CEN-356(V)-NP-A
REVISION 01-NP-A

MODIFIED STATISTICAL COMBINATION OF UNCERTAINTIES

MAY 1988

COMBUSTION ENGINEERING

LEGAL NOTICE

THIS REPORT WAS PREPARED AS AN ACCOUNT OF WORK SPONSORED BY COMBUSTION ENGINEERING, INC. NEITHER COMBUSTION ENGINEERING NOR ANY PERSON ACTING ON ITS BEHALF:

A. MAKES ANY WARRANTY OR REPRESENTATION, EXPRESS OR IMPLIED INCLUDING THE WARRANTIES OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY, WITH RESPECT TO THE ACCURACY, COMPLETENESS, OR USEFULNESS OF THE INFORMATION CONTAINED IN THIS REPORT, OR THAT THE USE OF ANY INFORMATION, APPARATUS, METHOD, OR PROCESS DISCLOSED IN THIS REPORT MAY NOT INFRINGE PRIVATELY OWNED RIGHTS; OR

B. ASSUMES ANY LIABILITIES WITH RESPECT TO THE USE OF, OR FOR DAMAGES RESULTING FROM THE USE OF, ANY INFORMATION, APPARATUS, METHOD OR PROCESS DISCLOSED IN THIS REPORT.

CEN-356(V)-NP-A
Revision 01-NP-A

MODIFIED STATISTICAL

COMBINATION OF UNCERTAINTIES

May 1988

NUCLEAR POWER SYSTEMS
COMBUSTION ENGINEERING, INC.
WINDSOR, CT.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

October 21, 1987

Docket No.: STN 50-528

Mr. E. E. Van Brunt, Jr.
Executive Vice President
Arizona Nuclear Power Project
Post Office Box 52034
Phoenix, Arizona 85072-2034

Dear Mr. Van Brunt:

SUBJECT: ISSUANCE OF AMENDMENT NO. 24 TO FACILITY OPERATING LICENSE NO. NPF-41 FOR THE PALO VERDE NUCLEAR GENERATING STATION, UNIT NO. 1 (TAC NOS. 65460, 65461, 65462 AND 65691 THROUGH 65706)

The Commission has issued the subject Amendment, which is enclosed, to the Facility Operating License for Palo Verde Nuclear Generating Station, Unit 1. The Amendment consists of changes to the Technical Specifications (Appendix A to the license) in response to your application transmitted by letter dated June 29, 1987, as supplemented by letters dated June 29, July 13, August 20 (two letters), September 4 and October 1, 1987.

The Amendment revises several portions of the Technical Specifications to incorporate changes in support of Cycle 2 operation for Palo Verde, Unit 1. One of the proposed changes to the Technical Specifications in your amendment request, involving the removal of the numerical values for the axial shape index limits, has not been granted. This request, which is not required for restart of Palo Verde Unit 1, is similar to requests from other licensees and is currently being reviewed on a generic basis by the staff. After the results of the staff's generic review become available, you may resubmit your request consistent with the resultant staff findings.

Page 3/4 3-41 of the Technical Specifications was revised in Amendment No. 21, which was issued September 4, 1987. This page is being reissued at this time, along with its overleaf page (3/4 3-42), in order to correctly represent the approval granted in Amendment No. 21.

A copy of the related Safety Evaluation is also enclosed. A Notice of Issuance will be included in the Commission's next regular bi-weekly Federal Register notice.

Sincerely,

E. A. Licitra

E. A. Licitra, Senior Project Manager
Project Directorate V
Division of Reactor Projects - III,
IV, V and Special Projects

Enclosures:

1. Amendment No. 24 to NPF-41
2. Safety Evaluation
3. Pages 3/4 3-41 and 3-42

cc: See next page

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO AMENDMENT NO. 24 TO FACILITY OPERATING LICENSE NO. NPF-41

ARIZONA PUBLIC SERVICE COMPANY, ET AL.

PALO VERDE NUCLEAR GENERATING STATION, UNIT NO. 1

DOCKET NO. STN 50-528

1.0 INTRODUCTION

By letter dated June 29, 1987 (Ref. 1), as supplemented by letters dated August 20, 1987 (Ref. 4) and October 1, 1987, the Arizona Public Service Company (APS) on behalf of itself, the Salt River Project Agricultural Improvement and Power District, Southern California Edison Company, El Paso Electric Company, Public Service Company of New Mexico, Los Angeles Department of Water and Power, and Southern California Public Power Authority (licensees), requested several changes to the Technical Specifications (Appendix A to Facility Operating License NPF-41) for the Palo Verde Nuclear Generating Station, Unit 1 (PVNGS1), relating to Cycle 2 operation for PVNGS1. In support of both the Technical Specification changes and Cycle 2 operation, the licensees submitted (1) a Reload Analysis Report by letter dated June 29, 1987 (Ref. 2), as supplemented by letters dated July 13 and August 20, 1987 (Ref. 5 and 6) and September 4, 1987, and (2) a report concerning a modified version for a Statistical Combination of Uncertainties (SCU), dated July 1987 (Ref. 3). The staff's evaluation of the SCU report and the reload analysis is presented in Sections 2.0 through 6.0 below. The evaluation of the specific changes to the Technical Specifications is presented in Section 7.0 below.

