as follows:

The speed, RPM(I), of each of the four reactor coolant pumps is compared with an input constant D1.

If RPM(I) > D1 then the I'th pump is running and the count is incremented. Having tested all four pumps, the total number of pumps running is NP.

That is,

TS

Flow factors are determined as follows:

TS

TS

If NP < 1, calculation of block D shall be terminated, and the output validity shall be set to BAD.

At this point NP = 2. Additional testing is required to determine whether the two operating pumps are in the same loop or in opposite loops:

TS

Otherwise, the two operating pumps are in opposite loops. Thus

TS

Module Two: Volumetric Flow and Mass Flow

a. Conversion of differential pressure to head

TS

TS

b. Flow model selection tests

If RPM(I) is less than or equal to D10(I), then reverse flow is calculated. Otherwise WP(I) is calculated as follows:

TS

If WP(I) is greater than D12(I), then the reverse flow through pump I is calculated. Otherwise forward flow through pump I is calculated.

c. Forward flow calculation

TS

TS

Having completed steps a, b, c or steps a, b, d for pumps 1 through 4, continue as follows.

e. Total flow calculation

TS

The mass flow rate should be calculated with the following equation for I = 1 to 4.

TS

The total mass flow of primary coolant to the reactor vessel is calculated by

TS

TS

The trended (time averaged) mass flow rate relative to the CPC design mass flow rate of the primary coolant through the reactor vessel is calculated by the following equations:

TS

4.1.2.6. Constants

D1 through D9

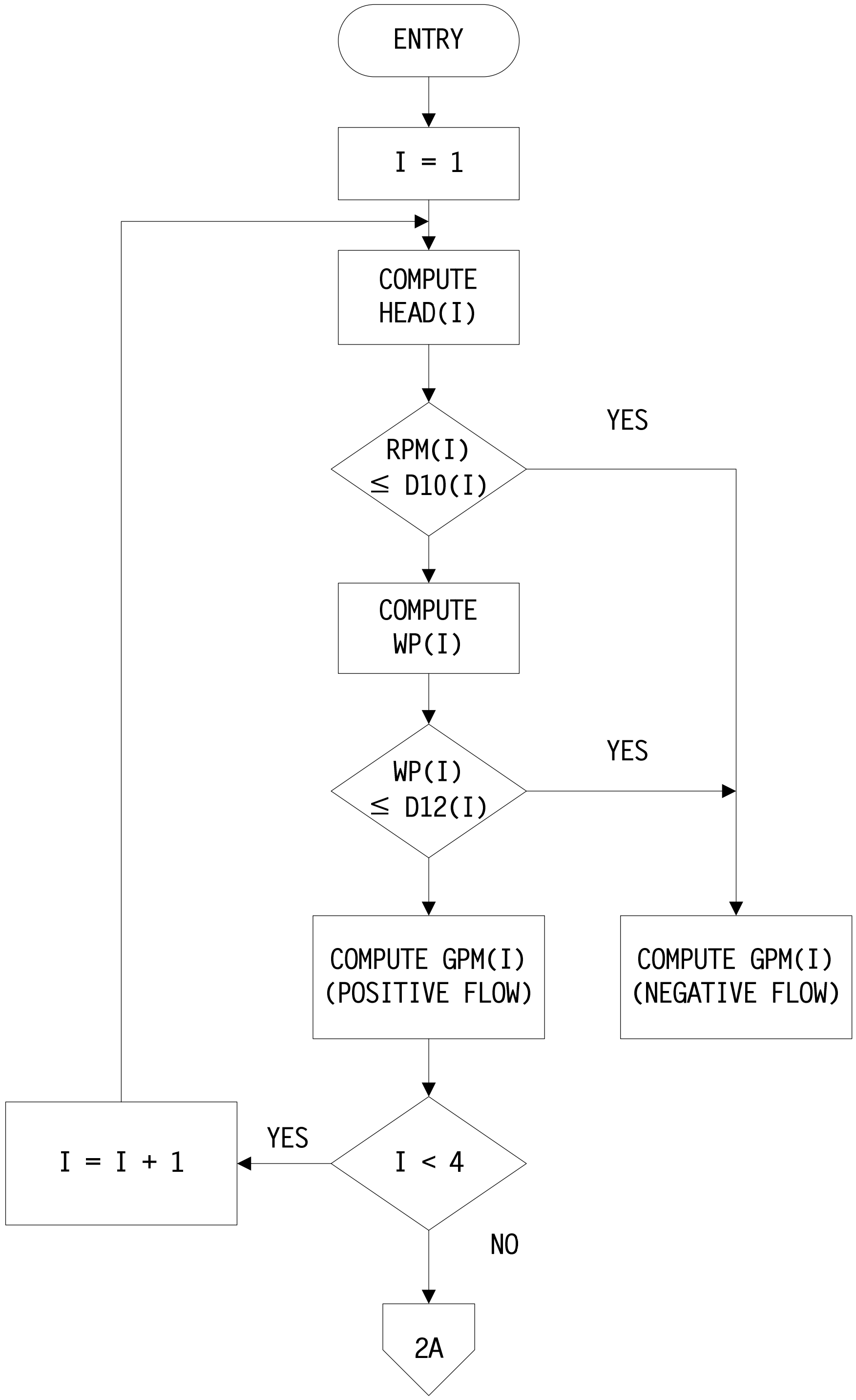
Dl0(I) through D28(I) (I = 1...4)

D29 through D31

TAU3, TAU4, CPCDMF

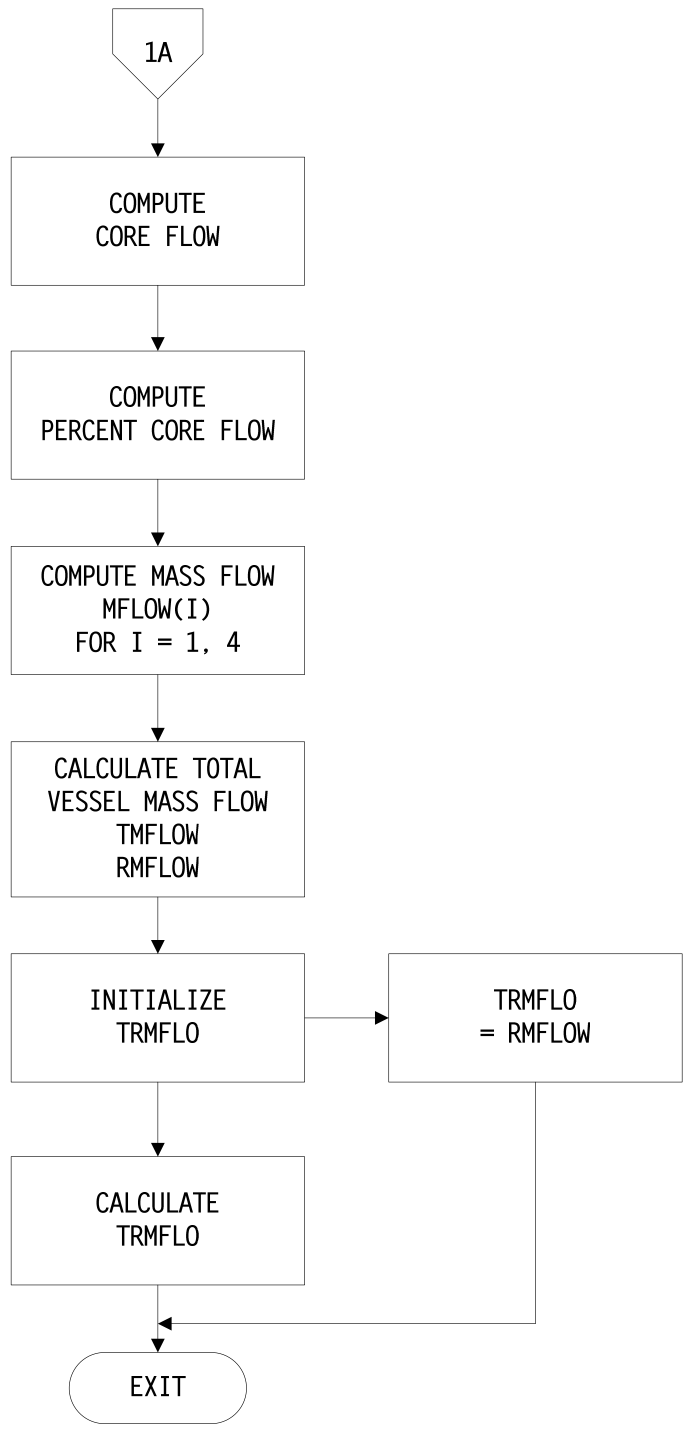
4.1.2.7. Sequence of Calculations

See Figure D-1.



SHEET 1 of 2

Figure D-1 CALCULATION OF VOLUMETRIC FLOW RATES



SHEET 2 of 2

Figure D-1 (Cont.) CALCULATION OF VOLUMETRIC FLOW RATES

4.1.3. (Block E) Primary Calorimetric Power

4.1.3.1. Description

Block E calculates primary calorimetric power and cross-calibrates it to secondary calorimetric power. These calculations are performed in four modules.

Module one calculates the net energy leaving a control volume taken about the reactor.

Module two calculates a dynamic correction for the change in control volume internal energy associated with changes in core outlet temperature.

Module three combines the static and dynamic terms to determine primary calorimetric power.

Module four cross-calibrates primary calorimetric power to secondary calorimetric power.

4.1.3.2. Timing

Block E shall be performed as a part of the one second group of calculations.

4.1.3.3. Inputs

Module One: Static Power

TCC(I)	-	Compensated cold leg temperature for I = 1 to 4 from block C
TH(I)	-	Hot leg temperature for I = 1 to 2 from block B
PPRI	-	Primary system pressure from block B
MFLOW(I)	-	Mass flow rate for I = 1 to 4 from block D
PLCTF	-	Cold leg flow factor from block D
PLHTF	-	Hot leg flow factor from block D

Module Two: Dynamic Power

TH(I)	-	Hot leg temperature for I = 1 to 2 from block B

Module Three: Total Power

BSTAT	-	Static primary calorimetric power from module 1
BDYN	-	Dynamic power from module 2

Module Four: Calibration

BDELT	-	Unfiltered primary calorimetric power from module 3
BDELTF	-	Filtered primary calorimetric power from module 3
BSCAL	-	Secondary calorimetric power from block F

4.1.3.4. Outputs

Module One: Static Power

BSTAT	-	Static Primary calorimetric power

Module Two: Dynamic Power

BDYN	-	Primary calorimetric power dynamic correction

Module Three: Core primary calorimetric Power

BDELT	-	Unfiltered primary calorimetric power from module 3
BDELTF	-	Filtered primary calorimetric power from module 3

Module Four: Calibration

CBDELT	-	Calibrated BDELT
CBDELTF	-	Calibrated BDELTF

4.1.3.5. Calculation

The calculations of block E shall not be performed, and the validities of BDELT, BDELTF, CBDELT and CBDELTF shall be set to BAD if any of the following conditions occur:

Any TH(I), TC(I), PPRI, or MFLOW(I) that has validity BAD

If BSCAL has BAD validity, then the calibration calculation of module four shall not be performed, and the validity of CBDELT and CBDELTF shall be set to BAD.

Module One: Static primary calorimetric Power

The static primary calorimetric power is calculated by

TS

TS

Module Two: Dynamic Power

The mean hot leg temperature is calculated by

TS

Initialization:

If the block is being executed for the first time after a COLSS restart or after a change in input validity to GOOD, then the following initialization shall be performed.

The dynamic power filter is initialized by setting the past value of the input equal to the current input and setting the past value of the output to zero.

TS

The filtered core primary calorimetric power is determined by

TS

Module Four: Calibration

TS

TS

Initialization:

The primary calorimetric power calibration requires initialization when one of the following events occurs:

1. COLSS is placed into the scheduled mode;

2. COLSS is restarted in response to a computer restart;

3. The conditions causing the calculation of BDELT or BDELTF to be skipped have cleared;

4. The validity of BSCAL changes from BAD to GOOD.

This initialization is performed as follows

TS

4.1.3.6. Constants

E1, TAU1, TAU2, TAUD, E4 through E9

4.1.3.7. Information Flow

See Figure E-1.

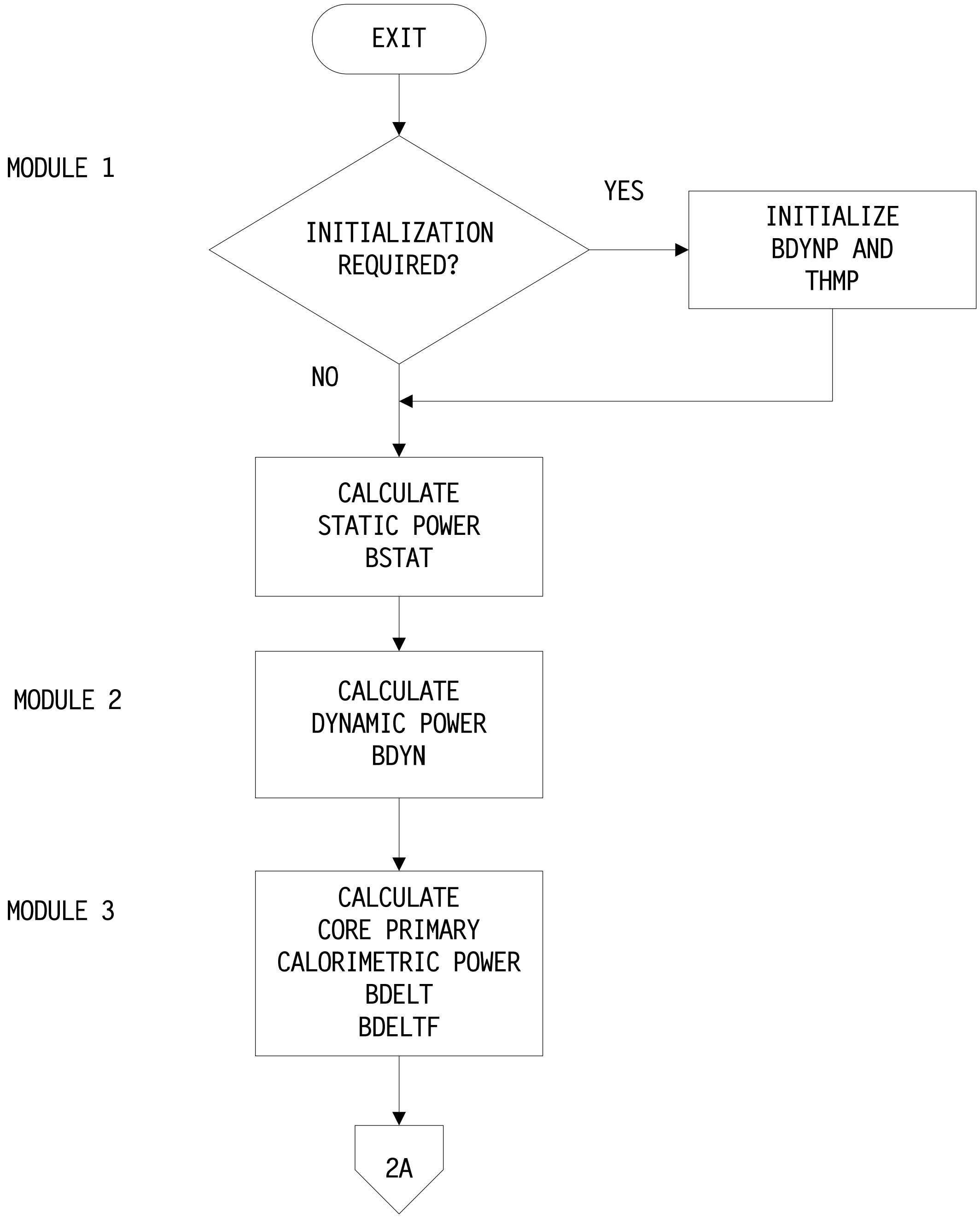


Figure E-1 SEQUENCE OF CALCULATIONS BLOCK E

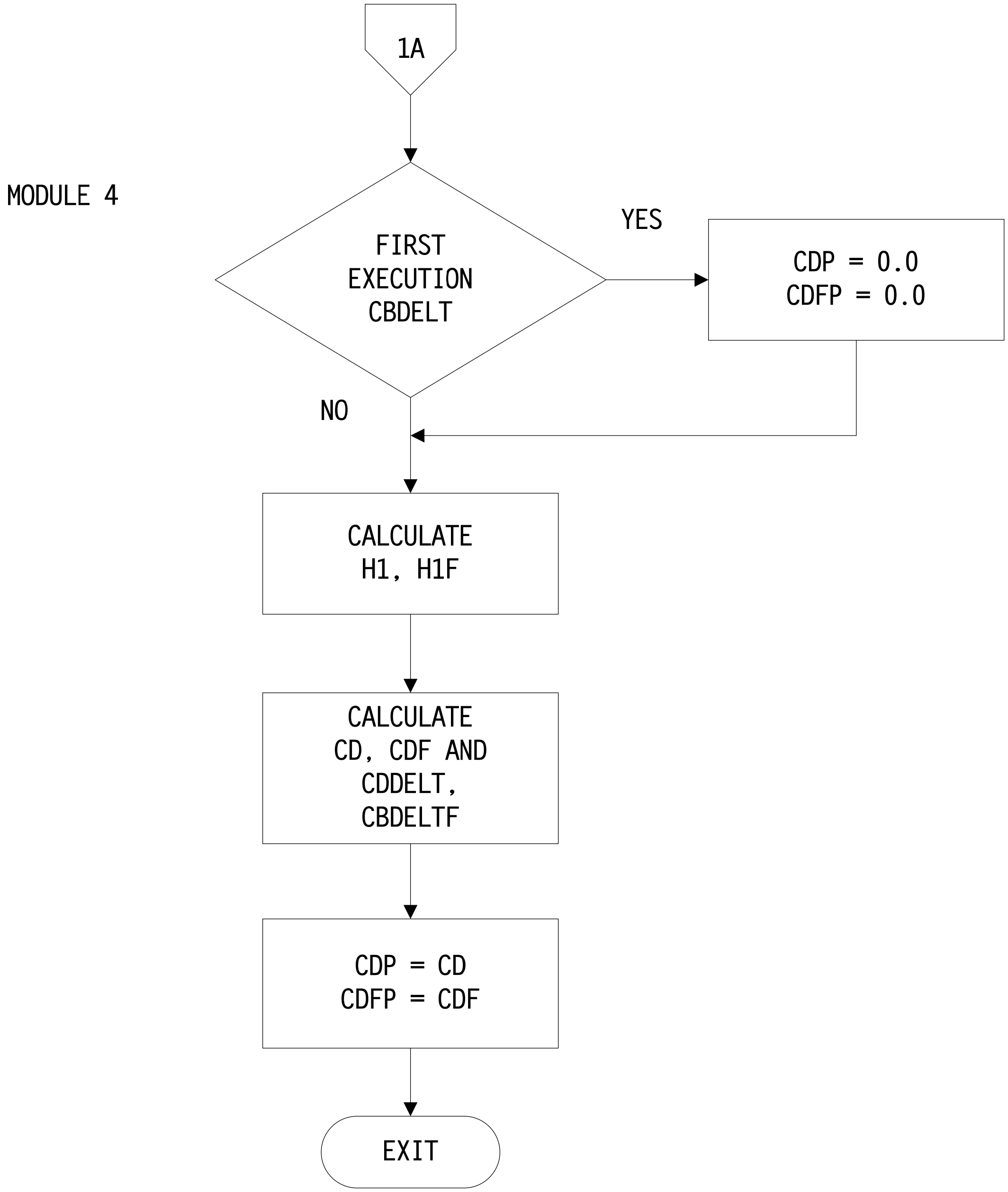


Figure E-1 (Cont.) SEQUENCE OF CALCULATION FOR CALIBRATION

4.1.4. (Block F) Secondary Calorimetric Power

4.1.4.1. Description

The purpose of this block is to calculate the reactor power based on a secondary side energy balance and the system energy losses and energy credits.

4.1.4.2. Timing

The secondary calorimetric power shall be calculated as a part of the 30 second group of calculations.

4.1.4.3. Inputs

FWF(I)	-	Feedwater flow to S.G. #1,2, from block A
SFLOW(I)	-	Steam flow S.G. #1,2, from block A
FWT(I)	-	Feedwater temperature S.G. #1,2, from block A
PSEC(I)	-	Secondary steam pressure S.G. #1,2, from block A

4.1.4.4. Outputs

BSCAL	-	Secondary calorimetric power to blocks E, G and X
BSCALAVG	-	Smoothed secondary calorimetric power to block X
QBSCAL	-	Secondary calorimetric power validity

4.1.4.5. Calculation

If any input has validity value BAD, then the calculation of BSCAL shall not be performed, and the validity of BSCAL shall be set to BAD. Otherwise, the block shall be performed and the quality of BSCAL shall be set equal to GOOD.

A. Energy Transferred Out of Steam Generators

The energy transferred to each steam generator is calculated using a steady state energy balance method. The calculations for this energy balance are shown in vector form. These calculations are performed for I = 1 to 2.

The feedwater pressure is calculated by

TS

TS

The steam generator pressure PSG(I) in psia is given by

TS

The steam mass flow rate is calculated by

TS

TS

FWH - Enthalpy of the subcooled feedwater calculated from FWT(I) and FWP(I), Btu/lbm

B. Energy Losses from the System

TS

TS

C. Energy Credits to the System

TS

D. Secondary Calorimetric Power

The secondary calorimetric power is

TS

The nominal secondary calorimetric power in percent of rated power is

TS

TS

NOTE :

The following power smoothing calculations are included here for completeness; the actual code is contained in subroutine BSCALAVG.

Smoothed secondary calorimetric power is calculated via a 1 hour average of secondary calorimetric power.

The averaging technique used in calculating BSCALVG is only to average “GOOD” values of BSCAL. For example, if only two GOOD values exist out of 120, the average will be the sum of the two values divided by 2. At initial startup, all values are initialized to “BAD”, hence, on the first iteration, BSCALAVG = BSCAL.

TS

Validity Propagation

If any GOOD values exist in BSCAL(KT-T), BSCAL(KT-2T),..,BSCAL(KT-119T), the BSCALAVG is calculated and BSCALAVG is used in block X only if QBSCAL is GOOD. If all values are BAD, BSCALAVG does not have any value.

4.1.4.6. Constants

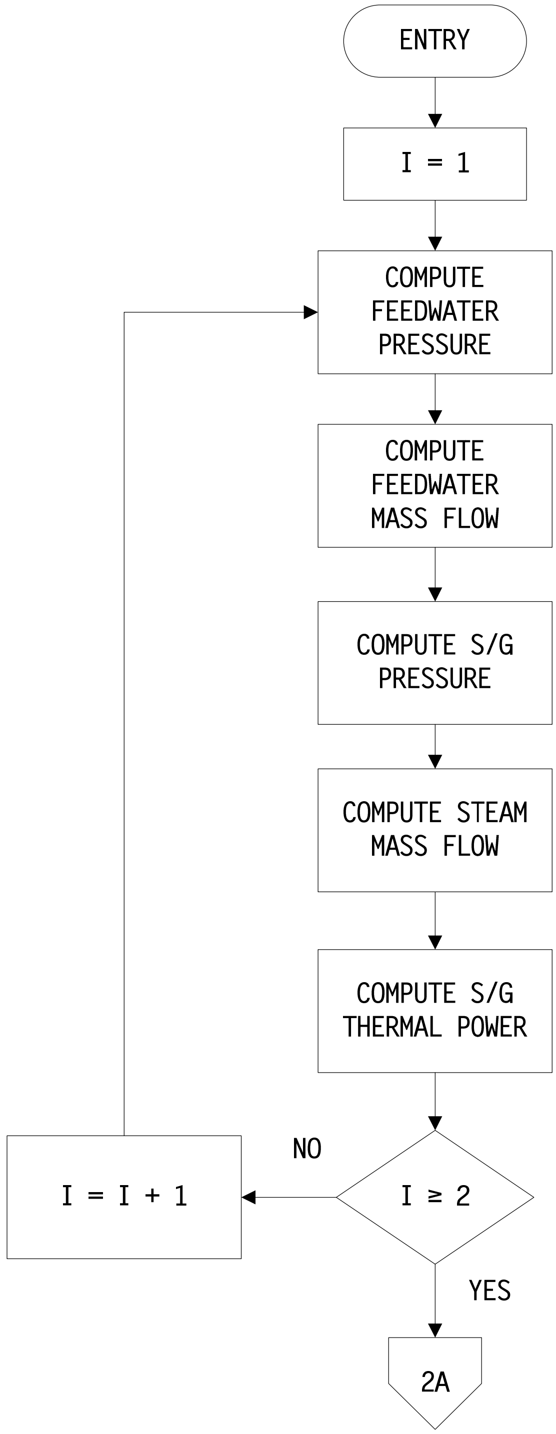
See Table F-1.

