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REGIONAL OVERPOWER PROTECTION SYSTEM ANALYSIS FOR A DUPIC FUEL CANDU CORE

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본 보고서를 2003년도 ″건식재가공핵연료 노심특성평가 기술개발″“과제의 기술보고서로 제출합니다.

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REGIONAL OVERPOWER PROTECTION SYSTEM ANALYSIS FOR A DUPIC FUEL CANDU CORE

ABSTRACT

The regional overpower protection (ROP) system was assessed a CANDU 6 reactor with the DUPIC fuel, including the validation of the WIMS/RFSP/ROVER-F code system used for the estimation of ROP trip setpoint. The validation calculation has shown that it is valid to use the WIMS/RFSP/ROVER-F code system for ROP system analysis of the CANDU 6 core. For the DUPIC core, the ROP trip setpoint was estimated to be 125.7%, which is almost the same as that of the standard natural uranium core. This study has shown that the DUPIC fuel does not hurt the current ROP trip setpoint designed for the natural uranium CANDU 6 reactor.

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1. INTRODUCTION

In CANDU reactors, the Regional Overpower Protection Trip (ROPT) system protects the reactor against overpowers in the reactor, which would be due to the local power or the reactor power level increases. The design requirements of the ROPT system, which have been established for the natural uranium CANDU 6 reactor, are summarized in Ref. 1. In the CANDU core there are two ROPT systems - one for each of the two fast-acting shutdown systems (SDS's). Each ROPT system consists of a number of fast-responding self-powered flux detectors, suitably distributed throughout the core within vertical or horizontal assemblies. The SDS1 ROPT detectors are located in some of the 26 vertical assemblies, which are shared with other flux detectors used for reactivity control and flux mapping. The SDS2 ROPT detectors are located in seven horizontal assemblies. Each ROPT detector has a pre-set trip setpoint and each SDS is connected to three logic channels. The reactor trip occurs when two channels out of three are tripped (see Figs. 1.1 and 1.2). Figures 1.3 and 1.4 show the SDS1 and SDS2 detector locations, respectively.

The ROPT system has detectors, which are distributed throughout the core to ensure the coverage of the local flux and power peaks that could arise due to normal maneuvering or abnormal combinations of reactivity devices. The design of the ROPT system is essentially a choice of a set of detector locations that could provide the overpower protection for a pre-defined "design-basis" set of flux shapes (device configurations), while maximizing operating margins of detectors for more common operating conditions.

The design and operation parameters of the ROPT systems are subject to errors and uncertainties, which are detector random, channel random, common random uncertainties and bias. To ensure the safe operation of the ROPT system, appropriate allowance must be made for the expected errors. This is done by a probabilistic assessment of the ROPT system, in which the setpoint level is determined to ensure, despite the error, a 98% probability of tripping prior to the critical channel power being exceeded for any of the design-basis flux shapes. This trip probability assessment is done on a 2-out-of-2 basis - assuming (for each SDS) the logic that the channel most likely to trip is unavailable.

This report describes the probabilistic assessment of the ROPT system for the CANDU 6 reactor with the DUPIC fuel. In Sec. 2, the ROP analysis methodology is described. The computer code system used for the DUPIC core analysis is validated in Sec. 3, and the ROP analysis results of the DUPIC core are given in Sec. 4. Finally, summary and future works are presented in Sec. 5.

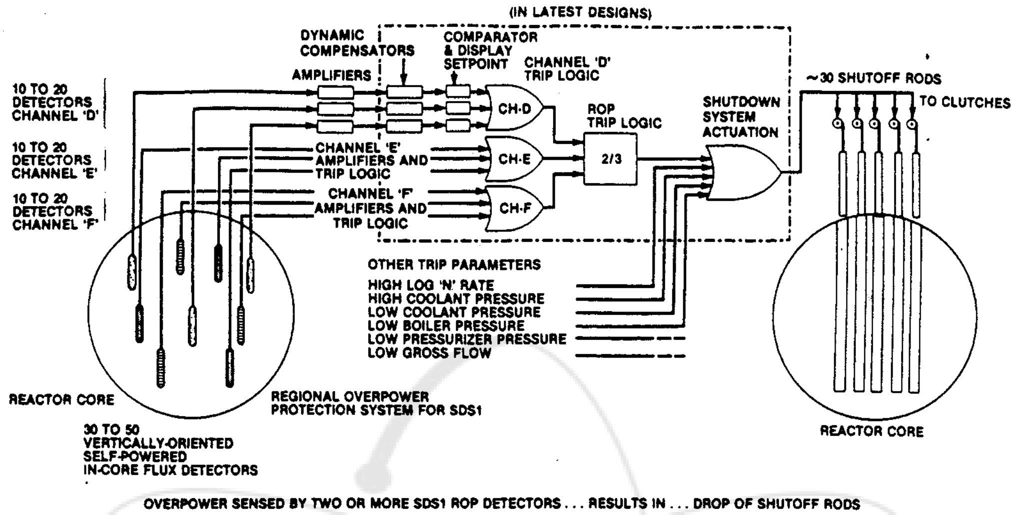

Fig. 1.1 ROP Trip Logic for Shutdown System No. 1

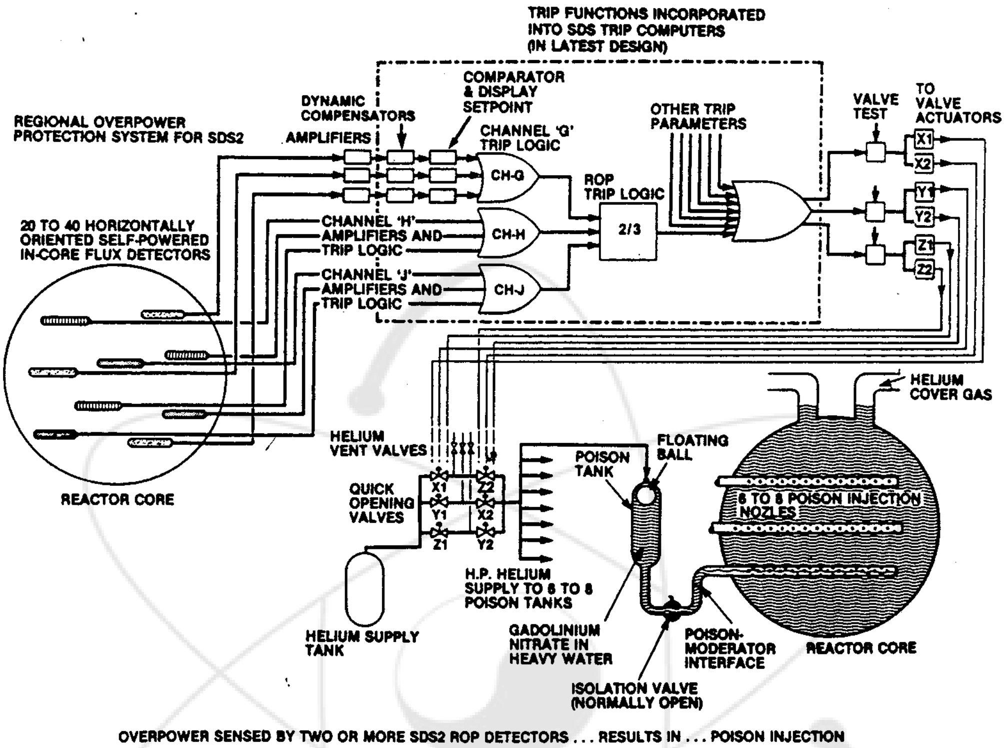

Fig. 1.2 ROP Trip Logic for Shutdown System No. 2

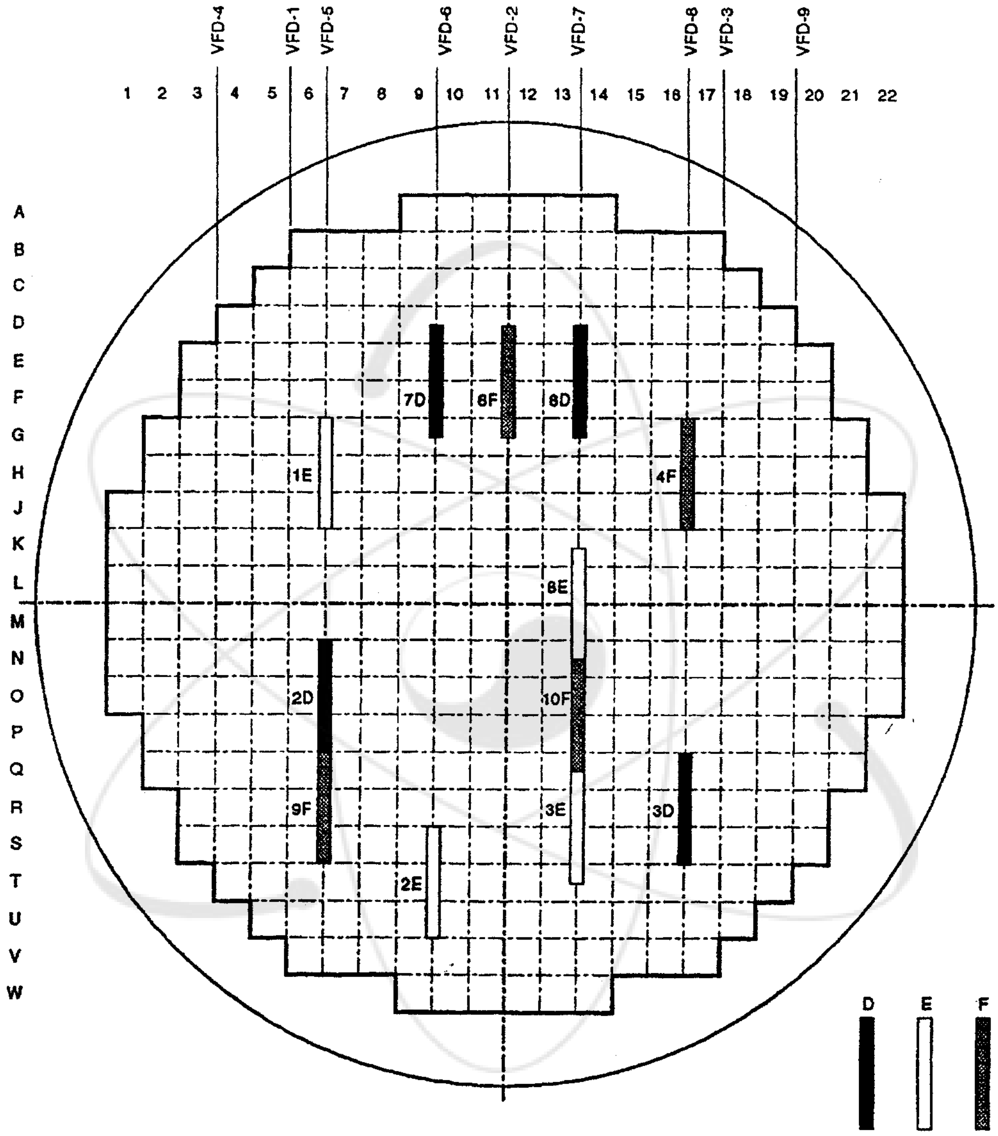

Fig. 1.3(a) SDS1 Detector Locations (Assemblies 1 to 9)

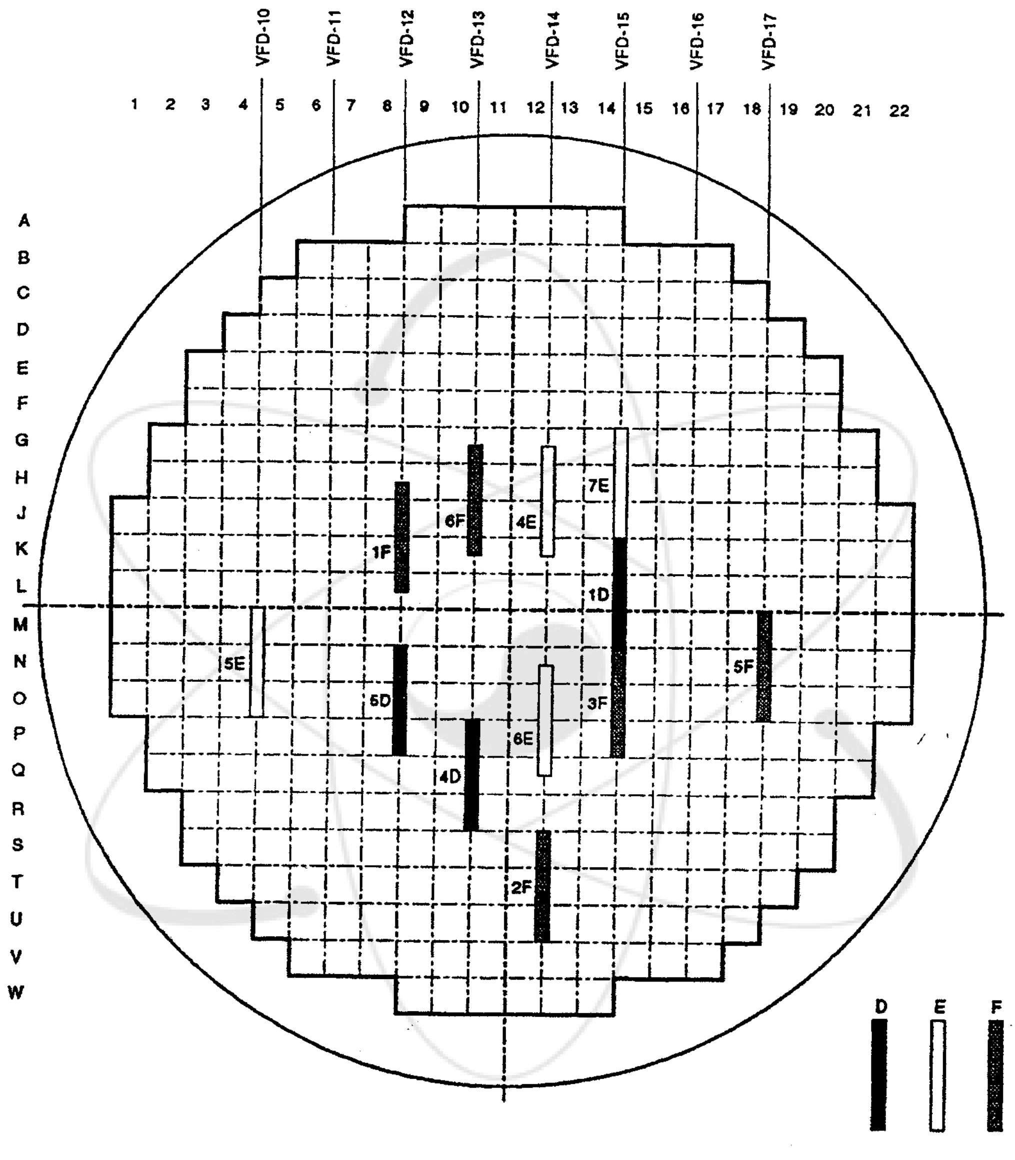

Fig. 1.3(b) SDS1 Detector Locations (Assemblies 10 to 17)

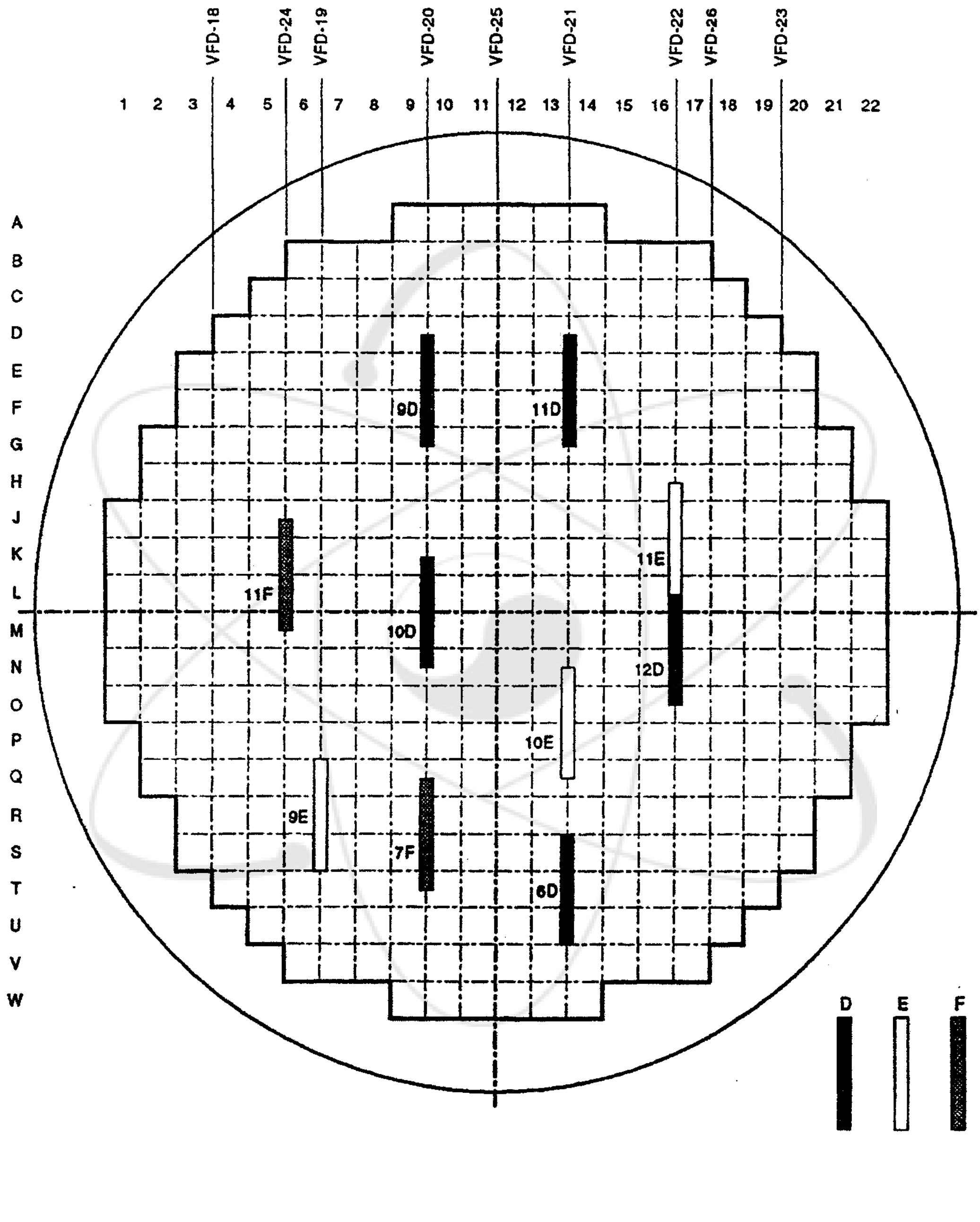

Fig. 1.3(c) SDS1 Detector Locations (Assemblies 18 to 26)