THE MODIFIED STATISTICAL COMBINATION OF UNCERTAINTIES REPORT WAS REVIEWED AS PART OF A LARGER PVNGS UNIT 1, CYCLE 2 RELOAD SAFETY EVALUATION. SECTIONS 2.0, 3.0, 6.0, 7.0, 9.0, 10.0 AND 11.0 ARE RELATED TO THE GENERAL RELOAD SAFETY EVALUATION AND NOT THE MODIFIED STATISTICAL COMBINATION OF UNCERTAINTIES. THESE SECTIONS ARE THUS NOT INCLUDED HERE.

4.0 EVALUATION OF THERMAL-HYDRAULIC DESIGN

Steady-state thermal-hydraulic analysis for Cycle 2 is performed by using the approved thermal-hydraulic code TORC (Ref. 9) and the CE-1 critical heat flux (CHF) correlation (Ref. 10). The design thermal margin analysis is performed with the fast running variation of the TORC code, CETOP-D (Ref. 11). The CETOP-D model has been verified to predict the minimum departure from nucleate boiling ratio (DNBR) conservatively relative to TORC.

The uncertainties associated with the system parameters are combined statistically using the modified statistical combination of uncertainties (SCU) methodology described in Reference 3, which is evaluated and approved below in Section 5.0 of this evaluation. Using this methodology, the engineering hot channel factors for heat flux, heat input, fuel rod pitch, and cladding diameter are combined statistically with other uncertainty factors to arrive at overall uncertainty penalty factors to be applied to the DNBR calculations performed by the core protection calculators (CPCs) and the core operating limit supervisory system (COLSS). When used with the Cycle 2 DNBR limit of 1.24, these overall uncertainty penalty factors provide assurance with a 95% confidence and a 95% probability (95/95 confidence/probability) that the hottest fuel rod will not experience DNB. The fuel rod bow penalty is incorporated directly in the DNBR limit. It has been calculated using the approved method described in Reference 13. The value used for this analysis, 1.75% DNBR, is valid for fuel assembly burnups up to 30,000 MWD/MTU. For those assemblies with average burnup in excess of 30,000 MWD/MTU, sufficient margin exists to offset rod bow penalties.

5.0 EVALUATION OF MODIFIED STATISTICAL COMBINATION OF UNCERTAINTIES (SCU)

The licensees requested NRC review and approval of the topical report, "Modified Statistical Combination of Uncertainties," CEN-356(V)-P, Revision 01-P, July 1987 (Ref. 3). This report describes changes to the methodology for statistically combining uncertainties to obtain overall uncertainty factors. The overall uncertainty factors are used to determine the limiting safety system setting (LSSS) and limiting condition for operation (LCO) for the PVNGS COLSS and CPC system.

The existing SCU method treats uncertainties in two groups. The uncertainties in one group (system parameter uncertainties) include engineering factors, critical heat flux (CHF) correlation uncertainties and code modeling uncertainties which are statistically combined to generate a DNBR probability density function. The 95/95 probability/confidence level limit of this function is then used as the setpoint analysis minimum DNBR. The uncertainties in the other group (state parameter uncertainties) include measured state parameter, COLSS and CPC algorithm, radial peaking factor measurement, simulator model, computer processing and startup measurement uncertainties. These uncertainties are also statistically combined to determine the CPC and COLSS overall uncertainty factors.

Although the uncertainties within each group are combined statistically and a 95/95 probability/confidence level generated for each group, the resultant uncertainties of the two groups are effectively combined in a deterministic manner due to the separate application of the two uncertainty limits. The proposed modified SCU methodology would statistically combine uncertainty components which were previously applied deterministically. In addition, the statistical treatment of several uncertainty components would be modified so that the overall uncertainty factors can be calculated and applied as a function of burnup, axial shape index (ASI), and power in COLSS and CPC.

