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BASSS

USE of the INCORE DETECTOR SYSTEM to MONITOR the DNB-LCO on CALVERT CLIFFS UNIT 1 and UNIT 2

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ABSTRACT

The Better Axial Shape Selection System (BASSS) uses the in-core detector system to monitor the Departure from Nucleate Boiling-Limiting Condition for Operation (DNB-LCO). An algorithm is used to determine allowable power level as a function of rod insertion, core average axial shape index, and total integrated radial peaking factor. The computer code PSINCA has been developed to evaluate this algorithm. A summary of this code is included. The implementation of this system for Calvert Cliffs Unit 1 and Unit 2 is also described.

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1.0 Introduction

The purpose of the Better Axial Shape Selection System (BASSS) is to use the in-core detector system to monitor the Departure from Nucleate Boiling-Limiting Condition for Operation (DNB-LCO). This document defines the algorithm which is used to determine allowable power level as a function of rod insertion, core average axial shape index, and total integrated radial peaking factor. The computer code PSINCA has been developed to evaluate this algorithm. A summary of what this code does is included in this document. Certain Technical Specification changes required for implementation of this system for Calvert Cliffs Unit 1 and Unit 2 are also outlined in this report.

2.0 Definition of Terms

Name	Meaning
ARO	All Rods Out
BASSS	Better Axial Shape Selection System
BLIM	Alarm Limit Power at which DNB-LCO is reached
C	Lead CEA group insertion (% inserted)
CEA	Control Element Assembly
DNB-LCO	Departure from Nucleate Boiling - Limiting Condition for Operation
F_R^T	Total Integrated Radial Peaking Factor (ARO)
IASI	Core Average Axial Shape Index

3.0 Functional Requirements of System

The Better Axial Shape Selection System's (BASSS) function is to monitor CEA position and core average axial shape index (IASI) and provide an alarm on power when the DNB-LCO is exceeded.

3.1 Power

The BASSS algorithm calculates a power alarm limit (BLIM) from knowledge of CEA position (C), total integrated radial peaking factor (F_R^T) and core average axial shape index (IASI). The calculated power limit is then compared to the measured power level of the reactor. An alarm is actuated if the measured power level exceeds the calculated limit. For this comparison, the measured power level is assumed to have an uncertainty of 2%. Updates on measured power level are available at two-minute intervals.

3.2 CEA Position

The CEA position input to the algorithm is that of the control rod of CEA Bank 5 with the greatest insertion including the measurement uncertainty of that position. The BASSS is valid for CEA insertions of Bank 5 from "all rods out" (ARO) to 55% inserted. Operation with insertions greater than 55% of Bank 5 will require monitoring the DNB-LCO with the ex-core DNB axial flux offset control limits.

3.3 Core Average Axial Shape Index

The core average axial shape index (IASI) is calculated by the online computer code PSINCA using the in-core detector signals as described in Section 4.2.1. Updates of the in-core detector signals are available at thirty-second intervals. Operability of the in-core detectors is established in accordance with the in-core detector Technical Specification (Section 3.3.3.2). Uncertainties and biases on IASI are included either in the determination of the coefficients for the BASSS algorithm or in PSINCA.

3.4 Total Integrated Radial Peaking Factor

The total integrated radial peaking factor (F_R^T) input to the BASSS algorithm is the higher of the total integrated radial peaking factor Technical Specification's limit (Section 3.2.3) or the measured value of F_R^T. Updates on measured values of F_R^T are available at intervals specified in surveillance requirements of the F_R^T Technical Specification (Section 4.2.3.2). The uncertainty on F_R^T is included in the determination of the coefficients for the BASSS algorithm.

3.5 Uncertainties

All applicable uncertainties and biases are included in either the BASSS algorithm or the PSINCA code with the exception of the measurement uncertainty on CEA position. The measurement uncertainty on CEA position is applied to the input value of CEA position used in the BASSS algorithm. The other applicable uncertainties are:

1) Temperature measurement
2) Flow measurement
3) Power measurement
4) Pressure measurement
5) Integrated Radial Peaking Factor measurement
6) Axial Shape Index measurement

4.0 Functional Description of PSINCA

4.1 Introduction

The computer code PSINCA has been developed to perform two tasks using the online computer. The first task is the calculation of the core average axial shape index based on the incore detector signals and the insertion of the first regulating bank. The second task is the evaluation of the allowable power level of the core based on the core average axial shape index, the amount of insertion of the first regulating bank, and the total integrated radial peaking factor. The allowable power level is calculated at two minute intervals.

4.2 PSINCA

Figure 1 displays a flow diagram of the computer code PSINCA. The following sections describe the algorithms used to calculate IASI and BLIM.