4.1.4.7. Calculation Sequence

See Figure F-1.

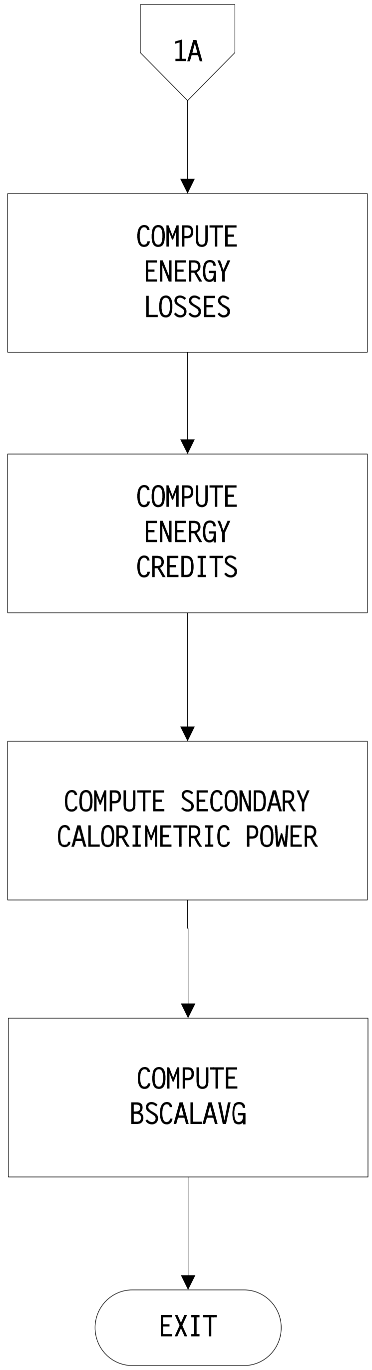
Table F-1 LIST OF INPUT CONSTANTS FOR SECONDARY CALORIMETRIC POWER

F01(1)	F01(2)
F02(1)	F02(2)
F03(1)	F03(2)
F04(1)	F04(2)
F05(1)	F05(2)
BMF(1)	BMF(2)
X(1)	X(2)
XB(1)	XB(2)
F09(1)	F09(2)
LDMF	EPIPL
LDH	ESG
SELMF	ENS
SELH	CGMF
CWMF	CGH
CWH	ECP
PCMF	EPHT
PCH	ELECT
EPRL	EMIS
F35	TAU



SHEET 1 of 2

Figure F-1 SEQUENCE OF SECONDARY CALORIMETRIC POWER CALCULATIONS



SHEET 2 of 2

Figure F-1 (Cont.) SEQUENCE OF SECONDARY CALORIMETRIC POWER CALCULATIONS

4.1.5. (Block G) Turbine Power

4.1.5.1. Description

Block G calculates turbine power, a measure of reactor power, and cross-calibrates it to secondary calorimetric power. This block is organized into two modules. Module one calculates turbine power from turbine first stage pressure using an empirical correlation. Module two cross-calibrates this power to secondary calorimetric power.

4.1.5.2. Timing

Turbine power is calculated as a part of the one second group of calculations.

4.1.5.3. Inputs

Module One: Turbine Power

TFSP - Turbine first stage pressure from block B

Module Two: Calibration

BTFSP - Unfiltered turbine power from module one

BTFSPF - Filtered turbine power from module one

BSCAL - Secondary calorimetric power from block F

4.1.5.4. Outputs

Module One: Turbine Power

BTFSP - Unfiltered turbine power from module one

BTFSPF - Filtered turbine power from module one

Module Two: Calibration

CBTFSP - Calibrated unfiltered turbine power

CBTFSPF - Calibrated filtered turbine power

4.1.5.5. Calculations

If TFSP has validity value BAD, then the calculations of block G shall not be performed, and the validity of BTFSP, BTFSPF, CBTFSP and CBTFSPF shall be set to BAD.

If BSCAL has validity of BAD, then the calculations of module two shall not be performed, and the validity of CBTFSP and CBTFSPF shall be set to BAD.

Module One: Turbine Power

Calculation of Unfiltered Turbine Power:

TS

Module Two: Calibration

Initialization:

The turbine power calibration requires initialization when one of the following events occurs:

1. COLSS is placed into the scheduled mode;

2. COLSS is restarted in response to a computer restart;

3. The conditions causing the calculation of BTFSP or BTFSPF to be skipped have been cleared;

4. The validity of BSCAL changes from BAD to GOOD.

This initialization is performed as follows:

TS

TS

4.1.5.6. Constants

G1 through G6, TAUT

4.1.5.7. Calculation Sequence

See Figure G-1.

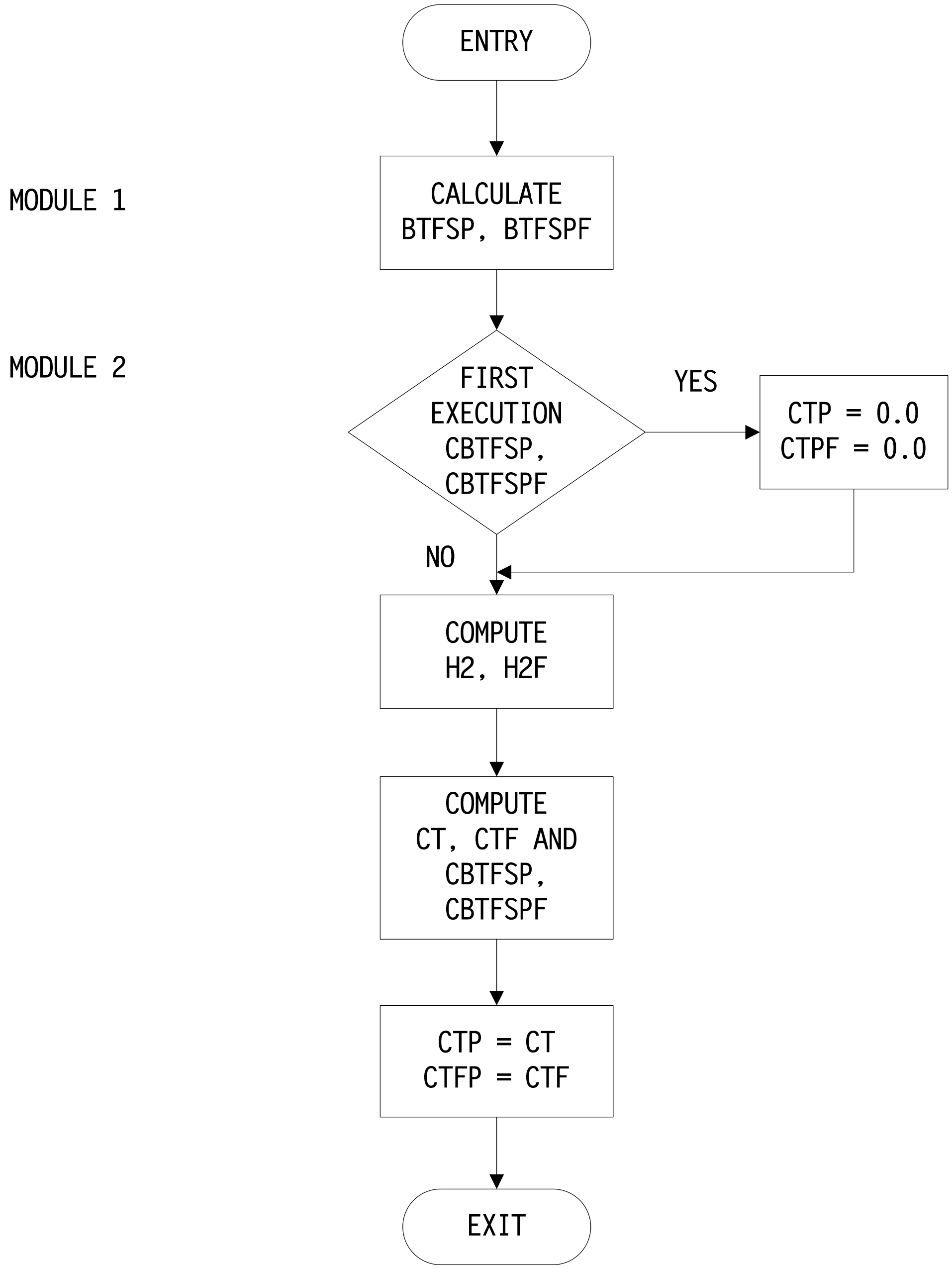


Figure G-1 CALCULATION OF TURBINE POWER

4.1.6. (Block I) Plant Power Selection

4.1.6.1. Description

Block I selects the larger of the calibrated primary calorimetric power or calibrated turbine power for use as plant power and calibrated filtered primary calorimetric power for use as filtered plant power. Alternate selection logic is provided for use when one or more of the inputs has BAD validity. Also calculated in the block are a margin bias, representing power measurement error, and a biased plant power, which is used in the CEA Application Program.

4.1.6.2. Timing

Block I shall be performed as a part of the one second group of calculations.

4.1.6.3. Inputs

CBDELT	-	Calibrated BDELT and validity from block E
CBDELTF	-	Calibrated BDELTF and validity from block E
CBTFSP	-	Calibrated BTFSP and validity from block G
CBTFSPF	-	Calibrated BTFSPF and validity from block G
BSCAL	-	Secondary calorimetric power and validity from block F
BDELT	-	Unfiltered primary calorimetric power and validity from block E
BDELTF	-	Filtered primary calorimetric power and validity from block E
BTFSP	-	Unfiltered turbine power and validity from block G
BTFSPF	-	Filtered turbine power and validity from block G

4.1.6.4. Outputs

PP	-	Plant power
QPP	-	Plant power validity
PPF	-	Filtered plant power
QPPF	-	Filtered plant power validity
BIAS	-	Margin bias
PPMAX	-	Biased Plant Power

4.1.6.5. Calculation

The calculations of this block are performed in three steps:

1. Selection of an input for use as plant power and filtered plant power, selection of a set of bias constants;

2. Calculation of the bias value from the value of plant power and the bias constants;

3. Calculation of biased plant power.

The rules for selection of plant power and its associated set of bias constants are shown in two decision tables, Table I-1 and Table I-2. The rules for selection of filtered plant power are shown in two decision tables, Table I-3 and Table I-4. No bias constant is required for filtered plant power. Each column of the table represents a case. Each row of the upper section of the table represents a test. Each entry in the upper section contains the result of a test for a given case.

Each row in the lower section represents an action. An entry in the lower section of the table indicates that the action in the row with the entry shall be taken for the case associated with the column. The set of bias constants to be used is the last entry in the column (Table I-1 and Table I-2).

Table I-1 and Table I-3 are used when the validity of BSCAL is BAD. Table I-2 and Table I-4 are used when the validity of BSCAL is GOOD.

Example:

For a BSCAL validity of BAD, the BDELT validity of GOOD and the BTFSP validity of BAD refer to column 3 of Table I-1. From column 3 note that the action taken is independent of the relative magnitudes of BDELT and BTFSP and that

TS

TS

Biased plant power is calculated from plant power and bias as follows:

TS

4.1.6.6. Constants

M(I)

B(I)

LOWLIM(I)

LOWBIAS(I)

HILIM(I)

HIBIAS(I)

All for I = 1....8

4.1.6.7. Sequence of Calculations

See Figure I-1.

Table I-1

TS

Table I-2

TS

Table I-3

TS

Table I-4

TS

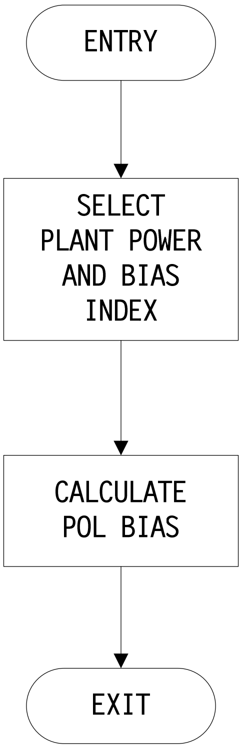


Figure I-1 SEQUENCE OF PLANT POWER SELECTION

4.2. Power Distribution Calculations

The power distribution calculations synthesize a core average axial power distribution, pseudo hot channel power distribution, and three dimensional power distribution from incore detector signals and CEA group position and group deviation signals.

These calculations are performed in seven major blocks:

1. Flux to power conversion;

2. Planar radial peaking factors;

3. Axial power distribution for Kw/ft;

4. Axial power distribution for DNBR;

5. Integrated radial peaking factor;

6. Azimuthal tilt;

7. Three dimensional power distribution.

4.2.1. (Block K) Conversion of Flux to Power

4.2.1.1. Description

This block converts incore detector compensated neutron flux to assembly power at each incore detector location. This block consists of three modules. Module one performs the flux to power calculation. Module two integrates the assembly power for calculation of fuel burnup factors. Module three calculates fuel burnup factors from the integrated assembly powers.

4.2.1.2. Timing

Modules one and two shall be performed at ten second intervals while the computer is in service, and the reactor is operated in the power range.

Module three shall be performed daily while the computer is in service and the reactor is operated in the power range.

4.2.1.3. Inputs

Module One: Flux to power conversion

CS(I, J)	-	Incore detector compensated flux
QS(I, J)	-	Incore detector quality flags
PP	-	Plant power
LSHUT(I)	-	Shutdown CEA group height
LPSR(I)	-	Part strength CEA group height
LREG(I)	-	Regulating CEA group height

Module Two: Ten second power integration

PHI(I, J) - Assembly power at detector location I, J, from Module 1

Module Three: Daily burnup factor calculation

TPHI(I, J) - Integrated power from module 2

4.2.1.4. Outputs

Module One: Flux to power

PHI(I, J) - Assembly power at detector location I, J

Module Two: Ten second integrated power

TPHI(I, J) - Cumulative power at location I,J

Module Three: Daily burnup factor

WP(I, J) - Burnup factor at location I,J

4.2.1.5. Calculation

If incore detector signal CS(I,J) has BAD quality, then the calculation of PHI(I,J) and TPHI(I,J) shall be skipped. If less than KO9 incore detectors have quality QS(I,J) of GOOD, or if plant power has validity BAD, then the calculations of block K shall not be performed.

Module One

CEA configuration dependent correction factors are calculated for use in converting the compensated incore detector flux CS(I,J) to power PHI(I,J). The calculation of this conversion factor is performed in two steps.

1. Calculation of the fractional insertion of each CEA group in each of the five detector axial levels.

2. Conversion of the insertion fraction to a correction for detector string I at level J.

Calculation of Fractional Insertion

For all CEA groups, the group fractional insertion is calculated by examining the lower tip of the lowest CEA. The fractional insertion is determined by calculating the distance between the lower tip of the CEA and the top of the axial detector level. The ratio of this distance to the level height is limited to be between 1.0 representing full insertion and 0.0 representing no insertion giving the fractional insertion.

To make the calculation of correction factors more convenient, the fractional insertions are stored in a matrix. The entire calculational procedure is illustrated below for one detector level.

Level boundaries are initialized

TS

Shutdown CEA groups 1 and 2 are examined

TS

Part strength CEA groups 1 and 2 are examined

TS

Regulating CEA groups 1 through NGROUP are examined

TS

Move to next level

TS

TS

Calculation of CEA Correction Factors

The CEA correction factor matrix is calculated from the CEA group fractional insertion matrix by matrix multiplication. That is

TS

The CEA insertion correction, the burnup correction, and a power dependent correction are applied to calculate the assembly power matrix PHI (I,J) for detector string I at level J.

TS

The power correction factor K(I) is used to adjust the burnup dependent correction WP(I,J) to give the unrodded conversion factor W(I,J) used to convert the flux in string I at level J to power. That is for I varying from 1 to 61 and J varying from 1 to 5:

TS

Module 2

Integrated assembly power is calculated for each detector.

TS

Module 3

Daily burnup factor update

Burnup correction factors are updated as follows:

TS

TS

The BUP(I,J) values are saved on a permanent file to facilitate updating the fuel burnups following a computer outage. This updating is performed in the IPS. Files of the most recent BUP and the next-most-recent BUP, together with their associated Effective Full Power Hours (determined in the IPS by time integration of COLSS Plant Power), are used to linearly extrapolate to current burnup, given the operator-entered value of the current EFPH.

4.2.1.6. Constants

a. Flux to power conversion

C(I,K) - Rod position correction constants, I = 1...61, K = 1...12

K1(I)-K3(I) - Flux to power conversion constants, I = 1...61

NGROUP - Number of CEA regulating groups

HLEVEL - Length of incore detector level

b. Ten second power integration

DT - Interval between ten second calculations in days

c. Daily burnup factor calculation

K4(I)-K8(I) - Burnup adjustment correlation constants, I = 1...61

d. Block execution

K09 - Number of good incore detectors required for block execution

4.2.1.7. Calculation Sequence

See Figure K-1.

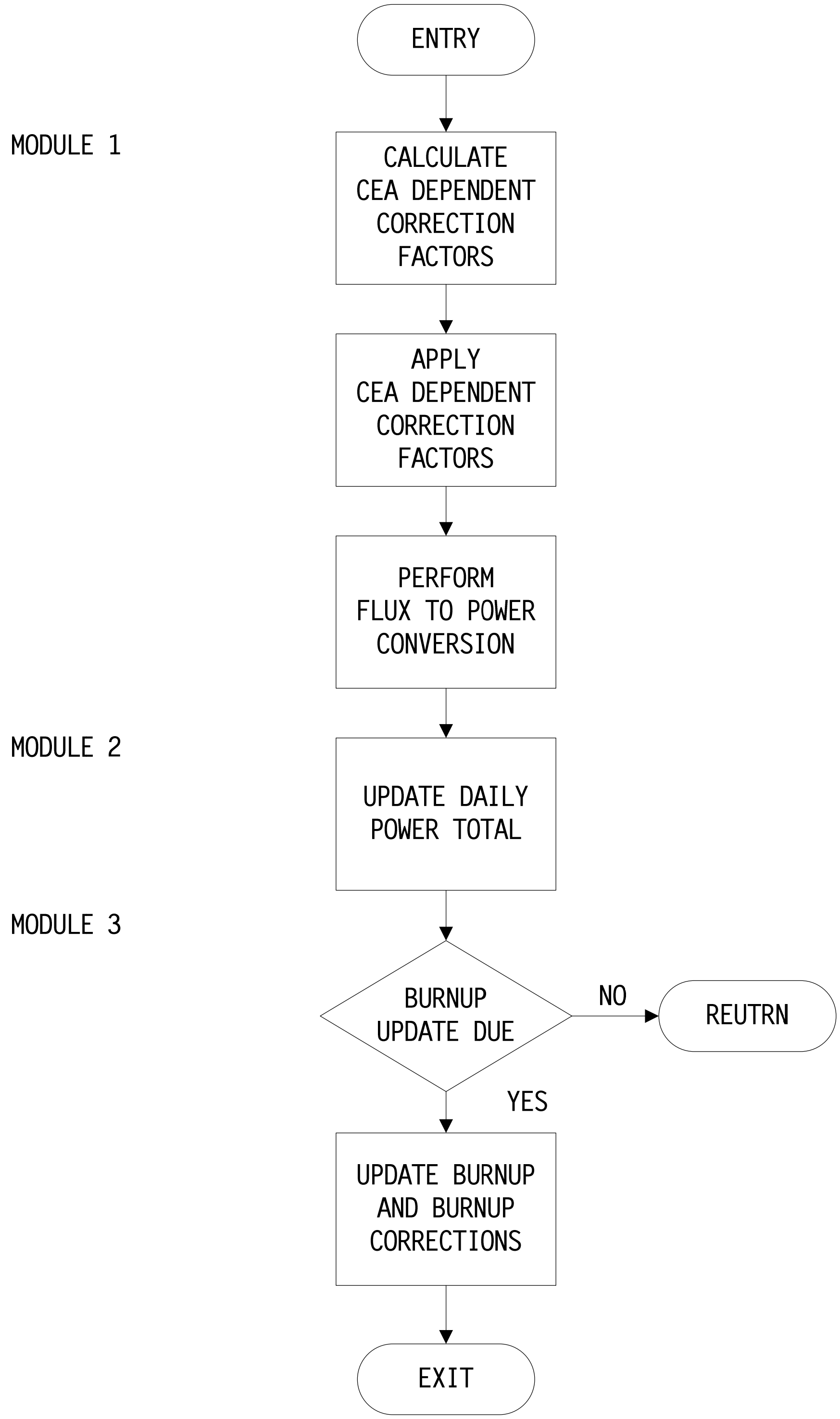


Figure K-1 SEQUENCE OF CALCULATIONS FOR FLUX TO POWER CONVERSION

4.2.2. (Block L) Planar Radial Peaking Factor Determination

4.2.2.1. Description

The purpose of this block is to determine the planar radial peaking factors based on indicated CEA group positions calculated in the CEA scan program and plant power.

4.2.2.2. Timing

The planar radial peaking factors shall be calculated as a part of the 10 second group of calculations.

4.2.2.3. Inputs

LREG(I)	-	Lowest rod in regulating group I
LSHUT(I)	-	Lowest rod in shutdown group I
LPSR(I)	-	Lower tip of part strength group I
DEVR(I)	-	Deviation of regulating group I
DEVS(I)	-	Deviation of shutdown group I
DEVP(I)	-	Deviation of part strength group I

4.2.2.4. Outputs

PLRAD(20)	-	Planar radial peaking factors for 20 axial nodes, to blocks P, S, U
QRADIAL	-	Flag denoting validity of block L outputs

4.2.2.5. Calculation

If any input has validity BAD, if less than K09 incore detectors have quality QS(I,J) of GOOD, if plant power PP is less than a constant STARTL, or if less than two reactor coolant pumps run (PUMPRUN < 2), then the calculations of block L shall not be performed and QRADIAL, a flag denoting the validity of block L outputs, shall be set to BAD.

The calculations of this block may be divided into three modules. Module one performs the calculation of group sequence and group deviation penalty factors. Module two determines core position and CEA configuration indices and density-dependent radial peaking penalty factors. The density-dependent penalty factors together with the sequence and deviation penalty factors from module one are applied to unpenalized planar radial peaking factors from module three to determine the COLSS planar radial peaking factors. Module 3 determines the unpenalized planar radial peaking factors from the position and configuration indices, and tabular data.

<u>Module One: Penalty Factor Calculation</u>

Two penalty factors, which account for out of sequence regulating CEA group insertion and excessive deviation of CEA's within a group are calculated in module one. In module two these penalty factors are used to modify the radial peaking factors. A discussion of procedures by which the radial peaking factors are determined and a sequence of calculations to implement that logic follow.

In performing the calculations of this block, the reactor core is divided into 20 axial nodes. Node 20 is the top node and node 1 is the bottom node. Several special conditions apply to the top and bottom nodes in determining CEA deviation and sequence penalty factors.

1. If the lowest rod in any rod group is above the bottom of node 20, then no deviation or sequence penalty factor is applied for that group.

2. If the lowest rod in a group is below the top of node one, no sequence penalty is applied for that group.

The Penalty Factors

PF1 is calculated based on regulating CEA sequence. If no out-of-sequence condition exists, then PF1 is set to one. If any regulating CEA group is positioned out-of-normal-sequence, then PF1 is set to PSEQ. The normal sequence of withdrawal is to withdraw group one, then group two, and so forth. Thus a regulating CEA group should have a height equal to or greater than that of any higher numbered regulating CEA group. A group is considered to be fully inserted when the lower tip of the lowest CEA in the group is below the top of node one.

The penalty factor PF2 is calculated from CEA group deviation. CEA group deviation is the difference in height between the top CEA in a group and the bottom CEA in a group. CEA height is the distance from the core bottom to the lower tip of active element of CEA. The deviation penalty factor PF2 is calculated from the following rules:

1. If the group deviation is less than a constant NO3, then the group penalty factor is one.

2. If the group deviation is between two limits NO3 and NO5, then the group penalty factor is given by:

TS

3. If the group deviation is greater than NO5, then the group penalty factor is a constant, $CDEV2_i$.

The composite penalty factor PF2 is given by

TS

Check top node

TS

For part strength groups 1 and 2

Check top node

TS

Check for last group

TS

Check top node

TS

TS

Module Two

The core is divided into 20 axial nodes. Planar radial peaking factor values are stored in an array for each of 15 possible CEA configurations. The array value for CEA configuration contains planar radial peaking factors for that particular CEA configuration.

TS

The planar radial peaking factors and density dependent radial peaking factors are determined by table lookup schemes. The proper locations in the tables are selected based upon the configuration of CEAs. Two indices, one describing the regulating CEA configuration (K) and one describing the configuration of part strength and shutdown CEAs (L), are used to look up the raw peaking and rod shadowing factors. The logic for determining the indices is as follows.