The staff has reviewed the uncertainties and the uncertainty treatment procedure described for the proposed modified SCU methodology and has determined that the resultant penalties applied to the COLSS power operating limit and the CPCS DNBR and local power density (LPD) calculations adequately incorporate all uncertainties at the 95/95 probability/confidence level. The analytical methods reviewed show that a DNBR limit of 1.24 with the uncertainty penalties derived in the report provides a 95/95 probability/confidence level assurance against DNB occurring during steady state operation or anticipated operational occurrences at the Palo Verde Nuclear Generating Station. The proposed methodology is, therefore, acceptable for use with the Palo Verde Nuclear Generating Station digital monitoring and protection systems.

8.0 EVALUATION FINDINGS

The staff has reviewed the fuels, physics, and thermal-hydraulics information presented in the PVNGS1 Cycle 2 reload report. The staff has also reviewed the proposed Technical Specification revisions, the SCU modification, and the safety reanalyses. Based on the evaluations given in the preceding sections, the staff finds the proposed reload and the Technical Specification changes to be acceptable.

REFERENCES

1. Reload Technical Specification Amendment, submitted by letter from J. G. Haynes (ANPP) dated June 29, 1987.

2. Reload Analysis Report for Palo Verde Nuclear Generating Station Unit 1 Cycle 2, submitted by letter from J. G. Haynes (ANPP) dated June 29, 1987.

3. "Modified Statistical Combination of Uncertainties," CEN-353(V)-P, Revision 01-P, Combustion Engineering, July 1987.

4. Revision to Reload Technical Specification Amendment - Attachment 2, Shutdown Margin, submitted by letter from J. G. Haynes (ANPP) dated August 20, 1987.

5. Letter from J. G. Haynes (ANPP) dated July 13, 1987.

6. Response to NRC Questions Regarding the Unit 1 Cycle 2 Reload Submittal, submitted by letter from J. G. Haynes (ANPP) dated August 20, 1987.

7. "CEPAN Method of Analyzing Creep Collapse of Oval Cladding, Volume 5: Evaluation of Interpellet Gap Formation and Clad Collapse in Modern PWR Fuel Rods," EPRI NP-3966-CCM, April 1985.

8. "The ROCS and DIT Computer Codes for Nuclear Design," CENPD-266-P-A, Combustion Engineering, April 1983.

9. "TORC Code, A Computer Code for Determining the Thermal Margin of a Reactor Core," CENPD-161-P, Combustion Engineering, July 1975.

10. "Critical Heat Flux Correlation for C-E Fuel Assemblies with Standard Sp 'es Grids, Part 1, Uniform Axial Power Distribution," CENPD-162-P-A, C stion Engineering, April 1975.

11. "CETOP-D Code Structure and Modeling Methods for San Onofre Nuclear Generating Station, Units 2 and 3," CEN-160(S)-P, Revision 1-P, Combustion Engineering, September 1981.

12. "Safety Evaluation of CEN-161 (FATES3)," submitted by letter from R. A. Clark (NRC), to A. E. Lundvall, Jr. (BG&E), March 31, 1983.

13. "Fuel and Poison Rod Bowing," CENPD-225-P-A, Combustion Engineering, June 1983.

14. "HERMITE Space-Time Kinetics," CENPD-188-A, Combustion Engineering, July 1976.

ABSTRACT

This report describes changes to the methodology for statistically combining uncertainties used to determine the LSSS and LCO overall uncertainty factors for C-E's digital monitoring and protection systems. The resultant overall uncertainty factors using the Modified Statistical Combination of Uncertainties (SCU) Program are determined and applied such that the Core Operating Limit Supervisory System (COLSS) Power Operating Limit (POL) and the Core Protection Calculator System (CPCS) DNBR and Local Power Density (LPD) calculations are conservative to at least a 95/95 probability/confidence level. The changes do not impact either the manner in which COLSS aids the operator in maintaining operating margin to limits on linear heat rate (LHR) and DNB or the manner in which the CPCS responds to transients and provides the low DNBR and LPD trips. Therefore the changes do not impact transient analysis assumptions or results and do not involve changes to Technical Specifications.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