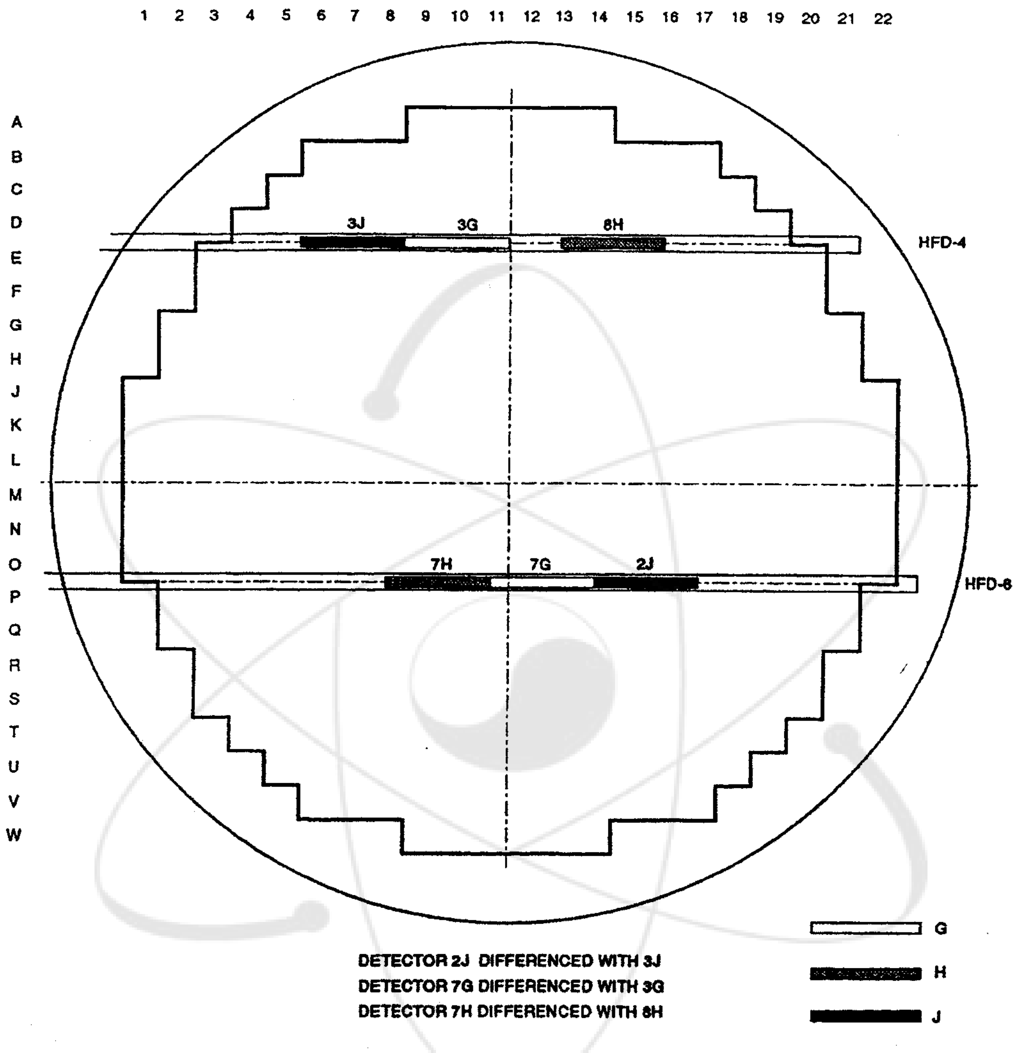

Fig. 1.4(a) SDS2 Detector Locations (Assemblies HFD-4 and 8)

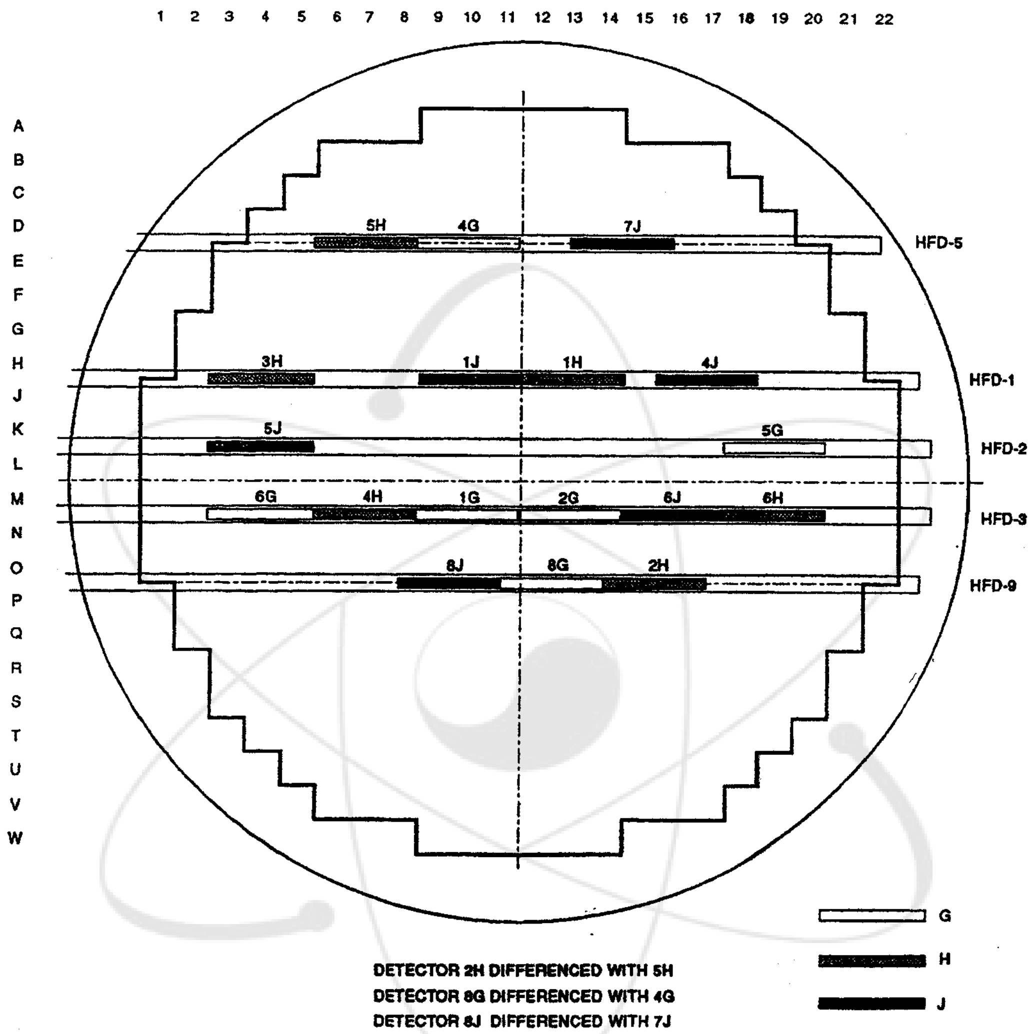

Fig. 1.4(b) SDS2 Detector Locations (Assemblies HFD-5 and 9)

2. ROPT ANALYSIS METHODOLOGY

The detailed analysis methods, assumptions and data intended to be used in the ROPT assessment are described in Ref. 2. In this section, the basic analysis methods are summarized.

2.1 Protection Equation

2.1.1 Basic Equation

a) In design and operation of the ROPT systems, the flux and power changes that occur in the reactor are separated into two components:
   - ripple, which is the variation in the core power distribution due to fueling and burnup; and
   - flux-shapes, which are the variation of flux and power from the nominal due to a perturbation in the device configuration (including zone controller water movements) or xenon changes.

b) The basic ROPT protection requirement is: for any flux-shape k and ripple q, the reactor shall be tripped (on all three safety channels) before any coolant channel reaches its critical channel power. That is, the ROPT systems shall have detector locations, channelizations and trip setpoints (TSP) such that for every design-basis flux-shape k, there is at least one detector j_p (the "protecting" detector) in each safety channel i, which can be written as,

$$TSP(j_p) \leq \Phi^T(j_p, k, q) \tag{1}$$

where $$\Phi^T(j,k,q) = D_o(j)\frac{\phi(j,k,q)}{\phi_o(j,q)} * r_{CPRL}(k,q) \tag{2}$$

and
- TSP is the trip setpoint for detector j,
- D_o is the detector's initial calibration at 100% full power (FP)
- Φ^T is the required trip setpoint for detector j_p if it is to protect flux-shape k with ripple q,
- ϕ is the flux at detector j for flux shape k and ripple q,
- ϕ_o is the nominal flux at detector j at 100% power FP ripple q,

r_{CPRL} is the minimum critical power ratio (CPR) for flux shape k and ripple q, that is the minimum value (over the 380 fuel channels) of the ratio of the channel critical channel power (CCP) to the actual channel power (CP).

That is, r_{CPRL} (k,q) $= \underset{m}{\text{Min}} \left[\frac{CCP(m,k)}{CP(m,k,q)} \right]$, (3)

where, m is the channel index.

2.1.2 Modification and Corrections

In practice, a number of modifications are made to these basic equations for took consider the calculation uncertainties and operating conditions.

a) Allowance for uncertainties

The final level of setpoints for the ROPT designs are determined by a trip probability calculation for each of the design-basis flux-shapes. In this calculation, the TSP's are in effect reduced to provide an implicit margin for errors and uncertainties (EAF), for each case, sufficient to ensure 98% 2-out-of-2 trip probability on all design-basis cases.

b) Superposition

A basic ROPT assumption is that the flux and power changes due to the device configuration are independent of the flux and power ripple: that is

$$\frac{\phi(j,k,q')}{\phi_o(j,q')} = \frac{\phi(j,k,q'')}{\phi_o(j,q'')} = \frac{\phi(j,k,TA)}{\phi_o(j,TA)} = \frac{\phi'(j,k)}{\phi_o'(j)} \quad (4a)$$

$$\frac{CP(m,k,q')}{CP_o(m,q')} = \frac{CP(m,k,q'')}{CP_o(m,q'')} = \frac{CP(m,k,TA)}{CP_o(m,TA)} = \frac{CP'(m,k,)}{CP_o'(m)} \quad (4b)$$

where q′ and q″ are particular ripples or times, TA is the time-average simulations used for the ROPT design, and ϕ' and CP′ are the general form of the flux and channel power, respectively, which are independent of q.

c) Reference powers

The CP terms in Eq. (3) can conveniently be separated into terms which measure the change due to the ripple and flux-shape:

$$CP(m,k,q) = CP_o(m,q) * \frac{CP'(m,k)}{CP_o(m)} \quad \text{(from 4b)}$$

$$= CP_{ref}(m) * \underbrace{\frac{CP_o(m,q)}{CP_{ref}(m)}}_{\text{due to ripple}} * \underbrace{\frac{CP'(m,k)}{CP'_o(m)}}_{\text{due to device perturbation}} \quad (4c)$$

where CP_{ref} is the reference power distribution. It could be the time-average nominal power, or any arbitrary set of channel powers. The process that changes the initial time-average nominal power (CP_{o-TA}) to CP_{ref} is called "Reforming".

d) Nominal CPR Limit (Reformed Nominal)

The r_{CPRL} (in Eq. (2)) is the limiting CPR for the flux-shape in a specific rippled power distribution q. It is also possible to define a limiting CPR for that case in the time-average CP distribution (as reformed to the CP_{ref}).

$$CPR_L(k) \equiv \min_m \left[\frac{CCP(m,k)}{CP'(m,k) * \frac{CP_{ref}(m)}{CP_o(m)}} \right] \quad (5)$$

This is the more usual definition of the limiting CPR at the design stage, when analyses are done with time-average values. Note that the second quantity in the denominator of Eq. (5) is the "Reform" factor for channel m.

e) Calibration and CPPF

i) If the ROPT detectors are calibrated to each ripple, i.e., to read 100% FP, then the calibration automatically divides out the rippled nominal flux distribution $\phi_o(j,q)$. In response to a device perturbation k, the detectors will then read $D_o[\phi'(j,k)/\phi_{o(j)}]$.

ii) Operational

This can be taken one step further by allowing for the maximum channel power ripple (CP_0/CP_{ref} in Eq. (4c)) in the detector calibrations. That is, for any ripple q, the ROPT detectors are all calibrated to a ripple factor called the Channel Power Peaking Factor (CPPF) - i.e., after calibration, all detectors will read the CPPF (at 100% FP) (D_o= CPPF on all detectors). The CPPF is defined as the maximum ratio of CP_0 to CP_{ref} over a specified potentially-limiting central-core region ('CPPF region').

$$CPPF(q) = \underset{m}{Max}\left[\frac{CP_o(m,q)}{CP_{ref}(m)}\right]_{CPPF\ Region} \quad (6)$$

The CPPF region is shown in Fig. 2.1. Limiting the CPPF to this central-region is necessary so that high ripples in peripheral channels will not unnecessarily penalize operating ROPT margins. The CPR's are much higher for the peripheral channels.

iii) Ripple Conservatism

Combining Eqs. (4c) and (6), the r_{CPRL} in equation Eq. (3) can be replaced as follows:

$$r_{CPRL}(k,q) = \underset{m}{Min}\left[\frac{CCP(m,k)}{CP(m,k,q)}\right] = \underset{m}{Min}\left[\frac{CCP(m,k)}{CP_{ref}(m) * \frac{CP_o(m,q)}{CP_{ref}(m)} * \frac{CP'(mk)}{CP'_o(m)}}\right] \quad (7a)$$

$$= \underset{m}{Min}\left[\frac{CCP(m,k)}{CP'(m,k) * \frac{CP_{ref}(m)}{CP'_o(m)}} / \frac{CP_o(m,q)}{CP_{ref}(m)}\right] \quad (7b)$$

This quantity looks like the CPR_L (Eq. (5)) divided by CPPF (Eq. (6)). However, the effect of the Min(m) must first be considered. In general, the channel m that is limiting in equation (7a) (i.e., in the rippled perturbed flux-shape) will not be the same as the channels that are limiting in Eqs. (5) and (6) (limiting CPR in time-average and limiting ripple, respectively). The effect of this difference in limiting channel location is non-trivial; the use of the limiting ripple (CPPF) combined with the limiting time-average CPR results in a significant conservatism relative to the limiting CPR, which is actually applied to the flux-shape/ripple combination. This conservatism is typically 4 to 5%. Hence, a quantity called the "ripple conservatism" (R_c) is defined, which accounts for the conservatism of the critical power ratio.

$$R_c(k,q) \equiv \frac{CPPF(q) * r_{CPRL}(k,q)}{CPR_L(k)} \quad (8)$$

In the ROPT probabilistic assessment the ripple conservation is assessed using representative set of ripples. The Eq. (8) allows Eq. (7b) to be taken out of the brackets, giving:

$$r_{CPRL}(k,q) = \underset{m}{\text{Min}}\left[\frac{CCP(m,k)}{CP(m,k,q)}\right] = \frac{R_c(k,q)\cdot CPR_L(k)}{CPPF(q)} \tag{7c}$$

iv) In practice, the ROPT detectors may be calibrated at powers other than 100% FP, e.g., at a rated power (RPc). The detectors are then calibrated to each reading D_c at that power level, where D_c = CPPF * RP_c. The detectors will then read the CPPF when the reactor power returns to 100% (assuming the linearity of the detector signal with reactor power). D_c may also incorporate other operating corrections.

f) Operating Corrections (CCPs)

The initially calculated CCPs are subject to several potential sources of variations. These are taken into account as follows:

i) CCP boundary-conditions correction $F_{TP}(k)$: The CCPs are calculated for reference thermo-hydraulic boundary conditions ($\triangle P_{HH}$, T_{RIH} and P_{ROH}) that are based on 100% FP values. However, for most flux-shapes, the reactor does not trip at 100% and the header conditions will differ. This correction factor accounts for the CCP change due to changes in $\triangle P_{HH}$ and T_{RIH} at the reactor power at which a case would (on average) reach the limiting CCP (reduced for errors). Since setpoints are not initially known, it is both convenient and conservative to evaluate this at the reactor power corresponding to the limiting CPR for that case, allowing for the average CPPF and error allowance EAF (i.e., critical power, not trip power). An uncertainty term accounts for the effect of variations in this critical power for the case.

ii) Changes in $\triangle P_{HH}$, P_{ROH} and T_{PIH} with time: The ptimary heat transport (PHT) boundary conditions ($\triangle P_{HH}$, P_{ROH} and T_{PIH}) are checked at regular intervals. The CCP effect of any changes are accounted for simply as an operational correction to the detector calibration D_C.

iii) CCP correction for each channel

Several types of CCP corrections (if and when present) will vary from channel t o channel. These include:

- Correction for NUCIRC [Ref. 3] systematic flow errors. These may vary with

feeder geometry, orificing, location on headers, etc.
- Operating corrections for changes in fuel type, or fuel bundles with excess mass [4]
- CCP corrections for pressure tube diametrical creep (if variable radially)

The channel-variable CCP corrections, available when the ROPT design analysis is done are incorporated directly into the analysis as correction factor F_{CH} (m). However, some channel-variable CCP corrections will only arise subsequently, while the reactor is operating. These are then accounted for as a correction to the CP_{ref}'s in the CPPF calculation. That is, the definition of the CPPF is revised as follows:

$$CPPF(q) = \underset{m}{Max}\left[\frac{CP_o(m,q)}{CP_{ref}(m) * F_{CR}(m)}\right], \quad (9)$$

where $F_{CR}(m)$ is the correction factor for those channel-related CCP corrections not included in F_{CH} (m) (or F_{TP} or D_C).

g) Flux-shape Correction for Coolant Boiling

In the flux-shape simulations, the effect of coolant boiling on the flux and power distribution was ignored in the core modelling. At the powers of the cases usual operating cases, the effect of boiling is small, and this simplifying assumption causes little error. However, at the powers at which the ROPT cases are likely to trip (e.g., 110 to 115% FP, depending on the case and ripple), there is more boiling, and it begins to have a measurable effect on the detector flux readings. This was analyzed in Ref. 3, for the nominal case trip at 120% FP (an upper limit to the likely range of trip powers). The resulting flux changes due to boiling were found to be generally negative for ROP setpoint (except at the ends of the reactor), strongly correlated with a detector's axial location within core, but fairly constant at a given axial location (i.e., along a given detector assembly a_j).