Initialization (Calculations done for first node only)

TS

The following sequence is performed for nodes 1 through 20.

Determine node centers

TS

Modify LN01 if testing top node

TS

Modify LN01 if testing bottom node

TS

Determine Index L

TS

TS

Determine Index K

The following test sequence is performed for regulating CEA group number, NREG.

TS

Density-Dependent Penalty Factor (FDEN)

If the average reactor coolant specific volume from block D has BAD validity, the density-dependent planar radial peaking penalty factor, FDEN, is assigned a default value and the processing skips to the calculation of PLRAD (N) on page 158. Otherwise the deviation from nominal inlet moderator density is determined (for N=1), and FDEN is calculated from the CEA configuration indices K and L and the density deviation.

TS

THEN SKIP TO KDEN CALCULATION

Otherwise (N=1), the inlet moderator density deviation is determined:

TS

KDEN Calculation

TS

See Table L-1 for KDEN summary.

Check to see if the CEA configuration is unchanged from the previous axial node

TS

Then bypass the density dependent penalty factor (FDEN) calculation for the present node since the value will not change.

TS

FDEN Calculation

Look up the slope of density dependent penalty factor

TS

Calculate the density dependent penalty factor at node N

TS

PLRAD(N) Calculation

The adjusted planar radial peaking factor is calculated. The planar radial peaking factor is adjusted for deviations, out-of-sequence, moderator density, and by an addressable adjustment factor (PF3) normally used to ensure conservatism relative to measurements.

TS

TS

TS

4.2.2.6. Constants

TS

TS

4.2.2.7. Sequence of Calculations

See Figure L-1.

Table L-1 Density Dependent Penalty Factor Slope Index (KDEN)

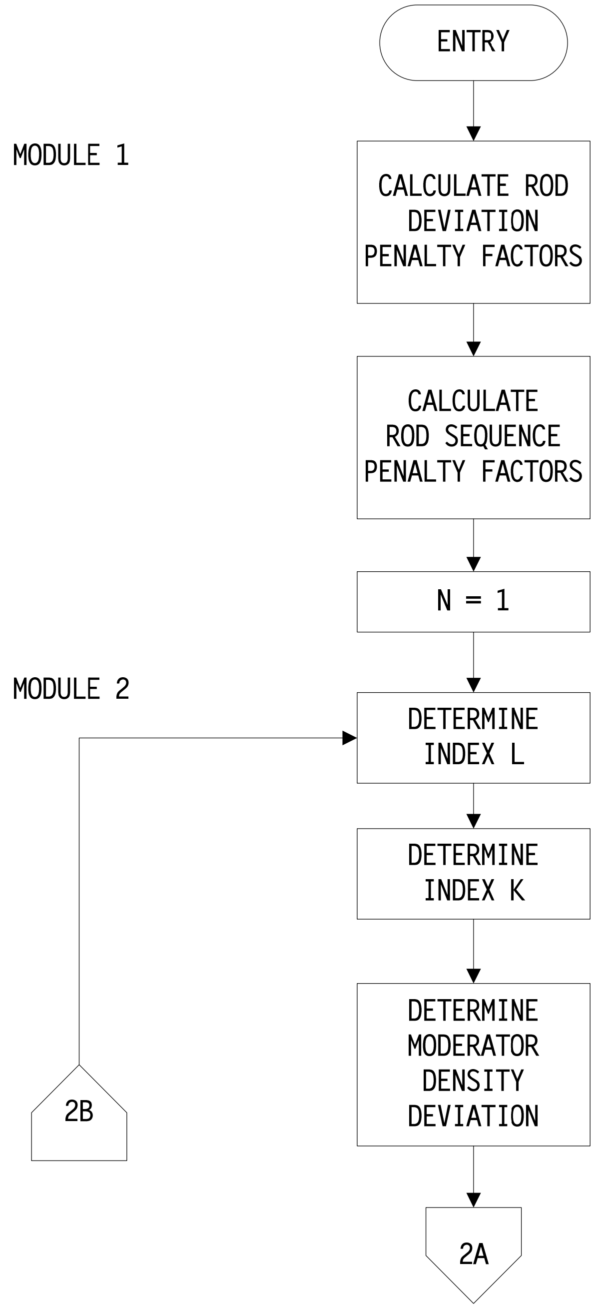
KDEN (K, L)

K	L = 1	2	3	4	5
1	1	2	2	2	19
2	3	4	4	4	19
3	5	6	6	6	19
4	7	8	8	8	19
5	9	10	10	10	19
6	11	12	12	12	19
7	13	14	14	14	19
8	15	16	16	16	19
9	17	18	18	18	19

Where K and L are as follows :

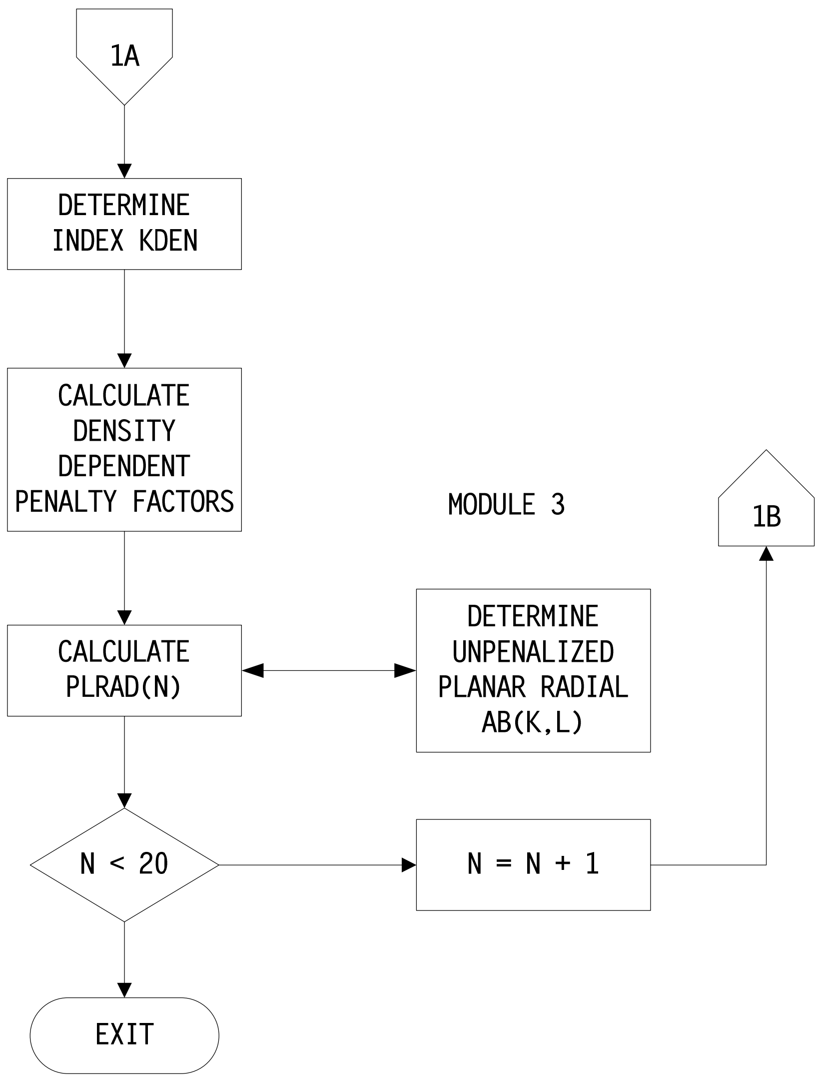
K	Configuration
1	No Regulating CEAs
2	Regulating CEAs NGROUP through 8
3	Regulating CEAs NGROUP through 7
4	Regulating CEAs NGROUP through 6
5	Regulating CEAs NGROUP through 5
6	Regulating CEAs NGROUP through 4
7	Regulating CEAs NGROUP through 3
8	Regulating CEAs NGROUP through 2
9	Regulating CEAs NGROUP through 1

L	Configuration
1	No PSRs and Shutdown
2	PSR Group 1
3	PSR Group 2
4	All PSRs
5	Shutdown



SHEET 1 of 2

Figure L-1 SEQUENCE OF PLANAR RADIAL PEAKING FACTOR CALCULATIONS



SHEET 2 of 2

Figure L-1 (Cont.) SEQUENCE OF PLANAR RADIAL PEAKING FACTOR CALCULATIONS

4.2.3. (Block M) Axial Power Distribution for Linear Heat Rate Power Operating Limit and ASI Alarms

4.2.3.1. Description

The purpose of this block is to calculate an axial power distribution from the detector power signals. The axial power distribution is calculated by the Fourier synthesis method or the cubic spline synthesis method according to the selected switching constant of APDSWITCH. When the cubic spline synthesis method is selected, the block determines the amplitudes of set of spline functions chosen from the available sets to best represent the current power shape. Core average axial shape index is also calculated and compared to alarm limits.

4.2.3.2. Timing

A new axial power distribution for an average detector string and a new axial shape index shall be calculated in the 10 second group of calculations.

4.2.3.3. Inputs

PHI(I, J)	-	Assembly power for string I level J from block K
QS(I, J)	-	Quality of incore detector string I level J
PP	-	Plant power from block I

4.2.3.4. Outputs

APKD(I)	-	Axial power distribution
ASI	-	Axial shape index to output tasks
ALARM4	-	Axial shape index out of limits
TIME4	-	Event duration ASI out of limits
QASI	-	Flag denoting validity of axial shape index
QAXIAL	-	Flag denoting validity of axial power distribution
TIME4A	-	Cumulative duration ASI out of limits

4.2.3.5. Calculation

According to the selected switching constant of APDSWITCH given by the utility, the calculation is divided into two parts, one for the Fourier synthesis method and the other for the cubic spline synthesis method.

4.2.3.5.1. Calculation for Fourier synthesis method

If the validity of PHI(I,J) is BAD, then PHI(I,J) is excluded from the calculations of block M. The validity of PHI(I,J) equals the validity of QS(I,J). If less than K09 detectors have quality QS(I,J) of GOOD, if less than two reactor coolant pumps runs (PUMPRUN < 2), if plant power has validity BAD, or if plant power is less than a constant STARTL, then the calculations of block M shall not be performed and QAXIAL, a flag denoting the validity of block M outputs, shall be set to BAD.

When the calculations of block M are not performed, ALARM4 shall be reset and TIME4 shall be set to zero, and the validity of ASI shall be set to BAD.

This block has seven major steps:

1. Averaging of assembly powers for each level;

2. Normalization of power signals;

3. Calculation of Fourier series coefficients;

4. Power distribution fitting;

5. Calculation of axial shape index;

6. Alarm processing;

7. Normalization of axial power distribution.

These steps are performed as follows:

Averaging of Assembly Powers for Each Level

At each axial level the power signals with validity of GOOD are averaged. That is

TS

For detector strings I varying from 1 to 61

TS

The average is calculated, provided N ≠ O

TS

If N = 0 (all detectors at level J have BAD validity), the remaining calculations of block M are skipped, and QAXIAL and QASI are set to BAD.

Normalization of Average Power Signals for Each Level

The power signals are normalized by

TS

Calculation of Fourier Series Coefficients

The normalized power signals are transformed into five Fourier series weighting coefficients by evaluating the matrix product.

TS

Power Distribution Fitting

A 40 node power distribution is constructed by forming the product of the Fourier series matrix SPLIN and the Fourier coefficient vector A.

TS

TS

Calculation of Axial Shape Index

TS

To prevent possible negative values at the core axial boundaries the absolute value of each element of APKD is taken after the summation. This value is low-limited at 0.01 to insure proper operation of the DNBR calculation. This adjustment must not be made until after SUMB and SUMT are calculated.

That is

TS

<u>Alarm Processing</u>

Both the upper and lower alarm setpoints on axial shape index are power-dependent. When any limit is exceeded, ALARM4 is set. ALARM4 is set and reset as follows:

```
IF(PP .LT. POWERBP(1)) THEN

    IF(ASI .LT. ASINBP(1) .OR. ASI .GT. ASIPBP(1)) THEN

        ALARM4 is set

        ELSE ALARM4 is reset

    ENDIF

ELSEIF (PP .LT. POWERBP(2)) THEN

    IF(ASI .LT. ASINBP(2) .OR. ASI .GT. ASIPBP(2)) THEN

        ALARM4 is set

        ELSE ALARM4 is reset

    ENDIF

ELSE

    IF(ASI .LT. ASINBP(3) .OR. ASI .GT. ASIPBP(3)) THEN

        ALARM4 is set

        ELSE ALARM4 is reset

    ENDIF

ENDIF
```

When ALARM4 is set, MSG4 is displayed.

When ALARM4 is reset, MSG4 is cleared.

When ALARM4 is set, two times are accumulated. TIME4 is an event duration time which is accumulated when ALARM4 is set and zeroed when ALARM4 is reset. TIME4A is a cumulative event duration which is accumulated when ALARM4 is set and held fixed when ALARM4 is reset. TIME4A is initialized manually. When TIME4 and TIME4A exceed their associated time limits, MO1 and MO2, an alarm message is displayed.

When block M cannot be executed ALARM4 shall be reset, MSG4 shall be cleared, and TIME4 shall be set to zero.

<u>Normalization of Axial Power Distribution</u>

Normalization of the axial power distribution is done as follows:

TS

I

4.2.3.5.2. Calculation for cubic spline synthesis method

If the validity of PHI(I,J) is BAD, then PHI(I,J) is excluded from the calculations of block M. The validity of PHI(I,J) equals the validity of QS(I,J). If less than K09 detectors have quality QS(I,J) of GOOD, if less than two reactor coolant pumps run (PUMPRUN < 2), if plant power has validity of BAD, or if plant power is less than a constant STARTL, then the calculations of block M shall not be performed, and QAXIAL, a flag denoting the validity of the block M outputs, shall be set to BAD.

When the calculations of block M are not performed, ALARM4 shall be reset and TIME4 shall be set to zero, and the validity of ASI shall be set to BAD.

This block has ten major steps:

1. Averaging of assembly powers for each level;

2. Normalization of power signals;

3. Renumbering of power signals;

4. Calculation of boundary point powers;

5. Selection of appropriate node set and matrix values;

6. Calculation of spline function amplitudes;

7. Calculation of axial power distribution;

8. Calculation of axial shape index;

9. Alarm processing;

10. Normalization of axial power distribution.

These steps are performed as follows:

<u>Averaging of Assembly Powers for Each Level</u>

At each axial level the power signals with validity of GOOD are averaged. That is

TS

For detector string I varying from 1 to 61

TS

The average is calculated, provided N $\neq$ 0

TS

If N = 0 (all detectors at level J have BAD validity), the remaining calculations of block M are skipped and QAXIAL and QASI are set to BAD.

Normalization of Average Power Signals for Each Level

TS

TS

Renumbering of Power Signals

The order of the five power signals, D(1) through D(5), bottom to top, is inverted and renumbered as BB(6) through BB(2) to be consistent with the remainder of the algorithm as it was developed based on the equivalent CPC algorithm.

TS

Calculation of Boundary Point Powers

The boundary point powers are calculated using the final normalized power signals. The power vector used to calculate the spline function amplitudes requires the generation of boundary point power values for both the top of the core, BB(1), and the bottom of the core, BB(7), based on the average power in the end regions of the core. The correlations are empirically based on four constants, BPPCCA through BPPCCD, and minimum permitted boundary point powers. The boundary point powers are calculated as follows:

TS

In order to avoid negative boundary point power values for excessively low normalized detector power signals D(J), the following checks are applied:

TS

TS

Selection of Appropriate Node Set and Matrix Values

The synthesis of axial power distribution involves the selection of a set of spline functions and determination of function amplitudes. The selection of functions is determined by the gross power shape of the core as indicated by the values of average detector power signals, D(J). The general form of functions is fixed so that the selection involves only the determination of break point locations, which permits the use of a pre-calculated set of inverse matrices. This section of block M selects one of these matrices via the determination of index K.

The following tests, based on the power signals at each level, are used to determine K and the direction flag KDIR for calculation of axial shape.

TS

TS

Tests are made to evaluate shape characteristics based on two test parameters which are calculated using the integer function, INT(value), which returns the largest integer that does not exceed the input value.

TS

These test parameters are used in evaluating characteristics of axial shape, such as center weighting and asymmetry, in order to choose pointers for the spline synthesis.

The value of ITEST1 is compared with five breakpoints, IPWRS1(I) for I=1 through 5, to choose the index I in the range from 1 to 6. I is chosen to be the value which satisfies one of the following expressions:

TS

A second index J is chosen based on the comparison of ITEST2 and breakpoint IPWRS2(I) for the index I chosen above.

TS

A final index K is then determined from the array of functions sets, KVAL, using the index J just determined.

TS

The index K is then available for use in determining spline amplitudes.

Calculation of Spline Function Amplitudes

The normalized detector signals and boundary point power values that are stored in the BB array are used to determine the amplitudes of spline functions by performing the matrix multiplication,

TS

The matrix inversion for each H matrices is performed off line and the resulting inverse matrix elements are stored in the array HC. The expression used to evaluate the equation for spline amplitudes is therefore only dependent on the storage order of the items in the HC array. The equation to be used for the actual evaluation takes advantage of the relationship between the end spline function amplitudes and, thus, only determines the amplitudes of seven interior spline functions.

TS

The following equations are used in combination with the pre-calculated values to determine the spline function amplitudes:

TS

The amplitude of end splines is related by a ratio of -1 to 4 to the next inner spline, therefore: TS

Calculation of Axial Power Distribution

The axial power distribution is calculated based on the use of pre-calculated values and by taking advantage of the symmetries introduced by the choice of spline functions. There are always six regions in the core which have different sets of non-zero spline functions as follows:

Region	Non-Zero Spline Functions
1	1, 2, 3, 4
2	2, 3, 4, 5
3	3, 4, 5, 6
4	4, 5, 6, 7
5	5, 6, 7, 8
6	6, 7, 8, 9

Thus in region I1, spline functions I1 through I1+3 are always used although the portion of the core covered will vary depending on the node set selected (index K). The following equations describe the calculation of 40 node axial power distribution. (Note that this calculation again inverts the order of indexing in the axial direction so that node 1 of 40 for axial power distribution in the FZ array is the core bottom, to be consistent with the following blocks):

TS

TS

For each of the six spline function regions (I1=1 through 6) the constant location indices are determined starting with I1=1.

TS

Once the indices have been found, the axial power FZ(I) for those nodes I in the spline function region is given by

TS

TS

The axial power in each node I in the spline function region is checked to assure that the synthesis did not introduce any spurious small or negative power values which would interfere with the DNBR calculations in later blocks. Note that the value of relative axial power prior to this correction must be preserved for use in determining the axial shape index and the axial power normalization factor later in this block.

TS

If all six spline function regions have not been processed, the indices are adjusted:

TS

and the evaluation should be repeated which begins with the equation following the sentence, "For each of the six spline function regions … starting with I1=1."

Calculation of Axial Shape Index

The powers in the upper and lower halves of the core are calculated from the 40 node axial power distribution before correction for small or negative values:

TS

TS

Alarm Processing

Both the upper and lower alarm setpoints on the the axial shape index are power-dependent. When any limit is exceeded, ALARM4 is set. ALARM4 is set and reset as follows:

IF(PP .LT. POWERBP(1)) THEN

IF(ASI .LT. ASINBP(1) .OR. ASI .GT. ASIPBP(1)) THEN

ALARM4 is set

ELSE ALARM4 is reset

END IF

ELSEIF (PP .LT. POWERBP(2)) THEN

IF(ASI .LT. ASINBP(2) .OR. ASI .GT. ASIPBP(2)) THEN

ALARM4 is set

ELSE ALARM4 is reset

END IF

ELSE

IF(ASI .LT. ASINBP(3) .OR. ASI .GT. ASIPBP(3)) THEN

ALARM4 is set

ELSE ALARM4 is reset.

END IF

END IF

When ALARM4 is set, MSG4 is displayed.

When ALARM4 is reset, MSG4 is cleared.

When ALARM4 is set, two times are accumulated. TIME4 is an event duration time which is accumulated when ALARM4 is set and zeroed when ALARM4 is reset. TIME4A is a cumulative event duration which is accumulated when ALARM4 is set and held fixed when ALARM4 is reset. TIME4A is initialized manually. When TIME4 or TIME4A exceeds their associated time limits M01 and M02, an alarm message is displayed.

When block M cannot be executed, ALARM4 shall be reset, MSG4 shall be cleared, and TIME4 shall be set to zero.

Normalization of Axial Power Distribution

Normalization of the axial power distribution is done as follows:

TS

4.2.3.6. Constants

According to the selected switching constant of APDSWITCH, the calculation is divided into two parts, one for Fourier synthesis method and the other for cubic spline synthesis method.

APDSWITCH - Switching constant for axial power distribution synthesis method, 0 for Fourier synthesis and 1 for cubic spline synthesis method

4.2.3.6.1. Constants for Fourier synthesis method

H(I,J) I = 1...5, J = 1...5

SPLIN(K,I) K = 1...5, I = 1...40

POWERBP(I=1,2) - Power breakpoints

ASINBP(I=1,3) - Negative axial shape index breakpoints*

ASIPBP(I=1,3) - Positive axial shape index breakpoints*

ASIOFF - ASI OFFSET

MO1 - TIME4 alarm limit

MO2 - TIME4A alarm limit

* ASILL (addressable) = ASINBP(3)

ASIHL (addressable) = ASIPBP(3)

4.2.3.6.2. Constants for cubic spline synthesis method

K09	-	Minimum number of GOOD detectors to perform block M (also used in block K)
SIGU, SIGL, BMINU1, BMINL1, BEPSU, BEPSL, BMINU2, BMINL2	-	Parameters to control the minimum boundary point power calculations
BPPCCA, BPPCCB, BPPCCC, BPPCCD	-	Boundary Point Power Correlation Coefficients
IPWRS1(I=1,5), IPWRS2(I=1,6), KVAL(I=1,12)	-	Test parameters used to select the set of spline functions for the synthesis (node set)
HC(N=1,600)	-	Pre-calculated inverse matrices for the spline synthesis
NOD(I=1,72)	-	Number of axial mesh intervals in each axial region for each spline function set
IBEG(I=1,17)	-	Starting points for the spline function values in the TERM1 and TERM2 arrays.
TERM1(J=1,100), TERM2(J=1,100)	-	Spline function values for relative positions in regions of specified number of axial mesh
POWERBP(I=1,2), ASINBP(I=1,3), ASIPBP(I=1,3)	-	Parameters for evaluation of the ASI alarm
FZMIN	-	Minimum allowed relative axial power
ASIOFF	-	Axial offset available to make the ASI alarm range symmetric if required
M01, M02	-	Time limits for ASI alarm duration

4.2.3.7. Sequence of Calculations

See Figure M-1 and Figure M-2.