DEFINITION OF ABBREVIATIONS

ASI	Axial Shape Index
BERR1-4	CPC Overall Uncertainty Factors
BPPCC	Boundary Point Power Correlation Coefficient
C-E	Combustion Engineering, Inc.
CEA	Control Element Assembly
CETOP-D	CE Thermal-Hydraulic Design Code
CHF	Critical Heat Flux
CIP	CPC Improvement Program
CPC	Core Protection Calculator
CPCS	Core Protection Calculator System
COLSS	Core Operating Limit Supervisory System
DNB	Departure from Nucleate Boiling
DNBOPM	DNB Overpower Margin
DNBR	DNB Ratio
EPOL	COLSS DNBR Overall Uncertainty Factor
FLAIR	CE Neutronics Simulator
Fq	3-Dimensional Peaking Factor
Fxy	Planar Radial Peaking Factor
HID-1	High Impact Design Spacer Grid (Type 1)
LCO	Limiting Condition for Operation
LHR	Linear Heat Rate
LPD	Local Power Density
LSSS	Limiting Safety System Settings
NRC	Nuclear Regulatory Commission
pdf	Probability Density Function
POL	Power Operating Limit
PVNGS	Palo Verde Nuclear Generating Station
RCS	Reactor Coolant System
RPS	Reactor Protection System
RSF	Rod Shadowing Factor
SAM	Shape Annealing Matrix
SCU	Statistical Combination of Uncertainties
UNCERT	COLSS LHR Uncertainty Factor

1.0 INTRODUCTION

1.1 Purpose

The purpose of this report is to describe changes to the methodology for statistically combining uncertainties associated with the LCO and LSSS setpoints for CE's digital monitoring and protection systems. These changes are designed to improve plant operating performance and flexibility and reduce the incidence of unnecessary reactor trips by reducing the overall uncertainty factors applied in the COLSS and CPCS. Rigorous, statistically justified methods are used to establish the resultant uncertainty factors. The Core Operating Limit Supervisory System (COLSS) aids the operator in monitoring the Limiting Conditions for Operation (LCO) based on DNBR margin, Linear Heat Rate (LHR) margin, Axial Shape Index (ASI) and core power. The Core Protection Calculator System (CPCS) within the Reactor Protection System (RPS) initiates the reactor trips based on low DNBR and high Local Power Density (LPD). Overall uncertainty factors are determined and applied for both the COLSS and CPCS such that the COLSS Power Operating Limits (POL) and the CPCS DNBR and LPD calculations are conservative to at least a 95/95 probability/confidence level. The Modified Statistical Combination of Uncertainties Program resulting from the methodology changes described in this report has been developed in such a way that this level of conservatism is maintained.

1.2 Background

1.2.1 Protection and Monitoring Systems

The functions and interactions of the protection and monitoring systems, LCO's and LSSS's, and COLSS and CPCS are described in previous PVNGS SCU reports such as References 1 and 2 and in current COLSS and CPCS Reports such as

References 3, 4, and 5. The changes to the Statistical Combination of Uncertainties (SCU) methodology descrited in this report do not impact the functions of these systems.

1.2.2 Current SCU Program

References 6, 7, and 8 are the latest references for the currently approved SCU methodology. The methods documented in these SONGS references are similar to those used for System [illegible] (i.e. PVNGS Cycle 1) as documented in References 1, 2 and 11 As part of the CPC Improvement Program, several modifications were made to simplify the SCU analysis process. These modifications are documented in Reference 9. NRC approval of the CIP related modifications was provided in Reference 10. The changes to the SCU methodology for the Modified SCU program are presented in this report based on the current SCU program described in these references.

The uncertainties involved in the SCU methodology are divided into two categories. The first category, referred to as "system parameter" uncertainties, includes engineering factors, CHF correlation uncertainties and TORC code modeling uncertainties. The uncertainties in this group are statistically combined to generate a DNBR probability density function (pdf). The 95/95 probability/confidence level tolerance limit of this function has been used as the DNBR limit in COLSS and CPCS thus accounting for the uncertainties in this category.

The second category, referred to as "state parameter" uncertainties, includes measured state parameter, COLSS and CPC algorithm, radial peaking factor measurement, simulator model, computer processing and startup measurement uncertainties. The state parameter, algorithm and startup measurement uncertainties are stochastically simulated to generate a state parameter pdf. The 95/95 probability/confidence level of this function is then root-sum-squared with the other uncertainties to determine the CPC and COLSS overall uncertainty factors, hence accounting for the uncertainties in this group. The uncertainty analysis which determines these overall uncertainty factors in the heretofore approved SCU program is illustrated in Figure 1-1.

Even though uncertainties within each part are combined statistically and a 95/95 probability/confidence level is generated for each group, the resultant uncertainties of the two groups are effectively combined in a deterministic manner due to separate application in the DNBR limit and the overall uncertainty factors. Tables 1-1 and 1-2 list the uncertainties included in the system parameter and the state parameter categories, respectively. These uncertainties are defined and described further in References 6, 7, and 8.