4.2.1 Core Average Axial Shape Index Calculation

The core average axial shape index (IASI) is calculated using the incore detector signals and the signal to power coefficients which are also used by INCA (Reference 1). PSINCA performs this calculation by first folding the entire core's complement of detectors into one octant.

Figure 2 displays an octant representation of the distribution of incore detectors in the Calvert Cliffs Unit 1 and Unit 2 reactors. Each of the nonredundant locations is coupled to its nearest redundantly instrumented neighbor as shown in Figure 3.

If a nonredundant detector fails, PSINCA can provide a replacement signal for this detector using the signal from the nearest redundantly instrumented neighbor and the appropriate coupling coefficient. This technique is analogous to that used in INCA. PSINCA will abort only if a non-redundant detector and the entire set of redundant detectors which supply its replacement signal fail at a given level. In this situation, the DNB-LCO will be monitored with the ex-core DNB Axial Flux Offset Control Limits.

Only instrumented assemblies are used to calculate the core average axial shape index. A bias exists between the actual core average axial shape index and the shape index calculated by PSINCA. This bias is identified for each reload cycle using the computer code ROCS (Reference 2).

PSINCA evaluates IASI in the following manner:

1. All instrument signals are converted to equivalent powers over the length of the detector segment.
2. The full complement of powers is averaged into one set of octant powers.
3. A replacement power is substituted for any missing nonredundant powers.
4. All instrument powers are averaged at each of 4 detector levels (P1, P2, P3, P4).

5. Using burnup-dependent axial coefficients from INCA (C1, C2, C3, C4), IASI is calculated from the following relation:

[ ]

where BIAS accounts for the difference between the core average axial shape index and the PSINCA calculated index using only instrumented assembly powers.

4.2.2 Allowable Power Level Calculation

The algorithm used by PSINCA to calculate the allowable power level (BLIM) uses the core average axial shape index, the amount of insertion of the first regulating bank, and the associated total integrated radial peaking factor.

PSINCA calculates BLIM in the following manner:

[

This section describes C-E proprietary methods used in calculating BLIM.

]

4.3 Example of PSINCA Monitoring System

A sample calculation based on input data from the Calvert Cliffs Unit 1 Cycle 4 setpoint evaluation provides an example of the coefficients for the BASSS algorithm. These values are listed in Table 1.

Using these values in the BASSS algorithm defined above, power alarm limits have been calculated for the following rod configurations:

1. ARO
2. Bank 5 Inserted 15%
3. Bank 5 Inserted 25%

The results of this calculation are displayed in Figure 4 which shows an improved operating margin relative to the present ex-core DNB-LCO.

5.0 Technical Specification Changes

In order to implement the BASSS on Calvert Cliffs Unit 1 and Unit 2, several modifications to Technical Specifications are required. These modifications are identified in the following five pages (pp 3/4 1-27, 3/4 2-9, 2-10, 2-13, 3/4 2-14 of the Calvert Cliffs Technical Specifications for Unit 1 and Unit 2) with parentheses.