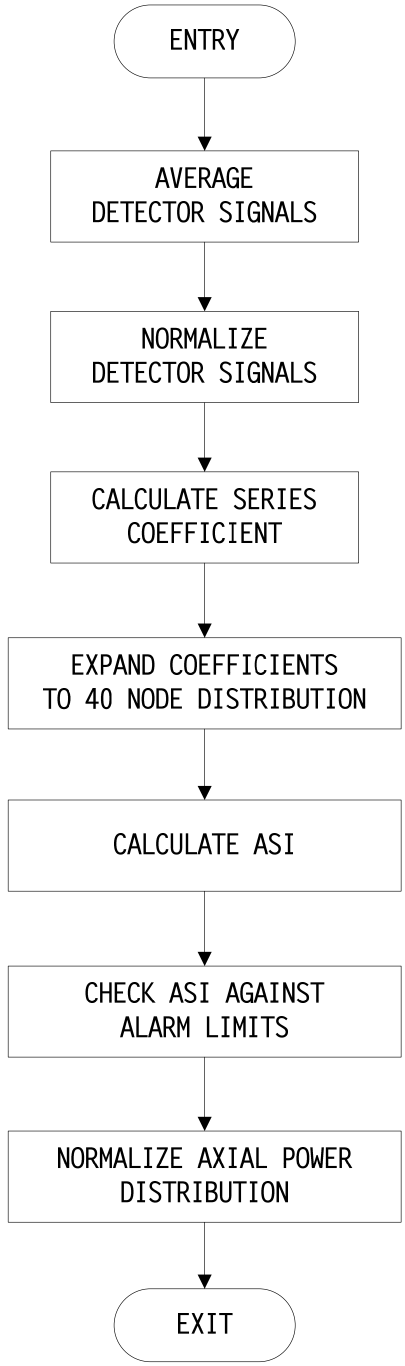


Figure M-1 SEQUENCE OF AXIAL POWER DISTRIBUTION CALCULATIONS FOR FOURIER SYNTHESIS METHOD

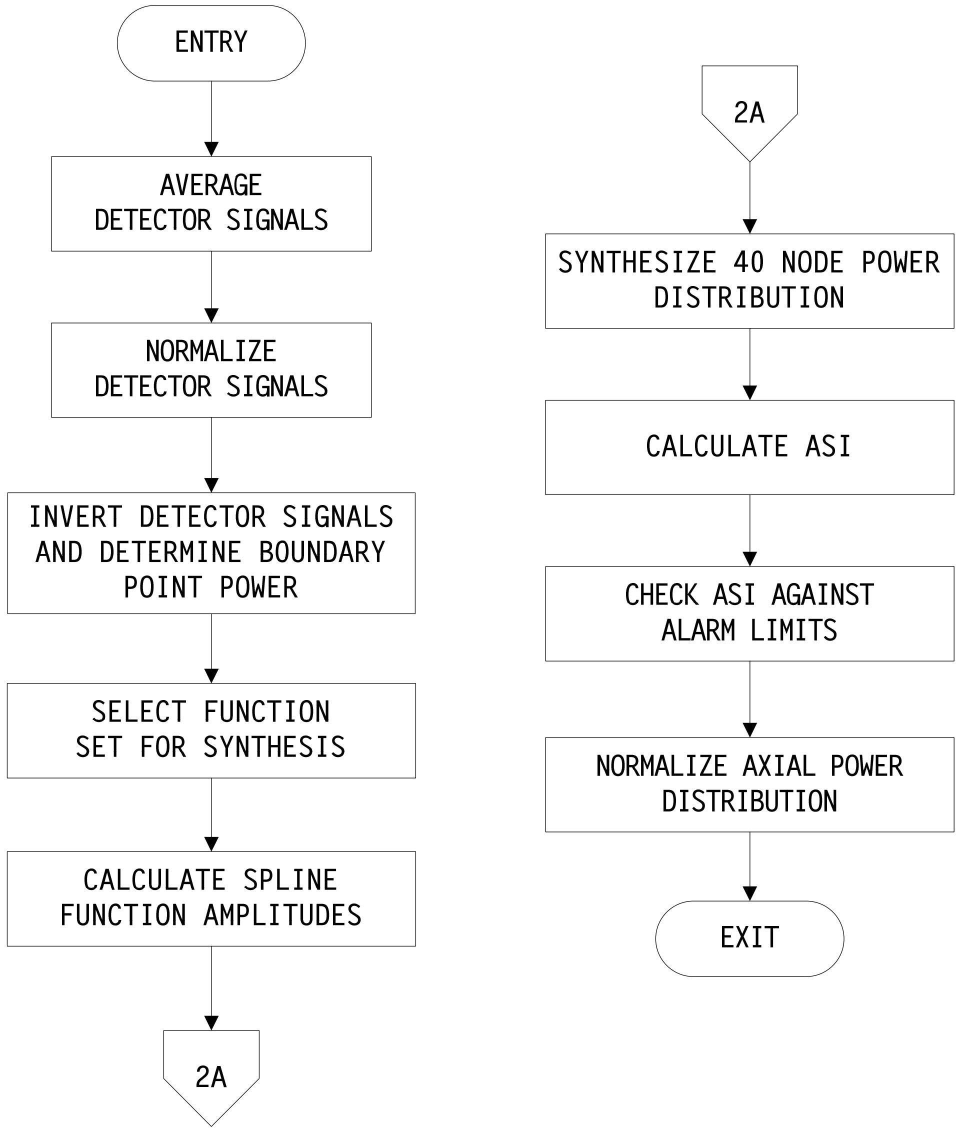


Figure M-2 SEQUENCE OF AXIAL POWER DISTRIBUTION CALCULATIONS FOR CUBIC SPLINE SYNTHESIS METHOD

4.2.4. (Block N) Axial Power Distribution for DNBR Power Operating Limit

4.2.4.1. Description

The purpose of this block is to reduce the 40 point distribution calculated in block M to a 20 point distribution for the integrated radial, hot pin axial shape index, and DNBR power operating limit calculations.

4.2.4.2. Timing

The 20 node power distribution shall be calculated as a part of the 10 second group of calculations.

4.2.4.3. Inputs

APKD(N)	-	Axial Power Distribution (40 Nodes), from block M.
QAXIAL	-	Flag denoting validity of axial power distribution, from block M.

4.2.4.4. Output

APDD(N)	-	Axial Power Distribution (20 Nodes), to blocks P and U.

4.2.4.5. Calculations

If QAXIAL = BAD, then the calculations of block N shall not be performed.

Otherwise, starting at the bottom of the core, a new axial power distribution is calculated for 20 nodal points as follows:

TS

Adjust the power distribution APDD to retain the same peak power as APKD.

TS

4.2.4.6. Constants

None

4.2.4.7. Calculational Sequence

See Figure N-1.

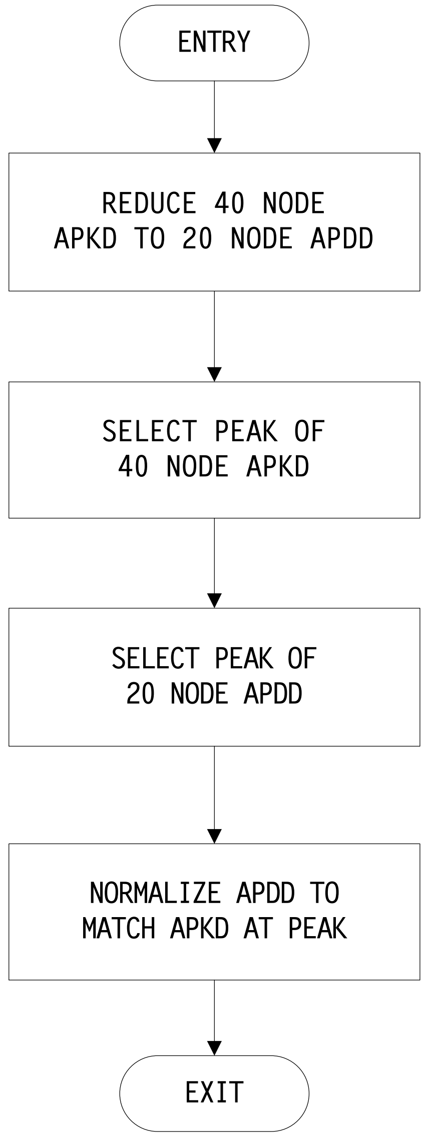


Figure N-1 SEQUENCE OF CALCULATIONS FOR 20 NODE AXIAL POWER DISTRIBUTION

4.2.5. (Block P) Integrated Radial Peaking Factor and Hot-Channel - Axial Shape Index Calculation

4.2.5.1. Description

The purpose of this block is to calculate the integrated radial peaking factor and hot channel axial shape index from the 20 node axial power distribution and planar radial peaking factors. The integrated radial peaking factor is used in the DNBR Power Operating Limit and Update calculations; the hot channel axial shape index is determined for inclusion in CRT and printer reports.

4.2.5.2. Timing

The integrated radial peaking factor and the hot-channel axial shape index shall be calculated as a part of the10 second block of calculations.

4.2.5.3. Inputs

PLRAD(N)	-	Planar radial peaking factors from block L
APDD(N)	-	Axial power distribution from block N
QRADIAL	-	Flag denoting validity of radial peaking factor array from block L
QAXIAL	-	Flag denoting validity of axial power distribution from block M

4.2.5.4. Outputs

INTRAD	-	Integrated radial peaking factor to blocks U and W
ASIHC	-	Hot channel ASI to CRT and printer reports

4.2.5.5. Calculation

If QRADIAL or QAXIAL = BAD, then the calculations of block P shall not be performed, and the block output validities are set to BAD. Otherwise, the following calculations shall be performed.

TS

TS

4.2.5.6. Constants

No constants needed for this block

4.2.5.7. Calculational Sequence

See Figure P-1.

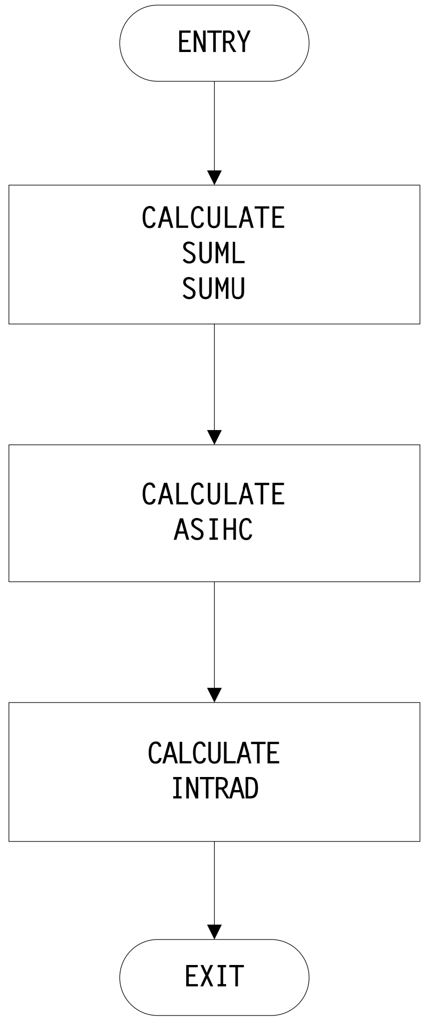


Figure P-1 SEQUENCE OF INTEGRATED RADIAL CALCULATIONS

4.2.6. (Block R) Azimuthal Tilt

4.2.6.1. Description

The purpose of this block is to calculate the azimuthal tilt magnitude from the maximum of NRING selected rings of 4 in-core detector strings at each axial level.

4.2.6.2. Timing

The azimuthal tilt shall be calculated as a part of the 10 second block of calculations.

4.2.6.3. Inputs

PP	-	Plant power, from block I
PHI(I, J)	-	Assembly powers, from block K
S(I, J)	-	Uncompensated incore detector fluxes, from block A
CS(I, J)	-	Compensated incore detector fluxes, from block J
QS(I, J)	-	Incore detector qualities
RFLAG(K)	-	Flag indicator for replacement technique
V1(K)-V4(K)	-	Detector location - dependent constants

4.2.6.4. Outputs

AZTILT	-	Azimuthal tilt magnitude, to blocks T, U and W
ALARM2	-	CPC tilt limit alarm, to annunciator and alarm CRT
ALARM3	-	Tech. Spec. tilt alarm, to annunciator and alarm CRT
TIME2	-	Event duration AZTILT > TL2
TIME2A	-	Annual duration AZTILT > TL2
TIME3	-	Event duration AZTILT > TL3
TIME3A	-	Annual duration AZTILT > TL3

4.2.6.5. Calculation

If less than KO9 incore detectors have quality QS(I,J) of GOOD, or if plant power is less than a constant, STARTL or has validity of BAD, or if less than two reactor coolant pumps run (PUMPRUN < 2) then the calculations of block R shall not be performed, the quality of AZTILT shall be set to BAD, ALARM2 and ALARM3 shall be reset, and TIME2 and TIME3 shall be set to zero and the associated alarms shall be reset.

Azimuthal tilt is calculated for NRING rings of four detectors at each of the five axial levels (NRING = 9). At each level the detector ring tilts are averaged into a level average tilt by two different methods, which will be called the planar vector average and the arithmetic average. The two sets of level tilts are weighted and summed to construct two composite core average azimuthal tilt indexes. Which one of them is selected for further calculations depends on the magnitude of tilt.

The string numbers associated with each individual ring are determined by a table lookup in Table ISTRING (K,L). K denotes the ring to which assignment is made and L the detector position in ring K.

Prior to the start of the azimuthal tilt calculations, the count of GOOD detector rings at each level is zeroed. That is

TS

The accumulator for the tilt components and the total "g-squared" weight are zeroed. That is,

TS

The assembly power values, PHI (I,J), for 4 detectors associated with ring K, at axial level J are stored in four element vector D. That is for L varying from 1 to 4 by 1;

TS

To reduce the effect on AZTILT of noise on the compensated incore detector fluxes, the tilt calculations are based, in effect, on uncompensated detector fluxes:

TS

If the quality QS(I,J) is BAD or if CS(I,J) equals zero for any detector in ring K at level J, a test is performed to determine whether that detector value may be replaced by a calculated value. The conditions for replacement are:

1. Not more than one detector in the ring has validity:

QS(I,J) = BAD or value CS(I,J) = 0.0.

2. The detectors in the ring possess geometric and fuel-exposure symmetry, denoted by the value of the flag RFLAG(K). If RFLAG(K) = 1, the ring has the required symmetry, and replacement is allowed. Otherwise, i.e., RFLAG(K) = 0, replacement is not performed.

When replacement is permitted, the computed value is obtained as follows:

TS

If replacement is not allowed for ring K at level J, the tilt calculation for that ring at that level is skipped, TAZIM(K,J) is set to zero, and the value of KT(J) is not incremented.

The tilt calculation is performed for each of NRING rings of detectors at each of the 5 axial levels.

Tilt calculation

TS

To prevent division by zero the remaining tilt calculations for the ring are skipped for the set of detectors if DB is zero or DD is zero. The TAZIM(K,J) for the ring skipped is set to zero, and KT(J) is not incremented.

TS

A1 and A2 are the X and Y components of the tilt estimate for that detector group, and A4 and A5 are the "g-squared" weighted components of the tilt.

The X and Y components and the weighting factors of tilt estimates at every level are accumulated for further use in the calculation of planar vector average tilt calculation.

TS

The unit weighted X and Y components of every individual tilt are combined next to obtain the resultant tilt magnitude estimate for the arithmetic average tilt calculation, and the count of good detector rings is incremented.

TS

The tilt calculations are performed at each axial level J=1,2,...,5 before proceeding to the next detector ring K for K varying between 1 and NRING.

TS

At each level J, a planar average tilt and an arithmetic average tilt are calculated. The planar average tilt is the magnitude of resultant vector tilt obtained by adding vectorially the individual vector tilts of every detector group. Every individual tilt is "g-squared" weighted.

TS

The arithmetic average tilt at each level J is calculated by summing over the raw tilt indexes at level J and dividing by the number of rings of detectors in the sum, that is,

TS

In the event that KT(J) is zero, the value of TR(J) is set to be zero. If the value less than a constant RO9 of KT(J) is nonzero, the calculation of core average azimuthal tilt index shall be skipped, the validity of AZTILT shall be set to BAD, and an alarm message shall be displayed.

TS

After average azimuthal tilt indexes have been computed at each level, the raw indexes are combined into a core averaged azimuthal tilt index as follows:

A weighting factor WT is calculated

TS

If the total number of tilt estimates is less than constant RO4, then the calculation of AZTILT shall be skipped, the validity of AZTILT shall be set to BAD and an alarm message shall be displayed.

TS

If the number of good tilt estimates is larger than or equal to RO4, an adjusted weighting factor for level J is calculated as follows for J = 1 to 5.

TS

Two core averaged azimuthal tilt indexes are computed as follows:

Planar vector average tilt,

TS

Arithmetic average tilt,

TS

The core averaged azimuthal tilt index will be the planar vector average tilt for tilt magnitudes smaller than or equal to a constant, R10, and the arithmetic average tilt for tilt magnitudes larger than R10, i.e.,

TS

Alarm Processing

Two alarm setpoints are associated with azimuthal tilt. The lower of these, TL2, is normally set to alarm before exceeding the azimuthal tilt allowance in the Core Protection Calculators (CPC) including the power dependence implicit in other CPC constants. The CPC azimuthal tilt allowance is comprised of the CPC addressable constant TR and a power-dependent tilt allowance implicit in other CPC constants. The higher of these, TL3, is normally set at the higher azimuthal tilt limit in the Technical Specification action statements. Azimuthal tilt is checked as follows.

The lower setpoint, TL2, is power dependent. TL2 is therefore determined as follows.

a. The available tilt credit is selected in CPC conservatism.

TS

b. The power dependent tilt alarm limit is determined.

TS

If block R is not performed or if its execution is interrupted because either the RO4 or RO9 test is failed, then ALARM2 and ALARM3 shall be reset. Otherwise alarm processing shall be performed as follows.

If AZTILT is greater than TL2, ALARM2 is initiated. If AZTILT is greater than TL3, ALARM3 is initiated. ALARM2 and ALARM3 are reset when AZTILT is below TL2 and TL3, respectively.

When ALARM2 is set, two times are accumulated. TIME2 is an event duration time which is accumulated while ALARM2 is set and zeroed when ALARM2 is reset. TIME2A is a cumulative event duration which is accumulated while ALARM2 is set and held fixed while ALARM2 is reset. TIME2A is initialized manually. When TIME2 or TIME2A exceeds its associated time limit, RO5 or RO6, respectively, an alarm message is displayed.

When ALARM3 is set, two times are accumulated. TIME3 is an event duration time which is accumulated while ALARM3 is set and zeroed when ALARM3 is reset. TIME3A is a cumulative event duration which is accumulated while ALARM3 is set and held fixed when ALARM3 is reset. TIME3A is initialized manually. When TIME3 or TIME3A exceeds its associated time limit, RO7 or RO8, an alarm message is displayed.

When block R cannot be executed, the event times, TIME2 and TIME3, shall be set to zero, and the associated alarms shall be reset.

Typical messages are shown in Figure 3-4.

4.2.6.6. Constants

ISTRING(NRING,4) - Detector set assignments.

KO9 - Minimum number of good detectors required for COLSS power distribution calculations

V1(NRING) - Detector location dependent constants

V2(NRING) - Detector location dependent constants

V3(NRING) - Detector location dependent constants

V4(NRING) - Detector location dependent constants

RFLAG(NRING) - Flag indicator for replacement technique

RFLAG(K) = 1, Substitution allowed.

RFLAG(K) = 0, Substitution not allowed.

RO4 - Low limit on number of tilt estimates for continuing tilt calculation.

GSQ(NRING) - "g-squared" weighting factor for detector group K. Axially independent constants.

PBRK(I) - Tilt limit region boundaries, I=1,2, % of rated power

CLOW,CMED, CHIGH - Tilt credits taken from the available conservatism in CPC

TR - CPC tilt allowance at full power (Addressable)

TL3 - Tech. Spec. tilt limit

RO5 - TIME2 time limit

RO6 - TIME2A time limit

RO7 - TIME3 time limit

RO8 - TIME3A time limit

RO9 - Minimum number of levels with GOOD rings required for tilt calculations

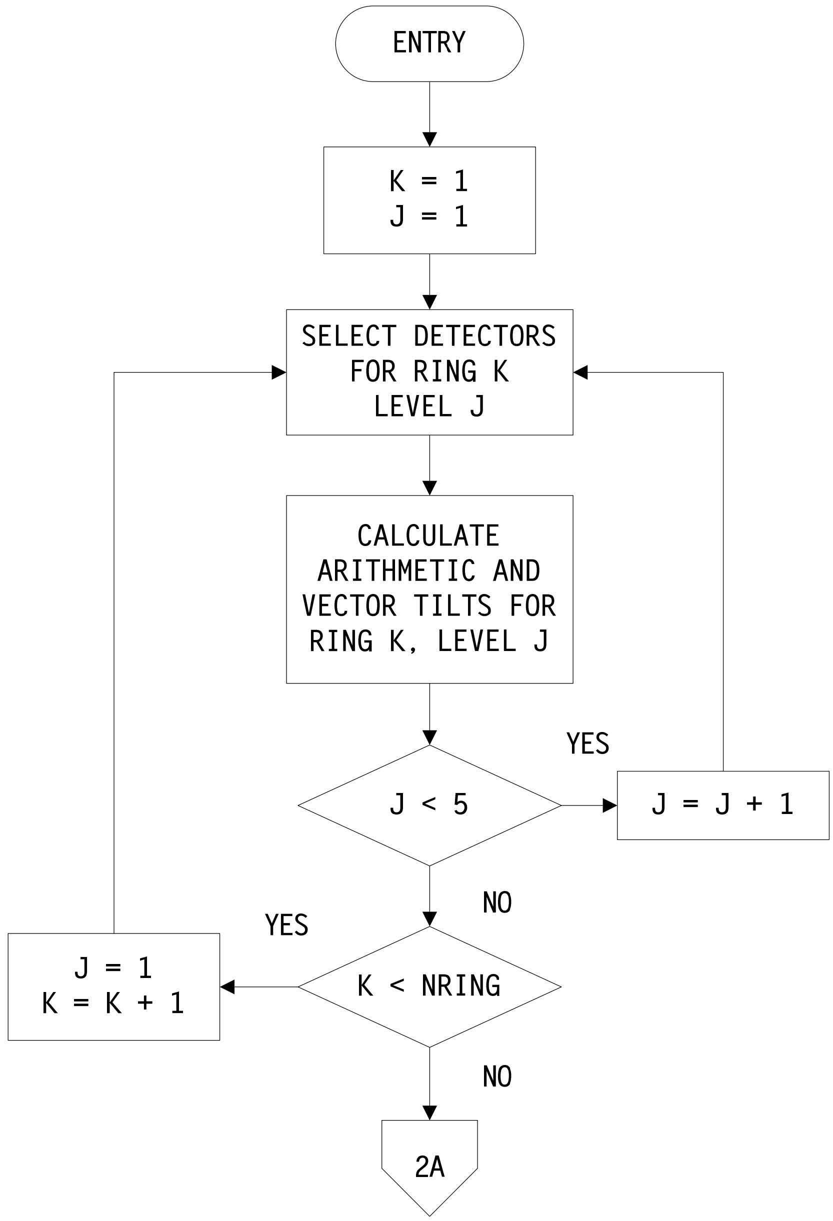
R10 - Limiting vector tilt magnitude, above which arithmetic tilt average is used for COLSS tilt

WI(5) - Level tilt to core average tilt weighting factors

NRING - Number of detector sets per level (NRING = 9)

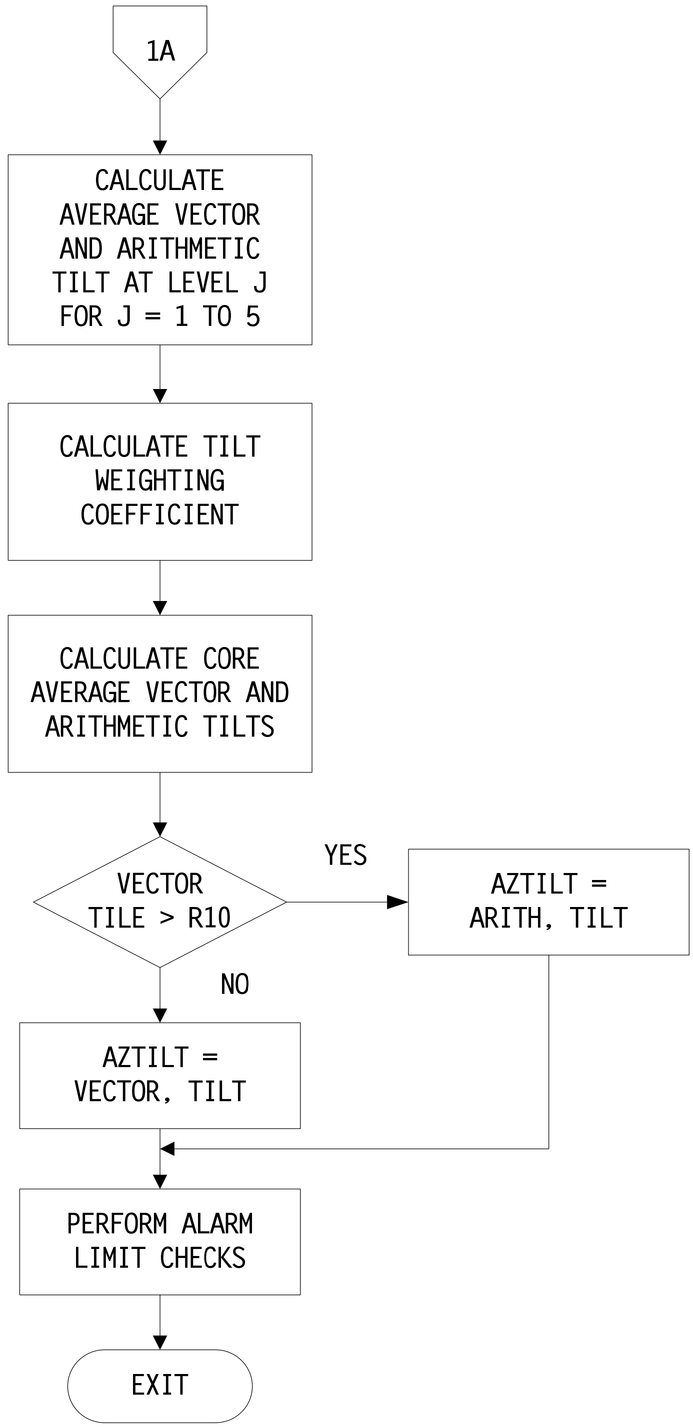
4.2.6.7. Sequence of Calculations

See Figure R-1.