Hence, the flux changes due to coolant boiling at trip power are implemented as an assembly-related correction factor, F_B (a_j). This correction is assumed to be independent of the flux-shape based on the following logic:
- The limiting (central-core) CCPs are fairly similar for all flux-shapes (the maximum difference is 5-6%); hence, at the trip power, the limiting channels for any flux-shape will be at a trip power, and have a degree of boiling, comparable to the nominal case analyzed. Other channels may have less, but the limiting channels will have a similar

degree of boiling.

- Then, conservatively, it is assumed that the protecting detectors for this flux-shape are located in the region of the peak-power channels, and will therefore see a similar degree of boiling-related flux change.

h) Dynamic Compensation

The signal from the ROPT detectors is subject to various dynamic delays, and is compensated electronically to ensure that the detector signal seen equals or exceeds the fuel power during any transient. The compensated signal ratio can be designated C(t).

i) Setpoint Handswitch Positions

To ensure that the ROPT coverage is maintained during various abnormal operating conditions, the detectors have three different levels of setpoints which are selected by hand switches on the SDS1 and SDS2 control panels:

- Hand switch position No. 1 (HSP-1) = setpoints for normal operations
- HSP-2: setpoints for abnormal flux-shapes (device configurations that are either unanalyzed, or have been found not to be covered by the HSP-1 setpoints)
- HSP-3: setpoints for symmetric one HTS pump per coolant loop operation.

2.1.3 Final Form of Protection Equation

a) Taking into account all these modifications and corrections, Eqs. (1) and (2) may thus be re-written for the protecting detectors j_p:

$$TSP(j_p) \leq D_o \frac{\left[\dfrac{\phi(j,k)}{\phi_o(j)}\right]_{prot}}{\left[\dfrac{CP(m,k)}{CP_o(m)}\right]_{Lim}} \cdot \left[\frac{CCP(m,k)}{CP_{ref}(m)}\right]_{Lim} \cdot \frac{R_c(k,q) \cdot F_B(a_j) \cdot F_{CH}(m) \cdot F_{TP}(k)}{CPPF(q)} \cdot \frac{C(t)}{EAF(k)} \qquad (10)$$

where "prot" identifies the detector(s) relied on to protect case k, and "Lim" is the CPR limiting channel. For conventional, the primes on ϕ and CP are dropped. Note that CPPF is determined using Eqs. (6) or (9), as appropriate. Note also that if D_o = CPPF (i.e., detectors calibrated to the CPPF), TSP becomes constant and independent of the actual ripple.

b) A "protecting" detector is one that satisfies the above equation. For each flux-shape, there must be at least one "protecting" detector in each trip channel (usually the one with the largest ϕ/ϕ_o). Taking into account the randomizing effects of detector-to-detector errors in calibration, simulation, setpoints, etc., the "protecting" detectors for a flux-shape are those likely to trip first in each trip channel. A "Limiting" channel is one with the minimum ratio of CCP/CP for a given flux-shape k and ripple q, which may also vary due to channel-related errors.

2.2 Probabilistic Assessment Methodology

The ROP coverage equation is so structured that independent aspects of the ROP coverage (flux shapes, CCPs, ripples) are each separately represented by a different error and uncertainty terms. The purpose of the probabilistic assessment is to evaluate the adequacy of a given ROP error allowance, or conversely to determine the error allowance needed to meet a certain confidence limit, given spevified ROP system and the expected errors and uncertainties.

The trip probability for a particular flux-shape is an average over various rippled power distributions and for the estimated errors used in the assessment. The probabilistic assessment may include a determination of a set of CP_{ref}'s that maximize the level of setpoints (probabilistic "Reform"). Once the level of setpoints has been determined for the design-basis cases, trip probabilities may also be determined for the non-design-basis cases. The detailed probabilistic assessment methodology is described in Refs. 5, 6 and 7.

2.3 ROP Design Data

2.3.1 Flux Shapes

2.3.1.1 Design-Basis Cases

The first step in the ROPT design is the choice of design basis cases (flux-shapes). The choice of cases for the design-basis set determines the coverage capabilities and characteristics of the ROPT systems during normal operations (i.e., with HSP-1 setpoints).

a) Design Goals

The design goals for the ROPT system are:

i) that the ROPT covers all normal operating device configurations, reactor conditions, and normal device configurations with the HSP-1 setpoints, without regard to:
- presence or absence of spatial control
- variations in average zone controller levels
- variations in xenon, concentration, whether local or global; and

ii) that the ROPT coverage be robust, that is, the design shall have a high probability of covering a non-design-basis device configuration (with HSP-1 setpoints).

b) Design-set Required

To achieve the above design goals, the design-basis cases should include the following categories of cases:

i) a complete set of cases with a single reactivity device withdrawn or inserted (adjusters, MCAs or zone controllers)

ii) a set of cases with partial insertions or withdrawals of devices (i.e., devices half-in or out, zone controllers drained from 50% or 20% full)

iii) all cases done with spatial control

iv) a full range of adjuster transients (shim, short startup, startup after poison-out, stepback) to ensure the range of xenon distribution is covered

v) for all other perturbations, instantaneous simulations (no xenon transients)

vi) a full set of harmonic flux tilts.

The design-basis (D/B) case-set for the CANDU 6 ROPT systems arising from these requirements is summarized in Table A.1 of Appendix. It totals 232 cases.

2.3.1.2 Flux-shape Processing

a) The thermal neutron fluxes calculated by RFSP[10] for each flux-shape must be processed to obtain the detector responses at each ROPT detector location. This processing includes:
- interpolation to obtain fluxes along assembly axes
- summation along the detector and lead-cables
- corrections for core-model differences
- division by the nominal detector flux to get (ϕ/ϕ_o).

b) Correction for Boiling

Flux-shape corrections are performed for the coolant boiling as a function of assembly number. This correction is implemented in the probabilistic assessment. [4]

2.3.2 Critical Channel Power (CCP)

2.3.2.1 Design Criterion

The design criterion for the ROPT system is the prevention of fuel dryout - specifically, the onset of intermittent dryout (OID). For a given flux-shape, this criterion translates into a set of CCPs (critical channel powers) for each channel - the channel power at which dryout (OID) is reached somewhere along the channel.

2.3.2.2 Design Calculation

The CCPs are calculated for all 232 design basis cases. The CCPs are calculated using the critical quality and boiling length (X_c-L_b) CHF correlation, which isbased on Chalk River National Laboratory (CRNL) tests for 37-element simulated fuel bundles. [8] The Wolsong-1 CCPs are corrected to the following HTS reference header boundary conditions:

T_{RIH}:	266°C
$\triangle P_{HH}$:	1342 kPa
P_{ROH}:	9.998 MPa(g)

2.3.3 Probabilistic Assessment

2.3.3.1 Applicable Errors and Uncertainties

The random and systematic errors used in the Wolsong-1 ROPT assessment are listed in Table 2.1. The detailed uncertainties are described in Ref. 4. Table 2.1 gives the ROPT errors for Wolsong-1, with the error totals in each category are:

Detector-random uncertainty:	σ_{d-r}	= ±2.60%
Channel-random uncertainty:	σ_{ch-r}	= ±1.49%
Common-random uncertainty:	σ_{com-r}	= ±4.18%
Overall bias (systematic errors):	$\bar{\varepsilon}$	= ±0.14%

2.3.3.2 Ripples

The probabilistic assessment uses a set of rippled power distributions, representative of the ripples expected in the operating reactor, to estimate the ripple conservatism found for each flux-shape and ripple. The ripples can be obtained from actual plat operating data or refueling simulation calculation.

Table 2.1 Estimated ROP Errors and Uncertainties for Wolsong-1

Source of Errors	Estimated Magnitude (%)			
	Detector Random	Channel Random	Common Random	Bias Error
1.Detector-Related Errors				
Trip Setpoint	±0.18%		±0.14%	~0
Buffer Amplifier	±0.10		±0.10	
Dynamic Compensation	±0.60			
2. Flux-Shape Errors				
Simulation Error	±1.88	±1.06	±1.07	+0.14
Change due to Boiling				-0.20
Lead-Cable Contributions	±0.20		±0.10	-0.20
Off-Nominal Core			±0.80	
3. CCP Errors				
CHF Correlation Errors			±1.70	0.66
Incomplete Instrumentation				-0.19
NUCIRC Pressure Loss Term		±0.89	±0.83	-2.20
Uncert. In HTS Bndy Conds			±2.32	
Chge in Ref. HTS Bndy Conds				4.18
HTS variations			±0.15	
Channel Age Correction		±0.15		
CCP Change		±0.10		
Normal Operating Flux Tilt				-0.20
Different Fuel Type		±0.44		
Allowance for PT Creep				-1.00
4. Calibration Errors				
CP/CPPF Calculation			±1.50	0.20
Thermal Power Calculation			±1.70	
CPPF Drift Error			±0.80	
Calibration Drift Error	±1.60			
TOTALS	±2.55%	±1.46%	±4.07%	+0.19%

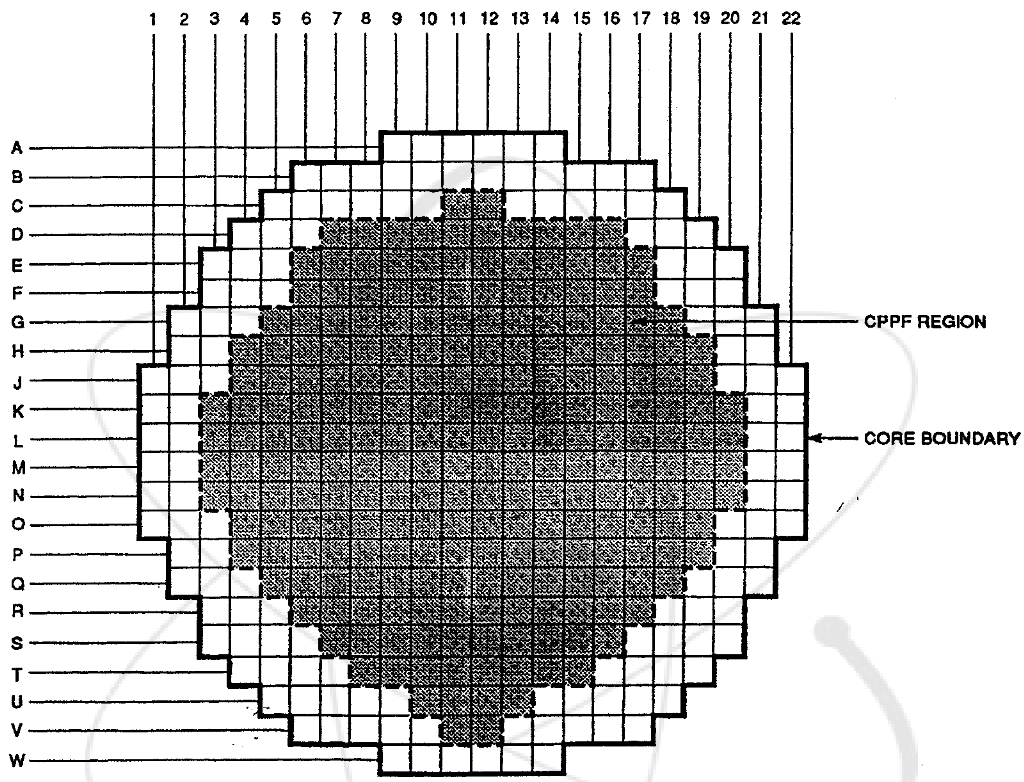

Fig. 2.1 CPPF Region

3. VALIDATION CALCULATION FOR WIMS/RFSP/ROVER-F SYSTEM

In the ROP analysis of the DUPIC core, a lattice code WIMS-AECL [Ref. 9] is used instead of POWDERPUFS-V (PPV) [Ref. 10], which is used for the standard 37-element natural uranium fuel core. This section describes the validation results of the WIMS/RFSP [Ref. 11]/ROVER-F [Ref. 12] system for ROP analysis by comparing the results with the PPV/RFSP/ROVER-F calculation. The validation calculations are performed for the standard 37-element natural uranium core. Probabilistic assessment of ROPT system for the CANDU reactor with DUPIC fuel has been performed. In this study, 26 limiting cases were chosen based on the results of the Ref. 13. The cross-sections were produced by WIMS-AECL and PPV separately, and the flux shape and detector response were generated by RFSP, critical channel powers (CCPs) were calculated by NUCIRC (Version 1.505), and finally ROVER-F was used to estimate the ROP trip setpoint.

3.1. Calculation Procedure

3.1.1 RFSP Physics Calculations

The RFSP physics calculations are performed to obtain flux shapes and channel powers. The bundle powers are used for CCP calculations. The physics calculations are performed for 26 limiting design basis cases [13], which are shown in Table 3.1. The thermal neutron fluxes calculated for each case are processed to obtain the detector responses at each detector location. This process is performed by INTREP module of the RFSP code.

3.1.2 CCP Calculations

The CCPs are calculated for all flux shape cases. For both fuel types, the same operating conditions were used. The detailed methodology and calculation procedure are described in Ref. 14.

3.1.3 RIPPLE Data

The ripple data presents changes of the instantaneous channel powers for the operating reactor, based on operating plant data. For this study, the ripple data of Wolsong-1 reactor, based on the operating history, were used. The ripple data consist of 150 sets obtained from 1997 to 1999. This data has an average CPPF of 1.0706.

3.2 Calculation Results and Summary

Table 3.2 presents the uncertainty data used for the probabilistic assessment. The calculation results are shown in Table A.2 and Table A.3 of Appendix for each code system. The trip setpoint based on WIMS-AECL is 122.90%, and the setpoint based on PPV is 121.77%. The difference is <1%, which is small enough to accept that the Therefore, it can be concluded that the WIMS/RFSP/ROVER-F system is consistent with the PPV/RFSP/ROVER-F system.

Table 3.1 Case Set for Natural Uranium Core Analysis

Case	Description
1	SSSC50 STEADY-STATE WITH S.C.
37	D14C50 ZONE DRAIN 14 FROM 50%
39	D02C80 ZONE DRAIN 02 FROM 80%
42	D05C80 ZONE DRAIN 05 FROM 80%
44	D07C80 ZONE DRAIN 07 FROM 80%
46	D09C80 ZONE DRAIN 09 FROM 80%
49	D12C80 ZONE DRAIN 12 FROM 80%
51	D14C80 ZONE DRAIN 14 FROM 80%
53	D02N50 ZONE DRAIN 02 FROM 50%
58	D07N50 ZONE DRAIN 07 FROM 50%
60	D09N50 ZONE DRAIN 09 FROM 50%
65	D14N50 ZONE DRAIN 14 FROM 50%
114	MCAN2H MCA 1ST FI & 2ND HI
122	ZTSFSE 1ST AZIMUTHAL SIDE/SIDE
123	ZTSESF 1ST AZIMUTHAL SIDE/SIDE
130	ZT2A01 2ND AZIMUTHAL 135,315 HI
131	T2A02 2ND AZIMUTHAL 045,225 HI
152	SSSD03 BANK 7 FULL-IN/NO TIMESTEP
171	SA4403 BANK 7 FULL-IN
173	SA4405 BANK 6 FULL-IN
174	SA4406 BANK 6 FULL-IN/Xe @ 4.3 MIN
177	SA4409 BANK 4 FULL-IN
178	SA4410 BANK 4 FULL-IN/Xe @ 3.9 MIN
195	SBCK05 BANK 2 OUT/Xe @ 18.3 MIN
196	SBCK06 BANK 3 OUT
197	SBCK07 BANK 3 OUT/Xe @ 28.5 MIN
222	ABHO01 STARTUP BANK 7 HALF-IN

Table 3.2 Uncertainty Data for Natural Uranium Core Analysis

Uncertainty	Value (%)
Detector Random	2.60
Channel Random	1.49
Common Random	4.18
Bias	+0.14

4. ROPT SETPOINT ASSESSMENT FOR DUPIC CORE

This section describes the probabilistic assessment of ROPT system for the CANDU reactor with DUPIC fuel. For the ROPT assessment, 232 design base cases were considered with some exceptional cases of harmonic tilts and restart after long shutdown. The cross-sections of the DUPIC fuel were produced by WIMS-AECL (Version 2.3), and the rest of the procedure to estimate the ROP trip setpoint of the DUPIC core is the same as that of the natural uranium core.

4.1 Calculation Procedure

The physics calculations were performed for 232 design basis cases with exception of some cases; 4 cases of startup after long shutdown and 10 cases of harmonic top-to-bottom and side-to-side tilt. The ROP detector responses at each detector location were obtained from the thermal neutron fluxes calculated for each flux shape, which is performed by *INTREP module in the RFSP code. The ripples used in this assessment were obtained from 600 FPD refueling simulation. A total of 121 ripples were generated for every 5 FPDs.

4.2 ROVER-F Input Data Files

In this study, the input files of the ROVER-F are prepared based on Ref. 13. It includes an overview of the data files used for components of the ROP analysis.,

4.2.1 CASE Data

The design basis cases are the standard ROP case data set consisting of 232 cases. The case data file lists ROP cases sequentially, with identifiers, names, and pointers to the CCP, CP and DET1 files for each of the 232 cases. In this study, 4 cases of startup after long shutdown and 10 cases of harmonic tilts are not considered, but will be performed later.

4.2.2 CCP Data

The CCP data files are generated for the DUPIC core using NUCIRC code. This data set consists of 232 ROP cases for 380 channels. The CCPs are stored in Mega Watt (MW).

4.2.3 CP Data

The CP data files consists of 232 ROP cases for 380 channels. This file contains CP values calculated by RFSP code for the DUPIC core. The CP data are stored in MW too.

4.2.4 CPPF Data

The CPPF consists of the maximum ripple within the CPPF region for each ripple case. A CPPF region is chosen to exclude the outer channels that have representatively high ripples. The data file contains information on which channels comprise the CPPF region.

4.2.5 DET1 Data

The detector layout specifies the arrangement of the ROP detectors, both in logic channels and shutdown systems. It identifies the setpoints, boiling point correction factors, and response data for each detector, as well as detector failure and compensation. This data provides linkage to the logic system and the detector response data in the DET2 data file.

To re-calculate the Ref. 13 setpoint for Wolsong-1, a change must be made to the detector pointers. The Canadian CANDU plants have swapped the locations of detectors 1H and 1J, which is reflected in the detector response data. Since this has not been implemented in Wolsong-1, the pointers for detectors 1H and 1J must instead be swapped to reflect this difference. Detector 1H is pointed at detector response number 51 for each flux shape, in the set of 58 detector responses. Detector 1J is similarly pointed to response 43. All other detectors remain unchanged. The detector layout is the same as before and four plateaus are used, which is consistent with Ref. 13.

4.2.6 DET2 Data

The DET2 data file contains the ROP detector responses for each of the ROP flux shapes. Thus, data for the 58 ROP detector responses for each of the 232 ROP design basis cases are included.