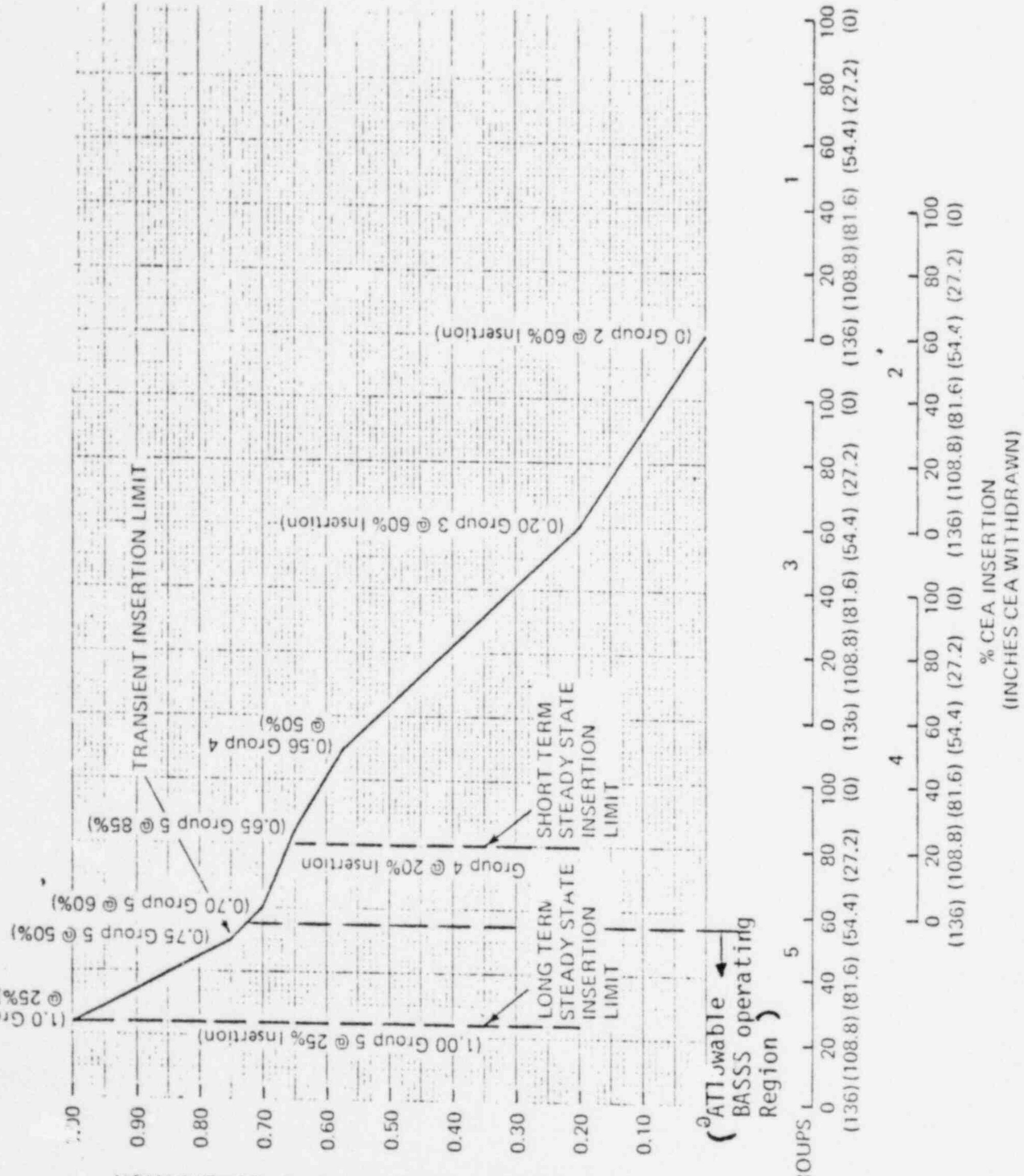


Figure 3.1-2

CEA INSERTION LIMITS VS. FRACTION OF ALLOWABLE THERMAL POWER FOR EXISTING RCP COMBINATION

DNB PARAMETERS

LIMITING CONDITION FOR OPERATION

3.2.5 The following DNB related parameters shall be maintained within the limits shown on Table 3.2-1:

a. Cold Leg Temperature

b. Pressurizer Pressure

c. Reactor Coolant System Total Flow Rate

d. (AXIAL SHAPE INDEX , Core Power)

APPLICABILITY: MODE 1.

ACTION:

With any of the above parameters exceeding its limit, restore the parameter to within its limit within 2 hours or reduce THERMAL POWER to less than 5% of RATED THERMAL POWER within the next 4 hours.

SURVEILLANCE REQUIREMENTS

4.2.5.1 Each of the parameters of Table 3.2-1 shall be verified to be within their limits at least once per 12 hours.

4.2.5.2 The Reactor Coolant System total flow rate shall be determined to be within its limit by measurement at least once per 18 months.

TABLE 3.2-1

DNB PARAMETERS

Parameter	LIMITS Four Reactor Coolant Pumps Operating	Three Reactor Coolant Pumps Operating	Two Reactor Coolant Pumps Operating-Same Loop	Two Reactor Coolant Pumps Operating-Opposite Loop
Cold Leg Temperature	≤ 548°F	**	**	**
Pressurizer Pressure	≥ 2225 psia*	**	**	**
Reactor Coolant System Total Flow Rate	≥ 370,000 gpm	**	**	**
(AXIAL SHAPE INDEX, Core Power)	(***)	**	**	**

*Limit not applicable during either a THERMAL POWER ramp increase in excess of 5% of RATED THERMAL POWER per minute or a THERMAL POWER step increase of greater than 10% of RATED THERMAL POWER.

**These values left blank pending NRC approval of ECCS analyses for operation with less than four reactor coolant pumps operating.

(*** The AXIAL SHAPE INDEX,Core Power shall be maintained within the limits established by the Better Axial Shape Selection System (BASSS) for CEA insertions of the lead bank of ≤55% when BASSS is operable, or within the limits of FIGURE 3.2-4 for CEA insertions specified by FIGURE 3.1-2.)

TOTAL INTEGRATED RADIAL PEAKING FACTOR - F_r^T

LIMITING CONDITION FOR OPERATION

3.2.3 The calculated value of F_r^T, defined as $F_r^T = F_r(1+T_q)$, shall be limited to $\leq$ 1.54.

APPLICABILITY: MODE 1*.