SHEET 1 of 2

Figure R-1 SEQUENCE OF AZIMUTHAL TILT CALCULATIONS



SHEET 2 pf 2

Figure R-1 (Cont.) SEQUENCE OF AZIMUTHAL TILT CALCULATIONS

4.2.7. (Block S) Three-D Power Distribution

4.2.7.1. Description

The purpose of this block is to determine the product of planar radial peaking factors and axial power distribution for use in the linear heat rate power operating limit calculation.

4.2.7.2. Timing

The three-D power calculation shall be performed as a part of the 10 second group of calculations.

4.2.7.3. Inputs

PLRAD(I)	-	Planar radial peaking factors, 20 nodes, from block L
APKD(I)	-	Axial power distribution, 40 nodes, from block M
QRADIAL	-	Flag denoting validity of radial peaking factor array, from block L
QAXIAL	-	Flag denoting validity of axial power distribution, from block M

4.2.7.4. Output

TDPEAK(I)	-	3-D power peaking factors, to block T

4.2.7.5. Calculations

If QRADIAL = BAD or QAXIAL = BAD, then the calculations of block S shall not be performed.

Otherwise, for each node I from 1 to 40, the three dimensional power distribution is calculated. TS

Since 40 values exist for APKD(I) and only 20 values exist for PLRAD(J), each value of PLRAD(J) is used for two successive nodes.

TS

4.2.7.6. Calculational Sequence

See Figure S-1.

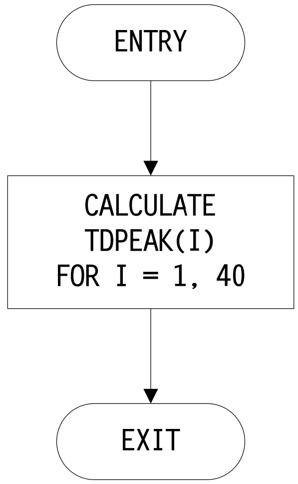


Figure S-1 SEQUENCE OF 3-D POWER DISTRIBUTION CALCULATIONS

4.3. Power Operating Limits

The power operating limits calculations determine the limiting conditions for operation for DNBR and linear heat rate. These calculations include:

1. Linear heat rate (kW/ft) power operating limit;

2. DNBR power operating limit;

3. DNBR power operating limit update.

4.3.1. (Block T) Linear Heat Rate Power Operating Limit Calculation

4.3.1.1. Description

The purpose of this block is to determine the core power operating limit based on the linear heat rate (kW/ft) limit.

4.3.1.2. Timing

The linear heat rate power operating limit shall be calculated as a part of the 10 second block of calculations.

4.3.1.3. Inputs

TDPEAK(I)	-	3-D power peaking factor distribution, from block S
AZTILT	-	Azimuthal tilt magnitude, from block R
TCMIN	-	Minimum compensated cold leg temperature, from block C
PP	-	Plant power, from block I
QRADIAL	-	Flag denoting validity of radial peaking factor array, from block L
QAXIAL	-	Flag denoting validity of axial power distribution, from block M

4.3.1.4. Outputs

KWPFPOL	-	Linear heat rate power operating limit, to block X
KWFT(I)	-	Linear heat rate at node I (I=1, 40), to CRT and printer reports

4.3.1.5. Calculations

If QRADIAL = BAD or QAXIAL = BAD or TCMIN or AZTILT has validity BAD, then the calculations of block T shall not be performed, and the validity of KWPFPOL shall be set to BAD.

Otherwise, the temperature dependent kW/ft limit is calculated based on the inlet temperature as follows:

TS

TS

The following calculations are performed for **I** = 1 to 40 axial nodes.

TS

Select the minimum value of KWPFPL(**I**) and set it equal to KWPFPOL.

TS

4.3.1.6. Constants

TLIM0

TLIM1

FLIM0

FLIM1

T41

T42

UNCERT

4.3.1.7. Calculation Sequence

See Figure T-1.

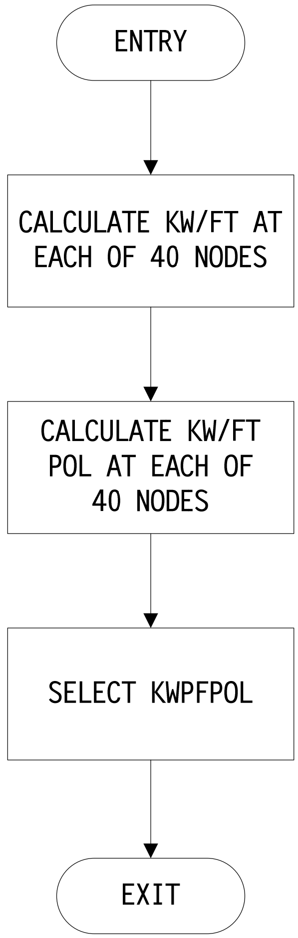


Figure T-1 SEQUENCE OF KW/FT POWER LIMIT CALCULATIONS

4.3.2. (Block U) DNBR Power Operating Limit Calculation

4.3.2.1. Description

The purpose of this block is to determine the POL based on the limiting DNBR or quality at the node of minimum DNBR. The limiting DNBR and quality are calculated and compared to predetermined limits. The core thermal power is the independent variable in these thermal hydraulic calculations. Core power is adjusted and the calculations are repeated until a convergent condition has been obtained.

To model the reactor core, an open-core thermal hydraulic method is employed wherein the mass, momentum and energy equations are solved in three dimensions (one axial and two lateral).

First, a three-dimensional lumped subchannel model is introduced to radially group the flow subchannels for the thermal-hydraulic fluid properties calculation. A lumped subchannel is comprised of one or more flow subchannels, each of which is surrounded by up to four fuel rods and several fuel assemblies. Conservation equations of mass, momentum and energy for lumped subchannels were derived using transport coefficients. Utilizing the above method, a total of four thermal hydraulic modeling channels is considered to model the open-core fluid phenomena.

Second, a simplified, non-iterative numerical method, called the Prediction-Correction method, is applied. The success of this method lies in the fact that the upstream transverse pressure difference predicted by using the "estimated" downstream diversion cross-flows is a very good approximation.

Thus, for each finite-difference node from the core inlet to outlet, the diversion cross-flow, and in turn the flow rate and coolant enthalpy, can be accurately determined.

The numerical solution used to obtain the power operating limit has been segmented into fourteen modules. Figure U-1 is a simplified flow diagram of the sequence of calculations.

Note - The equations specified in the modules employ the FORTRAN hierarchy of operations.

4.3.2.2. Timing

The DNBR power operating limit shall be calculated as a part of the 30 second block of calculations.

4.3.2.3. Inputs

PPRI	-	Primary system pressure, from block B, psia
CFLOW	-	Coolant volumetric flow rate, from block D, GPM
NP	-	Index for pump configuration, from block D
TCMAX	-	Maximum compensated cold leg temperature, from block C, °F
PP	-	Plant power, from block I
PLRAD(I)	-	Planar radial peaking factors for 20 axial nodes (I), from block L
QRADIAL	-	Flag denoting validity of radial peaking factor array, from block L
ASI	-	Axial shape index, from block M
QAXIAL	-	Flag denoting validity of axial power distribution, from block M
APDD(I)	-	20 element normalized core average power distribution, from block N
INTRAD	-	Integrated radial peaking factor, from block P

AZTILT	-	Azimuthal tilt, from block R
DNBRPOL	-	Final power operating limit, from block W
QDNBPC	-	Flag indicating validity of DNBRPOL, from block W
DNBRP1	-	Initial power operating limit, from block W
INITU	-	Initialization flag, TRUE or FALSE. (NOTE -TRUE means block U is to be initialized)
FRLIMIT	-	Integrated radial factor limit for Block U execution

4.3.2.4. Outputs

DNBPOLC	-	DNBR power operating limit to block W
INTRADC	-	Reference integrated radial peaking factor for update procedure, to block W.
AZTILTC	-	Reference azimuthal tilt for update procedure, to block W.
CFLOWC	-	Reference volumetric flow rate, for update procedure, to block W.
FDNBC	-	Reference F-correction factor at minimum DNBR for update procedure, to block W.
QLDNBC	-	Reference hot channel quality at node of minimum DNBR at POL condition for update procedure, to block W.
QDNBC	-	Reference critical heat flux at minimum DNBR for update procedure, to block W.
GDNBC	-	Reference hot channel mass velocity at node of minimum DNBR at POL condition for update procedure, $l0^6$ lbm/ft^2-hr, to block W.
DNBRC	-	Reference minimum DNBR at POL condition for update procedure, to block W.
DENTHC	-	Reference enthalpy rise from inlet to node of minimum DNBR at POL condition for update procedure, Btu/lbm, to block W.
DNBDEV	-	Reference POL derivative with respect to DNBR at POL condition for update procedure, to block W.
QULDEV	-	Reference POL derivative with respect to quality at POL condition for update procedure, to block W.
CHNMUL	-	Channel multiplier for update procedure, to block W.
IFLAGD	-	Type D convergence flag for update procedure, to block W.
DNBRP1	-	Initial block W value of POL which is set equal to zero after completion of block U. Block W will test for zero and replace it with its first calculated POL.

4.3.2.5. Calculations

The DNBR power operating limit calculations of block U are skipped if any of the following conditions exist.

1. Plant power, PP, has BAD validity or is less than a constant, STARTU.

2. PUMPRUN, the number of pumps running, is less than a constant, NDOU.

3. NP, the operating pump configuration index, has BAD validity.

4. The total volumetric flow, CFLOW, has BAD validity.

5. The maximum compensated core inlet temperature, TCMAX, has BAD validity.

6. Azimuthal tilt, AZTILT, has BAD validity.

7. Primary system pressure, PPRI, has BAD validity.

8. The planar radial, integrated radial or power distribution calculations were skipped or failed to execute to completion. (QRADIAL = BAD or QAXIAL = BAD)

9. INTRAD (from Block P) greater than FRLIMIT

The power operating limit is initialized when any of the following conditions occurs.

1. On the first execution of block U following a return of COLSS execution to the scheduled mode

2. On the first execution of block U following a computer restart

3. On the first execution of block U following the clearing of the conditions causing the block to be skipped

4. On the first execution of block U following a failure of block U to converge or failure to execute to completion

If the calculations of block U are skipped or fail to converge, then the validity of the block output DNBPOLC shall be set to BAD.

Depending on the value of addressable constant IAUCT, up to two POL calculations may be performed. The first POL is based upon a reduced flow, the second assumes full flow. (Note that each POL calculation will also include its own required over power margin adjustments). An executive routine, BLOCKU, calls modules 1 through 10 and 12 in sequence. Modules 13 and 14 are called by modules 5 and 6 as needed. (Note that module 11 does not exist). After execution of module 1, the constant IAUCT is examined to determine if one or two POL calculations will be performed.

If IAUCT=1, perform modules 2 through 10 and 12 assuming reduced flow by setting ITERPOL=1.

If IAUCT=2, perform modules 2 through 10 and 12 assuming full flow by setting ITERPOL=2 (underflow fraction calculated in Module 2 is set to 1.0).

If IAUCT=3, perform modules 2 through 10 and 12 with ITERPOL=1 and repeat modules 2, 4 through 10, and 12 with ITERPOL=2. The lower value from two POL calculations is then chosen and passed to Block W with its associated derivatives. (If the value of IAUCT is less than 3, only one POL will be calculated and only it and its derivatives will be passed to Block W.)

4.3.2.5.1. Module 1, Pressure and Temperature Dependent Parameters

This module calculates pressure and temperature dependent parameters.

Input

PPRI and TCMAX, previously defined.

Outputs

FF01 - Pressure dependent coefficient to be used in module 14

FF02 - Pressure dependent coefficient to be used in module 14

FF03 - Pressure dependent coefficient to be used in module 14

FF04 - Pressure dependent coefficient to be used in module 14

FF05 - Pressure dependent coefficient to be used in module 14

FF06 - Pressure dependent coefficient to be used in module 14

FF07 - Pressure dependent coefficient to be used in module 14

FF08 - Pressure dependent coefficient to be used in module 14

FF09 - Pressure dependent coefficient to be used in module 14

FF10 - Pressure dependent coefficient to be used in module 14

FF11 - Pressure dependent coefficient to be used in module 14

FF12 - Pressure dependent coefficient to be used in module 14

FF13 - Pressure dependent coefficient to be used in module 14

FF14 - Pressure dependent coefficient to be used in module 14

FF15 - Pressure dependent coefficient to be used in module 14

FF16 - Pressure dependent coefficient to be used in module 14

FF17 - Pressure dependent coefficient to be used in module 14

FF18 - Pressure dependent coefficient to be used in module 14

BALPL1 - Pressure dependent coefficient to be used in module 13

BALPL2 - Pressure dependent coefficient to be used in module 13

BALPL3 - Pressure dependent coefficient to be used in module 13

BALPL4 - Pressure dependent coefficient to be used in module 13

BALPH1 - Pressure dependent coefficient to be used in module 13

BALPH2 - Pressure dependent coefficient to be used in module 13

BALPH3 - Pressure dependent coefficient to be used in module 13

BALPH4 - Pressure dependent coefficient to be used in module 13

TF - Coolant saturation temperature (°F) at PPRI

VF - Liquid specific volume at saturation (ft^3/lbm)

VG - Vapor specific volume at saturation (ft^3/lbm)

HF - Liquid enthalpy at saturation (Btu/lbm)

HFG - Coolant latent Heat (Btu/lbm) at PPRI

VISCF - Coolant viscosity at saturation (lbm/hr-ft)

CE1B - KCE-1 critical heat flux coefficient

CE1C - KCE-1 critical heat flux coefficient

CE1D - KCE-1 critical heat flux coefficient

HIN - Channel inlet coolant enthalpy (Btulbm)

VIN - Channel inlet specific volume (lbm/ft^3)

<u>Data Constants</u>

CF(37) - Coefficients for pressure dependent variables in friction factor correlation (Table U-1)

ALL11 - Coefficient for Martinelli-Nelson void fraction

ALL12 - Coefficient for Martinelli-Nelson void fraction

ALL13 - Coefficient for Martinelli-Nelson void fraction

ALL14 - Coefficient for Martinelli-Nelson void fraction

ALL21 - Coefficient for Martinelli-Nelson void fraction

ALL22 - Coefficient for Martinelli-Nelson void fraction

ALL23 - Coefficient for Martinelli-Nelson void fraction

ALL24 - Coefficient for Martinelli-Nelson void fraction

ALL31 - Coefficient for Martinelli-Nelson void fraction

ALL32 - Coefficient for Martinelli-Nelson void fraction

ALL33 - Coefficient for Martinelli-Nelson void fraction

ALL34 - Coefficient for Martinelli-Nelson void fraction

ALL41 - Coefficient for Martinelli-Nelson void fraction

ALL42 - Coefficient for Martinelli-Nelson void fraction

ALL43 - Coefficient for Martinelli-Nelson void fraction

ALL44 - Coefficient for Martinelli-Nelson void fraction

ALH11 - Coefficient to determine BALPH coefficients

ALH12 - Coefficient to determine BALPH coefficients

ALH13 - Coefficient to determine BALPH coefficients

ALH14 - Coefficient to determine BALPH coefficients

ALH21 - Coefficient to determine BALPH coefficients

ALH22 - Coefficient to determine BALPH coefficients

ALH23 - Coefficient to determine BALPH coefficients

ALH24 - Coefficient to determine BALPH coefficients

ALH31 - Coefficient to determine BALPH coefficients

ALH32 - Coefficient to determine BALPH coefficients

ALH33 - Coefficient to determine BALPH coefficients

ALH34 - Coefficient to determine BALPH coefficients

ALH41 - Coefficient to determine BALPH coefficients

ALH42 - Coefficient to determine BALPH coefficients

ALH43 - Coefficient to determine BALPH coefficients

ALH44 - Coefficient to determine BALPH coefficients

AHF1 - Coefficient to determine HF

AHF2 - Coefficient to determine HF

AHF3 - Coefficient to determine HF

AHF4 - Coefficient to determine HF

ATF1 - Coefficient for determining TF

ATF2 - Coefficient for determining TF

ATF3 - Coefficient for determining TF

ATF4 - Coefficient for determining TF

AVF1 - Coefficient for determining VF

AVF2 - Coefficient for determining VF

AVF3 - Coefficient for determining VF

AVF4 - Coefficient for determining VF

AVG1 - Coefficient for determining VG

AVG2 - Coefficient for determining VG

AVG3 - Coefficient for determining VG

AVG4 - Coefficient for determining VG

AHFG1 - Coefficient for determining HFG

AHFG2 - Coefficient for determining HFG

AHFG3 - Coefficient for determining HFG

AHFG4 - Coefficient for determining HFG

AVIF1 - Coefficient for determining VISCF

AVIF2 - Coefficient for determining VISCF

AVIF3 - Coefficient for determining VISCF

AVIF4 - Coefficient for determining VISCF

CCE3 - Coefficient for determining KCE-1 parameter

CCE4 - Coefficient for determining KCE-1 parameter

CCE5 - Coefficient for determining KCE-1 parameter

CCE6 - Coefficient for determining KCE-1 parameter

CCE7 - Coefficient for determining KCE-1 parameter

AEN11 - Coefficient for determining HIN

AEN12 - Coefficient for determining HIN

AEN13 - Coefficient for determining HIN

AENl4 - Coefficient for determining HIN

AEN21 - Coefficient for determining HIN

AEN22 - Coefficient for determining HIN

AEN23 - Coefficient for determining HIN

AEN24 - Coefficient for determining HIN

AEN31 - Coefficient for determining HIN

AEN32 - Coefficient for determining HIN

AEN33 - Coefficient for determining HIN

AEN34 - Coefficient for determining HIN

AEN41 - Coefficient for determining HIN

AEN42 - Coefficient for determining HIN

AEN43 - Coefficient for determining HIN

AEN44 - Coefficient for determining HIN

BSVOL1 - Coefficient for determining VIN

BSVOL2 - Coefficient for determining VIN

BSVOL3 - Coefficient for determining VIN

BSVOL4 - Coefficient for determining VIN

Calculations

Pressure dependent coefficients to be used in the friction factor calculation:

TS

TS

Calculation of the Martinelli-Nelson Void Vs. Quality Coefficients for Low Quality:

TS

Calculation of the Martinelli-Nelson Void Vs. Quality Coefficients for High Quality:

TS

Calculation of the Saturated Coolant Properties:

TS

Calculation of the Coolant Inlet Properties:

TS

Calculation of the KCE-1 parameters:

TS

4.3.2.5.2. Module 2, Channel Inlet Conditions

This module determines pump dependent constants, the underflow fraction (UFF) and flow split factors. In addition, the module determines an initial estimate for the power operating limit.

Inputs

ASI - Axial shape index from block M

CFLOW - Coolant volumetric flow rate, block D, GPM

INITU - Initialization flag, TRUE or FALSE (Note - TRUE means block U is to be initialized)

NP - Operating pump configuration index from block D

TCMAX - Maximum cold leg temperature from block C, °F

PPRI - Primary pressure from block B

DNBRP1 - Initial power operating limit from block W

DNBRPOL - Final power operating limit from block W

VIN - Inlet coolant specific volume (ft^3/LBM)

INTRAD - Integrated radial peaking factor from block P

QDNBPC - Flag indicating quality of DNBRPOL from Block W. (TRUE = GOOD quality)

ITERPOL - Power operating limit calculation index set in block U executive routine

Outputs

GIN - Inlet mass velocity (LBM/ft^2-sec)

FSPLIT - Channel flow split factor

POLG(1) - Initial estimate of the POL

ITERNO - Number of iterations (set equal to one)

RFLAG2 - Initialization of convergence flag used in Module 12

RFLAG3 - Initialization of convergence flag used in Module 12

Data Constants

U20 - Four pump dependent constant

U21 - Four pump dependent constant

U22 - Three pump dependent constant

U23 - Three pump dependent constant

U24 - Two pump (opposite loop) dependent constant

U25 - Two pump (opposite loop) dependent constant

U26 - Two pump (same loop) dependent constant

U27 - Two pump (same loop) dependent constant

CC3 - UFF slope constant

CC4 - UFF bias constant

ASILOW - ASI lower limit for UFF function

ASIHI - ASI upper limit for UFF function

UFFLOW - UFF lower limit

UFFHI - UFF upper limit

GPMTOFS - Conversion constant (GPM to ft^3/sec)

FLOAREA - Total core flow area (ft^2)

ASIBRK - ASI limit in Flow Split Factor

FSPLIT1 - Flow split factor for lower limit ASI

FSPLIT2 - Flow split factor for upper limit ASI

POLCF1 - Coefficient for initial POL Calculation

POLCF2 - Coefficient for initial POL Calculation

POLCF3 - Coefficient for initial POL Calculation

POLCF4 - Coefficient for initial POL Calculation

POLCF5 - Coefficient for initial POL Calculation

POLCF6 - Coefficient for initial POL Calculation

POLCFC - Normalization constant for core average mass velocity

POLCFD - Coefficient for initial POL calculation

POLCFA - Coefficient for initial POL calculation

UBIAS(I=1,6) - Intercepts of UFF correlation

USLOPE(I=1,6) - Slopes of UFF correlation

ASIBP(I=1,5) - ASI breakpoints in UFF calculation

Calculation of the Underflow Fraction (UFF)

Pump dependent constants (which depend only on the number of pumps operating and core bypass) are selected as follows:

i) If all four pumps are operating (NP=4):

TS

ii) If three coolant pumps are operating (NP=3):

TS

iii) If two pumps are operating, each in a different loop (NP=-2):

TS

iv) If two pumps are operating in the same loop (NP=2):

TS

The underflow fraction is calculated as follows:

TS

The UFF is limited as follows:

TS

TS

The pump dependency and core bypass corrections are applied by the following correlation:

TS

Calculation of the Inlet Mass Velocity (GIN) (lbm/ft^2-sec)

The core inlet mass velocity is calculated using the following equation for both the full flow and flow reduction POL calculation:

TS

Calculation of the Flow Split Factor

If the absolute value of ASI is less than ASIBRK,

TS

Initial Power Operating Limit

The following equation, POLG(1), is used to determine an initial estimate of the power operating limit if one of the following conditions exist:

a) Block U is being initialized;

b) DNBRPOL from Block W has BAD validity;

c) Block U has been initialized and the absolute difference between the initial Block W POL (DNBRP1) and final Block W POL (DNBRPOL) is greater than 10.0.

TS

Otherwise,

TS

TS

The iteration counter, ITERNO, is set equal to one.

ITERNO = 1

The convergence flags used in Module 12 are set equal to 0.

TS

4.3.2.5.3. Module 3, Calculation of the Local Axial Power Distribution

This module calculates a twenty and a twenty-one node normalized local heat flux distribution. This module is executed only once per block U execution, independent of the value of IAUCT in the block U executive.

Inputs

APDD(20) - Twenty node core average power distribution from block N

PLRAD(20) - An array of planar radial peaking factors for twenty axial nodes from block L

INTRAD - The integrated radial peaking factor from block P

Outputs

FZHC(20) - A twenty node normalized local heat flux distribution

FZHC21(21) - A twenty-one node normalized local heat flux distribution

Data Constants

FZCOF(1)...FZCOF(9) - Constants for Newton's difference formulas and Bessel's formula for interpolating to halves.

Calculations

The twenty node normalized local heat flux distribution is calculated first:

TS

The twenty-one node normalized local heat flux distribution is calculated next. The first two nodes are determined with Newton's forward difference formula:

TS

The next seventeen nodes are determined with Bessel's formula for interpolating to halves:

TS

The last two nodes are determined with Newton's backward difference formula:

TS

From the defining equations for INTRAD in block P and FZHC(I) in this module, it follows that the FZHC(I) distribution sums to twenty. The FZHC21(I) distributions are accordingly adjusted so that the area under each FZHC21(I) distribution also equals twenty. The area is approximated using Simpson's rule, as follows:

TS

Then for the even numbered nodes,

TS

And then for the odd numbered nodes, (except nodes 1 and 21)

TS

The total area under the curve is:

TS

The FZHC21(I) distributions are adjusted to integrate to twenty as follows:

TS

The last calculation in this module restricts FZHC21(I) to positive values:

TS

TS

4.3.2.5.4. Module 4, 20 Element Linear Heat Distribution for the 4 Thermal-Hydraulic Channels

Inputs

ITERNO - POL iteration index

POLG(ITERNO) - Power operating limit for ITERNO indexing

AZTILT - Azimuthal tilt factor

FZHC(20) - Normalized local heat flux distribution

INTRAD - Integrated radial peaking factor

Outputs

QPRIME1(I) - Channel 1 linear heat rate array (Btu/FT-SEC)

QPRIME2(I) - Channel 2 linear heat rate array (Btu/FT-SEC)

QPRIME3(I) - Channel 3 linear heat rate array (Btu/FT-SEC)

QPRIME4(I) - Channel 4 linear heat rate array (Btu/FT-SEC)

Data Constants

QAVG - Core average heat flux at rated power

PI - Constant, 3.l415926

DH1 - Heated diameter for channel 1

DH2 - Heated diameter for channel 2

DH3 - Heated diameter for channel 3

DH4 - Heated diameter for channel 4

P40VRPN - Ratio of channel 4 to hot pin flux power

P30VRPN - Ratio of channel 3 to hot pin flux power

P20VRPN - Ratio of channel 2 to hot pin flux power

Calculation of the core and hot channel average heat flux

Core average heat flux is defined by: TS

[ ]

Define HTFXHCH by: TS

[ ]

Calculation of the four channel heat flux distributions

TS

4.3.2.5.5. Module 5, Channels 1 and 2 Fluid and Flow Properties

NOTE:

This module calculates the mass velocity and coolant enthalpy for twenty nodes for channel 1 and channel 2. In addition, the nodal pressure drops, and cross-flows for the first two channels are calculated. The looping (I) is indexed from one to twenty.