4.2.7 ERR Data

The ERR data file contains the uncertainties used in the calculation of the ROP setpoint, which are described in detail in Ref. 4. The boundary conditions for the ROVER-F calculation are also set in this file, which are the widths of the bins used to sort the limiting rippled critical power ratios.

For DUPIC core analysis, the channel random uncertainty for fuel types is 0.93% [6], which increases the channel random error from 1.49% to 1.97%. The other uncertainties are same as those of Ref. 13. The boundaries of the calculation were set to 0.7 and 1.2, which are typically used in ROVER-F analysis. This is a slight change from the original TTR-289 analysis that used 1.1 as an upper boundary; however, this change provides an additional accuracy. The width of the bins remains the same as the standard 0.5%. Table 4.1 shows the uncertainty data used in this study.

4.2.8 MAP Data

The MAP data file contains data on the layout of the channels in the core for the purpose of generating printed maps. In this study, the standard layout file is used.

4.2.9 ORIF Data

The ORIF correction file contains a number of modifications to the CCP values. These modifications pertain to the orifices, the power correction factor, and the NUCIRC version correction factors. Additionally the nominal and reference ROP cases are defined in this file. For DUPIC core analysis, the correction values are the same as described in Ref. 13. The nominal and reference cases are both set to ROP case 001.

4.2.10 RIPPLE Data

The ripple data presents a description of the changes to instantaneous channel power of the operating reactor, based on the operating history of the plant. For DUPIC core analysis, the ripple data were generated from the 600-FPD refueling simulation. A set of 121 ripple cases was chosen from the refueling simulation. The average CPPF of the ripple data is 1.0681.

4.2.11 SIZE Data

The size data file sets the sizes of the data sets to be read, and the number of points used in the analysis. In the TTR-289 analysis, the number of shapes for cases, CPs, CCPs, and detector responses is 926. Only the first 232 cases are used for the DUPIC core calculation. The number of ripples is 121. The number of detectors and detector responses are 58. The number of fuel channels is 380. The number of safety channels and shutdown systems are 6 and 2, which are the standard values. The number of plateaus is 4; however, all plateaus are set to be the same as in Wolsong-1. The number of integration points is 51.

4.2.12 TASK Data

This specifies the calculation to be performed by ROVER-F and the ROP cases that are to be used for that calculation. In TTR-289 analysis, the setpoint is calculated based on ROP cases 1 to 232. The trip confidence calculation is performed for these ROP cases.

4.3 ROVER-F Calculation

Using the input data, described in Sec. 4.2, ROVER-F calculations were performed to assess the ROP system characteristics of the DUPIC core.

4.3.1 Trip Setpoint

The trip setpoint was calculated for DUPIC core. The ROVER-F calculation results of each case are shown in Appendix. The uncertainties used are shown in Table A.4 of Appendix. From this results, the trip setpoint (based on a 98% 2 out of 2 trip probability over 232 design basis cases) of the DUPIC core is 123%, which is almost the same as that of the current ROP setpoint of the natural uranium core (Wolsong-1), 122%. Therefore, it is expected that the loading of the DUPIC fuel in the CANDU-6 reactor does not affect in ROP setpoint.

4.3.2 Single Detector Failure

The trip setpoint was evaluated for the case of a single detector failure, which may change the trip setpoint. Table 4.2 shows the trip setpoint change for single detector failure case. It can be seen that the trip setpoint does not change in case of SDS1 detector failure, but the maximum decrease in the trip setpoint is ~11% in case of some SDS2 detector failures.

4.3.3 Reform Calculation

REFORM is a process that attempts to improve ROP margin by changing the reference power shape of the core. The REFORM process follows several steps. First the excess margin (the amount by which the margin to dryout exceeds the margin to trip) is determined for each channel in the core. The channel power in each fuel channel is then adjusted, in small increments, to minimize this excess margin. Since overall reactor power is to be conserved, the revised power shape is normalized. This has the effect of adding powers to the channels with excess margin and the removal of power from channels with small excess margins. The result is that, in the most limiting channels, the channel power is decreased, leading to a larger margin to dryout and increased permissible ROP setpoints.

In order to investigate the possibility of increasing of the trip setpoint in DUPIC core, the REFORM calculation has been performed. The calculation result shows that the trip setpoint increases to 125.73%, which is 3% higher than that of the normal trip setpoint. This is the theoretical improvement, and would have to be checked against operational considerations. The margin improvement indicated by ROVER-F is not currently required.

Table 4.1 Uncertainty Data for DUPIC Core Analysis

Uncertainty	Value (%)
Detector Random	2.60
Channel Random	1.97
Common Random	4.18
Bias	+0.14

Table 4.2 Trip Setpoint for Single Detector Failure

SDS1 Detector		SDS2 Detector	
Detector	Setpoint	Detector	Setpoint
1D	1.2336	1G	1.2336
2D	1.2336	2G	1.2226
3D	1.2336	3G	1.2334
4D	1.2336	4G	1.2332
5D	1.2336	5G	1.2336
6D	1.2336	6G	1.2336
7D	1.2336	7G	1.2100
8D	1.2336	8G	1.2202
9D	1.2336		
10D	1.2336		
11D	1.2254		
12D	1.2336		
1E	1.2159	1H	1.2332
2E	1.2336	2H	1.2312
3E	1.2336	3H	1.2165
4E	1.2336	4H	1.2111
5E	1.2336	5H	1.2323
6E	1.2336	6H	1.2336
7E	1.2336	7H	1.1204
8E	1.2336	8H	1.2002
9E	1.2336		
10E	1.2336		
11E	1.2336		
1F	1.2336	1J	1.2333
2F	1.2336	2J	1.2326
3F	1.2336	3J	1.2215
4F	1.2336	4J	1.1689
5F	1.2336	5J	1.2336
6F	1.2336	6J	1.2336
7F	1.2336	7J	1.1947
8F	1.2336	8J	1.1960
9F	1.2336		
10F	1.2336		
11F	1.2336		

5. SUMMARY AND FUTURE WORKS

The ROP assessments have been performed for CANDU 6 reactor with the DUPIC fuel. First, the validation calculation was performed for natural uranium core by comparing the results of the WIMS/RFSP/ROVER-F calculation with the PPV/RFSP/ ROVER-F one.

The validation calculation has shown that the difference between WIMS/RFSP/ ROVER-F and PPV/RFSP/ROVER-F calculation is less than 1%, and therefore, it is expected that the WIMS-based calculation has the validity to be used for ROP system analysis of the CANDU 6 core.

Then, the probabilistic ROP assessment was carried out for the DUPIC fuel CANDU core. The probabilistic ROP assessment for the DUPIC core has shown that the ROP trip setpoint of the DUPIC core is almost the same as that of the natural uranium core. The maximum decrease in the trip setpoint for a single detector failure is ~11%. However, the trip setpoint can be increased by 3% through the reforming of the channel power distribution.

Consequently, it is expected that the loading of the DUPIC fuel in a CANDU 6 reactor does not cause any adverse effects on the ROP trip setpoint. In future, the harmonic tilt and startup after long shutdown cases should be included for this study.

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APPENDIX

Table A.1 Master List of Design Basis Cases

STEADY-STATE CASES WITH AND WITHOUT SPATIAL CONTROL

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
1	SSSC50	STEADY-STATE WITH S.C	50.0	100.0	N	1
2	SSSC20	STEADY-STATE WITH S.C	50.0	100.0	Y	1
3	SSSC40	STEADY-STATE WITH S.C	50.0	100.0	Y	1
4	SSSC60	STEADY-STATE WITH S.C	50.0	100.0	Y	1
5	SSSC80	STEADY-STATE WITH S.C.	50.0	100.0	Y	1
6	SSNC10	STEADY-STATE WITHOUT S.C	50.0	100.0	N	1
7	SSNC20	STEADY-STATE WITHOUT S.C	50.0	100.0	N	1
8	SSNC80	STEADY-STATE WITHOUT S.C	50.0	100.0	N	1
9	SSNC90	STEADY-STATE WITHOUT S.C	50.0	100.0	N	1

ZONE DRAINS FROM 20%, 50% AND 80%

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
10	D01C20	ZONE DRAIN 01 FROM 20%	50.0	100.0	Y	1
11	D02C20	ZONE DRAIN 02 FROM 20%	50.0	100.0	Y	1
12	D03C20	ZONE DRAIN 03 FROM 20%	50.0	100.0	Y	1
13	D04C20	ZONE DRAIN 04 FROM 20%	50.0	100.0	Y	1
14	D05C20	ZONE DRAIN 05 FROM 20%	50.0	100.0	Y	1
15	D06C20	ZONE DRAIN 06 FROM 20%	50.0	100.0	Y	1
16	D07C20	ZONE DRAIN 07 FROM 20%	50.0	100.0	Y	1
17	D08C20	ZONE DRAIN 08 FROM 20%	50.0	100.0	Y	1
18	D09C20	ZONE DRAIN 09 FROM 20%	50.0	100.0	Y	1
19	D10C20	ZONE DRAIN 10 FROM 20%	50.0	100.0	Y	1
20	D11C20	ZONE DRAIN 11 FROM 20%	50.0	100.0	Y	1
21	D12C20	ZONE DRAIN 12 FROM 20%	50.0	100.0	Y	1
22	D13C20	ZONE DRAIN 13 FROM 20%	50.0	100.0	Y	1
23	D14C20	ZONE DRAIN 14 FROM 20%	50.0	100.0	Y	1
24	D01C50	ZONE DRAIN 01 FROM 50%	50.0	100.0	Y	1
25	D02C50	ZONE DRAIN 02 FROM 50%	50.0	100.0	Y	1
26	D03C50	ZONE DRAIN 03 FROM 50%	50.0	100.0	Y	1
27	D04C50	ZONE DRAIN 04 FROM 50%	50.0	100.0	Y	1
28	D05C50	ZONE DRAIN 05 FROM 50%	50.0	100.0	Y	1
29	D06C50	ZONE DRAIN 06 FROM 50%	50.0	100.0	Y	1
30	D07C50	ZONE DRAIN 07 FROM 50%	50.0	100.0	Y	1
31	D08C50	ZONE DRAIN 08 FROM 50%	50.0	100.0	Y	1
32	D09C50	ZONE DRAIN 09 FROM 50%	50.0	100.0	Y	1
33	D10C50	ZONE DRAIN 10 FROM 50%	50.0	100.0	Y	1
34	D11C50	ZONE DRAIN 11 FROM 50%	50.0	100.0	Y	1
35	D12C50	ZONE DRAIN 12 FROM 50%	50.0	100.0	Y	1
36	D13C50	ZONE DRAIN 13 FROM 50%	50.0	100.0	Y	1
37	D14C50	ZONE DRAIN 14 FROM 50%	50.0	100.0	Y	1
38	D01C80	ZONE DRAIN 01 FROM 80%	50.0	100.0	Y	1
39	D02C80	ZONE DRAIN 02 FROM 80%	50.0	100.0	Y	1
40	D03C80	ZONE DRAIN 03 FROM 80%	50.0	100.0	Y	1
41	D04C80	ZONE DRAIN 04 FROM 80%	50.0	100.0	Y	1
42	D05C80	ZONE DRAIN 05 FROM 80%	50.0	100.0	Y	1
43	D06C80	ZONE DRAIN 06 FROM 80%	50.0	100.0	Y	1
44	D07C80	ZONE DRAIN 07 FROM 80%	50.0	100.0	Y	1
45	D08C80	ZONE DRAIN 08 FROM 80%	50.0	100.0	Y	1
46	D09C80	ZONE DRAIN 09 FROM 80%	50.0	100.0	Y	1
47	D10C80	ZONE DRAIN 10 FROM 80%	50.0	100.0	Y	1
48	D11C80	ZONE DRAIN 11 FROM 80%	50.0	100.0	Y	1
49	D12C80	ZONE DRAIN 12 FROM 80%	50.0	100.0	Y	1
50	D13C80	ZONE DRAIN 13 FROM 80%	50.0	100.0	Y	1
51	D14C80	ZONE DRAIN 14 FROM 80%	50.0	100.0	Y	1

ZONE DRAIN FROM 50% WITHOUT S.C.

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
52	D01N50	ZONE DRAIN 01 FROM 50%	50.0	100.0	N	1
53	D02N50	ZONE DRAIN 02 FROM 50%	50.0	100.0	N	1
54	D03N50	ZONE DRAIN 03 FROM 50%	50.0	100.0	N	1
55	D04N50	ZONE DRAIN 04 FROM 50%	50.0	100.0	N	1
56	D05N50	ZONE DRAIN 05 FROM 50%	50.0	100.0	N	1
57	D06N50	ZONE DRAIN 06 FROM 50%	50.0	100.0	N	1
58	D07N50	ZONE DRAIN 07 FROM 50%	50.0	100.0	N	1
59	D08N50	ZONE DRAIN 08 FROM 50%	50.0	100.0	N	1
60	D09N50	ZONE DRAIN 09 FROM 50%	50.0	100.0	N	1
61	D10N50	ZONE DRAIN 10 FROM 50%	50.0	100.0	N	1
62	D11N50	ZONE DRAIN 11 FROM 50%	50.0	100.0	N	1
63	D12N50	ZONE DRAIN 12 FROM 50%	50.0	100.0	N	1
64	D13N50	ZONE DRAIN 13 FROM 50%	50.0	100.0	N	1
65	D14N50	ZONE DRAIN 14 FROM 50%	50.0	100.0	N	1

SINGLE ADJUSTER WITHDRAWN WITH SPATIAL CONTROL

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
66	AJFO01	ADJUSTER 01 FULL-OUT	50.0	100.0	Y	1
67	AJFO02	ADJUSTER 02 FULL-OUT	50.0	100.0	Y	1
68	AJFO03	ADJUSTER 03 FULL-OUT	50.0	100.0	Y	1
69	AJFO04	ADJUSTER 04 FULL-OUT	50.0	100.0	Y	1
70	AJFO05	ADJUSTER 05 FULL-OUT	50.0	100.0	Y	1
71	AJFO06	ADJUSTER 06 FULL-OUT	50.0	100.0	Y	1
72	AJFO07	ADJUSTER 07 FULL-OUT	50.0	100.0	Y	1
73	AJFO08	ADJUSTER 08 FULL-OUT	50.0	100.0	Y	1
74	AJFO09	ADJUSTER 09 FULL-OUT	50.0	100.0	Y	1
75	AJFO10	ADJUSTER 10 FULL-OUT	50.0	100.0	Y	1
76	AJFO11	ADJUSTER 11 FULL-OUT	50.0	100.0	Y	1
77	AJFO12	ADJUSTER 12 FULL-OUT	50.0	100.0	Y	1
78	AJFO13	ADJUSTER 13 FULL-OUT	50.0	100.0	Y	1
79	AJFO14	ADJUSTER 14 FULL-OUT	50.0	100.0	Y	1
80	AJFO15	ADJUSTER 15 FULL-OUT	50.0	100.0	Y	1
81	AJFO16	ADJUSTER 16 FULL-OUT	50.0	100.0	Y	1
82	AJFO17	ADJUSTER 17 FULL-OUT	50.0	100.0	Y	1
83	AJFO18	ADJUSTER 18 FULL-OUT	50.0	100.0	Y	1
84	AJFO19	ADJUSTER 19 FULL-OUT	50.0	100.0	Y	1
85	AJFO20	ADJUSTER 20 FULL-OUT	50.0	100.0	Y	1
86	AJFO21	ADJUSTER 21 FULL-OUT	50.0	100.0	Y	1
87	AJHO01	ADJUSTER 01 HALF-OUT	50.0	100.0	Y	1
88	AJHO02	ADJUSTER 02 HALF-OUT	50.0	100.0	Y	1
89	AJHO03	ADJUSTER 03 HALF-OUT	50.0	100.0	Y	1
90	AJHO04	ADJUSTER 04 HALF-OUT	50.0	100.0	Y	1
91	AJHO05	ADJUSTER 05 HALF-OUT	50.0	100.0	Y	1
92	AJHO06	ADJUSTER 06 HALF-OUT	50.0	100.0	Y	1
93	AJHO07	ADJUSTER 07 HALF-OUT	50.0	100.0	Y	1
94	AJHO08	ADJUSTER 08 HALF-OUT	50.0	100.0	Y	1
95	AJHO09	ADJUSTER 09 HALF-OUT	50.0	100.0	Y	1
96	AJHO10	ADJUSTER 10 HALF-OUT	50.0	100.0	Y	1
97	AJHO11	ADJUSTER 11 HALF-OUT	50.0	100.0	Y	1
98	AJHO12	ADJUSTER 12 HALF-OUT	50.0	100.0	Y	1
99	AJHO13	ADJUSTER 13 HALF-OUT	50.0	100.0	Y	1
100	AJHO14	ADJUSTER 14 HALF-OUT	50.0	100.0	Y	1
101	AJHO15	ADJUSTER 15 HALF-OUT	50.0	100.0	Y	1
102	AJHO16	ADJUSTER 16 HALF-OUT	50.0	100.0	Y	1
103	AJHO17	ADJUSTER 17 HALF-OUT	50.0	100.0	Y	1
104	AJHO18	ADJUSTER 18 HALF-OUT	50.0	100.0	Y	1
105	AJHO19	ADJUSTER 19 HALF-OUT	50.0	100.0	Y	1
106	AJHO20	ADJUSTER 20 HALF-OUT	50.0	100.0	Y	1
107	AJHO21	ADJUSTER 21 HALF-OUT	50.0	100.0	Y	1

MCA CASES

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
108	MCAC1H	MCA 1ST BANK HALF-IN	50.0	100.0	Y	1
109	MCAC1F	MCA 1ST BANK FULL-IN	50.0	100.0	Y	1
110	MCAC2H	MCA 1ST FI & 2ND HI	50.0	100.0	Y	1
111	MCAC2F	MCA 1ST FI & 2ND HI	50.0	100.0	Y	1
112	MCAN1H	MCA 1ST BANK HALF-IN	50.0	100.0	N	1
113	MCAN1F	MCA 1ST BANK FULL-IN	50.0	100.0	N	1
114	MCAN2H	MCA 1ST FI & 2ND HI	50.0	100.0	N	1
115	MCAN2F	MCA 1ST FI & 2ND FI	50.0	100.0	N	1
116	MCASI1	MCA ROD 01 STUCK-IN	50.0	100.0	Y	1
117	MCASI2	MCA ROD 02 STUCK-IN	50.0	100.0	Y	1
118	MCASI3	MCA ROD 03 STUCK-IN	50.0	100.0	Y	1
119	MCASI4	MCA ROD 04 STUCK-IN	50.0	100.0	Y	1