In the current SCU methodology, power measurement uncertainties are applied separately from the system and state parameter uncertainty factors. COLSS normally uses secondary calorimetric power as the standard and therefore the power measurement uncertainty for COLSS consists of the secondary calorimetric uncertainty. The CPC neutron flux power measurement uncertainty factor is calculated by a deterministic combination of the secondary calorimetric uncertainty, a calibration allowance, and the neutron flux power synthesis uncertainty. The CPC thermal power measurement uncertainty factor is calculated by a deterministic combination of the secondary calorimetric uncertainty, a calibration allowance, and a thermal power transient offset, if needed.

Figure 1-2 is a schematic of what will henceforth be referred to as the "current SCU" program.

1.3 Modified SCU Program

This document describes the changes to the current SCU program designed to improve plant operating performance and flexibility and reduce the incidence of unnecessary reactor trips by reducing excess conservatism in the DNBR overall uncertainty factors for COLSS and CPCS. The reduction in overall uncertainty factors results primarily from statistical combination of several uncertainty components previously applied deterministically. In addition, minor changes have been made in the statistical treatment of several components and the methodology has been developed so that the overall uncertainty factors can be calculated and applied in discrete regions of core burnup, power, and axial shape index (ASI). The changes made to the SCU program are the following:

1. [ ]

2. [ ]

3. [ ]

4. [ ]

5. Develop the methodology for determining and implementing Burnup, ASI, and Power dependent uncertainty factors in COLSS and CPCS.

These changes are described in more detail in Section 2.0. The SCU program with all these modifications will henceforth be referred to as the "Modified SCU" program. Figure 1-3 provides a schematic of the Modified SCU program.

1.4 Summary of Results

The methodology of the Modified SCU program will generate overall uncertainty factors such that the COLSS Power Operating Limit (POL) and CPCS DNBR and LPD calculations are conservative to at least a 95/95 probability/confidence level. The changes to the SCU methodology described in this report do not impact either the manner in which COLSS aids the operator in maintaining operating margin to limits on linear heat rate (LHR) and DNB or the manner in which the CPCS responds to transients and provides the low DNBR and high LPD trips. Therefore, the changes do not impact transient analysis assumptions or results and do not involve changes to Technical Specifications.

In Section 3.0, the Modified SCU program methodology has been applied to PVNGS using typical models and input data and results in DNBR overall uncertainty factors of [ ] for COLSS and [ ] for CPCS.

Table 1-1

Uncertainties Included in the System Parameter SCU

Core inlet flow distribution [1]
Engineering factor on enthalpy rise
Systematic fuel rod pitch
Systematic fuel clad O.D.
Engineering factor on heat flux
CE-1 CHF correlation (Including cross validation uncertainty)
TORC code uncertainty
Fuel rod bow penalty [2]
HID-1 grid penalty [2]

(1) Core inlet flow distribution uncertainty [ ] for System 80 plants

(2) [ ]

Table 1-2

General Categories of Uncertainties Included in State Parameter SCU

Measured State Parameter Uncertainties

Algorithm Uncertainties

Startup Measurement Uncertainties

Radial Peaking Factor Measurement Uncertainty

Computer Processing Uncertainties

Simulator Model Uncertainties

Rod Bow Penalty on F_{xy}

FIGURE 1-1
COLSS AND CPCS UNCERTAINTY ANALYSIS
FOR CURRENT SCU

FIGURE 1-2

CURRENT SCU PROGRAM SCHEMATIC

FIGURE 1-3
MODIFIED SCU PROGRAM SCHEMATIC

2.0 METHODS

2.1 INTRODUCTION

The current SCU program is described in References 6, 7, and 8 with CPC Improvement Program modifications described in Reference 9. The following sections describe the changes made to the SCU methodology in the Modified SCU program. Section 3.0 will provide a typical DNBR overall uncertainty factor calculation using the Modified SCU program.

The changes to the SCU methodology primarily impact the treatment of system parameters, secondary calorimetric power measurement, and neutron flux power synthesis uncertainties as described in Sections 2.2, 2.3, and 2.4, respectively. Section 2.5 presents other minor methodology changes.

2.2 SYSTEM PARAMETER SCU METHODOLOGY

The uncertainties considered in the system parameter SCU include engineering factors, CHF correlation uncertainties and TORC code modeling uncertainties. In the current system parameter SCU analysis, described in Reference 6, these uncertainties are combined statistically to arrive at the DNBR limit. The Modified SCU methodology [

] Thus the DNBR overall uncertainty factors for COLSS and CPC [

]

The individual uncertainties that are combined in the system parameter SCU are as follows:

a) Core inlet flow distribution [(1)]
b) Engineering factor on enthalpy rise
c) Systematic fuel rod pitch
d) Systematic fuel rod diameter
e) Engineering factor on heat flux
f) CE-1 CHF correlation
g) CE-1 CHF correlation cross validation penalty (5% increase in CHF correlation standard deviation)
h) T-H code uncertainty penalty (5%, equal to two standard deviations)

These uncertainties are statistically combined to yield the DNBR probability density function (pdf).