ACTION:

With F_r^T > 1.54, within 6 hours either:

a. Be in at least HOT STANDBY, or

(b. Reduce THERMAL POWER to bring the combination of THERMAL POWER and F_r^T to within the limits of Figure 3.2-3, withdraw the full length CEAs to or beyond the Long Term Steady State Insertion Limits of Specification 3.1.3.6, and insert new value of F_r^T in BASSS; or

c. Reduce THERMAL POWER to bring the combination of THERMAL POWER and F_r^T to within the limits of Figure 3.2-3 and withdraw the full length CEAs to or beyond the Long Term Steady State Insertion Limits of Specification 3.1.3.6. The THERMAL POWER limit determined from Figure 3.2-3 shall then be used to establish a revised upper THERMAL POWER level limit on Figure 3.2-4 and subsequent operation shall be maintained within the reduced acceptable operation region of Figure 3.2-4.)

* See Special Test Exception 3.10.2.

4.2.3.1 The provisions of Specification 4.0.4 are not applicable.

4.2.3.2 F_r^T shall be calculated by the expression $F_r^T = F_r(1+T_q)$ and F_r^T shall be determined to be within its limit at the following intervals:

a. Prior to operation about 70 percent of RATED THERMAL POWER after each fuel loading.

b. At least once per 31 days of accumulated operation in MODE 1, and

c. Within four hours if the AZIMUTHAL POWER TILT (T_q) is > 0.030.

4.2.3.3 F_r shall be determined each time a calculation of F_r^T is required by using the in-core detectors to obtain a power distribution map with all full length CEAs at or above the Long Term Steady State Insertion Limit for the existing Reactor Coolant Pump combination.

4.2.3.4 T_q shall be determined each time a calculation of F_r^T is required and the value of T_q used to determine F_r^T shall be the measured value of T_q.

6.0 References

1. "INCA, Method of Analyzing In-Core Detector Data in Power Reactors", CENPD-145-P, April, 1975

2. BG&E Application for Cycle 4 Reload, A. E. Lundvall (BG&E) to R. W. Reid (NRC), February 23, 1979

TABLE 1

Typical BASSS Coefficients for Calvert Cliffs I and II

A_1 = 99.0	SA_1 = -3.1
A_2 = -.04	SA_2 = 0.00
A_3 = .00040	SA_3 = 0.00
A_4 = -.00008	SA_4 = -3.1
XM_1 = 99.0	SM_1 = -0.35
XM_2 = -.04	SM_2 = 0.00
XM_3 = .00040	SM_3 = 0.00
XM_4 = -.00008	SM_4 = 1.28
B_1 = 99.0	SB_1 = 1.02425
B_2 = -0.04000	SB_2 = 1.03400
B_3 = 0.00040	SB_3 = 1.03400
B_4 = -0.00008	SB_4 = 0.90200
R_0 = 2.100	$IASI_1$ = -0.05
R_1 = -.647	$IASI_2$ = 0.00
BIAS = +0.004	$IASI_3$ = 0.20
F_R^T = 1.70	