ZONE INDUCED TILTS

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
120	ZT1ATB	1ST AZIMUTHAL TOB/BOTTOM	50.0	100.0	N	1
121	ZT1ABT	1ST AZIMUTHAL BOTTOM/TOP	50.0	100.0	N	1
122	ZTSFSE	1ST AZIMUTHAL SIDE/SIDE	50.0	100.0	N	1
123	ZTSESF	1ST AZIMUTHAL SIDE/SIDE	50.0	100.0	N	1
124	ZTEFEE	1ST AXIAL END/END	50.0	100.0	N	1
125	ZTEEEF	1ST AXIAL END/END	50.0	100.0	N	1
126	ZTT045	1ST AZIMUTHAL TOP AT 045	50.0	100.0	N	1
127	ZTT135	1ST AZIMUTHAL TOP AT 135	50.0	100.0	N	1
128	ZTT225	1ST AZIMUTHAL TOP AT 225	50.0	100.0	N	1
129	ZTT315	1ST AZIMUTHAL TOP AT 315	50.0	100.0	N	1
130	ZT2A01	2ND AZIMUTHAL 135,315 HI	50.0	100.0	N	1
131	ZT2A02	2ND AZIMUTHAL 045,225 HI	50.0	100.0	N	1
132	ZT2A03	2ND AZIMUTHAL T/B HI	50.0	100.0	N	1
133	ZT2A04	2ND AZIMUTHAL SIDES HI	50.0	100.0	N	1
134	ZTAX01	1ST AZIMUTHAL-AXIAL S=HI	50.0	100.0	N	1
135	ZTAX02	1ST AZIMUTHAL-AXIAL S=LO	50.0	100.0	N	1
136	ZTAX03	1ST AZIMUTHAL-AXIAL T=HI	50.0	100.0	N	1
137	ZTAX04	1ST AZIMUTHAL-AXIAL T=LO	50.0	100.0	N	1
138	ZT1R01	1ST RADIAL CENTER HI	50.0	100.0	N	1
139	ZT1R02	1ST RADIAL OUTER HI	50.0	100.0	N	1

HARMONIC TILTS

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
140	HTTB00	HARMONIC TILT TOP/BOTTOM	50.0	100.0	N	1
141	HTTB01	HARMONIC TILT TOP/BOTTOM	50.0	100.0	N	1
142	HTTB02	HARMONIC TILT TOP/BOTTOM	50.0	100.0	N	1
143	HTTB03	HARMONIC TILT TOP/BOTTOM	50.0	100.0	N	1
144	HTTB04	HARMONIC TILT TOP/BOTTOM	50.0	100.0	N	1
145	HTSS00	HARMONIC TILT SIDE/SIDE	50.0	100.0	N	1
146	HTSS01	HARMONIC TILT SIDE/SIDE	50.0	100.0	N	1
147	HTSS02	HARMONIC TILT SIDE/SIDE	50.0	100.0	N	1
148	HTSS03	HARMONIC TILT SIDE/SIDE	50.0	100.0	N	1
149	HTSS04	HARMONIC TILT SIDE/SIDE	50.0	100.0	N	1

STARTUP AFTER SHORT SHUTDOWN (38 MIN)

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
150	SSSD01	ALL BANKS OUT/Xe @ 38.1 MIN	50.0	100.0	N	1
151	SSSD02	ALL BANKS OUT/Xe @ 22.3 MIN	50.0	100.0	Y	1
152	SSSD03	BANK 7 FULL-IN/NO TIMESTEP	50.0	100.0	Y	1
153	SSSD04	BANK 7 FULL-IN/Xe @ 27.4 MIN	50.0	100.0	Y	1
154	SSSD05	BANK 6 FULL-IN/NO TIMESTEP	50.0	100.0	Y	1
155	SSSD06	BANK 6 FULL-IN/Xe @ 26.7 MIN	50.0	100.0	Y	1
156	SSSD07	BANK 5 FULL-IN/NO TIMESTEP	50.0	100.0	Y	1
157	SSSD08	BANK 5 FULL-IN/Xe @ 26.5 MIN	50.0	100.0	Y	1
158	SSSD09	BANK 4 FULL-IN/NO TIMESTEP	50.0	100.0	Y	1
159	SSSD10	BANK 4 FULL-IN/Xe @ 23.5 MIN	50.0	100.0	Y	1
160	SSSD11	BANK 3 FULL-IN/NO TIMESTEP	50.0	100.0	Y	1
161	SSSD12	BANK 3 FULL-IN/Xe @ 27.8 MIN	50.0	100.0	Y	1
162	SSSD13	BANK 2 FULL-IN/NO TIMESTEP	50.0	100.0	Y	1
163	SSSD14	BANK 2 FULL-IN/Xe @ 43.6 MIN	50.0	100.0	Y	1
164	SSSD15	BANK 1 FULL-IN/NO TIMESTEP	50.0	100.0	Y	1
165	SSSD16	BANK 1 FULL-IN/Xe @ 90.0 MIN	50.0	100.0	Y	1
166	SSSD17	ALL BANKS IN/Xe @ 180. MIN	50.0	100.0	Y	1
167	SSSD18	ALL BANKS IN/Xe @ 270. MIN	50.0	100.0	Y	1

STARTUP AFTER POISON OUT

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
168	SA4400	ALL BANKS OUT/Xe @ 36. HRS	50.0	100.0	-	1
169	SA4401	ALL BANKS OUT/Xe @ 46.4 MIN	50.0	100.0	N	1
170	SA4402	ALL BANKS OUT/Xe @ 5.3 MIN	50.0	100.0	Y	1
171	SA4403	BANK 7 FULL-IN	50.0	100.0	Y	1
172	SA4404	BANK 7 FULL-IN/Xe @ 5.2 MIN	50.0	100.0	Y	1
173	SA4405	BANK 6 FULL-IN	50.0	100.0	Y	1
174	SA4406	BANK 6 FULL-IN/Xe @ 4.3 MIN	50.0	100.0	Y	1
175	SA4407	BANK 5 FULL-IN	50.0	100.0	Y	1
176	SA4408	BANK 5 FULL-IN/Xe @ 4.3 MIN	50.0	100.0	Y	1
177	SA4409	BANK 4 FULL-IN	50.0	100.0	Y	1
178	SA4410	BANK 4 FULL-IN/Xe @ 3.9 MIN	50.0	100.0	Y	1
179	SA4411	BANK 3 FULL-IN	50.0	100.0	Y	1
180	SA4412	BANK 3 FULL-IN/Xe @ 3.9 MIN	50.0	100.0	Y	1
181	SA4413	BANK 2 FULL-IN	50.0	100.0	Y	1
182	SA4414	BANK 2 FULL-IN/Xe @4.2 MIN	50.0	100.0	Y	1
183	SA4415	BANK 1 FULL-IN	50.0	100.0	Y	1
184	SA4416	BANK 1 FI+0.5PPM/Xe @ 12.9 MIN	50.0	100.0	Y	1
185	SA4417	ALL BANKS IN+2.0PPM/Xe @ 83.7 MIN	50.0	100.0	Y	1
186	SA4418	ALL BANKS IN+2.0PPM/Xe @ 263.7MIN	50.0	100.0	Y	1

STARTUP AFTER PROLONGED SHUTDOWN

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
187	SPSD01	00% XENON TIME 00 HOURS 3.374 ppm OF BORON	50.0	100.0	Y	1
188	SPSD02	00% XENON TIME 00 HOURS 3.374 ppm OF BORON	50.0	100.0	Y	1
189	SPSD03	00% XENON TIME 00 HOURS 3.374 ppm OF BORON	50.0	100.0	Y	1
190	SPSD04	00% XENON TIME 00 HOURS 3.374 ppm OF BORON	50.0	100.0	Y	1

STEBBACK TO 60% FP

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
191	SBCK01	ALL BANKS IN/Xe @ 12.3 MIN	50.0	100.0	Y	1
192	SBCK02	BANK 1 OUT	50.0	100.0	Y	1
193	SBCK03	BANK 1 OUT/Xe @ 10.5 MIN	50.0	100.0	Y	1
194	SBCK04	BANK 2 OUT +	50.0	100.0	Y	1
195	SBCK05	BANK 2 OUT/Xe @ 18.3 MIN	50.0	100.0	Y	1
196	SBCK06	BANK 3 OUT	50.0	100.0	Y	1
197	SBCK07	BANK 3 OUT/Xe @ 28.5 MIN	50.0	100.0	Y	1
198	SBCK08	BANK 4 OUT	50.0	100.0	Y	1
199	SBCK09	BANK 4 OUT/Xe @ 310.9 MIN	50.0	100.0	Y	1
200	SBCK10	BANK 4 IN	50.0	100.0	Y	1
201	SBCK11	BANK 4 IN/Xe @ 270.4 MIN	50.0	100.0	Y	1

SHIM CASES

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
202	SHIM01	ALL BANKS IN/SS Xe	50.0	100.0	Y	1
203	SHIM02	BANK 1 OUT	50.0	100.0	Y	1
204	SHIM03	BANK 1 OUT/Xe @240. MIN	50.0	100.0	Y	1
205	SHIM04	BANK 1 OUT/SS Xe	50.0	100.0	Y	1
206	SHIM05	BANK 2 OUT	50.0	100.0	Y	1
207	SHIM06	BANK 2 OUT/Xe A 240.MIN	50.0	100.0	Y	1
208	SHIM07	BANK 2 OUT/SS Xe	50.0	100.0	Y	1
209	SHIM08	BANK 3 OUT	50.0	100.0	Y	1
210	SHIM09	BANK 3 OUT/Xe @ 240. MIN	50.0	100.0	Y	1
211	SHIM10	BANK 3 OUT/SS Xe	50.0	100.0	Y	1
212	SHIM11	BANK 4 OUT	50.0	100.0	Y	1
213	SHIM12	BANK 4 OUT/Xe @ 240.0 MIN	50.0	100.0	Y	1
214	SHIM13	BANK 4 OUT/SS Xe	50.0	100.0	Y	1
215	SHIM14	BANK 5 OUT	50.0	100.0	Y	1
216	SHIM15	BANK 5 OUT/Xe @ 240.0 MIN	50.0	100.0	Y	1
217	SHIM16	BANK 5 OUT/SS Xe	50.0	100.0	Y	1
218	SHIM17	BANK 6 OUT	50.0	100.0	Y	1
219	SHIM18	BANK 6 OUT/SS Xe	50.0	100.0	Y	1
220	SHIM19	BANK 7 OUT	50.0	100.0	Y	1
221	SHIM20	BANK 7 OUT/SS Xe	50.0	100.0	Y	1

ADJUSTER BANKS AND MCA'S HALF OUT

CASE NUMBER	FILE NAME	DESCRIPTION	AVZL	POWER (%FP)	S.C.	REF
222	ABHO01	STARTUP BANK 7 HALF-IN	50.0	100.0	N	1
223	ABHO02	STARTUP BANK 6 HALF-IN	50.0	100.0	N	1
224	ABHO03	STARTUP BANK 5 HALF-IN	50.0	100.0	N	1
225	ABHO04	STARTUP BANK 4 HALF-IN	50.0	100.0	N	1
226	ABHO05	STARTUP BANK 3 HALF-IN	50.0	100.0	N	1
227	ABHO06	SHIM BANK 1 HALF-OUT	50.0	100.0	N	1
228	ABHO07	SHIM BANK 2 HALF-OUT	50.0	100.0	N	1
229	MCASH1	MCA ROD 1 HALF-IN	50.0	100.0	Y	1
230	MCASH2	MCA ROD 2 HALF-IN	50.0	100.0	Y	1
231	MCASH3	MCA ROD 3 HALF-IN	50.0	100.0	Y	1
232	MCASH4	MCA ROD 4 HALF-IN	50.0	100.0	Y	1

Table A.2 Calculation Result of PPV/RFSP/ROVER-F

```
ROVER-F Version 2.00        : Mon Nov  8 10:17:49 1999
 Confidence Calculation


------------------------------------------------------------
Echo Base Parameters
------------------------------------------------------------
 Number of Channels =  380
 Number of Cases =  232
 Number of CP Cases =  232
 Number of CCP Cases =  232
 Number of Det Cases =  232
 Number of Ripple Cases =  150
 Number of Bins =  21
 Number of Detector Sites =  58
 Number of Detectors =  58
 Number of Detector Channels =  6
 Number of Shutdown Systems =  2
 Number of Det Setpoint Plateaus =  4
 Number of x space meshes =  51
 Debug case ID =  1
 reading rover-case.data
Basis Case Data DB_W1_DUP_0
 Reading    232 cases of    999 available.


 reading rover-cp.data

 Reading    232 cases of    232 available.


 reading rover-ccp.data

 Reading    232 cases of    232 available.


 reading rover-rip.data
  Ripple data for Wolsong 1
 Reading    150 cases of    150 available.


 reading rover-err.data
Errors Data(DB_W1_TTR289)
Detector Random Error =        .0260
Channel Random Error =         .0149
Common Random Error =          .0418
Systematic Error =            .0014
Low X Space Limit =            .7000
High X Space Limit =          1.2000
Bins Width =                   .0050
Trip Confidence Limit =       .9800


Probability Mesh Parameters:
  21 Bins of Width :           .0050 running from     1.0000 to      1.1050
  51 Mesh points of Width :    .0100 running from      .7000 to      1.2000


------------------------------------------------------------
Reading Detector Data
------------------------------------------------------------
 W1 Flat Plateaus - 1H and 1J NOT Switched

 Detector Calibration Case =     1
 Channel  1 includes detectors 1-12 (1D  -12D )
```

Channel 2 includes detectors13-23 (1E -11E)
Channel 3 includes detectors24-34 (1F -11F)
Channel 4 includes detectors35-42 (1G -8G)
Channel 5 includes detectors43-50 (1H -8H)
Channel 6 includes detectors51-58 (1J -8J)
SDS 1 includes detector channels 1- 3
SDS 2 includes detector channels 4- 6
Detector 7G compensated with detector 3G
Detector 8G compensated with detector 4G
Detector 2H compensated with detector 5H
Detector 7H compensated with detector 8H
Detector 2J compensated with detector 3J
Detector 8J compensated with detector 7J