In the current SCU analysis the 95/95 probability/confidence limit of this DNBR pdf is deterministically combined with the fuel rod bow and the HID-1 grid penalties to determine the minimum DNBR limit to be applied in COLSS and CPC. This DNBR limit is then used in the state parameter SCU stochastic simulation to determine the COLSS and CPCS DNBR overall uncertainty factors. This limit is also used in the on-line COLSS DNBR power operating limit calculation and as the CPCS DNBR trip setpoint.

In the Modified SCU methodology, the system parameter uncertainties are combined in the same way to determine the DNBR pdf. However, [

]

(1) Core inlet flow distribution uncertainty [
] for System 80 plants.

[

]

This modification to the SCU program is consistent with statistical methods approved in the current SCU program. [

]
are chosen such that the COLSS DNBR POL and CPCS DNBR calculations are conservative at a 95/95 probability/confidence level.

2.3 SECONDARY CALORIMETRIC POWER MEASUREMENT UNCERTAINTY METHODOLOGY

Both COLSS and CPC use Secondary Calorimetric power as a measure of true core power for their LHR/LPD and DNBR calculations. The calculation of Secondary Calorimetric power has an uncertainty associated with it. Currently, this uncertainty is calculated statistically as described in Reference 7 and applied deterministically in both COLSS and CPC. The Modified SCU methodology will apply this uncertainty [

]

The Secondary Calorimetric power measurement uncertainty (ECAL) is core power dependent. Figure 2-1 shows a typical example of the uncertainty as a function of power. In the current SCU program, this uncertainty is applied as [ ] directly on the core power used in the COLSS and on the thermal and neutron flux power used in CPC. This uncertainty is implemented [ ] in both COLSS and CPC.

In the Modified SCU methodology, the Secondary Calorimetric power measurement uncertainty will be represented by[

] The DNBR overall uncertainty analysis will statistically[

] The method of application of this uncertainty will remain deterministic, unchanged from the current methodology, [

]

The Modified SCU approach is consistent with statistical methods approved in the current SCU program. Application of this uncertainty[ ]will continue to assure conservative DNBR POL calculations by COLSS and DNBR calculations by CPCS to at least a 95/95 probability/confidence level.

2.4 CPC NEUTRON FLUX POWER SYNTHESIS UNCERTAINTY METHODOLOGY

The CPC Neutron Flux Power calculation based on ex-core detector signals includes a neutron flux power measurement uncertainty. One component of this uncertainty is the power synthesis uncertainty. The current SCU method for determining and applying this uncertainty is described in Reference 7. The Modified SCU methodology will[

]

In the current SCU analysis, a pdf of the power synthesis uncertainty is produced at the same time that the DNBR uncertainty factor is determined. The 95/95 probability/confidence tolerance limit of the pdf is applied[

]in the CPC Neutron Flux Power calculation.

In the Modified SCU analysis, the power synthesis uncertainty will be applied[

]

The Modified SCU program approach is consistent with statistical methods approved in the current SCU program. Application of this uncertainty[ ]will continue to assure a conservative DNBR calculation by CPCS at a 95/95 probability/confidence level.

2.5 OTHER MODIFICATIONS TO SCU METHODOLOGY

The Modified SCU methodology includes several minor changes to the techniques of determining and applying uncertainty components. These changes, described in the following section, are consistent with statistical methods approved in the current SCU program and retain conservatism in the resultant uncertainty factors to at least a 95/95 probability/confidence level.

2.5.1 RADIAL PEAKING FACTOR MEASUREMENT UNCERTAINTY APPLICATION

Both COLSS and CPC use Radial Peaking factors (Fxy's) that are verified, and adjusted if necessary, during startup testing. The Fxy measurement which is used for this verification has an uncertainty associated with it.

In the current SCU analysis, the Fxy measurement uncertainty is combined with other uncertainty components [
]

In the Modified SCU methodology the Fxy uncertainty will be [.] Thus the Fxy uncertainty will be [.] This modification involves only a change in the statistical combination technique for this particular uncertainty component.

2.5.2 APPLICATION OF UNCERTAINTY FACTORS AS A FUNCTION OF BURNUP, ASI, AND POWER

The COLSS and CPC overall uncertainty factors calculated in the SCU analysis typically vary as a function of power level, cycle burnup, and Axial Shape Index (ASI). In the current SCU methodology, limiting values of these uncertainty factors are chosen and applied for all conditions.