Figure 1
FLOW DIAGRAM OF PSINCA

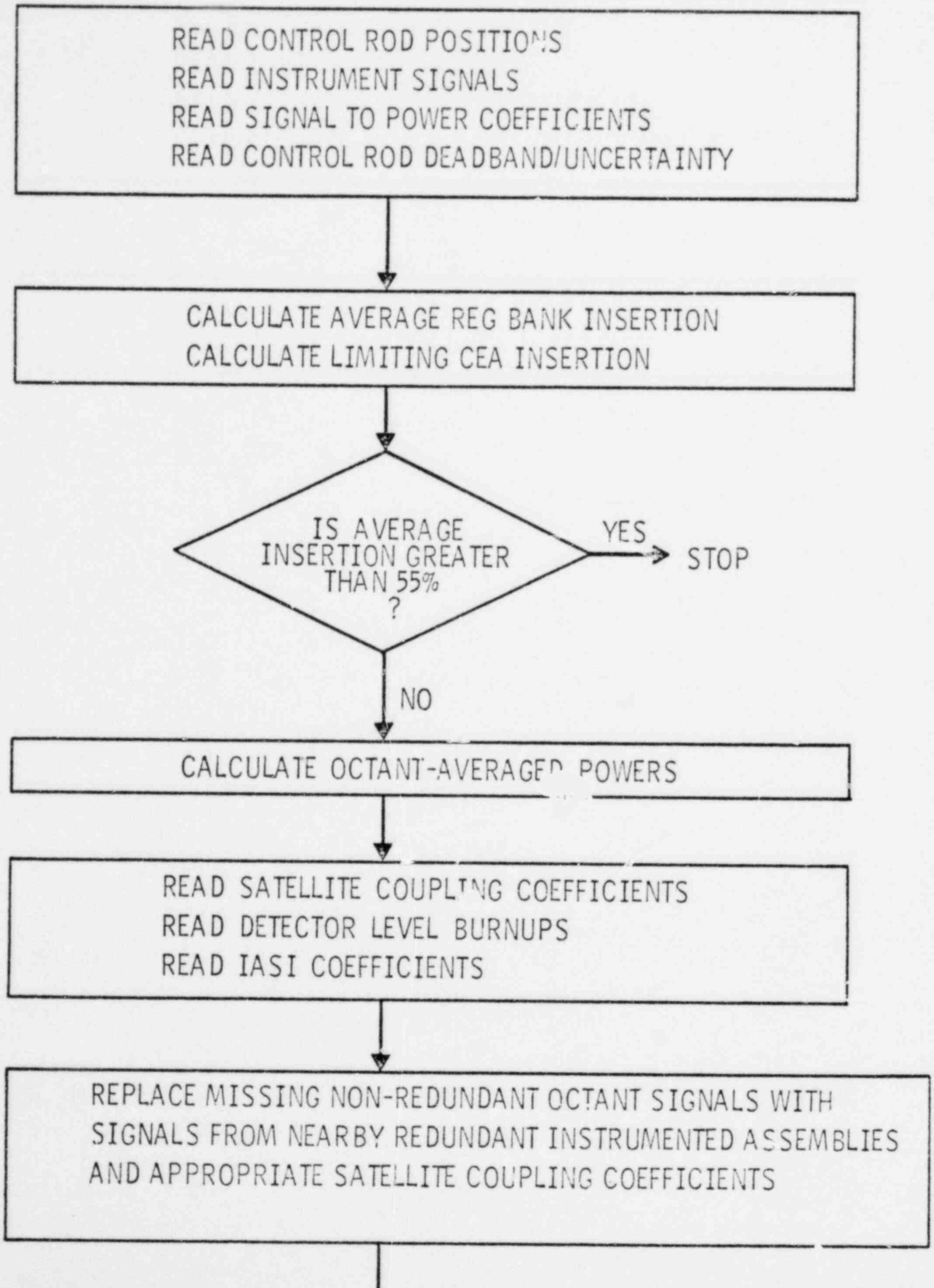