#	Det	Setpoint	Boil Corr.	Fail	Site
1	1D	1.240000	-.008700	1	1
2	2D	1.240000	-.002300	1	2
3	3D	1.240000	-.002300	1	3
4	4D	1.240000	-.008300	1	4
5	5D	1.240000	-.008700	1	5
6	6D	1.240000	-.000700	1	6
7	7D	1.240000	-.000700	1	7
8	8D	1.240000	-.000700	1	8
9	9D	1.240000	-.000700	1	9
10	10D	1.240000	-.000700	1	10
11	11D	1.240000	-.000700	1	11
12	12D	1.240000	-.002300	1	12
13	1E	1.240000	-.002300	1	13
14	2E	1.240000	-.000700	1	14
15	3E	1.240000	-.000700	1	15
16	4E	1.240000	-.008300	1	16
17	5E	1.240000	-.008700	1	17
18	6E	1.240000	-.008300	1	18
19	7E	1.240000	-.008700	1	19
20	8E	1.240000	-.000700	1	20
21	9E	1.240000	-.002300	1	21
22	10E	1.240000	-.000700	1	22
23	11E	1.240000	-.002300	1	23
24	1F	1.240000	-.008700	1	24
25	2F	1.240000	-.008300	1	25
26	3F	1.240000	-.008700	1	26
27	4F	1.240000	-.002300	1	27
28	5F	1.240000	-.008700	1	28
29	6F	1.240000	-.008300	1	29
30	7F	1.240000	-.000700	1	30
31	8F	1.240000	.007300	1	31
32	9F	1.240000	-.002300	1	32
33	10F	1.240000	-.000700	1	33
34	11F	1.240000	.006000	1	34
35	1G	1.240000	-.008700	1	35
36	2G	1.240000	-.008700	1	36
37	3G	1.240000	.005500	1	37
38	4G	1.240000	.005500	1	38
39	5G	1.240000	-.008700	1	39
40	6G	1.240000	-.008700	1	40
41	7G	1.240000	.005500	1	41
42	8G	1.240000	.005500	1	42
43	1H	1.240000	-.008700	1	51
44	2H	1.240000	.005500	1	44
45	3H	1.240000	-.008700	1	45
46	4H	1.240000	-.008700	1	46
47	5H	1.240000	.005500	1	47
48	6H	1.240000	-.008700	1	48
49	7H	1.240000	.005500	1	49
50	8H	1.240000	.005500	1	50
51	1J	1.240000	-.008700	1	43
52	2J	1.240000	.005500	1	52
53	3J	1.240000	.005500	1	53
54	4J	1.240000	-.008700	1	54
55	5J	1.240000	-.008700	1	55
56	6J	1.240000	-.008700	1	56

```
57   7J            1.240000    .005500           1    57
58   8J            1.240000    .005500           1    58

 Reading Detector Readings

 Reading      58 detectors of      58 sites available.
 Reading    232 cases of    232 available.
Performing 7G     with 3G     compensation.
Performing 8G     with 4G     compensation.
Performing 2H     with 5H     compensation.
Performing 7H     with 8H     compensation.
Performing 2J    with 3J     compensation.
Performing 8J    with 7J     compensation.


Performing Precalculation
reading cppf.data
CPPF Data W1

Average CPPF =        1.0706
reading rover-orif.data
Nucirc Data (DB_W1_DUP_0)
Completed Precalculation


--------------------------------------------------------------
Results
--------------------------------------------------------------
Case                                                                    CPRL          Avg. Cons.     SDS1
 SDS2      LimDets
   1      1   SSSC50   STEADY-STATE WITH S.C.                            1.394336      1.020443      .999387
   .999236   6D    3G
  37     37   D14C50   ZONE DRAIN 14 FROM 50%                            1.350021      1.035591      .998359
   .997461   10E   4J
  39     39   D02C80   ZONE DRAIN 02 FROM 80%                            1.288055      1.042705      .999385
   .991575   2E    2G
  42     42   D05C80   ZONE DRAIN 05 FROM 80%                            1.260331      1.034663      .992885
   .955936   4D    7J
  44     44   D07C80   ZONE DRAIN 07 FROM 80%                            1.280216      1.033913      .995333
   .978196   4E    4H
  46     46   D09C80   ZONE DRAIN 09 FROM 80%                            1.281121      1.051178      .997264
   .993562   6D    3H
  49     49   D12C80   ZONE DRAIN 12 FROM 80%                            1.261377      1.039092      .996700
   .964214   9E    8H
  51     51   D14C80   ZONE DRAIN 14 FROM 80%                            1.288607      1.030578      .992883
   .985867   10E   4G
  53     53   D02N50   ZONE DRAIN 02 FROM 50%                            1.320378      1.048829      .999252
   .996725   2E    7G
  58     58   D07N50   ZONE DRAIN 07 FROM 50%                            1.318054      1.035807      .997710
   .994978   3F    4H
  60     60   D09N50   ZONE DRAIN 09 FROM 50%                            1.319606      1.050913      .998692
   .997229   6D    3H
  65     65   D14N50   ZONE DRAIN 14 FROM 50%                            1.319468      1.036770      .996794
   .995963   9F    2J
 114    114   MCAN2H    MCA 1ST FI & 2ND HI                              1.041749      1.024332      .991849
   .964652   11D   7H
 122    122   ZTSFSE    1ST AZIMUTHAL SIDE/SIDE                          1.247081      1.037228      .993653
   .990868   11E   1G
 123    123   ZTSESF    1ST AZIMUTHAL SIDE/SIDE                          1.248250      1.044385      .996808
   .993310   1D    2G
 130    130   ZT2A01    2ND AZIMUTHAL 135,315 HI                         1.301482      1.051439      .998524
  .995807   1D    2G
 131    131   ZT2A02    2ND AZIMUTHAL 045,225 HI                         1.300313      1.039521      .995054
  .994965   9F    7G
 152    152   SSSD03    BANK 7 FULL-IN/NO TIMESTEP                       1.082631      1.030492      .997640
   .973417   6F    4J
 171    171   SA4403    BANK 7 FULL-IN                                   1.208533      1.030256      .999224
 .991729   3F    4J
 173    173   SA4405    BANK 6 FULL-IN                                   1.186291      1.029392      .961503
 .960538   5F    4J
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174  174  SA4406  BANK 6 FULL-IN/Xe @ 4.3 MIN        1.203234   1.023040   .999274
  .999613  5F   4J
177  177  SA4409  BANK 4 FULL-IN                      1.302997   1.040742   .997302
.995159  4F   7J
178  178  SA4410  BANK 4 FULL-IN/Xe @ 3.9 MIN         1.272422   1.027372   .995873
  .974758  7D   4J
195  195  SBCK05  BANK 2 OUT/Xe @ 18.3 MIN            1.327840   1.035960   .999714
  .997965  4F   7J
196  196  SBCK06  BANK 3 OUT                          1.250053   1.039790   .999121
.991757  6F   4J
197  197  SBCK07  BANK 3 OUT/Xe @ 28.5 MIN            1.262964   1.041612   .999033
  .994038  4F   4J
222  222  ABHO01  STARTUP BANK 7 HALF-IN              1.005048   1.040352   .999983
  .997623  7E   4J

 25 Worst Cases.
   42    D05C80  ZONE DRAIN 05 FROM 80%               .9929   .9559
  173    SA4405  BANK 6 FULL-IN                       .9615   .9605
   49    D12C80  ZONE DRAIN 12 FROM 80%               .9967   .9642
  114    MCAN2H  MCA 1ST FI & 2ND HI                  .9918   .9647
  152    SSSD03  BANK 7 FULL-IN/NO TIMESTEP           .9976   .9734
  178    SA4410  BANK 4 FULL-IN/Xe @ 3.9 MIN          .9959   .9748
   44    D07C80  ZONE DRAIN 07 FROM 80%               .9953   .9782
   51    D14C80  ZONE DRAIN 14 FROM 80%               .9929   .9859
  122    ZTSFSE  1ST AZIMUTHAL SIDE/SIDE              .9937   .9909
   39    D02C80  ZONE DRAIN 02 FROM 80%               .9994   .9916
  171    SA4403  BANK 7 FULL-IN                       .9992   .9917
  196    SBCK06  BANK 3 OUT                           .9991   .9918
  123    ZTSESF  1ST AZIMUTHAL SIDE/SIDE              .9968   .9933
   46    D09C80  ZONE DRAIN 09 FROM 80%               .9973   .9936
  197    SBCK07  BANK 3 OUT/Xe @ 28.5 MIN             .9990   .9940
  131    ZT2A02  2ND AZIMUTHAL 045,225 HI             .9951   .9950
   58    D07N50  ZONE DRAIN 07 FROM 50%               .9977   .9950
  177    SA4409  BANK 4 FULL-IN                       .9973   .9952
  130    ZT2A01  2ND AZIMUTHAL 135,315 HI             .9985   .9958
   65    D14N50  ZONE DRAIN 14 FROM 50%               .9968   .9960
   53    D02N50  ZONE DRAIN 02 FROM 50%               .9993   .9967
   60    D09N50  ZONE DRAIN 09 FROM 50%               .9987   .9972
   37    D14C50  ZONE DRAIN 14 FROM 50%               .9984   .9975
  222    ABHO01  STARTUP BANK 7 HALF-IN              1.0000   .9976
  195    SBCK05  BANK 2 OUT/Xe @ 18.3 MIN             .9997   .9980


Minimum trip confidence =      .9559 for case    42


 Calculating Required Setpoint Adjustment
Setpoint Adjustment =      .9820 (   .9800)   Case :    42
Base Setpoint Result =    1.2177
```

Table A.3 Calculation Result of WIMS/RFSP/ROVER-F

```
ROVER-F Version 2.00        : Mon Nov  8 11:03:34 1999
 Confidence Calculation


------------------------------------------------------------
Echo Base Parameters
------------------------------------------------------------
 Number of Channels =  380
 Number of Cases =  232
 Number of CP Cases =  232
 Number of CCP Cases =  232
 Number of Det Cases =  232
 Number of Ripple Cases =  150
 Number of Bins =  21
 Number of Detector Sites =  58
 Number of Detectors =  58
 Number of Detector Channels =  6
 Number of Shutdown Systems =  2
 Number of Det Setpoint Plateaus =  4
 Number of x space meshes =  51
 Debug case ID =  1
 reading rover-case.data
Basis Case Data DB_W1_DUP_0
 Reading    232 cases of    999 available.


 reading rover-cp.data

 Reading    232 cases of    232 available.


 reading rover-ccp.data

 Reading    232 cases of    232 available.


 reading rover-rip.data
  Ripple data for Wolsong 1
 Reading    150 cases of    150 available.


 reading rover-err.data
Errors Data(DB_W1_TTR289)
Detector Random Error =         .0260
Channel Random Error =          .0149
Common Random Error =           .0418
Systematic Error =              .0014
Low X Space Limit =             .7000
High X Space Limit =           1.2000
Bins Width =                    .0050
Trip Confidence Limit =         .9800


Probability Mesh Parameters:
  21 Bins of Width :            .0050 running from     1.0000 to      1.1050
  51 Mesh points of Width :     .0100 running from      .7000 to      1.2000


------------------------------------------------------------
Reading Detector Data
------------------------------------------------------------
 W1 Flat Plateaus - 1H and 1J NOT Switched

 Detector Calibration Case =     1
 Channel  1 includes detectors 1-12 (1D  -12D )
```

Channel 2 includes detectors13-23 (1E -11E)
Channel 3 includes detectors24-34 (1F -11F)
Channel 4 includes detectors35-42 (1G -8G)
Channel 5 includes detectors43-50 (1H -8H)
Channel 6 includes detectors51-58 (1J -8J)
SDS 1 includes detector channels 1- 3
SDS 2 includes detector channels 4- 6
Detector 7G compensated with detector 3G
Detector 8G compensated with detector 4G
Detector 2H compensated with detector 5H
Detector 7H compensated with detector 8H
Detector 2J compensated with detector 3J
Detector 8J compensated with detector 7J

#	Det	Setpoint	Boil Corr.	Fail	Site
1	1D	1.240000	-.008700	1	1
2	2D	1.240000	-.002300	1	2
3	3D	1.240000	-.002300	1	3
4	4D	1.240000	-.008300	1	4
5	5D	1.240000	-.008700	1	5
6	6D	1.240000	-.000700	1	6
7	7D	1.240000	-.000700	1	7
8	8D	1.240000	-.000700	1	8
9	9D	1.240000	-.000700	1	9
10	10D	1.240000	-.000700	1	10
11	11D	1.240000	-.000700	1	11
12	12D	1.240000	-.002300	1	12
13	1E	1.240000	-.002300	1	13
14	2E	1.240000	-.000700	1	14
15	3E	1.240000	-.000700	1	15
16	4E	1.240000	-.008300	1	16
17	5E	1.240000	-.008700	1	17
18	6E	1.240000	-.008300	1	18
19	7E	1.240000	-.008700	1	19
20	8E	1.240000	-.000700	1	20
21	9E	1.240000	-.002300	1	21
22	10E	1.240000	-.000700	1	22
23	11E	1.240000	-.002300	1	23
24	1F	1.240000	-.008700	1	24
25	2F	1.240000	-.008300	1	25
26	3F	1.240000	-.008700	1	26
27	4F	1.240000	-.002300	1	27
28	5F	1.240000	-.008700	1	28
29	6F	1.240000	-.008300	1	29
30	7F	1.240000	-.000700	1	30
31	8F	1.240000	.007300	1	31
32	9F	1.240000	-.002300	1	32
33	10F	1.240000	-.000700	1	33
34	11F	1.240000	.006000	1	34
35	1G	1.240000	-.008700	1	35
36	2G	1.240000	-.008700	1	36
37	3G	1.240000	.005500	1	37
38	4G	1.240000	.005500	1	38
39	5G	1.240000	-.008700	1	39
40	6G	1.240000	-.008700	1	40
41	7G	1.240000	.005500	1	41
42	8G	1.240000	.005500	1	42
43	1H	1.240000	-.008700	1	51
44	2H	1.240000	.005500	1	44
45	3H	1.240000	-.008700	1	45
46	4H	1.240000	-.008700	1	46
47	5H	1.240000	.005500	1	47
48	6H	1.240000	-.008700	1	48
49	7H	1.240000	.005500	1	49
50	8H	1.240000	.005500	1	50
51	1J	1.240000	-.008700	1	43
52	2J	1.240000	.005500	1	52
53	3J	1.240000	.005500	1	53
54	4J	1.240000	-.008700	1	54
55	5J	1.240000	-.008700	1	55
56	6J	1.240000	-.008700	1	56

```
57  7J          1.240000   .005500       1   57
58  8J          1.240000   .005500       1   58

 Reading Detector Readings

 Reading     58 detectors of     58 sites available.
 Reading    232 cases of    232 available.
Performing 7G    with 3G    compensation.
Performing 8G    with 4G    compensation.
Performing 2H    with 5H    compensation.
Performing 7H    with 8H    compensation.
Performing 2J    with 3J    compensation.
Performing 8J    with 7J    compensation.


Performing Precalculation
reading cppf.data
CPPF Data W1

Average CPPF =      1.0706
reading rover-orif.data
Nucirc Data (DB_W1_DUP_0)
Completed Precalculation



------------------------------------------------------------
Results
------------------------------------------------------------
Case                                                  CPRL        Avg. Cons.    SDS1
 SDS2      LimDets
   1     1   SSSC50   STEADY-STATE WITH S.C.            1.369820    1.030835    .999099
   .998877  6D    3G
  37    37   D14C50   ZONE DRAIN 14 FROM 50%            1.342749    1.033680    .997696
   .996358  10E   4G
  39    39   D02C80   ZONE DRAIN 02 FROM 80%            1.254138    1.047924    .998724
   .980224  2E    2G
  42    42   D05C80   ZONE DRAIN 05 FROM 80%            1.321333    1.032727    .999533
   .994815  4D    7J
  44    44   D07C80   ZONE DRAIN 07 FROM 80%            1.271005    1.029804    .994233
   .970054  9F    4H
  46    46   D09C80   ZONE DRAIN 09 FROM 80%            1.261530    1.040759    .992497
   .987357  5D    3H
  49    49   D12C80   ZONE DRAIN 12 FROM 80%            1.320805    1.035371    .999837
   .996091  10E   8H
  51    51   D14C80   ZONE DRAIN 14 FROM 80%            1.263583    1.033302    .989258
   .980038  10E   1G
  53    53   D02N50   ZONE DRAIN 02 FROM 50%            1.295884    1.049199    .998295
   .991499  2E    7G
  58    58   D07N50   ZONE DRAIN 07 FROM 50%            1.294957    1.044964    .996691
   .991885  3F    4H
  60    60   D09N50   ZONE DRAIN 09 FROM 50%            1.286652    1.055838    .996440
   .992331  6D    3H
  65    65   D14N50   ZONE DRAIN 14 FROM 50%            1.304970    1.036724    .995509
   .994199  9F    2J
 114   114   MCAN2H   MCA 1ST FI & 2ND HI               1.031774    1.030312    .998782
   .989729  11D   7H
 122   122   ZTSFSE   1ST AZIMUTHAL SIDE/SIDE           1.214275    1.041828    .989290
   .984092  11E   1G
 123   123   ZTSESF   1ST AZIMUTHAL SIDE/SIDE           1.207210    1.046220    .989658
   .981221  1D    2G
 130   130   ZT2A01   2ND AZIMUTHAL 135,315 HI          1.275247    1.052517    .996174
  .989044  1D    2G
 131   131   ZT2A02   2ND AZIMUTHAL 045,225 HI          1.283343    1.042180    .991632
  .991670  9F    7G
 152   152   SSSD03   BANK 7 FULL-IN/NO TIMESTEP        1.101796    1.026248    .999826
   .980611  6F    4J
 171   171   SA4403   BANK 7 FULL-IN                    1.191923    1.023887    .999697
 .983201  3F    4J
 173   173   SA4405   BANK 6 FULL-IN                    1.266028    1.040944    .999068
 .998280  8F    2H
```

174 174 SA4406 BANK 6 FULL-IN/Xe @ 4.3 MIN 1.263860 1.042245 .999093
.998354 8F 2H
177 177 SA4409 BANK 4 FULL-IN 1.341410 1.027288 .999098
.997958 11F 7J
178 178 SA4410 BANK 4 FULL-IN/Xe @ 3.9 MIN 1.342183 1.027765 .999152
.998046 11F 7J
195 195 SBCK05 BANK 2 OUT/Xe @ 18.3 MIN 1.327127 1.036370 .999769
.998193 4F 7J
196 196 SBCK06 BANK 3 OUT 1.276083 1.037626 .999652
.996550 6F 4J
197 197 SBCK07 BANK 3 OUT/Xe @ 28.5 MIN 1.288818 1.033968 .999539
.996713 4F 7J
222 222 ABHO01 STARTUP BANK 7 HALF-IN .985926 1.037645 .999998
.994597 5D 4J

25 Worst Cases.

44	D07C80 ZONE DRAIN 07 FROM 80%	.9942	.9701
51	D14C80 ZONE DRAIN 14 FROM 80%	.9893	.9800
39	D02C80 ZONE DRAIN 02 FROM 80%	.9987	.9802
152	SSSD03 BANK 7 FULL-IN/NO TIMESTEP	.9998	.9806
123	ZTSESF 1ST AZIMUTHAL SIDE/SIDE	.9897	.9812
171	SA4403 BANK 7 FULL-IN	.9997	.9832
122	ZTSFSE 1ST AZIMUTHAL SIDE/SIDE	.9893	.9841
46	D09C80 ZONE DRAIN 09 FROM 80%	.9925	.9874
130	ZT2A01 2ND AZIMUTHAL 135,315 HI	.9962	.9890
114	MCAN2H MCA 1ST FI & 2ND HI	.9988	.9897
53	D02N50 ZONE DRAIN 02 FROM 50%	.9983	.9915
131	ZT2A02 2ND AZIMUTHAL 045,225 HI	.9916	.9917
58	D07N50 ZONE DRAIN 07 FROM 50%	.9967	.9919
60	D09N50 ZONE DRAIN 09 FROM 50%	.9964	.9923
65	D14N50 ZONE DRAIN 14 FROM 50%	.9955	.9942
222	ABHO01 STARTUP BANK 7 HALF-IN	1.0000	.9946
42	D05C80 ZONE DRAIN 05 FROM 80%	.9995	.9948
49	D12C80 ZONE DRAIN 12 FROM 80%	.9998	.9961
37	D14C50 ZONE DRAIN 14 FROM 50%	.9977	.9964
196	SBCK06 BANK 3 OUT	.9997	.9966
197	SBCK07 BANK 3 OUT/Xe @ 28.5 MIN	.9995	.9967
177	SA4409 BANK 4 FULL-IN	.9991	.9980
178	SA4410 BANK 4 FULL-IN/Xe @ 3.9 MIN	.9992	.9980
195	SBCK05 BANK 2 OUT/Xe @ 18.3 MIN	.9998	.9982
173	SA4405 BANK 6 FULL-IN	.9991	.9983

Minimum trip confidence = .9701 for case 44

Calculating Required Setpoint Adjustment
Setpoint Adjustment = .9911 (.9800) Case : 44
Base Setpoint Result = 1.2290

Table A.4 ROP Assessment Result for DUPIC Core

```
ROVER-F Version 2.00        : Mon Nov  8 10:06:02 1999
 Confidence Calculation


------------------------------------------------------------
Echo Base Parameters
------------------------------------------------------------
 Number of Channels =  380
 Number of Cases =  232
 Number of CP Cases =  232
 Number of CCP Cases =  232
 Number of Det Cases =  232
 Number of Ripple Cases =  121
 Number of Bins =  21
 Number of Detector Sites =  58
 Number of Detectors =  58
 Number of Detector Channels =  6
 Number of Shutdown Systems =  2
 Number of Det Setpoint Plateaus =  4
 Number of x space meshes =  51
 Debug case ID =  -1
 reading rover-case.data
Basis Case Data DB_W1_DUP_0
 Reading    232 cases of    999 available.


 reading rover-cp.data

 Reading    232 cases of    232 available.


 reading rover-ccp.data

 Reading    232 cases of    232 available.


 reading rover-rip.data
  Ripple data for DUPIC core
 Reading    121 cases of    121 available.


 reading rover-err.data
Errors Data(CHRAN BY DATA OF JWPARK)
Detector Random Error =        .0260
Channel Random Error =         .0197
Common Random Error =         .0418
Systematic Error =             .0014
Low X Space Limit =            .7000
High X Space Limit =          1.2000
Bins Width =                   .0050
Trip Confidence Limit =        .9800


Probability Mesh Parameters:
  21 Bins of Width :             .0050 running from     1.0000 to      1.1050
  51 Mesh points of Width :      .0100 running from      .7000 to      1.2000


------------------------------------------------------------
Reading Detector Data
------------------------------------------------------------
 W1 Flat Plateaus - 1H and 1J NOT Switched

 Detector Calibration Case =     1
 Channel  1 includes detectors 1-12 (1D  -12D )
```

Channel 2 includes detectors13-23 (1E -11E)
Channel 3 includes detectors24-34 (1F -11F)
Channel 4 includes detectors35-42 (1G -8G)
Channel 5 includes detectors43-50 (1H -8H)
Channel 6 includes detectors51-58 (1J -8J)
SDS 1 includes detector channels 1- 3
SDS 2 includes detector channels 4- 6
Detector 7G compensated with detector 3G
Detector 8G compensated with detector 4G
Detector 2H compensated with detector 5H
Detector 7H compensated with detector 8H
Detector 2J compensated with detector 3J
Detector 8J compensated with detector 7J