The Modified SCU methodology will allow calculation and application of these uncertainty factors over several burnup, power, and ASI ranges. Choice of parameters and ranges will be made on a cycle-by-cycle basis in order to optimize the uncertainty factors for nominal full power operation throughout the cycle, while retaining conservatism at a 95/95 probability/confidence level for all conditions.

FIGURE 2-1

SECONDARY CALORIMETRIC
POWER MEASUREMENT UNCERTAINTY
(SAMPLE PVNGS VALUES)

[ ]

3.0 TYPICAL OVERALL UNCERTAINTY FACTOR CALCULATION

3.1 INTRODUCTION

The changes to the SCU Program described in Section 2.0 result in a Modified SCU methodology which can be applied to all C-E plants with digital monitoring and protection systems. The Modified SCU Program will be initially applied to PVNGS Unit 1 Cycle 2. Therefore, a calculation of COLSS and CPC DNBR overall uncertainty factors is presented here using typical PVNGS models and input data. This calculation will illustrate the application of the Modified SCU methodology and its results.

3.2 DNBR pdf

The System Parameter SCU methods used to determine the DNBR limit and pdf remain unchanged from that described in Reference 6. The uncertainties combined to derive this pdf are listed in Table 3-1 with typical values for PVNGS. The resultant pdf is shown in Figure 3-1.

As in the current SCU methodology, the DNBR limit for COLSS, CPC, and transient analyses is defined by the following equation:

$$\text{DNBR limit} = TL * P_{BOW} + P_{HID}$$

where

TL = 95/95 probability/confidence tolerance limit of DNBR pdf.

P_{BOW} = Rod Bow Penalty

P_{HID} = HID-1 Grid Penalty

[

] the DNBR limit generated by this method is used in the on-line COLSS and CPC and in the transient analyses.

The tolerance limit for the pdf shown in Figure 3-1 is 1.205. Combining this with the rod bow penalty (1.75%) and the HID-1 grid penalty (0.01) yields a DNBR limit of 1.237.

3.3 SECONDARY CALORIMETRIC POWER MEASUREMENT UNCERTAINTY pdf

The secondary calorimetric power measurement uncertainty is calculated from the uncertainties of the various measured parameters used to calculate the secondary calorimetric power. These components are listed in Table 3-2 with typical values for PVNGS [ ]

3.4 COLSS DNBR OVERALL UNCERTAINTY FACTOR CALCULATION

The COLSS DNBR overall uncertainty analysis process using Modified SCU is illustrated in Figure 3-2.

[

]

As in the current SCU Program (Reference 8), [

]

Table 3-3 lists the state parameter measurement uncertainty components[ ]in the COLSS overall uncertainty analysis, including typical ranges and uncertainty values for PVNGS. The uncertainty components[ ]are listed with typical PVNGS values in Table 3-4 and the remaining uncertainty components[ ]are presented in Table 3-5.

The COLSS DNBR overall uncertainty analysis using the typical PVNGS input values results in a DNBR overall uncertainty factor of[ ]

3.5 CPCS DNBR OVERALL UNCERTAINTY FACTOR CALCULATION

The CPC DNBR overall uncertainty analysis process is illustrated in Figure 3-3.

[ ]

As in the current SCU program (Reference 7), [ ]

[ ]

Table 3-6 lists the state parameter measurement uncertainty components [ ] in the CPC overall uncertainty analysis, including typical ranges and uncertainty values for PVNGS. The uncertainty components [ ] are listed with typical PVNGS values in Table 3-7 and the remaining uncertainty components [ ] are presented in Table 3-8.

The CPC DNBR overall uncertainty analysis using the typical PVNGS input values results in a DNBR overall uncertainty factor of [ ]

Table 3-1

Components Combined in the DNBR pdf

Parameter	Mean	Std. Deviation at 95% Confidence
Inlet flow distribution	[	]
Enthalpy rise factor		
Systematic pitch (in)		
Systematic clad OD (in)		
Heat flux factor		
CE-1 CHF correlation		
TORC code uncertainty		
DNBR pdf	[	]

* Inlet flow distribution uncertainty[ ]for System 80 plants

** Includes 5% cross-validation uncertainty

Table 3-2

Secondary Calorimetric Power Measurement Uncertainty Components

Parameters	Units	STD. Deviation at 95% Confidence*
Feedwater Flow (delta P transmitter)	IN. of H_2O	
Feedwater Temperature	^oF	
Steam Flow (delta P transmitter)	IN. of H_2O	
Blowdown Mass Flow Rate	KPPH	
Steam Quality	-	
Secondary Pressure	PSIA	

[ ]