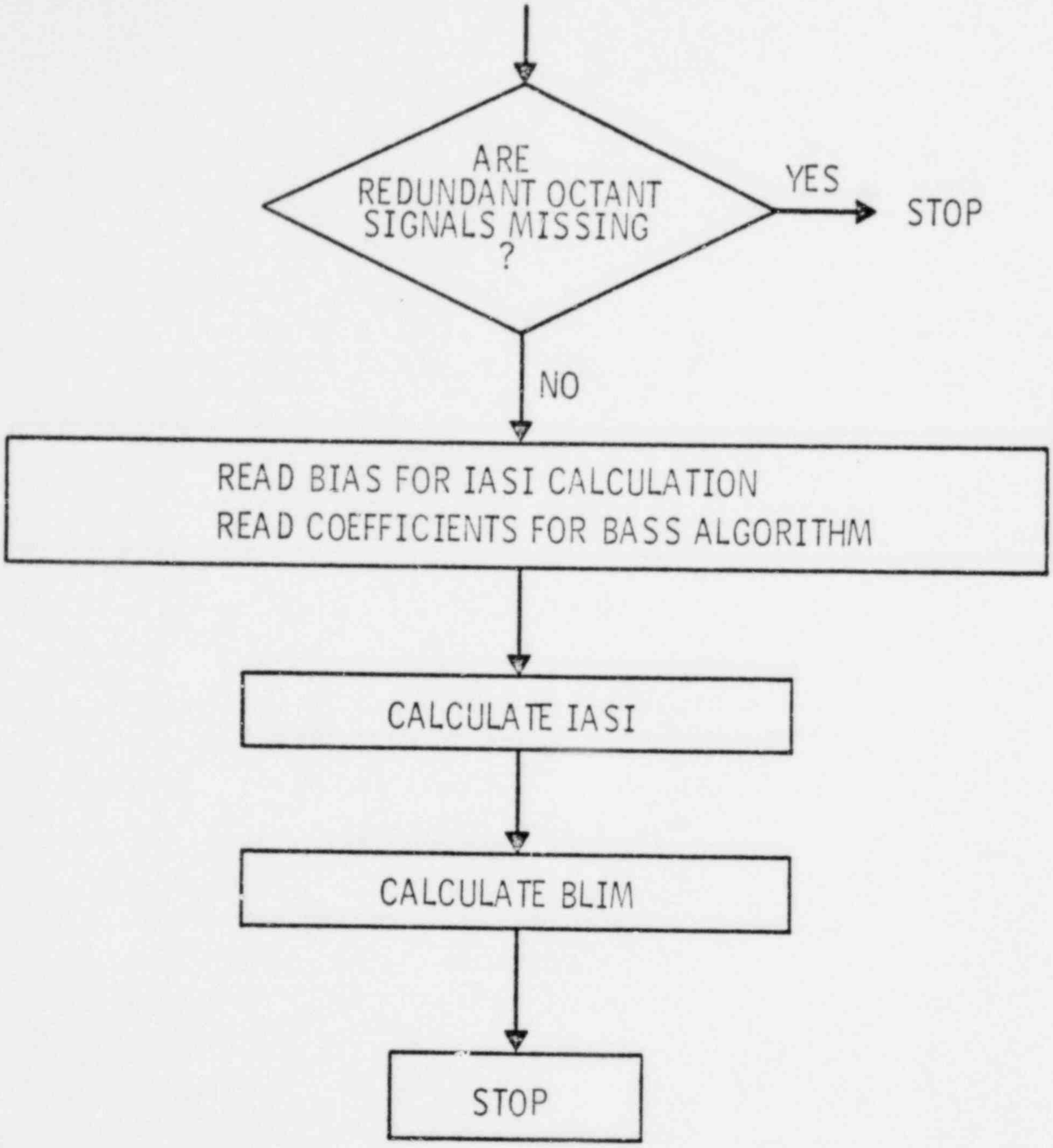