#	Det	Setpoint	Boil Corr.	Fail	Site
1	1D	1.240000	-.008700	1	1
2	2D	1.240000	-.002300	1	2
3	3D	1.240000	-.002300	1	3
4	4D	1.240000	-.008300	1	4
5	5D	1.240000	-.008700	1	5
6	6D	1.240000	-.000700	1	6
7	7D	1.240000	-.000700	1	7
8	8D	1.240000	-.000700	1	8
9	9D	1.240000	-.000700	1	9
10	10D	1.240000	-.000700	1	10
11	11D	1.240000	-.000700	1	11
12	12D	1.240000	-.002300	1	12
13	1E	1.240000	-.002300	1	13
14	2E	1.240000	-.000700	1	14
15	3E	1.240000	-.000700	1	15
16	4E	1.240000	-.008300	1	16
17	5E	1.240000	-.008700	1	17
18	6E	1.240000	-.008300	1	18
19	7E	1.240000	-.008700	1	19
20	8E	1.240000	-.000700	1	20
21	9E	1.240000	-.002300	1	21
22	10E	1.240000	-.000700	1	22
23	11E	1.240000	-.002300	1	23
24	1F	1.240000	-.008700	1	24
25	2F	1.240000	-.008300	1	25
26	3F	1.240000	-.008700	1	26
27	4F	1.240000	-.002300	1	27
28	5F	1.240000	-.008700	1	28
29	6F	1.240000	-.008300	1	29
30	7F	1.240000	-.000700	1	30
31	8F	1.240000	.007300	1	31
32	9F	1.240000	-.002300	1	32
33	10F	1.240000	-.000700	1	33
34	11F	1.240000	.006000	1	34
35	1G	1.240000	-.008700	1	35
36	2G	1.240000	-.008700	1	36
37	3G	1.240000	.005500	1	37
38	4G	1.240000	.005500	1	38
39	5G	1.240000	-.008700	1	39
40	6G	1.240000	-.008700	1	40
41	7G	1.240000	.005500	1	41
42	8G	1.240000	.005500	1	42
43	1H	1.240000	-.008700	1	51
44	2H	1.240000	.005500	1	44
45	3H	1.240000	-.008700	1	45
46	4H	1.240000	-.008700	1	46
47	5H	1.240000	.005500	1	47
48	6H	1.240000	-.008700	1	48
49	7H	1.240000	.005500	1	49
50	8H	1.240000	.005500	1	50
51	1J	1.240000	-.008700	1	43
52	2J	1.240000	.005500	1	52
53	3J	1.240000	.005500	1	53
54	4J	1.240000	-.008700	1	54
55	5J	1.240000	-.008700	1	55
56	6J	1.240000	-.008700	1	56

```
57   7J          1.240000   .005500       1   57
58   8J          1.240000   .005500       1   58

 Reading Detector Readings
   DETECTOR READING FOR DUPIC
 Reading     58 detectors of     58 sites available.
 Reading    232 cases of    232 available.
Performing 7G    with 3G    compensation.
Performing 8G    with 4G    compensation.
Performing 2H    with 5H    compensation.
Performing 7H    with 8H    compensation.
Performing 2J    with 3J    compensation.
Performing 8J    with 7J    compensation.


Performing Precalculation
reading cppf.data
CPPF Data (DB_W1_DUP_0)

Average CPPF =       1.0681
reading rover-orif.data
Nucirc Data (DB_W1_DUP_0)
 Low Conservatism Channel Map Generated
 in file rover-lccm.output.
Completed Precalculation



----------------------------------------------------------------
Results
----------------------------------------------------------------
Case                                                          CPRL        Avg. Cons.    SDS1
 SDS2      LimDets
   1    1  SSSC50   STEADY-STATE WITH S.C.                        1.414206    1.028029     .999692
  .999607  6D    3G
   2    2  SSSC20   STEADY-STATE WITH S.C.                        1.395865    1.036093     .999797
  .999491  4D    7J
   3    3  SSSC40   STEADY-STATE WITH S.C.                        1.406428    1.032348     .999670
  .999587  9D    7G
   4    4  SSSC60   STEADY-STATE WITH S.C.                        1.412592    1.030130     .999727
  .999631  7D    4G
   5    5  SSSC80   STEADY-STATE WITH S.C.                        1.408862    1.026107     .999767
  .999546  11D   3G
   6    6  SSNC10   STEADY-STATE WITHOUT S.C                      1.389107    1.038523     .999853
  .999337  4D    8H
   7    7  SSNC20   STEADY-STATE WITHOUT S.C                      1.393898    1.037761     .999790
  .999485  4D    7G
   8    8  SSNC80   STEADY-STATE WITHOUT S.C                      1.391360    1.031004     .999734
  .999296  11D   3G
   9    9  SSNC90   STEADY-STATE WITHOUT S.C                      1.367126    1.030056     .999607
  .998001  11D   2H
  10   10  D01C20   ZONE DRAIN 01 FROM 20%                        1.377052    1.047484     .999707
  .999405  4D    7J
  11   11  D02C20   ZONE DRAIN 02 FROM 20%                        1.381608    1.044669     .999786
  .999392  1E    7J
  12   12  D03C20   ZONE DRAIN 03 FROM 20%                        1.401072    1.032172     .999829
  .999553  1E    7J
  13   13  D04C20   ZONE DRAIN 04 FROM 20%                        1.398209    1.031460     .999742
  .999527  4D    7J
  14   14  D05C20   ZONE DRAIN 05 FROM 20%                        1.401251    1.033608     .999782
  .999467  4D    8H
  15   15  D06C20   ZONE DRAIN 06 FROM 20%                        1.380699    1.045517     .999757
  .999433  11D   7J
  16   16  D07C20   ZONE DRAIN 07 FROM 20%                        1.382403    1.044872     .999766
  .999490  4F    8H
  17   17  D08C20   ZONE DRAIN 08 FROM 20%                        1.378235    1.046617     .999748
  .999416  9D    8H
  18   18  D09C20   ZONE DRAIN 09 FROM 20%                        1.379968    1.045677     .999743
  .999396  4D    8H
  19   19  D10C20   ZONE DRAIN 10 FROM 20%                        1.400977    1.032297     .999758
  .999535  4F    8H
```

20 20 D11C20 ZONE DRAIN 11 FROM 20% 1.397961 1.031610 .999769
.999545 4F 8H
21 21 D12C20 ZONE DRAIN 12 FROM 20% 1.401111 1.033665 .999833
.999471 1E 7J
22 22 D13C20 ZONE DRAIN 13 FROM 20% 1.379708 1.046367 .999744
.999465 12D 7J
23 23 D14C20 ZONE DRAIN 14 FROM 20% 1.383986 1.043767 .999746
.999473 11D 7J
24 24 D01C50 ZONE DRAIN 01 FROM 50% 1.361253 1.048300 .999142
.998901 5F 5G
25 25 D02C50 ZONE DRAIN 02 FROM 50% 1.370617 1.043195 .999515
.998821 2E 3G
26 26 D03C50 ZONE DRAIN 03 FROM 50% 1.394047 1.033045 .999620
.999558 6E 5J
27 27 D04C50 ZONE DRAIN 04 FROM 50% 1.395797 1.029699 .999496
.999428 7D 7J
28 28 D05C50 ZONE DRAIN 05 FROM 50% 1.400845 1.025726 .999525
.999061 4D 7J
29 29 D06C50 ZONE DRAIN 06 FROM 50% 1.361760 1.051598 .999349
.999253 8E 1G
30 30 D07C50 ZONE DRAIN 07 FROM 50% 1.368929 1.045871 .999291
.998762 4E 4G
31 31 D08C50 ZONE DRAIN 08 FROM 50% 1.351563 1.050516 .998862
.999102 5E 2G
32 32 D09C50 ZONE DRAIN 09 FROM 50% 1.366453 1.045382 .999287
.998846 9D 3H
33 33 D10C50 ZONE DRAIN 10 FROM 50% 1.390649 1.034124 .999333
.999593 8E 6H
34 34 D11C50 ZONE DRAIN 11 FROM 50% 1.396212 1.029354 .999511
.999549 11F 2H
35 35 D12C50 ZONE DRAIN 12 FROM 50% 1.400824 1.025706 .999635
.999070 10E 8H
36 36 D13C50 ZONE DRAIN 13 FROM 50% 1.363539 1.049519 .999281
.998970 9F 7H
37 37 D14C50 ZONE DRAIN 14 FROM 50% 1.372773 1.043367 .999317
.998897 10E 4G
38 38 D01C80 ZONE DRAIN 01 FROM 80% 1.315854 1.052419 .997377
.996684 5F 2H
39 39 D02C80 ZONE DRAIN 02 FROM 80% 1.293773 1.040400 .999591
.990010 2E 2G
40 40 D03C80 ZONE DRAIN 03 FROM 80% 1.364467 1.039226 .999456
.999120 8E 2J
41 41 D04C80 ZONE DRAIN 04 FROM 80% 1.395829 1.027762 .999677
.999230 7D 2J
42 42 D05C80 ZONE DRAIN 05 FROM 80% 1.287262 1.028766 .996570
.975111 4D 7J
43 43 D06C80 ZONE DRAIN 06 FROM 80% 1.322822 1.052011 .998388
.998585 8E 1G
44 44 D07C80 ZONE DRAIN 07 FROM 80% 1.287740 1.043119 .998230
.985932 9F 4H
45 45 D08C80 ZONE DRAIN 08 FROM 80% 1.321406 1.051443 .997355
.998645 5E 6G
46 46 D09C80 ZONE DRAIN 09 FROM 80% 1.285568 1.043843 .996776
.991792 6D 3H
47 47 D10C80 ZONE DRAIN 10 FROM 80% 1.363646 1.039392 .998981
.999476 6F 2H
48 48 D11C80 ZONE DRAIN 11 FROM 80% 1.395630 1.027605 .999641
.999730 10E 3G
49 49 D12C80 ZONE DRAIN 12 FROM 80% 1.287278 1.028124 .998436
.974891 9E 8H
50 50 D13C80 ZONE DRAIN 13 FROM 80% 1.318809 1.052684 .997691
.996780 9F 4H
51 51 D14C80 ZONE DRAIN 14 FROM 80% 1.296551 1.039896 .996514
.991889 10E 4G
52 52 D01N50 ZONE DRAIN 01 FROM 50% 1.325814 1.050498 .997843
.997819 1F 5G
53 53 D02N50 ZONE DRAIN 02 FROM 50% 1.337646 1.045217 .999488
.997223 2E 3J
54 54 D03N50 ZONE DRAIN 03 FROM 50% 1.368012 1.034919 .999339
.999555 1E 5J
55 55 D04N50 ZONE DRAIN 04 FROM 50% 1.392386 1.031032 .999573
.999599 3D 7J
56 56 D05N50 ZONE DRAIN 05 FROM 50% 1.370491 1.030885 .999321

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 .998788  4D   7J
57   57  D06N50  ZONE DRAIN 06 FROM 50%      1.329980   1.051091   .998648
 .998845  3E   1G
58   58  D07N50  ZONE DRAIN 07 FROM 50%      1.332767   1.047279   .999205
 .997700  3F   7H
59   59  D08N50  ZONE DRAIN 08 FROM 50%      1.329111   1.049924   .997608
 .998797  5E   6G
60   60  D09N50  ZONE DRAIN 09 FROM 50%      1.331552   1.046805   .998800
 .997231  6D   3H
61   61  D10N50  ZONE DRAIN 10 FROM 50%      1.365883   1.035486   .998350
 .999649  8E   6H
62   62  D11N50  ZONE DRAIN 11 FROM 50%      1.392707   1.030721   .999615
 .999750  11F  8H
63   63  D12N50  ZONE DRAIN 12 FROM 50%      1.370404   1.030528   .999624
 .998821  10E  8H
64   64  D13N50  ZONE DRAIN 13 FROM 50%      1.327207   1.051348   .998006
 .997810  9F   1G
65   65  D14N50  ZONE DRAIN 14 FROM 50%      1.339731   1.045304   .998801
 .998506  9F   2J
66   66  AJFO01  ADJUSTER 01 FULL-OUT        1.410034   1.030928   .999704
 .999635  12D  8G
67   67  AJFO02  ADJUSTER 02 FULL-OUT        1.384712   1.039736   .999742
 .999477  2F   3G
68   68  AJFO03  ADJUSTER 03 FULL-OUT        1.383456   1.033341   .999580
 .999151  1E   3J
69   69  AJFO04  ADJUSTER 04 FULL-OUT        1.392627   1.036860   .999702
 .999527  7D   7J
70   70  AJFO05  ADJUSTER 05 FULL-OUT        1.385955   1.032506   .999920
 .999331  3D   1H
71   71  AJFO06  ADJUSTER 06 FULL-OUT        1.388980   1.036997   .999778
 .999471  3E   2H
72   72  AJFO07  ADJUSTER 07 FULL-OUT        1.411660   1.029542   .999702
 .999629  3E   2H
73   73  AJFO08  ADJUSTER 08 FULL-OUT        1.411462   1.029289   .999712
 .999812  5D   3H
74   74  AJFO09  ADJUSTER 09 FULL-OUT        1.383080   1.039716   .999784
 .999763  5E   3J
75   75  AJFO10  ADJUSTER 10 FULL-OUT        1.387114   1.031647   .999732
 .999442  7E   3J
76   76  AJFO11  ADJUSTER 11 FULL-OUT        1.391376   1.035501   .999844
 .999630  6D   2J
77   77  AJFO12  ADJUSTER 12 FULL-OUT        1.387850   1.031575   .999997
 .999900  8E   2J
78   78  AJFO13  ADJUSTER 13 FULL-OUT        1.385468   1.038651   .999972
 .999752  8E   1H
79   79  AJFO14  ADJUSTER 14 FULL-OUT        1.410839   1.029897   .999729
 .999814  8E   4H
80   80  AJFO15  ADJUSTER 15 FULL-OUT        1.414070   1.027965   .999708
 .999664  9D   3H
81   81  AJFO16  ADJUSTER 16 FULL-OUT        1.387398   1.037783   .999670
 .999603  5F   8J
82   82  AJFO17  ADJUSTER 17 FULL-OUT        1.384890   1.032941   .999580
 .999682  9E   8J
83   83  AJFO18  ADJUSTER 18 FULL-OUT        1.392854   1.036356   .999718
 .999621  10E  8J
84   84  AJFO19  ADJUSTER 19 FULL-OUT        1.385102   1.033115   .999758
 .999608  8F   2J
85   85  AJFO20  ADJUSTER 20 FULL-OUT        1.386716   1.038958   .999789
 .999583  8F   1H
86   86  AJFO21  ADJUSTER 21 FULL-OUT        1.412401   1.028529   .999762
 .999652  9F   4G
87   87  AJHO01  ADJUSTER 01 HALF-OUT        1.413713   1.028049   .999678
 .999609  3E   3J
88   88  AJHO02  ADJUSTER 02 HALF-OUT        1.393236   1.039224   .999710
 .999586  2E   3J
89   89  AJHO03  ADJUSTER 03 HALF-OUT        1.395192   1.034829   .999717
 .999517  2F   3J
90   90  AJHO04  ADJUSTER 04 HALF-OUT        1.397455   1.035694   .999730
 .999549  6D   3J
91   91  AJHO05  ADJUSTER 05 HALF-OUT        1.389832   1.037230   .999821
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.999382 4D 2H
92 92 AJHO06 ADJUSTER 06 HALF-OUT 1.391426 1.038601 .999738
.999482 3E 2H
93 93 AJHO07 ADJUSTER 07 HALF-OUT 1.413311 1.028427 .999675
.999599 3E 4G
94 94 AJHO08 ADJUSTER 08 HALF-OUT 1.414268 1.027557 .999711
.999644 10D 2J
95 95 AJHO09 ADJUSTER 09 HALF-OUT 1.392035 1.038848 .999740
.999712 5E 3J
96 96 AJHO10 ADJUSTER 10 HALF-OUT 1.391247 1.036841 .999691
.999548 8F 3J
97 97 AJHO11 ADJUSTER 11 HALF-OUT 1.402522 1.027348 .999663
.999648 1F 6J
98 98 AJHO12 ADJUSTER 12 HALF-OUT 1.391822 1.034479 .999876
.999465 7D 5H
99 99 AJHO13 ADJUSTER 13 HALF-OUT 1.394739 1.036694 .999760
.999669 7E 4H
100 100 AJHO14 ADJUSTER 14 HALF-OUT 1.412771 1.028656 .999682
.999626 1E 4G
101 101 AJHO15 ADJUSTER 15 HALF-OUT 1.414759 1.027279 .999689
.999615 8E 3G
102 102 AJHO16 ADJUSTER 16 HALF-OUT 1.393342 1.039483 .999734
.999678 10F 8J
103 103 AJHO17 ADJUSTER 17 HALF-OUT 1.389099 1.039590 .999753
.999567 9E 3H
104 104 AJHO18 ADJUSTER 18 HALF-OUT 1.397831 1.035169 .999694
.999550 10E 5H
105 105 AJHO19 ADJUSTER 19 HALF-OUT 1.395955 1.032431 .999773
.999446 11D 8H
106 106 AJHO20 ADJUSTER 20 HALF-OUT 1.395645 1.036986 .999767
.999615 11E 8H
107 107 AJHO21 ADJUSTER 21 HALF-OUT 1.413633 1.028180 .999674
.999597 3E 3J
108 108 MCAC1H MCA 1ST BANK HALF-IN 1.290789 1.026019 .999303
.990789 2E 8J
109 109 MCAC1F MCA 1ST BANK FULL-IN 1.328571 1.031350 .999625
.999911 9D 5H
110 110 MCAC2H MCA 1ST FI & 2ND HI 1.168160 1.024127 .997186
.995469 2E 7H
111 111 MCAC2F MCA 1ST FI & 2ND HI 1.217153 1.037688 .997927
.999791 2E 8J
112 112 MCAN1H MCA 1ST BANK HALF-IN 1.172954 1.027881 .999304
.978490 11D 7H
113 113 MCAN1F MCA 1ST BANK FULL-IN 1.258388 1.041295 .999603
.999873 9D 5H
114 114 MCAN2H MCA 1ST FI & 2ND HI 1.102006 1.028476 .995134
.994428 11D 7H
115 115 MCAN2F MCA 1ST FI & 2ND FI 1.148860 1.041988 .995429
.999736 2E 8J
116 116 MCASI1 MCA ROD 01 STUCK-IN 1.295200 1.035216 .999301
.999389 11E 4H
117 117 MCASI2 MCA ROD 02 STUCK-IN 1.293585 1.038309 .998963
.999379 5D 2H
118 118 MCASI3 MCA ROD 03 STUCK-IN 1.295996 1.038131 .999452
.999332 11E 4H
119 119 MCASI4 MCA ROD 04 STUCK-IN 1.293626 1.039588 .999275
.999461 9D 2G
120 120 ZT1ATB 1ST AZIMUTHAL TOB/BOTTOM 1.283709 1.033527 .999690
.996461 10F 8H
121 121 ZT1ABT 1ST AZIMUTHAL BOTTOM/TOP 1.271510 1.026232 .995749
.999252 1E 6J
122 122 ZTSFSE 1ST AZIMUTHAL SIDE/SIDE 1.257559 1.045506 .997442
.996167 11E 1G
123 123 ZTSESF 1ST AZIMUTHAL SIDE/SIDE 1.255475 1.044012 .997591
.995215 1D 2G
124 124 ZTEFEE 1ST AXIAL END/END 1.401662 1.032974 .999999
1.000000 9E 8H
125 125 ZTEEEF 1ST AXIAL END/END 1.399796 1.035667 .999999
1.000000 4D 7J