Inputs

GIN - Core average mass velocity (lbm/ft^2-sec)

HIN - Core inlet enthalpy (Btu/lbm)

VIN - Core inlet specific volume (ft^3/lbm)

QPRIME1(I) - 20 element core average linear heat rate distribution (I=1,20)

QPRIME2(I) - 20 element hot assembly linear heat rate distribution (I=1,20)

FSPLIT - Inlet flow split

PPRI - Primary pressure

TF - Saturated coolant temperature

HF - Saturated coolant enthalpy

HFG - Coolant latent heat

VF - Saturated coolant specific volume

VG - Saturated steam specific volume

VISCF - Saturated coolant viscosity

BALPL1 - Coefficient for void fraction, previously defined

BALPL2 - Coefficient for void fraction, previously defined

BALPL3 - Coefficient for void fraction, previously defined

BALPL4 - Coefficient for void fraction, previously defined

BALPH1 - Coefficient for void fraction, previously defined

BALPH2 - Coefficient for void fraction, previously defined

BALPH3 - Coefficient for void fraction, previously defined

BALPH4 - Coefficient for void fraction, previously defined

FF01 ~ FF18 - Pressure dependent coefficients previously defined in Module 1

Outputs

H1(I) - 21 node (Channel 1) enthalpy distribution (Btu/lbm)

H2(I) - 21 node (Channel 2) enthalpy distribution (Btu/lbm)

G1(I) - 21 node (Channel 1) mass velocity distribution (lbm/ft^2-sec)

G2(I) - 21 node (Channel 2) mass velocity distribution (lbm/ft^2-sec)

W12(I) - 21 node cross flow between channel 1 and 2 (lbm/ft-sec)

DELTAP2(I) - 21 node (channel 2) pressure drop distribution

AAA21(I) - 21 node matrix element

Data Constants

CIJCON1 - Cross-flow resistance factor

DXOVA1 - Ratio of nodal length to flow area

DXOVA2 - Ratio of nodal length to flow area

HPERIM1 - Channel one equivalent heated perimeter

HPERIM2 - Channel two equivalent heated perimeter

QFUEL - Fraction of heat generated in the fuel

KG(20) - An array of twenty spacer loss coefficients

TWODE1 - Channel one equivalent hydraulic diameter times two

TWODE2 - Channel two equivalent hydraulic diameter times two

DELTAX - Nodal length

DXOVGC - Ratio of nodal length to gravity constant

TWOGC - Two times the gravity constant

CN2 - Constant for pressure drop calculation

SL - Transverse momentum factor

DE1 - Channel one hydraulic diameter

DE2 - Channel two hydraulic diameter

TWODX - DELTAX times two.

Calculation

There are a total of twenty nodes. The index **I** will be used to denote the node. For **I** equal 1, the initial boundary values are defined as follows:

TS

The flow rate at node (**I**+1) is predicted:

TS

Enthalpy at node (**I**+1) is predicted:

TS

To obtain the fluid specific volume for friction pressure drops and the fluid specific volume for momentum pressure drops for the two channels at node **I**+1 Module 13 is called.

First with H=H1(**I**+1), P=PPR**I** and the Module 13 output is defined as:

TS

Note: The remaining inputs to Module 13 are not changed during internal Block U iterations and need to be passed to Module 13 only once per call of Block U. These inputs are identical in nomenclature and value to Module 1 outputs.

Next Module 13 is called with H=H2(I+1), P=PPRI and the Module 13 output is defined as:

TS

The equivalent heat flux is computed for the two channels by:

TS

To obtain the fluid friction coefficient Module 14 is called for the two channels: First with

TS

and the Module 14 output is defined as:

FT1

Note: The remaining inputs to Module 14 are not changed during internal Block U iterations and need to be passed to Module 14 only once per call of Block U. These inputs are identical in nomenclature and value to Module 1 outputs.

Next Module l4 is called with:

TS

and the Module 14 output is defined as:

FT2

In order to simplify the equations for the pressure drop calculations at node I+1, the following two intermediate parameters are defined:

TS

Prediction of Cross Flow at Node I+1

By using the flow rates at I, the pressure drops at I+1 for the first two channels are determined by:

TS

The coolant velocities in the two channels are computed as follows:

TS

The cross-flow at node I+1 is calculated from the pressure difference and the cross-flow resistance between the two channels:

TS

Calculation of Corrected Cross-Flow at Node I

The pressure difference between channel 1 and 2 at node I due to the cross-flow at node I+1 is calculated by:

TS

The corrected pressure drops at node I for the two channels are calculated by:

TS

Several intermediate results are computed in order to simplify the calculation of the corrected cross-flow at node I for the two channels.

TS

The corrected cross-flow between channels one and two at node I is calculated by:

TS

Reference Data Storage

Channel two pressure drop (DP2) and the product of (–XG2 * CN2 * SL) are stored for subsequent calculations.

TS

From the corrected cross-flow at node I, the corrected flows at node I are obtained by:

TS

The second prediction of flows at node I+1 from the corrected flow rate at node I and the previously predicted cross-flow at node I+1 (W12(I+1)) is given by:

TS

The corrected cross-flow at node I and the flows at node I and node I+1 are used to calculate the enthalpies at node I+1:

If W12(I) is negative,

TS

If W12(I) is greater than zero,

TS

Once the direction of cross-flow is known (determined from the sign of its value) the enthalpy rise (DELTAH1, DELTAH2) in both channels is computed and the corrected enthalpies at node I+1 are obtained by:

TS

Module 13 is called first with H=H1(I+1) and P = PPRI and the Module 13 output is defined as:

TS

Module 13 is called next with H=H2(I+1), P=PPRI and the Module 13 output defined as:

TS

Module 14 is called with:

TS

and the Module 14 output is defined as:

FT1

Module 14 is called with:

TS

and the Module 14 output is defined as:

FT2

The intermediate pressure drop calculation is corrected by:

TS

The previous cross-flow resistance is stored:

TS

The direction of cross-flow W12(I+1) is checked as follows:

If W12(I+1) is less than zero,

TS

If W12(I+1) is greater than or equal to zero,

TS

Variable Storage

The fluid properties needed for the next nodal calculation are saved as follows:

TS

NOTE: The I indexing is completed at this point (I=1,.....20).

The fluid properties in the last node are calculated again:

TS

4.3.2.5.6. Module 6, Channels 3 and 4 Fluid and Flow Properties

This module is similar in calculation techniques to module 5.

A three dimensional lumped subchannel model and the prediction - correction method are employed to derive the resultant fluid flow properties along the axial channels.

<u>Inputs</u>

G2(I) - 21 node (channel 2) mass flux profile

H2(I) - 21 node (channel 2) enthalpy profile

DELTAP2(I) - 21 node (channel 2) pressure drop distribution

W12(I) - 21 node cross-flow between channel 1 and 2

AAA21(I) - 21 node matrix element

HIN - Core inlet enthalpy

VIN - Core inlet specific volume

QPRIME3(I) - 20 element linear heat rate distribution for channel 3

QPRIME4(I) - 20 element linear heat rate distribution for channel 4

PPRI - Primary system pressure, psia

HF - Saturated liquid enthalpy, Btu/lbm.

HFG - Liquid latent heat, Btu/lbm

VF - Saturated liquid specific volume, ft^3/lbm

VG - Saturated steam specific volume, ft^3/lbm

BALPL1,...BALPL4 - Coefficients for void fraction at low quality

BALPH1,...BALPH4 - Coefficients for void fraction at high quality

FFO1,...FF18 - Pressure dependent parameters

TF - Saturated liquid temperature, °F

VISCF - Saturated liquid viscosity

<u>Outputs</u>

G3(I) - 21 node buffer channel mass velocity profile (lbm/ft^2-sec)

G4(I) - 21 node hot channel mass velocity profile (lbm/ft^2-sec)

H3(I) - 21 node buffer channel enthalpy distribution

H4(I) - 21 node hot channel enthalpy profile

HX(I) - 21 node 2nd candidate hot channel enthalpy profile

<u>Data Constants</u>

AREA2 - Channel two flow area

AREA3 - Channel three flow area

AREA4 - Channel four flow area

AREAX - Matrix channel flow area

DE2 - Channel two hydraulic diameter

DE3 - Channel three hydraulic diameter

DE4 - Channel four hydraulic diameter

GC - Gravitational acceleration

SL - Ratio of channel gap to length

CN2 - Momentum cross flow coefficient

CN3 - Momentum cross flow coefficient

CH2 - Energy cross flow coefficients

CIJCON2 - Cross flow resistance constant

CIJCON3 - Cross flow resistance constant

DELTAX - Node length

DXOVA3 - Ratio of node length to flow area

DXOVA4 - Ratio of node length to flow area

DXOVGC - Ratio of node length to GC

TWODE3 - Twice the hydraulic diameter

TWODE4 - Twice the hydraulic diameter

TWODX - Twice the nodal length

TWOGC - Twice GC

CU2 - Axial velocity transport coefficients

QFUEL - Fraction of heat generated in the fuel

WP23CON - Turbulent interchange coefficient

WP34CON - Turbulent interchange coefficient

HPERIM3 - Equivalent heat perimeter, channel 3

HPERIM4 - Equivalent heat perimeter, channel 4

WPXCON - Coefficient for Matrix Channel Enthalpy

HC - Coefficient for Matrix Channel Enthalpy

KG(I) - 20 element spacer loss coefficients

Calculations

Initial Boundary Conditions

TS

I is defined as the loop index. I has an initial value of 2 and is indexed by one to twenty-one.

Calculation of the Mass Velocities at Node I

TS

The Turbulent Interchanges at Node I

By using the flows at node I-1, the turbulent interchanges at node I are calculated as follows:

TS

Calculation of Enthalpies at Node I

The enthalpy rises from node I-1 to node I in the two channels are calculated based on the linear heat rates at node I-I, the enthalpy transport at node I-1 and the energy interchanges due to turbulence at node I-1. The enthalpy transport coefficient (CH2) is introduced to correct the energy transport between lumped channels. The calculations are:

TS

Calculation of Fluid Properties at Node I

To obtain the specific volume, fluid specific volume for friction pressure drop and the fluid specific volume for momentum pressure Module 13 is called three times:

First with H=H2(I), P=PPRI as inputs and the output is defined as:

TS

Second with H = H3(I), P = PPRI as inputs and the output is defined as:

TS

Last with H = H4(I), P = PPRI as inputs and the output is defined as:

TS

The equivalent heat fluxes which are required in Module 14 to derive the fluid friction factor are computed.

TS

To obtain the friction factors for channels three and four, Module 14 is called twice:

First with H = H3(I), G = G3(I), QFLUX = WFLX3, DE = DE3, P = PPRI and the output is defined as: TS

Next with H = H4(I), G = G4(I), QFLUX = WFLX4, DE = DE4, P = PPRI and the output is defined as TS

Prediction of the Cross-Flows and Fluid Velocities at Node I

The corrected cross-flows between channels one and two at node I are used to predict the cross-flows between the other channels. TS

The fluid velocities are calculated by: TS

The Parameters for Momentum Transport Calculation

The effective axial velocity carried by cross-flow and the average axial velocity are calculated by: TS

Calculation of the Cross-Flow Resistances Between Channels

If W23(I) is greater than or equal to zero, then TS

If W23(I) is less than zero, then TS

If W34(I) is greater than or equal to zero, then TS

If W34(I) is less than zero, then

TS

Calculation of the Pressure Drops between Node I-l and Node I

Two intermediate parameters BETA3 and BETA4 for the pressure drop calculations at node I are defined by:

TS

Using the flows at node I-1, the pressure drops in channels three and four are computed by:

TS

Calculation of Corrected Cross-Flows

The cross-flows between channels two, three and four are determined by a matrix solution:

TS

The cross-flows are determined by:

TS

Calculation of Corrected Flows at Node I

From the corrected cross-flows between channels, the flow changes between node I-1 and node I are calculated as follows:

TS

The corrected flows at node I are calculated by:

TS

Calculation of the 2nd Candidate Hot Channel Enthalpy at Node I

Based on the turbulent mixing between Channel 3 and 4, the hot channel mixing with the buffer channel 3 is calculated by:

TS

Variable Storage

The fluid properties needed for the next nodal calculation are saved:

TS

NOTE: The I indexing for Module 6 is completed at this point (I=2,...21).

4.3.2.5.7. Module 7, 21 Node Quality and Flow Distributions

This module calculates the quality distributions and flow distributions for the DNBR calculation.

Inputs

H4(I) - 21 node channel enthalpy distribution for channel 4

HX(I) - 21 node channel enthalpy distribution for matrix channel

G3(I) - 21 node mass velocity distribution for channel 3

G4(I) - 21 node hot channel mass velocity distribution for channel 4

HF - Previously defined

HFG - Previously defined

Outputs

QUALH(I) - 21 node quality distribution for DNBR calculation

QUALX(I) - 21 node quality distribution for DNBR calculation

GPRFH(I) - 21 node mass velocity distribution for DNBR calculation

GPRFX(I) - 21 node mass velocity distribution for DNBR calculation

Calculation

For I = 1 to 21:

Quality Distributions

The equilibrium quality equation is used to calculate the qualities at node I

TS

An upper limit of one is imposed on the quality:

TS

Mass Velocities Distribution

TS

4.3.2.5.8. Module 8, Critical and Local Heat Flux Distributions

The KCE-1 critical heat flux correlation is used to compute the critical heat flux distribution for two channels.

Inputs

CE1B - KCE-1 pressure dependent coefficient

CE1C - KCE-1 pressure dependent coefficient

CE1D - KCE-1 pressure dependent coefficient

ITERNO - Current iteration number

POLG(ITERNO) - POL for iteration ITERNO

INTRAD - Integrated radial peaking factor

AZTILT - Azimuthal tilt factor

FZHC21(I) - Normalized local heat flux distributions. I=1 to 21

QUALH(I) - Twenty-one node quality distribution

QUALX(I) - Twenty-one node quality distribution

GPRFH(I) - Twenty-one node mass velocity distribution

GPRFX(I) - Twenty-one node mass velocity distribution

HFG - Coolant latent heat

Outputs

QLOCH(I) - 21 node hot pin heat flux distribution

QLOCX(I) - 21 node second candidate hot channel heat flux distribution

QDNBH(I) - 21 node critical heat flux distribution

QDNBX(I) - 21 node critical heat flux distribution

Data Constants

CCEO - KCE-1 coefficient

CCE8 - KCE-1 coefficient

QHOT - Hot pin heat flux at rated power

CE1XTOH -Channel power ratio

PXOVRPN - Second candidate hot channel peak over hot pin peak

Calculation

Calculate a multiplier for the power distributions:

TS

Calculate the axial heat flux distributions for the hot channel (QLOCH) and the matrix channel (QLOCX).

TS

where

I is indexed from one to twenty-one.

TS

4.3.2.5.9. Module 9, The Correction Factors for Non-uniform Heat Flux Distribution

Inputs

QLOCH(I) - 21 node hot pin heat flux distribution

QLOCX(I) - 21 node second candidate hot channel heat flux distribution

QUALH(I) - 21 node quality distribution

QUALX(I) - 21 node quality distribution

GPRFH(I) - 21 node mass velocity profile

GPRFX(I) - 21 node mass velocity profile

Outputs

FCORH(I) - An array of twenty-one F-correction factors

FCORX(I) - An array of twenty-one F-correction factors

Data Constants

K1 - Coefficient for F-correction factor

EX1 - Constant for F-correction factor

EX2 - Constant for F-correction factor

SKECDK - Engineering uncertainty factor on local heat flux

DELTAX - Nodal length

Calculation

Calculate F-correction factors FCORH(2)...FCORH(21)

Note: I is indexed from two to twenty-one

TS

Note: The following calculation is done from two to I. The loop index is defined as L (Thus L is indexed from two to I)

TS

This ends the "L" indexing and the "I" looping continues:

TS

This ends the "I" indexing, where I has been indexed from two to twenty-one.

Note: I is again indexed from two to twenty-one.Calculate F-correction factors FCORX(2)...FCORX(21)

TS

TS

The following calculation is done from two to I. The loop index is defined as L (thus L is indexed from two to I)

TS

This ends the "L" indexing and the "I" looping continues:

TS

This ends the "I" loop where I has been indexed from two to twenty-one.

4.3.2.5.10. Module 10, Minimum DNB Ratio

This module computes the minimum DNB ratio of the two channels and stores various variables.

Inputs

QDNBH(I) - 21 node KCE-1 critical heat flux distribution

QDNBX(I) - 21 node KCE-1 critical heat flux distribution

QLOCH(I) - 21 node hot pin heat flux distribution

QLOCX(I) - 21 node second candidate hot channel heat flux distribution

FCORH(I) - F - correction factor array

FCORX(I) - F - correction factor array

QUALH(21) - An array of nodal quality

QUALX(21) - An array of nodal quality

H4(21) - An array of nodal enthalpy

HX(21) - An array of nodal enthalpy

GPRFH(21) - An array of nodal mass velocity

GPRFX(21) - An array of nodal mass velocity

HIN - Inlet enthalpy

Outputs

DNBRMIN - Minimum DNB ratio

QULMIN - Quality at minimum DNBR

DENTHM - Enthalpy rise to minimum DNBR

FCMIN - F correction factor at minimum DNBR

GDNBM - Mass velocity at minimum DNBR

QDNBM - Critical heat flux at minimum DNBR

CHNMULM - Channel dependent constant

Data Constant

CE1XTOH - Channel coefficient

Calculation

Calculation of minimum DNBR:

Initialize the following variables:

TS

then

TS

If DNBMIN1 equals DNBR1 then,

TS

If DNBMIN2 equals DNBR2 then,

TS

where

I is indexed from two to twenty-one

If DNBMIN1 is less than or equal to DNBMIN2, then

TS

Otherwise,

TS

TS

4.3.2.5.11. Module 11

This module does not exist.

4.3.2.5.12. Module 12, Core Power Operating Limit Iteration

The POL iteration is performed until one of the following conditions is satisfied:

A. The minimum DNBR is within its convergence criterion and the quality limit is not violated;

B. The quality at the node of minimum DNBR is within its convergence criterion and the DNBR limit is not violated;

C. The minimum DNBR and quality are within their respective convergence criteria;

D. At least two iterations have been performed and one POL exists for which the DNBR and quality limits are not violated and another POL exists for which both the DNBR and quality limits are violated;

E. The number of iterations is equal to a specified limit.

If the iteration is stopped for the preceding conditions A through D, the converged power operating limit is then adjusted by specified uncertainty factors. If the iteration is stopped by condition E, the associated output validities are set equal to BAD.

<u>Inputs</u>

INITU - Logical variable for block U initialization

DNBRMIN - Defined in Module 10

QULMIN - Defined in Module 10

DENTHM - Defined in Module 10

FCMIN - Defined in Module 10

GDNBM - Defined in Module 10

QDNBM - Defined in Module 10

CHNMULM - Defined in Module 10

ITERNO - Iteration index

RFLAG2 - Flag for convergent condition D

RFLAG3 - Flag for convergent condition D

AZTILT - Azimuthal tilt, from block R

INTRAD - Integrated radial peaking factor, from block P

CFLOW - Volumetric flow rate, from block D

PP - Plant power, from block I

ASI - Axial shape index, from block M

IAUCT - Constant indicating choice of power operating limit calculations

ITERPOL - Power operating limit calculation index

ITERPOL=1, POL calculation based on reduced flow

ITERPOL=2, POL calculation based on full flow

POLG - Array of power operating limit guesses

Outputs

IFLAG - Flag indicating POL convergence

IFLAGD - Flag for convergence by condition D

DNBRC - Minimum DNBR at POL condition

QLDNBC - Quality at DNBRC

DENTHC - Enthalpy rise at DNBRC

CFLOWC - Value of CFLOW used in current execution of block U

DNBDEV - DNBR derivative

QULDEV - Quality derivative

FDNBC - F-correction factor at DNBRC

GDNBC - Mass velocity at DNBRC

QDNBC - Critical heat flux at DNBRC

AZTILTC - Value of AZTILT used in current execution of block U

INTRADC - Value of INTRAD used in current execution of block U

DNBPL1 - Converged power operating limit, including uncertainty factors, for reduced flow.

(Value is assigned if IAUCT = 1). To test report and detailed print report.

DNBPL2 - Converged power operating limit, including uncertainty factors, for full flow. (Value is assigned if IAUCT = 2). To test report and detailed print report.

DNBPOLC - Block U power operating limit. Selected from DNBPL1 and DNBPL2.

CHNMUL - Channel multiplier

Note: If convergence has not been obtained (IFLAG equal zero), these outputs are not reset.

Data Constants

DN1 - DNBR limit

Q1 - Quality limit

KMAX - Maximum number of iterations

DN22 - Initialization value for DNBDEV

Q22 - Initialization value for QULDEV

Q3 - Quality convergence tolerance

DN3 - DNBR convergence tolerance

QTEST - Quality limit of heat flux correlation

EPOLG - Error correction for POL guess

EPOL1 - Additive uncertainty factor for ITERPOL=1

EPOL2 - Multiplicative uncertainty factor for ITERPOL=1

EPOL3 - Additive uncertainty factor for ITERPOL=2

EPOL4 - Multiplicative uncertainty factor for ITERPOL=2

Calculation

If ITERNO equals 1 then Module 12 variables are initialized.

TS

If Block U is being initialized (i.e., INITU = TRUE), then the DNBR and quality derivatives are set to their initialization values, but for INITU = TRUE and IAUCT = 3, initialization is performed for ITERPOL = 1 only; i.e.,

IF (INITU.AND..NOT.(IAUCT.EQ.3.AND.ITERPOL.EQ.2)) THEN

TS

Parameters are stored for the current iteration:

TS

The preceding arrays are dimensioned by KMAX.

Convergence error for DNBR and quality are calculated:

TS

Convergence should be checked to see that it is satisfied:

Explanation of Convergence Conditions

A. The minimum DNBR is within its convergence criterion and the quality limit is not violated;

B. The quality at the node of minimum DNBR is within its convergence criterion and the DNBR limit is not violated;

C. The minimum DNBR and quality are within their respective convergence criteria;

D. At least two iterations have been performed and one POL exists for which both the DNBR and quality limits are not violated, and another POL exists for which both the DNBR and quality limits are violated;

E. The number of iterations is equal to a specified limit.

If the iteration is stopped for conditions "A" through "D", the converged POL is then adjusted by specified uncertainty factors. If the iteration is stopped by condition "E", the associated output validity is set equal to "BAD".

Test for Convergent Condition A or C

If DNBERR is less than or equal to DN3 and QULMIN is less than or equal to Q1+Q3

then set

TS

and go to the procedure for "Converged Conditions".

Otherwise,

Test for Convergent Condition B or C

If QULERR is less than or equal to Q3 and DNBRMIN is greater than or equal to DN1 – DN3

then set

TS

and go to the procedure for "Converged Conditions".

Otherwise,

Test for Non Convergent Condition E

If ITERNO is greater than or equal to KMAX then stop the BLOCK U calculations and set the validity of DNBPLUC to BAD.