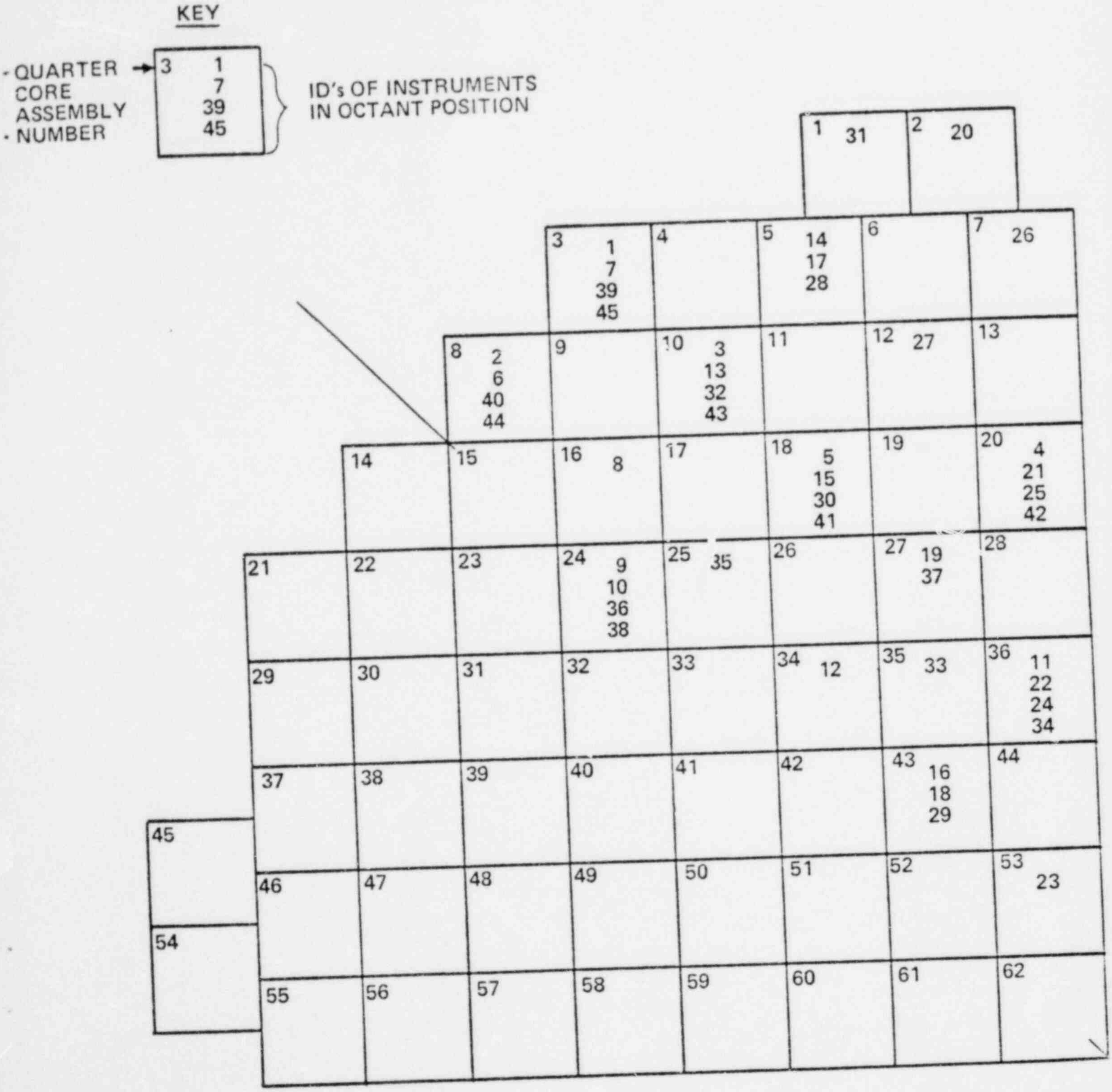
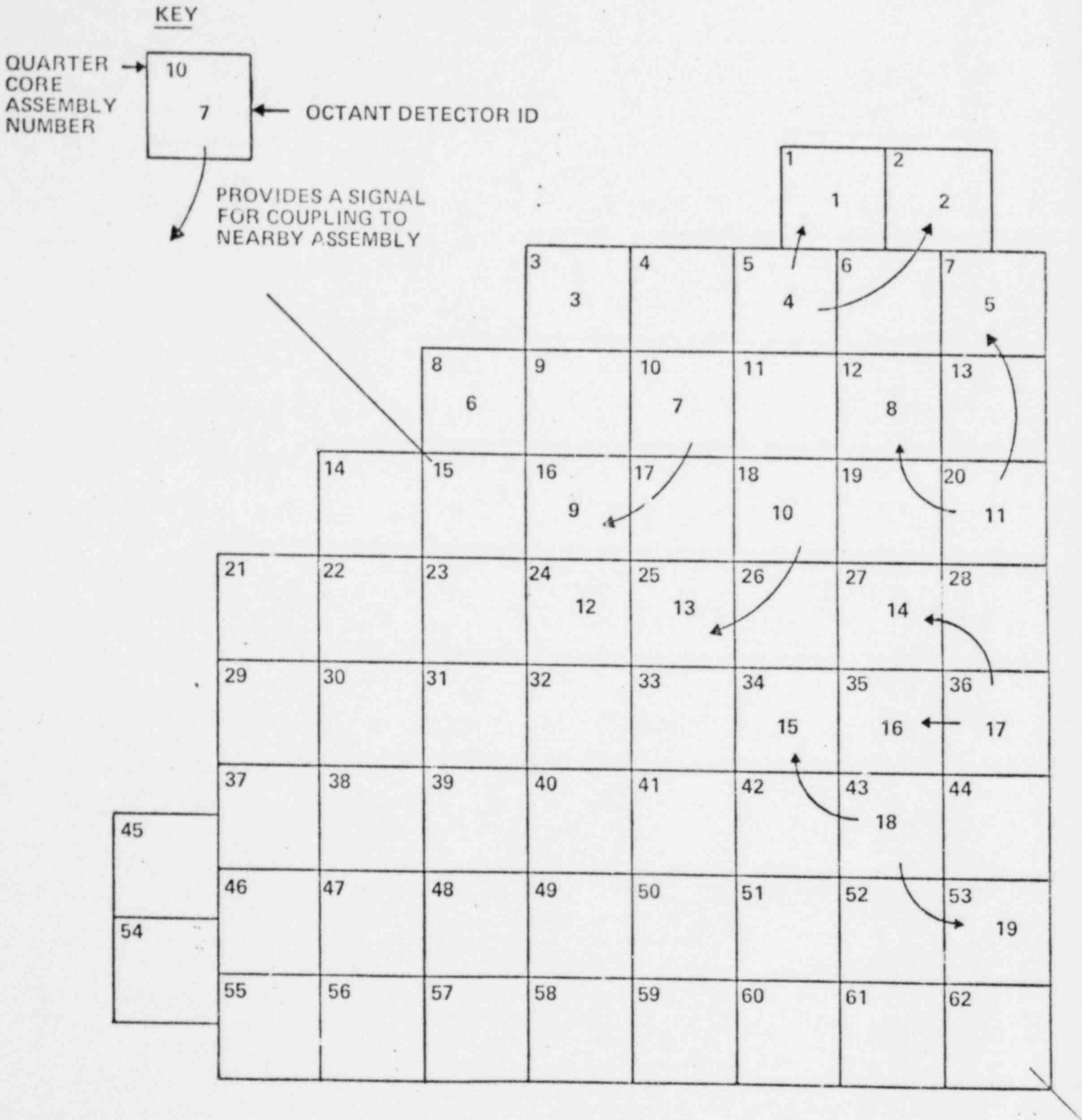