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126  126  ZTT045  1ST AZIMUTHAL TOP AT 045                1.265897   1.049862    .999178
 .995696  1D   8G
127  127  ZTT135  1ST AZIMUTHAL TOP AT 135                1.267906   1.048805    .998982
 .997482  7F   7G
128  128  ZTT225  1ST AZIMUTHAL TOP AT 225                1.259769   1.038682    .996810
 .997754  11E  6G
129  129  ZTT315  1ST AZIMUTHAL TOP AT 315                1.258256   1.036035    .995866
 .998567  1F   6H
130  130  ZT2A01  2ND AZIMUTHAL 135,315 HI                1.313649   1.053683    .998990
 .996852  1D   2G
131  131  ZT2A02  2ND AZIMUTHAL 045,225 HI                1.314865   1.053043    .998230
 .997950  9F   7G
132  132  ZT2A03  2ND AZIMUTHAL T/B   HI                  1.388958   1.034597    .999486
 .999060  1D   1G
133  133  ZT2A04  2ND AZIMUTHAL SIDES HI                  1.365828   1.039449    .999747
 .998610  10F  8J
134  134  ZTAX01  1ST AZIMUTHAL-AXIAL S=HI                1.407525   1.031624    .999913
 .999720  4D   7G
135  135  ZTAX02  1ST AZIMUTHAL-AXIAL S=LO                1.407655   1.032008    .999896
 .999684  2F   8G
136  136  ZTAX03  1ST AZIMUTHAL-AXIAL T=HI                1.410546   1.030756    .999976
 .999982  2F   7J
137  137  ZTAX04  1ST AZIMUTHAL-AXIAL T=LO                1.408859   1.030814    .999982
 .999982  9E   8H
138  138  ZT1R01  1ST RADIAL CENTER HI                    1.378173   1.036713    .999670
 .999190  10F  7G
139  139  ZT1R02  1ST RADIAL OUTER  HI                    1.340039   1.033573    .998181
 .997674  3F   7G
150  150  SSSD01  ALL BANKS OUT/Xe @ 38.1 MIN             1.112423   1.030503   1.000000
 .999995  6E   4J
151  151  SSSD02  ALL BANKS OUT/Xe @ 22.3 MIN             1.135780   1.027781   1.000000
1.000000  7E   4J
152  152  SSSD03  BANK 7 FULL-IN/NO TIMESTEP              1.228802   1.035893   1.000000
 .999999  7E   4J
153  153  SSSD04  BANK 7 FULL-IN/Xe @ 27.4 MIN            1.113894   1.030107   1.000000
1.000000  7E   4J
154  154  SSSD05  BANK 6 FULL-IN/NO TIMESTEP              1.196461   1.031300   1.000000
1.000000  7E   4J
155  155  SSSD06  BANK 6 FULL-IN/Xe @ 26.7 MIN            1.196468   1.034696   1.000000
1.000000  7E   4J
156  156  SSSD07  BANK 5 FULL-IN/NO TIMESTEP              1.248258   1.037239    .999999
1.000000  7E   4J
157  157  SSSD08  BANK 5 FULL-IN/Xe @ 26.5 MIN            1.240090   1.028835   1.000000
1.000000  7E   4J
158  158  SSSD09  BANK 4 FULL-IN/NO TIMESTEP              1.268363   1.040234    .999997
 .999949  8F   4J
159  159  SSSD10  BANK 4 FULL-IN/Xe @ 23.5 MIN            1.259796   1.038614    .999998
 .999956  8F   4J
160  160  SSSD11  BANK 3 FULL-IN/NO TIMESTEP              1.314008   1.041007    .999991
 .999897  8F   4J
161  161  SSSD12  BANK 3 FULL-IN/Xe @ 27.8 MIN            1.315019   1.040953    .999994
 .999943  7E   4J
162  162  SSSD13  BANK 2 FULL-IN/NO TIMESTEP              1.367433   1.035510    .999971
 .999945  8F   4J
163  163  SSSD14  BANK 2 FULL-IN/Xe @ 43.6 MIN            1.382607   1.035118    .999982
 .999982  8F   3J
164  164  SSSD15  BANK 1 FULL-IN/NO TIMESTEP              1.408853   1.028469    .999866
 .999852  8E   3J
165  165  SSSD16  BANK 1 FULL-IN/Xe @ 90.0 MIN            1.410949   1.028993    .999749
 .999657  2E   7H
166  166  SSSD17  ALL BANKS IN/Xe @ 180. MIN              1.412881   1.028548    .999669
 .999541  2E   8G
167  167  SSSD18  ALL BANKS IN/Xe @ 270. MIN              1.413801   1.028176    .999618
 .999517  2E   3J
168  168  SA4400  ALL BANKS OUT/Xe @ 36. HRS              1.137859   1.039423   1.000000
1.000000  5D   5G
169  169  SA4401  ALL BANKS OUT/Xe @ 46.4 MIN             1.131681   1.039279   1.000000
1.000000  5D   5G
170  170  SA4402  ALL BANKS OUT/Xe @ 5.3 MIN              1.149626   1.030334   1.000000
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1.000000 5D 5G
171 171 SA4403 BANK 7 FULL-IN 1.258770 1.036599 1.000000
1.000000 5D 5G
172 172 SA4404 BANK 7 FULL-IN/Xe @ 5.2 MIN 1.250600 1.030813 1.000000
1.000000 5D 5G
173 173 SA4405 BANK 6 FULL-IN 1.337852 1.029127 1.000000
1.000000 5D 5G
174 174 SA4406 BANK 6 FULL-IN/Xe @ 4.3 MIN 1.280011 1.027317 1.000000
1.000000 5D 5G
175 175 SA4407 BANK 5 FULL-IN 1.327186 1.039727 1.000000
1.000000 5D 5G
176 176 SA4408 BANK 5 FULL-IN/Xe @ 4.3 MIN 1.320873 1.031073 1.000000
1.000000 5D 5G
177 177 SA4409 BANK 4 FULL-IN 1.347448 1.038562 1.000000
1.000000 5D 5G
178 178 SA4410 BANK 4 FULL-IN/Xe @ 3.9 MIN 1.336708 1.036986 1.000000
1.000000 5D 5G
179 179 SA4411 BANK 3 FULL-IN 1.384288 1.038033 1.000000
1.000000 5D 5G
180 180 SA4412 BANK 3 FULL-IN/Xe @ 3.9 MIN 1.380823 1.038784 1.000000
1.000000 5D 5G
181 181 SA4413 BANK 2 FULL-IN 1.415281 1.028021 1.000000
1.000000 5D 5G
182 182 SA4414 BANK 2 FULL-IN/Xe @4.2 MIN 1.424749 1.026058 1.000000
1.000000 5D 5G
183 183 SA4415 BANK 1 FULL-IN 1.433245 1.024055 1.000000
1.000000 5D 5G
184 184 SA4416 BANK 1 FI+0.5PPM/Xe @ 12.9 MIN 1.411156 1.031896 1.000000
1.000000 5D 5G
185 185 SA4417 ALL BANKS IN+2.0PPM/Xe @ 83.7 MIN 1.402547 1.034089 1.000000
1.000000 5D 5G
186 186 SA4418 ALL BANKS IN+2.0PPM/Xe @ 263.7MIN 1.385965 1.034848 1.000000
1.000000 5D 5G
191 191 SBCK01 ALL BANKS IN/Xe @ 12.3 MIN 1.401273 1.033895 .999768
.999512 4D 7J
192 192 SBCK02 BANK 1 OUT 1.391246 1.036443 .999808
.999662 6F 3J
193 193 SBCK03 BANK 1 OUT/Xe @ 10.5 MIN 1.395328 1.033065 .999803
.999490 12D 7J
194 194 SBCK04 BANK 2 OUT + 1.366580 1.037189 .999928
.999597 7E 4J
195 195 SBCK05 BANK 2 OUT/Xe @ 18.3 MIN 1.381141 1.032195 .999958
.999420 4F 7J
196 196 SBCK06 BANK 3 OUT 1.327088 1.038162 .999959
.999610 6F 4J
197 197 SBCK07 BANK 3 OUT/Xe @ 28.5 MIN 1.344294 1.033694 .999965
.999566 4F 4J
198 198 SBCK08 BANK 4 OUT 1.285447 1.041753 .999995
1.000000 7E 4G
199 199 SBCK09 BANK 4 OUT/Xe @ 310.9 MIN 1.264932 1.034191 .999999
1.000000 7E 3G
200 200 SBCK10 BANK 4 IN 1.299704 1.039732 .999988
.999889 8F 4J
201 201 SBCK11 BANK 4 IN/Xe @ 270.4 MIN 1.304405 1.036661 .999984
.999770 6F 4J
202 202 SHIM01 ALL BANKS IN/SS Xe 1.394837 1.036854 .999786
.999492 4D 8H
203 203 SHIM02 BANK 1 OUT 1.387573 1.036765 .999836
.999716 6F 3J
204 204 SHIM03 BANK 1 OUT/Xe @240. MIN 1.387928 1.035187 .999856
.999606 4F 7J
205 205 SHIM04 BANK 1 OUT/SS Xe 1.391536 1.034359 .999830
.999567 12D 7J
206 206 SHIM05 BANK 2 OUT 1.360741 1.037334 .999932
.999656 7E 4J
207 207 SHIM06 BANK 2 OUT/Xe A 240.MIN 1.369541 1.034565 .999961
.999620 6F 4J
208 208 SHIM07 BANK 2 OUT/SS Xe 1.377985 1.032737 .999957
.999521 4F 7J

209	209	SHIM08	BANK 3 OUT	1.325058	1.037840	.999964	.999703	6F	4J
210	210	SHIM09	BANK 3 OUT/Xe @ 240. MIN	1.325789	1.037439	.999967	.999720	8F	4J
211	211	SHIM10	BANK 3 OUT/SS Xe	1.345943	1.034005	.999960	.999599	4F	4J
212	212	SHIM11	BANK 4 OUT	1.286884	1.042317	.999994	1.000000	8E	3G
213	213	SHIM12	BANK 4 OUT/Xe @ 240.0 MIN	1.280175	1.043635	.999996	1.000000	8E	3G
214	214	SHIM13	BANK 4 OUT/SS Xe	1.293748	1.043079	.999992	1.000000	11E	3G
215	215	SHIM14	BANK 5 OUT	1.255189	1.035155	.999999	1.000000	10E	4J
216	216	SHIM15	BANK 5 OUT/Xe @ 240.0 MIN	1.268748	1.035879	.999999	1.000000	10E	4J
217	217	SHIM16	BANK 5 OUT/SS Xe	1.288158	1.031478	.999999	1.000000	10E	4J
218	218	SHIM17	BANK 6 OUT	1.210067	1.033043	1.000000	1.000000	7E	4J
219	219	SHIM18	BANK 6 OUT/SS Xe	1.237281	1.037271	1.000000	.999999	7E	4J
220	220	SHIM19	BANK 7 OUT	1.148786	1.027506	1.000000	1.000000	6E	4J
221	221	SHIM20	BANK 7 OUT/SS Xe	1.175407	1.034304	1.000000	.999999	7E	4J
222	222	ABHO01	STARTUP BANK 7 HALF-IN	1.117708	1.036479	1.000000	1.000000	7E	4J
223	223	ABHO02	STARTUP BANK 6 HALF-IN	1.109436	1.033655	1.000000	1.000000	7E	4J
224	224	ABHO03	STARTUP BANK 5 HALF-IN	1.155840	1.043934	1.000000	1.000000	7E	3H
225	225	ABHO04	STARTUP BANK 4 HALF-IN	1.192824	1.041239	.999999	1.000000	7E	3H
226	226	ABHO05	STARTUP BANK 3 HALF-IN	1.206773	1.044020	.999981	.999762	5D	4J
227	227	ABHO06	SHIM BANK 1 HALF-OUT	1.343868	1.036276	.999715	.998311	10F	8H
228	228	ABHO07	SHIM BANK 2 HALF-OUT	1.288599	1.041409	.999792	.998419	7E	7H
229	229	MCASH1	MCA ROD 1 HALF-IN	1.372097	1.034713	.999745	.999376	2E	1G
230	230	MCASH2	MCA ROD 2 HALF-IN	1.372872	1.032033	.999626	.999436	2E	3J
231	231	MCASH3	MCA ROD 3 HALF-IN	1.375121	1.033641	.999772	.999162	7F	1G
232	232	MCASH4	MCA ROD 4 HALF-IN	1.371038	1.031761	.999557	.999285	2E	8H

25 Worst Cases.

49	D12C80	ZONE DRAIN 12 FROM 80%	.9984	.9749
42	D05C80	ZONE DRAIN 05 FROM 80%	.9966	.9751
112	MCAN1H	MCA 1ST BANK HALF-IN	.9993	.9785
44	D07C80	ZONE DRAIN 07 FROM 80%	.9982	.9859
39	D02C80	ZONE DRAIN 02 FROM 80%	.9996	.9900
108	MCAC1H	MCA 1ST BANK HALF-IN	.9993	.9908
46	D09C80	ZONE DRAIN 09 FROM 80%	.9968	.9918
51	D14C80	ZONE DRAIN 14 FROM 80%	.9965	.9919
114	MCAN2H	MCA 1ST FI & 2ND HI	.9951	.9944
123	ZTSESF	1ST AZIMUTHAL SIDE/SIDE	.9976	.9952
115	MCAN2F	MCA 1ST FI & 2ND FI	.9954	.9997
110	MCAC2H	MCA 1ST FI & 2ND HI	.9972	.9955
126	ZTT045	1ST AZIMUTHAL TOP AT 045	.9992	.9957
121	ZT1ABT	1ST AZIMUTHAL BOTTOM/TOP	.9957	.9993
129	ZTT315	1ST AZIMUTHAL TOP AT 315	.9959	.9986
122	ZTSFSE	1ST AZIMUTHAL SIDE/SIDE	.9974	.9962
120	ZT1ATB	1ST AZIMUTHAL TOB/BOTTOM	.9997	.9965
38	D01C80	ZONE DRAIN 01 FROM 80%	.9974	.9967
50	D13C80	ZONE DRAIN 13 FROM 80%	.9977	.9968

128	ZTT225	1ST AZIMUTHAL TOP AT 225	.9968	.9978
130	ZT2A01	2ND AZIMUTHAL 135,315 HI	.9990	.9969
53	D02N50	ZONE DRAIN 02 FROM 50%	.9995	.9972
60	D09N50	ZONE DRAIN 09 FROM 50%	.9988	.9972
45	D08C80	ZONE DRAIN 08 FROM 80%	.9974	.9986
127	ZTT135	1ST AZIMUTHAL TOP AT 135	.9990	.9975

Minimum trip confidence = .9749 for case 49

Calculating Required Setpoint Adjustment
Setpoint Adjustment = .9948 (.9800) Case : 49
Base Setpoint Result = 1.2336

KAERI/TR-2511/2003

서 지 정 보 양 식

수행기관보고서번호	위탁기관보고서번호	표준보고서번호	INIS 주제코드
KAERI/TR-2511/2003			

제목/부제	DUPIC 핵연료장전 중수로의 국부과출력 보호계통 해석
연구책임자 및 부서명 (TR, AR인 경우 주저자)	정 창 준 (건식재가공핵연료 노심특성평가 기술개발)
연 구 자 및 부 서 명	최 항 복 (건식재가공핵연료 노심특성평가 기술개발) 박 지 원 (건식재가공핵연료 노심특성평가 기술개발)

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연구위탁기관		계약 번호	

초록 (15-20줄내외)

DUPIC 핵연료가 장전된 CANDU 6 원자로의 과출력 보호계통에 대한 평가를 수행하였다. 본 계산에는 WIMS/RFSP/ROVER-F 코드 체계에 대한 타당성 계산도 포함되었다. 타당성 계산 결과, WIMS/RFSP/ROVER-F 코드 체계는 CANDU 6 원자로의 과출력 보호 계통 해석에 대해 타당성을 갖는 것으로 나타났다. DUPIC 핵연료가 장전된 노심의 ROP 트립 설정치는 125.7%로 나타났으며, 이는 천연 우라늄 핵연료 장전 노심의 트립 설정치와 거의 유사하다. 본 연구는 DUPIC 핵연료의 장전이 천연 우라늄 핵연료 장전 노심에 대해 설계된 국부 과출력 트립 설정치에 영향을 미치지 않음을 보여준다.

주제명키워드 (10단어내외)	ROP 계통, CANDU 6 원자로, DUPIC 핵연료, 트립설정치, 오차, 불확실도, 계측기, 원자로 정지계통

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Project Manager and Department	Chang-Joon Jeong (Dry-processed fuel core characteristics assessment technology development)
Researcher and Department	Hangbok Choi Jee Won Park

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Abstract (15-20 Lines)

The regional overpower protection (ROP) system was assessed a CANDU 6 reactor with the DUPIC fuel, including the validation of the WIMS/RFSP/ROVER-F code system used for the estimation of ROP trip setpoint. The validation calculation has shown that it is valid to use the WIMS/RFSP/ROVER-F code system for ROP system analysis of the CANDU 6 core. For the DUPIC core, the ROP trip setpoint was estimated to be 125.7%, which is almost the same as that of the standard natural uranium core. This study has shown that the DUPIC fuel does not hurt the current ROP trip setpoint designed for the natural uranium CANDU 6 reactor.

Subject Keywords (About 10 words)	ROP System, CANDU 6 Reactor, DUPIC Fuel, Trip Setpoint, Error, Uncertainty, Detector, Shutdown System