Table 3-3

COLSS State Parameter Ranges and Measurement Uncertainties

Parameters	Unit	Ranges	Measurement Uncertainty
Core Inlet Coolant Temperature	(°F)		
Primary Coolant Pressure	(psia)		
Primary Coolant Mass Flow	(10^6 lbm/hr. ft^2)		
Incore Detector Signal	(%)		
CEA Position	(inches)		

[ ]

Table 3-4

Uncertainty Component [ ] in COLSS DNBR Uncertainty Analysis

Parameter	Mean	Std. Deviation at 95% confidence
System Parameter Uncertainty DNBR pdf	[	]
Radial Peaking Factor Measurement Uncertainty		
Secondary Calorimetric Power Measurement Uncertainty*		

[ ]

Table 3-5

Uncertainty Components [ ] to Determine COLSS DNBR Overall Uncertainty Factors

Parameter	Value
Fuel Rod Bow Penalty on Fxy	[
Computer Processing Uncertainty	
Simulator Model Uncertainty	]

Table 3-6

CPCS State Parameter Ranges and Uncertainties

Parameters	Unit	Ranges	Measurement Uncertainty
Core Inlet Coolant Temperature	(°F)		
Primary Coolant Pressure	(psia)		
Primary Coolant Mass Flow	(10^6 lbm/hr-ft^2)		
Ex-core Detector Signals	(% power)		
CEA Positions	(inches)		

Startup Measurement Uncertainties

- Rod Shadowing Factor
- Shape Annealing Matrix**
- Boundary Point Power Correlation Coefficient

[*]

**Assumed Excore Noise Level During Test

Table 3-7

Uncertainty Component [ ] in CPC DNBR
Overall Uncertainty Analysis

Parameter	Mean	Std. Deviation of 95% Confidence
System Parameter Uncertainty DNBR pdf	[	]
Radial Peaking Factor Measurement Uncertainty		
Secondary Calorimetric Power Measurement Uncertainty		
Neutron Flux Power Synthesis Uncertainty*		

[ ]

Table 3-8

Uncertainty Components [ ] to Determine CPC DNBR Overall Uncertainty Factors

Parameter	Value
Fuel Rod Bow Penalty on Fxy	[
Computer Processing Uncertainty	
Simulator Model Uncertainty	]

Figure 3-1

DNBR PROBABILITY DENSITY FUNCTION

PROBABILITY DENSITY, F(X)

DNBR, X

FIGURE 3-2

COLSS DNBR OVERALL UNCERTAINTY ANALYSIS
WITH MODIFIED SCU

FIGURE 3-3

CPC DNBR OVERALL UNCERTAINTY ANALYSIS
WITH MODIFIED SCU

4.0 CONCLUSION

This report describes changes to the current SCU Program which are designed to improve plant operating performance and flexibility and reduce unnecessary trips. These changes result in a Modified SCU Program which is applicable to all C-E plants with digital monitoring and protection systems. The overall uncertainty factors determined using the Modified SCU program continue to ensure that the COLSS POL calculations and the CPCS DNBR and LPD calculations will be conservative to at least a 95% probability and 95% confidence level. The initial application of the Modified SCU program is planned for PVNGS Unit 1 Cycle 2. The Modified SCU program methodology has been applied to PVNGS using typical models and input data and results in DNBR overall uncertainty factors of [ ] for COLSS and [ ] for CPCS.

5.0 REFERENCES

1 "Statistical Combination of Uncertainties Part II", Enclosure 1-P to LD-83-010, January, 1983.

2 "Statistical Combination of Uncertainties Part III", Enclosure 2-P to LD-83-010, Rev. 01, August, 1983.

3 CEN-312-P, Rev 01-P "Overview Description of the Core Operating Limit Supervisory System (COLSS)", November, 1986.

4 CEN-304-P, Rev 01-P, "Functional Design Requirements for a Control Element Assembly Calculator", May, 1986.

5 CEN-305-P, Rev 01-P "Functional Design Requirements for a Core Protector Calculator", May, 1986.

6 "Statistical Combination of Uncertainties Part I", CEN-283(S)-P, October, 1984.

7 "Statistical Combination of Uncertainties Part II", CEN-283(S)-P, October, 1984.

8 "Statistical Combination of Uncertainties Part III", CEN-283(S)-P, October, 1984.

9 "Statistical Combination of Uncertainties for Waterford-3", CEN-343 (C)-P, October, 1986.

10 Letter from J. H. Wilson (NRC) to J. G. Dewease (Louisiana Power and Light Company), "Reload Analysis Report for Cycle 2 at Waterford 3", Docket 50-382, January, 1987.

11 "Statistical Combination of Uncertainties Part I", Enclosure 1-P to LD-83-010, January, 1983.