Figure 1 (Cont'd)

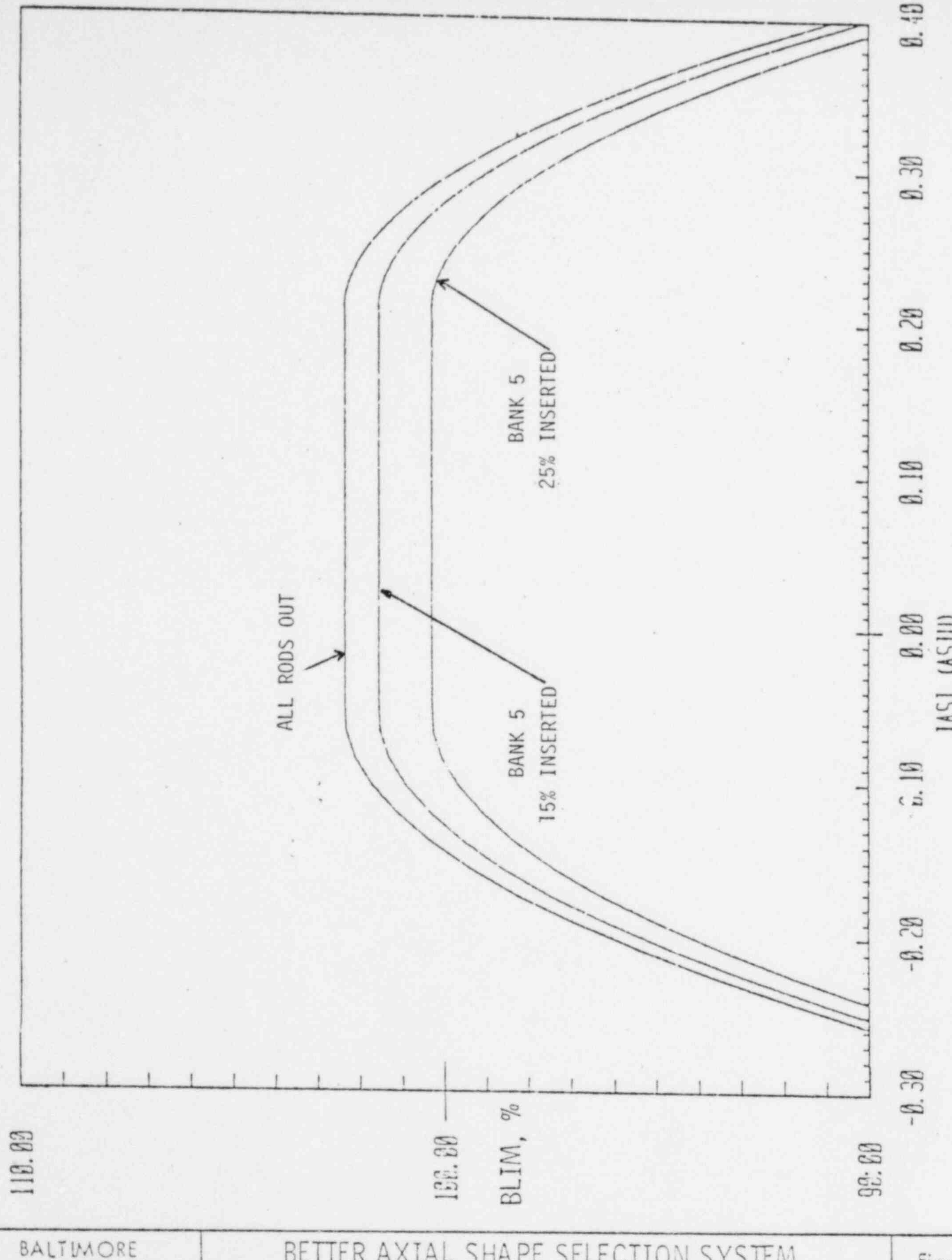




BALTIMORE GAS & ELECTRIC CO. Calvert Cliffs Nuclear Power Plant	OCTANT REPRESENTATION OF INCORE DETECTORS IN ENTIRE CORE	Figure 2



BALTIMORE GAS & ELECTRIC CO. Calvert Cliffs Nuclear Power Plant	NON-REDUNDANT DETECTOR COUPLING PATTERN	Figure 3



BALTIMORE GAS & ELECTRIC CO. Calvert Cliffs Nuclear Power Plant	BETTER AXIAL SHAPE SELECTION SYSTEM FOR CALVERT CLIFFS 1 CYCLE 4	Figure 4