Otherwise,

Test for Convergent Condition D

If ITERNO equals one, then set:

TS

Set RFLAG2 or RFLAG3 as indicated if either of the following

flag conditions exist:

If QULMIN is less than Q1-Q3 and DNBRMIN is greater than DN1+DN3, then TS

If QULMIN is greater than Q1+Q3 and DNBRMIN is less than DN1 – DN3, then TS

If RFLAG2 is greater than zero and RFLAG3 is greater than zero then set TS

If DNBG(ITERNO) is greater than or equal to DN1-DN3, then TS

If QULG(ITERNO) is less than or equal to Q1+Q3, then TS

If DNBPOLM equals POLG(ITERNO), then TS

If QULPOLM equals POLG(ITERNO), then TS

If type D convergence has been obtained (IFLAGD = 1), then skip to the procedure entitled "Power Operating Limit when IFLAGD Equals One". Otherwise, the next power operating limit guess should be determined as follows:

Next Power Operating Limit Guess When IFLAGD is zero

If ITERNO equals one, then

TS

[ ]

If, however, QULMIN is greater than (Q1 + Q3) or DNBRMIN is

less than (DN1 – DN3) then

TS

[ ]

If ITERNO is greater than one, then

TS

[ ]

If ITERNO equals two, then

TS

[ ]

If ITERNO is greater than two and QULG(ITERNO-1) is greater

than or equal to QTEST, then

POLG(ITERNO) = the minimum of POLDNB and POLQUL

At this point, the calculation returns to Module 4.

Power Operating Limit When IFLAGD Equals One

TS

Converged Conditions (IFLAG=1)

POLG(ITERCVG) should be stored for use in Module 2 as the first power operating limit guess in the next execution of Block U:

TS

The evaluation of the converged power operating limit, DNBPOLC, and other Block U parameters to be passed to Block W depend on the value of IAUCT, as described in the following equations. In these equations, DPOLU is a function of plant power, core ASI and type of calculation (ITERPOL).

TS

Now Block W inputs should be determined as described under "Storage of Block U Parameters for Use in Block W".

TS

Now Block W inputs should be determined as described under "Storage of Block U Parameters for Use in Block W".

TS

Now Block W inputs should be determined as described under "Storage of Block U Parameters for Use in Block W".

TS

If DNBPOLC = DNBPL1,

then, the Block U calculations have been completed at this

point.

Storage of Block U Parameters for Use in Block W

TS

The last two parameters, not used in block W, are stored for code testing and debugging.

Calculation of DNBR and Quality Derivatives:

If ITERCVG is greater than one, then

TS

TS

If IAUCT = 1 or 2, or if IAUCT = 3 and ITERPOL = 2 then Block U

execution has been completed at this point.

If IAUCT = 3 and ITERPOL = 1, then ITERPOL is set to 2, and the Block U calculations (Modules 2, 4-10, and 12) are repeated assuming full flow.

DPOLU Function

The calculation of DPOLU allows for two sets of power and ASI margin allowances which are selected through the POL calculation index ITERPOL. This allows the margin to be calculated for either full flow, reduced flow, or both, depending upon the constant IAUCT (see 4.3.2.5).

DPOLU is calculated as follows:

a. The segment of the margin curve containing the present core power is determined.

TS

b. The power dependent margin allowance should be determined.

TS

DPOLP - Power dependent margin allowance for the present power and POL calculation index ITERPOL. TS

c. The segment of the margin curve containing the present core ASI should be determined.

If ASI ≤ ABREAK(1) TS

d. The ASI dependent margin allowance should be determined TS

e. The overall Power and ASI dependent margin allowance are calculated TS

4.3.2.5.13. Module 13, Fluid Specific Volume

Module 13 determines fluid specific volumes which are used in calculating the friction and momentum pressure drops.

<u>Inputs</u>

P - Primary system pressure, psia

H - Fluid enthalpy, Btu/lbm

HF - Saturated liquid enthalpy, Btu/lbm

HFG - Liquid latent heat, Btu/lbm

VF - Saturated liquid specific volume, ft^3/lbm

VG - Saturated steam specific volume, ft^3/lbm

BALPL1,...BALPL4 - Coefficients for void fraction at low quality

BALPH1,...BALPH4 - Coefficients for void fraction at high quality

<u>Outputs</u>

V - Fluid specific volume, ft^3/lbm

VFRIC - Fluid specific volume for friction pressure drop, ft^3/lbm

VP - Fluid specific volume for momentum pressure drop, ft^3/lbm

<u>Data Constants</u>

ASVOL1,...ASVOL4 - Coefficients for the fluid correlation

PBRK - Coefficient for pressure break point below which the Martinelli-Nelson correlation for void fraction vs. quality is used

XBRK1,XBRK3 - Coefficients for quality break points

Calculation

The fluid quality is given by TS

If the quality is less than or equal to zero, then TS

and the calculations of module 13 are completed.

If the quality is greater than zero, then the pressure and quality dependent void fraction, ALPHA, is calculated as follows: TS

Otherwise, TS

The two-phase specific volumes are then calculated as follows: TS

4.3.2.5.14. Module 14, Fluid Friction Factor

Module 14 determines a fluid friction factor for single phase or two-phase fluid state.

Inputs

P - Pressure, psia

H - Fluid enthalpy, Btu/lbm

G - Fluid mass velocity, lbm/sec/ft^2

QFLUX - Heat flux, Btu/sec/ft^2

DE - Hydraulic diameter, ft

FF01,...FF18 - Pressure dependent parameters

TF - Saturated liquid temperature, °F

HF - Saturated liquid enthalpy, Btu/lbm

HFG - Liquid latent heat, Btu/lbm

VISCF - Saturated liquid viscosity

Output

FT - Fluid friction factor

Data Constants

BVISC1.....BVISC4 - Viscosity polynomial coefficients

BMPT21.....BMPT23 - Coefficients for (Re)$^{-0.2}$ fit

DBCON - Coefficient for Dittus-Boelter Correlation

KPRDF - Coefficient for Jens-Lottes temperature drops

FSPCON - Coefficient for single phase friction factor

BKPRD1,...BKPRD4 - Coefficients for polynomial fit of K * Pr$^{0.4}$ where K is a constant and Pr is the Prandtl number

BFRTH1,...BFRTH3 - Coefficients for polynomial fit to one fourth power of the heat flux

BTEMP1,...BTEMP3 - Coefficients for polynomial fit to subcooled temperature vs. enthalpy

C01,...C40 - Coefficients for friction factor correlation

PBRK1 - Pressure break point used in calculating FT

PBRK2 - Pressure break point used in calculating FT

XBRK2 - Quality break point used in calculating FT

XBRK4 - Quality break point used in calculating FT

Calculation:

Calculation of the Single Phase Friction Factor

A single phase friction factor (FSP) is calculated based on the local quality (X), viscosity (VISC), and Reynolds number (RE):

TS

.,

The Reynolds number is computed as follows:

TS

An approximation of $(RE)^{-.2}$ is given by:

TS

and the single phase friction factor is given by:

TS

Calculation of Subcooled Boiling Friction Factor (PHISQ1):

The convective film temperature difference (DTF) is based on the Dittus-Boelter convection film coefficient and is determined by:

TS

and KPRD is given by:

TS

when the quality (X) is less than zero, otherwise KPRD is given by:

TS

The Jens-Lottes temperature difference (DTJL) plus subcooling is given by:

TS

otherwise TSUBSAT is given by:

TS

QFOURTH is given by:

TS

and QF is given by:

TS

The subcooled boiling friction factor (PHISQ1) is given by:

TS

If the pressure (P) is less than PBRK1 and the convection film coefficient (DTF) is greater than the Jens-Lottes temperature difference (DTJL), then PHISQ1 is given by:

TS

If the pressure (P) is greater than or equal to PBKR1, then PHISQ1 is given by:

TS

If PHISQ1 is less than one, then set PHISQ1 equal to one.

TS

and GF is given by:

TS

NOTE: If the pressure (P) is less than PBRK1 and DTF is less than or equal to DTJL, then PHISQ1 remains equal to one.

If the quality (X) is less than or equal to zero then the fluid friction factor (FT) is given by: TS

[ ]

and the calculation of Module 14 is completed. Otherwise, a two-phase friction factor is calculated.

<u>Calculation of Two-Phase Friction Factor (PHISQ2)</u>

The two-phase friction factor is based on the local quality (X), the mass velocity (G), and the pressure (P). Note that the following calculations are performed if the quality (X) is greater than zero.

PHISQ2 is initialized to one: TS

[ ]

The calculation of PHISQ2 is divided into three pressure regions. Each region contains quality-dependent correlations for determining PHISQ2. The pressure dependent regions are:

REGION 1 - Pressure (P) less than PBRK1

REGION 2 - Pressure (P) greater than PBRK2

REGION 3 - (P) is greater than or equal to PBRK1 and (P) is less than or equal to PBRK2

NOTE: Calculation of PHISQ2 is performed for only one region.

<u>REGION 1: Calculation of PHISQ2 and FT</u>

If the quality (X) is less than XBRK2, then TS

[ ]

If the quality (X) is greater than XBRK4, then TS

[ ]

and the calculation of module 14 is completed.

REGION 2: Calculation of PHISQ2 and FT

If the quality (X) is less than XBRK2, then

TS

If the quality (X) is greater than XBRK4, then

TS

otherwise,

TS

The fluid friction factor (FT) is given by:

TS

and the calculation of Module 14 is completed.

REGION 3: Calculation of PHISQ2 and FT

If the quality (X) is less than XBRK2, then

TS

If the quality (X) is greater than XBRK4, then

TS

Otherwise,

TS

The fluid friction factor (FT) is given by:

TS

and the calculation of Module 14 is completed.

Table U-1 Constants

QAVG	CF(23)
P2OVRPN	CF(24)
P3OVRPN	CF(25)
P4OVRPN	CF(26)
DH1	CF(27)
DH2	CF(28)
DH3	CF(29)
DH4	CF(30)
PI	CF(31)
CF(01)	CF(32)
CF(02)	CF(33)
CF(03)	CF(34)
CF(04)	CF(35)
CF(05)	CF(36)
CF(06)	CF(37)
CF(07)	ALL11
CF(08)	ALL12
CF(09)	ALL13
CF(10)	ALL14
CF(11)	ALL21
CF(12)	ALL22
CF(13)	ALL23
CF(14)	ALL24
CF(15)	ALL31
CF(16)	ALL32
CF(17)	ALL33
CF(18)	ALL34
CF(19)	ALL41
CF(20)	ALL42
CF(21)	ALL43
CF(22)	

Table U-1 (Cont'd)

ALL44	AHF2
ALH11	AHF3
ALH12	AHF4
ALH13	AHFG1
ALH14	AHFG2
ALH21	AHFG3
ALH22	AHFG4
ALH23	AVIF1
ALH24	AVIF2
ALH31	AVIF3
ALH32	AVIF4
ALH33	AEN11
ALH34	AEN12
ALH41	AEN13
ALH42	AEN14
ALH43	AEN21
ALH44	AEN22
ATF1	AEN23
ATF2	AEN24
ATF3	AEN31
ATF4	AEN32
AVF1	AEN33
AVF2	AEN34
AVF3	AEN41
AVF4	AEN42
AVG1	AEN43
AVG2	AEN44
AVG3	BSVOL1
AVG4	BSVOL2
AHF1	BSVOL3

Table U-1 (Cont'd)

BSVOL4	DXOVGC
CC3	TWODX
CC4	TWODE1
U20	TWODE2
U21	SL
U22	CN2
U23	CN3
U24	CH2
U25	GC
U26	AREA2
U27	AREA3
ASILOW	AREA4
ASIHI	HPERIM3
UFFLOW	HPERIM4
UFFHI	CU2
GPMTOFS	CIJCON2
FLOAREA	CIJCON3
ASIBRK	AREAX
FSPLIT1	HC
FSPLIT2	WPXCON
CIJCON1	WP23CON
DELTAX	WP34CON
QFUEL	DXOVA3
HPERIM1	DXOVA4
HPERIM2	TWODE3
TWOGC	TWODE4
IAUCT	CCEO
DXOVA1	CCE3
DXOVA2	

Table U-1 (Cont'd)

CCE4	BTEMP2
CCE5	BTEMP3
CCE6	BVISC1
CCE7	BVISC2
CCE8	BVISC3
CE1XTOH	BVISC4
K1	BKPRD1
EX1	BKPRD2
EX2	BKPRD3
SKECDK	BKPRD4
PXOVRPN	KPRDF
DN22	C1
Q22	C2
KMAX	C3
DN1	C4
DN3	C5
Q1	C6
Q3	C7
EPOL1	C8
EPOL2	C9
EPOL3	C10
EPOL4	C11
ASVOL1	C12
ASVOL2	C13
ASVOL3	C14
ASVOL4	C15
PBRK	C16
XBRK1	C17
XBRK2	C18
XBRK3	C19
XBRK4	BTEMP1

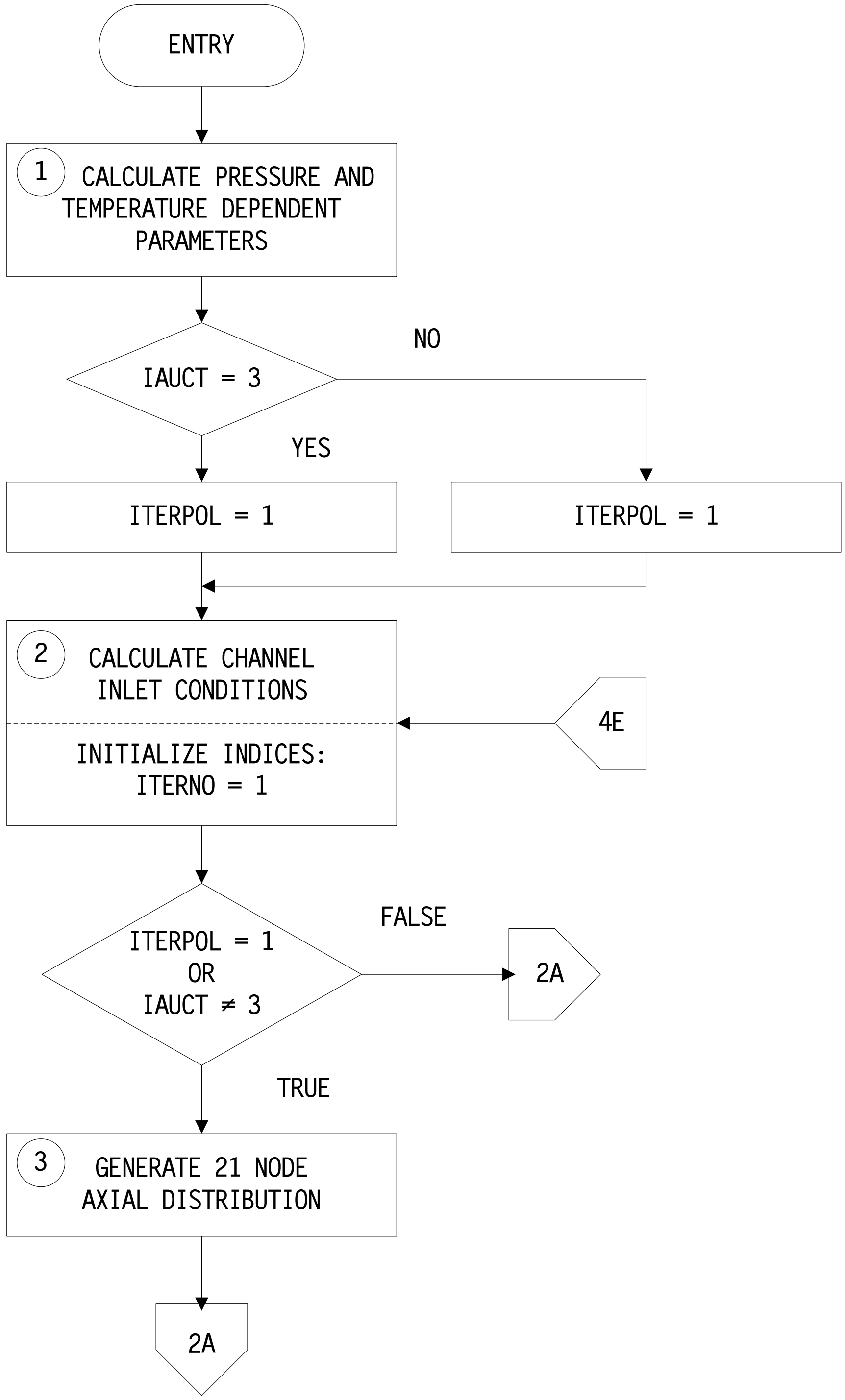
Table U-1 (Cont'd)

C21
C22
C23
C24
C25
C26
C27
C28
C29
C30
C31
C32
C33
C34
C35
C36
C37
C38
C39
C40
PBRK1
PBRK2
BMPT21
BMPT22
BMPT23
FSPCON
DBCON
BFRTH1
BFRTH2
BFRTH3
DE1
DE2
EPOLG
DE3
DE4
FZCOF(1)
FZCOF(2)
FZCOF(3)
FZCOF(4)
FZCOF(5)
FZCOF(6)
FZCOF(7)
FZCOF(8)
FZCOF(9)
POLCF1
POLCF2
POLCF3
POLCF4
POLCF5
POLCF6
POLCFA
POLCFC
POLCFD
QTEST
UBIAS
USLOPE

Table U-1 (Cont'd)

Spacer Loss Coefficients

KG(1)	KG(2)	KG(3)	KG(4)	KG(5)
KG(6)	KG(7)	KG(8)	KG(9)	KG(10)
KG(11)	KG(12)	KG(13)	KG(14)	KG(15)
KG(16)	KG(17)	KG(18)	KG(19)	KG(20)



SHEET 1 of 4

Figure U-1 SEQUENCE OF DNBR POWER OPERATING LIMIT CALCULATIONS

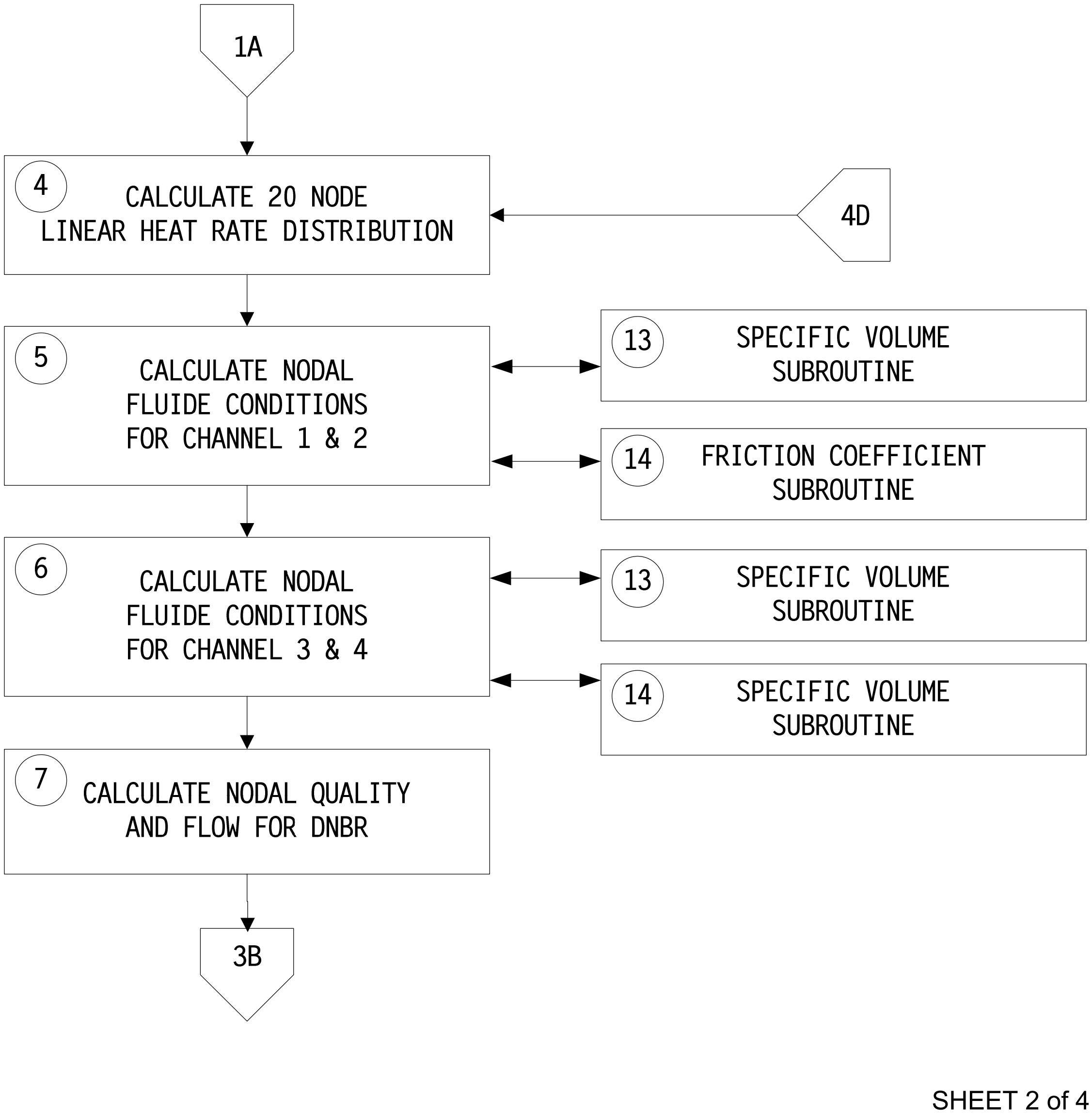
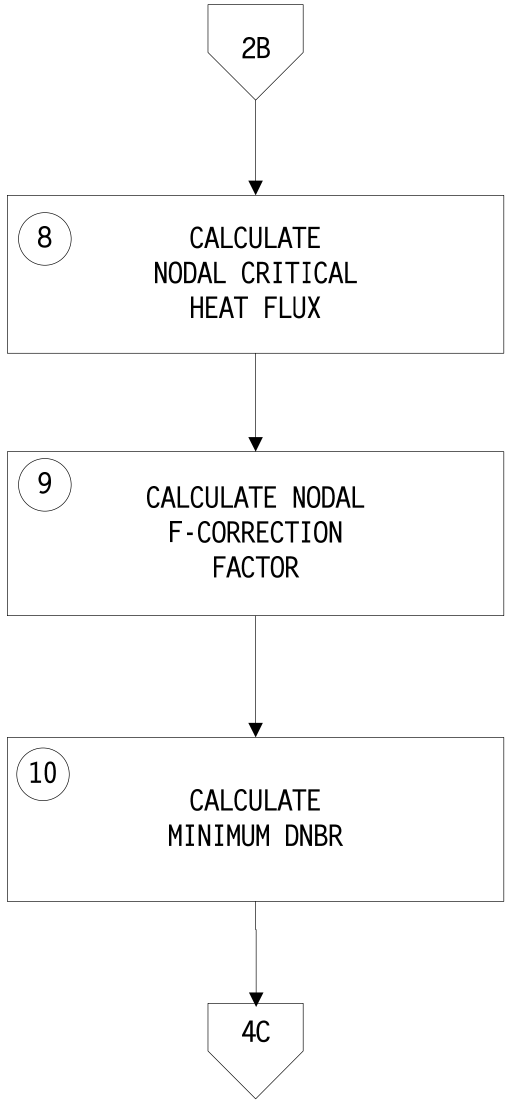
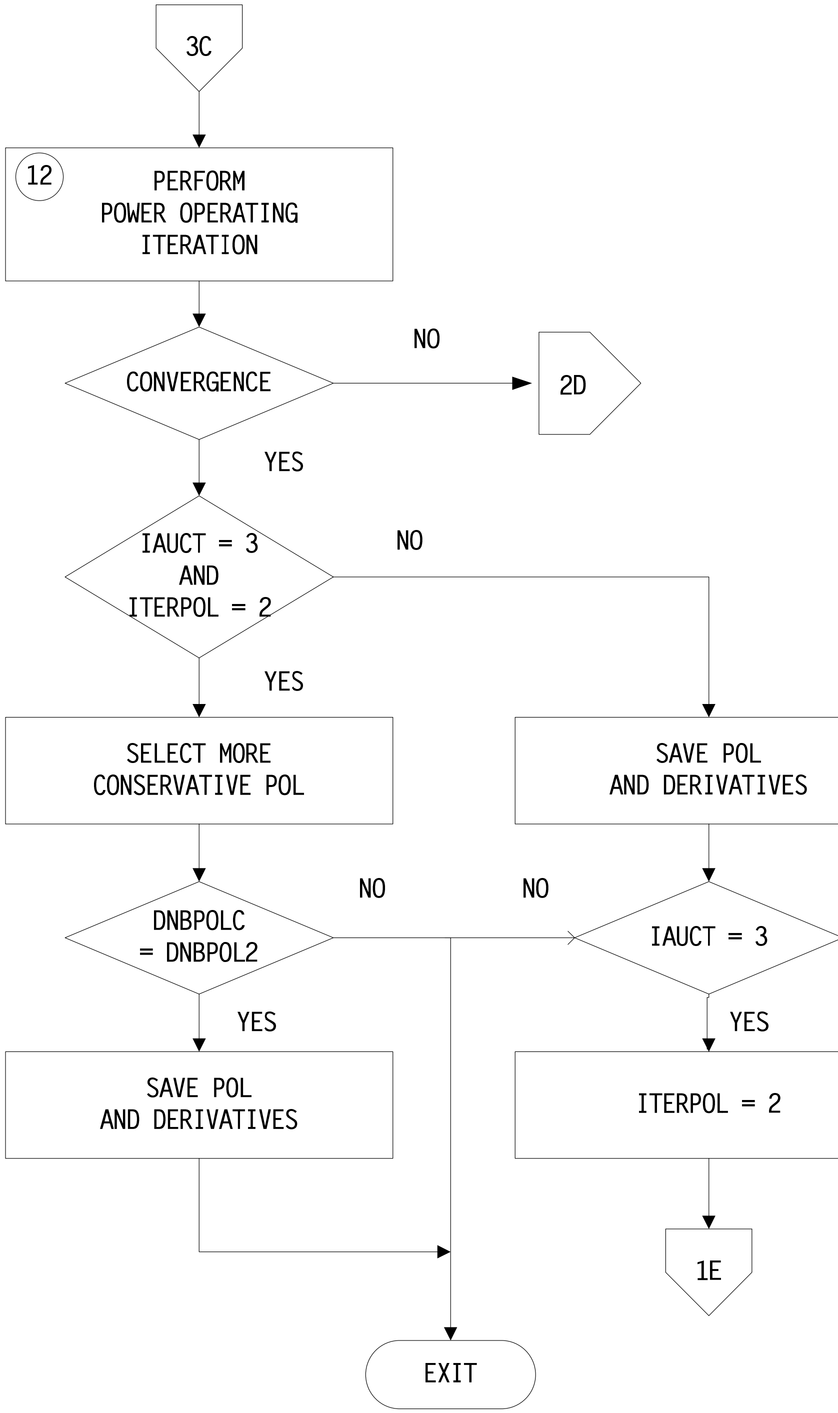


Figure U-1 (Cont.) SEQUENCE OF DNBR POWER OPERATING LIMIT CALCULATIONS



SHEET 3 of 4

Figure U-1 (Cont.) SEQUENCE OF DNBR POWER OPERATING LIMIT CALCULATIONS



SHEET 4 of 4

Figure U-1 (Cont.) SEQUENCE OF DNBR POWER OPERATING LIMIT CALCULATIONS

4.3.3. (Block W) DNBR Power Operating Limit Update

4.3.3.1. Description

A detailed DNBR power operating limit calculation is performed in BLOCK U every 30 seconds. The BLOCK U DNBR power operating limit is updated every second by the technique specified in this section, BLOCK W.

4.3.3.2. Timing

The specified update requirements shall be performed as a part of the one second block of calculations.

4.3.3.3. Inputs

PPRI	-	Primary coolant system pressure from Block B
TCMAX	-	Maximum cold leg temperature from Block C
CFLOW	-	Volumetric flow rate from Block D
INTRAD	-	Integrated radial peaking factor from Block P
AZTILT	-	Azimuthal tilt factor from Block R
NP	-	Number of pumps running from Block D
CFLOWC	-	Volumetric flow rate from Block U
INTRADC	-	Integrated radial peaking factor from Block U
AZTILTC	-	Azimuthal tilt factor from Block U
FDNBC	-	F correction factor at minimum DNBR from Block U
QLDNBC	-	Quality at minimum DNBR from Block U
GDNBC	-	Mass velocity at minimum DNBR from Block U
DNBRC	-	Minimum DNBR at DNBPOLC from Block U
DNBPOLC	-	Power operating limiting from Block U
QDNBC	-	KCE-1 critical heat flux at minimum DNBR from U
DNBRP1	-	Holder from Block U to receive initial Block W Power Operating Limit. Set to 0.0 in Block U on each completion of Block U.
DENTHC	-	Enthalpy rise to node of minimum DNBR from Block U
IFLAGD	-	Convergence flag from Block U
DNBDEV	-	DNBR derivative from Block U
QULDEV	-	Quality derivative from Block U
CHNMUL	-	Channel dependent critical heat flux multiplier from Block U

4.3.3.4. Outputs

DNBRPOL	-	Block W power operating limit

DNBRP1	-	Initial value of DNBRPOL determined on first execution of Block W following completion of Block U
QDNBPC	-	Flag indicating quality of DNBRPOL (TRUE = GOOD quality)

4.3.3.5. Data Constants

CCEO	-	Same value as in BLOCK U
CCE3	-	Same value as in BLOCK U
CCE4	-	Same value as in BLOCK U
CCE5	-	Same value as in BLOCK U
CCE6	-	Same value as in BLOCK U
CCE7	-	Same value as in BLOCK U
CCE8	-	Same value as in BLOCK U
AHF1	-	Same value as in BLOCK U
AHF2	-	Same value as in BLOCK U
AHF3	-	Same value as in BLOCK U
AHF4	-	Same value as in BLOCK U
AHFG1	-	Same value as in BLOCK U
AHFG2	-	Same value as in BLOCK U
AHFG3	-	Same value as in BLOCK U
AHFG4	-	Same value as in BLOCK U
AEN11…AEN44	-	Same value as in BLOCK U
QLCOF1	-	Uncertainty coefficient
QLCOF2	-	Uncertainty coefficient
POLCF1	-	Uncertainty coefficient for DNBDEV
POLCF2	-	Uncertainty coefficient for DNBDEV
QULCF1	-	Uncertainty coefficient for QULDEV
QULCF2	-	Uncertainty coefficient for QULDEV
QLIMIT	-	KCE-1 quality limit
AERR1	-	Uncertainty factor for POL
AERR2	-	Uncertainty factor for POL
SLOPE1	-	Change in core flow versus change in quality
SLOPE2	-	Change in core flow versus change in quality
CVGCF1	-	Convergence dead band coefficient
CVGCF2	-	Convergence dead band coefficient
SLPCOF	-	Convergence dead band coefficient
POLCVG	-	POL update error criterion

POLWIN - Power Operating Limit window

4.3.3.6. Calculations

The calculations of BLOCK W shall not be performed when any of the following conditions exists:

1. Less than K09 incore detectors have GOOD validity;
2. Plant power has BAD validity;
3. Less than two reactor coolant pumps are operating;
4. Coolant volumetric flow rate CFLOW has BAD validity;
5. Selected core inlet temperature TCMAX has BAD validity;
6. Primary system pressure PPRI has BAD validity;
7. The Block U DNBR power operating limit DNBPOLC has BAD validity;
8. AZTILT has BAD validity;
9. INTRAD has BAD validity (QRADIAL or QAXIAL = BAD).

If Block W is not performed, the validity of DNBRPOL shall be set to BAD and QDNBPC shall be set to FALSE. Otherwise the validity of DNBRPOL shall be set to GOOD and QDNBPC shall be set to TRUE.

A. Fluid Properties should be calculated:

TS

B. Change in Integrated Radial Peaking Factor should be calculated:

TS

TS

If QLDNB is greater than QLDNBC, then

TS

If QLDNB is less than QLDNBC, then

TS

If the absolute value of (QLDNB – QLDNBC) is less than SLPCOF, then

TS

The enthalpy and quality at the node of minimum DNBR is then determined by:

TS

D. The F - Correction Factor should be calculated:

TS

E. The KCE-1 critical heat flux and the DNBR should be calculated:

TS

F. The updated DNBR power operating limit should be calculated:

If DNBR is greater than or equal to DNBRC, then

TS

otherwise

TS

If the absolute value of (DNBRC – DNBR) is less than CVGCF1,

then

TS

If the absolute value of (QLDNB – QLDNBC) is less than

CVGCF2, then

TS

If QLDNB is greater than or equal to QLIMIT or IFLAGD is greater than zero, then

TS

otherwise

TS

If the absolute value of ((DNBRPOG/DNBPOLC) – 1.0) is greater than POLCVG, then

TS

If the absolute value of ((DNBRPOG/DNBPOLC) – 1.0) is less than or equal to POLCVG but greater than POLWIN, then

TS

If the absolute value of ((DNBRPOG/DNBPOLC) – 1.0) is less

than or equal to POLWIN, then

TS

Save the initial Block W POL following a Block U execution for use in the next execution of Block U: TS

[ ]

4.3.3.7. Constants

See Table W-1 for list of constants

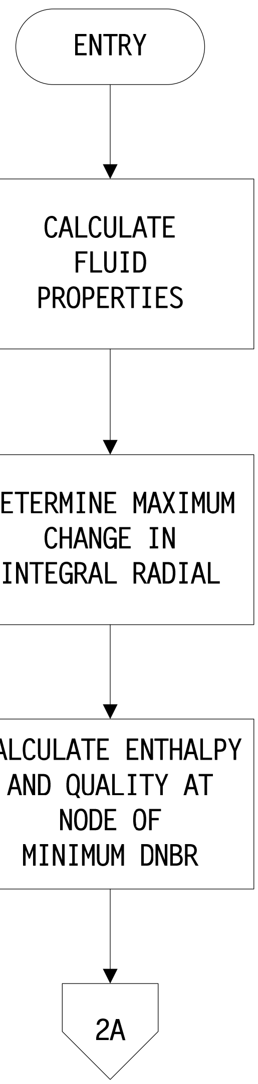
4.3.3.8. Calculation Sequence

See Figure W-1.

Table W-1* LIST OF CONSTANTS

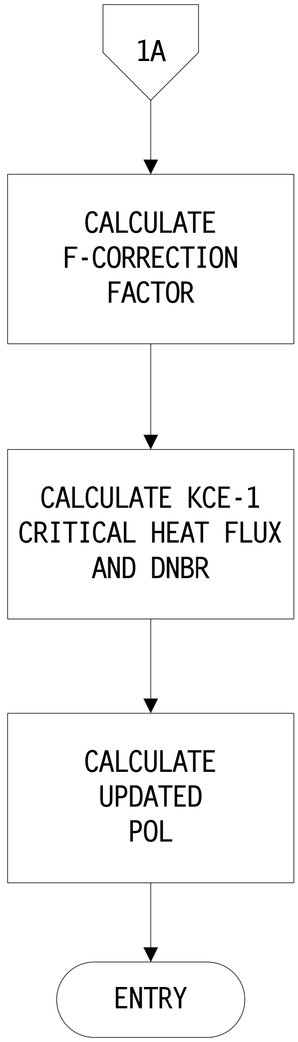
CONSTANT
QLCOF1
QLCOF2
POLCF1
POLCF2
QULCF1
QULCF2
QLIMIT
AERR1
AERR2
SLOPE1
SLOPE2
SLPCOF
CVGCF1
CVGCF2
POLCVG
POLWIN

* For constants not listed in Table U-1



SHEET 1 of 2

Figure W-1 SEQUENCE OF DNBR POL UPDATE CALCULATIONS



SHEET 2 of 2

Figure W-1 (Cont.) SEQUENCE OF DNBR POL UPDATE CALCULATIONS

4.4. Limiting Condition for Operation Monitoring

The limiting condition for operation monitoring consists of the calculation of the margin to each power operating limit, and to the licensed power limit, and the initiation of an alarm sequence when a margin is less than a threshold value.

4.4.1. (Block X) Core Power Margin and Alarm Annunciation

4.4.1.1. Description

Block X performs continuous monitoring of plant power with respect to the licensed power limit and the calculated core power operating limits. Two separate checks are done: an instantaneous check using unsmoothed power and unsmoothed power operating limits, and a steady state check using smoothed power and smoothed power operating limits. When plant power exceeds the power operating limit, an alarm sequence is started. When smoothed power exceeds a smoothed power operating limit, an alarm sequence is initiated. The duration of the event is also measured and monitored.

4.4.1.2. Timing

Block X shall be performed as part of the 1-second block of calculations.

4.4.1.3. Inputs

PP	-	Plant power from block I
QPP	-	Plant power validity from block I
PPF	-	Filtered plant power from block I
QPPF	-	Filtered plant power validity from block I
BSCAL	-	Secondary Calorimetric Power from block F
QBSCAL	-	Secondary Calorimetric Power validity from block F
BSCALAVG	-	Smoothed Secondary Calorimetric Power from block F
BIAS	-	Power operating limit bias from block I
KWPFPOL	-	Linear heat rate (kW/ft) power operating limit from block T
QKWPFPOL	-	Validity of KWPFPOL
DNBRPOL	-	DNBR power operating limit from block W
QDNBRPOL	-	Validity of DNBRPOL

4.4.1.4. Outputs

MARGIN	-	Limiting smoothed margin to the main control board and CRT
ALARM1	-	COLSS master alarm contact closure to annunciator
ALARM1A	-	Smoothed secondary calorimetric power exceeds licensed power limit
ALARM1B	-	Smoothed plant power exceeds smoothed thermal margin POL
ALARM1C	-	Smoothed plant power exceeds smoothed linear heat rate POL
ALARM1D	-	Unsmoothed plant power exceeds unsmoothed thermal margin POL
ALARM1E	-	Unsmoothed plant power exceeds unsmoothed linear heat rate POL
ALARM1L	-	Secondary calorimetric power exceeds instantaneous power limit
TIME1A	-	Length of time ALARM1A is set for this event
TIME1AA		Length of time ALARM1A is set summed over all events

TIME1B	-	Length of time ALARM1B is set for this event
TIME1BA	-	Length of time ALARM1B is set summed over all events
TIME1C	-	Length of time ALARM1C is set for this event
TIME1CA		Length of time ALARM1C is set summed over all events
DNBRPLB		Biased DNBR POL to the main control board and CRT
KWPFPLB		Biased linear heat rate POL to the main control board and CRT
PP		Plant power to the main control board and CRT
PPF		Filtered plant power to CRT
BSCAL		Secondary calorimetric power to CRT
PPS		Smoothed plant power to CRT
PPFS		Smoothed filtered plant power to CRT
BSCALAVG		Smoothed secondary calorimetric power to CRT

4.4.1.5. Calculation

The calculations of this block are performed in five steps.

1) Biasing of power operating limits.

2) Smoothing of the biased power operating limits and plant power.

3) Calculation of margins.

4) Alarm limit checking.

5) Accumulation of alarm duration.

1. Biasing of power operating limits **TS**

TS

DPOL, a piecewise-linear function of plant power, is determined as follows:

a. The segment of the margin curve containing the present core power is determined.

TS

b. The margin allowance is determined.

TS

2. Smoothing

The biased power operating limits and plant powers are smoothed using a two stage averaging procedure. The first stage is an NSTAGE1 point recursive average. When the first stage average calculation is completed, its output is used as input to the stage two running average calculation. NSTAGE2, the window width of the running average shall be adjustable between l and 30 points.

Stage 1: NSTAGE1 point recursive average

After stage initialization the calculation proceeds as follows

TS

When N reaches NSTAGE1, stage two is performed.

Stage 2: NSTAGE2 point running average

After stage initialization step 2 is performed as follows.

1. N is reset to zero.

2. A new value of DNBRS is calculated by averaging the current value of DNBRA and (NSTAGE2-l) past values.

3. A new value of KWPFS is calculated by averaging the current value of KWPFA and (NSTAGE2-1) past values.

4. A new value of PPS is calculated by averaging the current value of PPA and (NSTAGE2-1) past values.

5. A new value of PPFS is calculated by averaging the current value of PPFA and (NSTAGE2-1) past values.

<u>where</u>

DNBRS - Smoothed value of biased DNBR power operating limit

KWPFS - Smoothed value of biased linear heat rate power operating limit.

PPS - Smoothed value of Plant Power.

PPFS - Smoothed value of filtered plant power

Provision shall be made to process up to 30 values for each of the three running averages.

Validity Propagation

It is important for the four smoothed values to remain synchronized with each other. For this reason the calculation of biased margins and the execution of the filtering scheme are continued when their inputs have BAD validity. The validity of the averaged outputs is controlled as follows.

The stage one recursive averages and stage two running averages are calculated as described. When a first stage input has BAD validity, the validity of the first stage output is BAD. The validity of the second stage output remains good until a first stage output with validity of BAD is accepted from stage one. It then remains BAD until the running average has been flushed of past values with BAD validity.

The validity of the biased power operating limits equals the validity of the unbiased power operating limits.

Initialization

On a computer restart, or when COLSS execution in the SCHEDULED or TEST mode is begun, initialization of each of the four two-stage filters shall be attempted, as follows:

A. If the initial input to a first stage filter has validity GOOD, then:

1. The first stage output shall be equal to its input.

2. The second stage filter shall be filled with the first stage output value.

3. The second stage filter output shall be equal to the first stage output value.

4. The validities of the first and second stage filter outputs shall be set to GOOD.

B. If the initial input to a first stage filter has validity BAD, then

1. Initialization of the first and second stages of that filter shall be deferred until the validity of the first stage input changes to GOOD.

2. The validity of the first and second stage outputs of that filter shall be set to BAD.

3. When the validity of the first stage input changes to GOOD, the first and second stage filters shall be initialized by the procedure outlined in A, above.

3. Calculation of Margins

Six margins are calculated for display and alarm use. TS

TS

If the validity of either input is BAD, then the margin panel display shall indicate that the value displayed has BAD validity.

Except MRGNPS and MRGNPI, if the validity of an input for a margin calculation is BAD, then the validity of that margin shall be set to BAD. The validity of MRGNPS is set to BAD when both BSCAL and PPFS have BAD validity. The calculation of MRGNPI is not performed when BSCAL has BAD validity.

The smallest of three smoothed margins, MRGNPS, MRGNDS, and MRGNKS is selected for display on the digital panel meter and CRT display. This value shall be stored and is referenced as MARGIN.

4. Monitoring and Message Display

If either input to a margin calculation has BAD validity, then the message associated with that margin shall be cleared. The COLSS master alarm, ALARM1 shall be set.

To reduce chattering a comparison procedure using individual set and reset thresholds shall be used. A form which properly implements this checking is as follows.

TS

This procedure is used for each of the six with the following assignment of alarm flags and limits.

ALARM	DISPLAY		CLEAR
MARGIN	MESSAGE	THRESHOLD	THRESHOLD
MRGNPS	MSG1A	XO1A	XO2A
MRGNDS	MSG1B	XO1B	XO2B
MRGNKS	MSG1C	XO1C	XO2C
MRGNDI	MSG1D	XO1D	XO2D
MRGNKI	MSG1E	XO1E	XO2E
MRGNPI	MSG1L	XO1L	XO2L

The master alarm, ALARM1, is set when MSG1A, MSG1B, MSG1C, MSG1D, MSG1E or MSG1L is displayed. Additional requirements for setting ALARM1 are given in Section 5.

5. Accumulation of Alarmed Event Duration

Plant technical specification surveillance requirements require that corrective action be taken within a stated time period when the plant power operating limits are exceeded in the steady state. To meet these requirements the length of time over which the reactor was operated with a margin alarm set is measured and monitored for each event and accumulated on an annual basis. Specific requirements are as follows.

Two times are accumulated while ALARM1A is set. TIME1A is an event duration time which is accumulated while ALARM1A is set, and zeroed when ALARM1A is reset. TIME1AA is a cumulative time which is annually accumulated when ALARM1A is initialized. When these times exceed their associated time limits XO3 and XO4 then messages are displayed.

This same procedure is used for messages MSG1B and MSG1C

<u>where</u>

TIME1B - Event duration for ALARM1B

TIME1BA - Cumulative duration for ALARM1B

XO5 - TIME1B alarm limit

XO6 - TIME1BA alarm limit

TIME1C - Event duration for ALARM1C

TIME1CA - Cumulative duration for ALARM1C

XO7 - TIME1C alarm limit

XO8 - TIME1CA alarm limit

Typical alarm messages are shown in Figure 3-4.

4.4.1.6. Constants

See Table X-1.

4.4.1.7. Sequence of Calculations

See Figure X-1.

Table X-1 LIST OF BLOCK X CONSTANTS

NSTAGE1	NSTAGE2
X01A	X02A
X01B	X02B
X01C	X02C
X01D	X02D
X01E	X02E
X01L	X02L
X03	X04
X05	X06
X07	X08
BIASCU	LPL
PBREAK(I)	I = 1…4
SLOPE(I)	I = 1…4
OFFSET(I)	I = 1…4
LPLB	

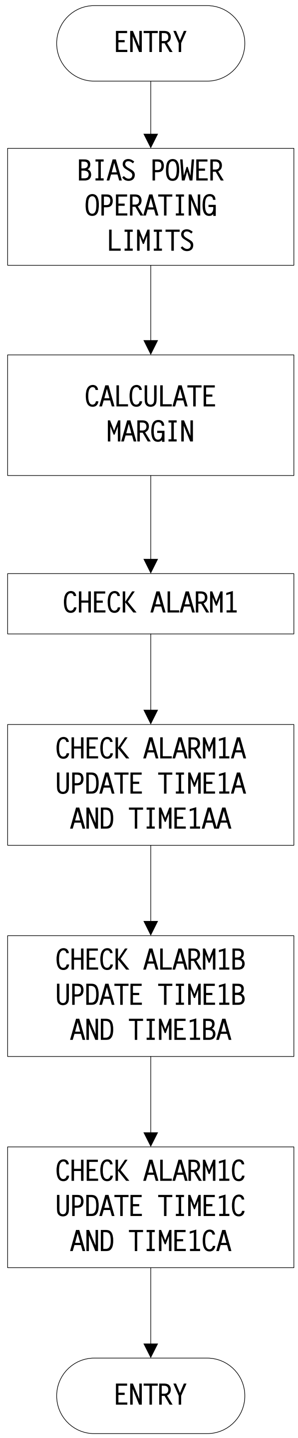


Figure X-1 SEQUENCE OF BLOCK X CALCULATIONS

4.5. Supporting Programs

Calculation of the sensor cross check thresholds used in block A requires measurement of difference means and standard deviations. Various monitoring process calculations require calculation of thermodynamic properties. This section describes the supporting programs required to perform these functions.

4.5.1. Thermodynamic Properties

4.5.1.1. Description

A set of thermodynamic property subroutines which are called to calculate thermodynamic properties is required to support the COLSS calculations. The reactor coolant volumetric flow and mass flow algorithm (Block D) and the primary calorimetric power algorithm (Block E) call the compressed liquid property routines which are applicable for the primary side. The secondary calorimetric power algorithm (Block F) calls the compressed liquid and saturated property routines which are applicable for the secondary side. The thermodynamic property routines for use in the DNBR power operating limit calculation algorithm (Block U) are included in Module 1 and Module 13 of Block U. The applicable ranges of pressure and temperature are the same as in the primary side. The properties calculated, range of calculation, and function name used to reference the property called in Blocks D, E and F are shown in Table 4-1.

4.5.1.2. Calculations

The calculation of thermodynamic properties used in COLSS shall be consistent with the latest version of the ASME Steam tables. Only those properties and regions defined below need be programmed for execution of COLSS. Numerical methods used to compute thermodynamics properties shall not result in differences between the COLSS calculated thermodynamic properties and the values tabulated in the most recent version of the ASME Steam tables of greater than 0.2 percent at any point in the region.

The calculation of the compressed liquid properties should be restricted to the compressed liquid region. Should an out of range condition occur, the calculation of the module or block affected should be terminated and its associated output validity should be set to BAD.

4.5.1.3. Constants

None

Table 4-1 REQUIRED WATER PROPERTIES

Function	Argument	Description	Range
HPT1	P, T	Primary Side Compressed Liquid Enthalpy	1500 ≤ P ≤ 2500 450 ≤ T ≤ 650
VPT1	P, T	Primary Side Compressed Liquid Specific Volume	1500 ≤ P ≤ 2500 450 ≤ T ≤ 650
HPT2	P, T	Secondary Side Compressed Liquid Enthalpy	500 ≤ P ≤ 1500 50 ≤ T ≤ 500
VPT2	P, T	Secondary Side Compressed Liquid Specific Volume	500 ≤ P ≤ 1500 50 ≤ T ≤ 500
HFP	P	Secondary Side Saturated Liquid Enthalpy	500 ≤ P ≤ 1500
HGP	P	Secondary Side Saturated Vapor Enthalpy	500 ≤ P ≤ 1500

4.5.2. Collection of Sensor Cross Check Statistics

In order to compute sensor cross check thresholds for use in the sensor cross check procedure of Section 3.1.3 the mean and standard deviation of each of the addressable differences specified in Section 3.1.3.5 is required. This section describes a procedure for measuring these statistics.

The mean of each addressable difference shall be calculated as follows:

TS

N is initialized to zero on the first calculation and incremented by 1 on each subsequent calculation.

The standard deviation of each addressable difference shall be calculated as follows:

TS

The iteration count is maintained as described in the recursive mean calculation description.

It shall be possible to initiate and terminate this calculation from the operator console, and to print or display the point ID, mean, and standard deviation using standard console functions. The iteration rate shall not exceed that of low speed data acquisition nor be less than that of the ten second block of calculations. The program shall automatically terminate after 2000 iterations.

It shall be possible to compute statistics for other points by recompilation of the program with new input designations.

All of the sensor pair differences shall be processed at each iteration.