ATTACHMENT 6

WCAP-17787, *Palo Verde Nuclear Generating Station STAR Program Implementation Report*

(Non-Proprietary Version)

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Palo Verde Nuclear Generating Station STAR Program Implementation Report

Westinghouse

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List of Acronyms and Terms

Acronym / Term	Definition
ADAMS	Agencywide Documents Access and Management System
Ag-In-Cd	Silver-Indium-Cadmium control rod absorber alloy
ANS	American Nuclear Society
ANSI	American National Standards Institute
APS	Arizona Public Service
ARO	All Rods Out
B&W	Babcock and Wilcox
B-10	Isotope Boron 10
B_4C	Boron Carbide – Absorber material
BOC	Beginning of Cycle
CalcNote	Westinghouse Calculation Note
CASMO/SIMULATE	Core Design Software
CBC	Critical Boron Concentration
CE	Combustion Engineering
CEA	Control Element Assembly
CEDM	Control Element Drive Mechanism
CIPS	Crud Induced Power Shift
DIT/ROCS	Core Design Software
EDMS	Electronic Document Management System
EFPM	Effective Full Power Month
EOC	End of Cycle
Er2O3 or Erbia	Erbium Oxide - Absorber material
F_Q	Local peaking factor
F_r	Radial peaking factor
F_{xy}	Planer peaking factor

Acronym / Term	Definition
Feltmetal™[1]	Compressible stainless steel sponge-like material
FSCEA	Full Strength CEA
Gd_2O_3	Gadolinium Oxide - Absorber material
GWD/T	Giga Watt Days/Tonne (U)
HFP	Hot Full Power
HZP	Hot Zero Power
IBW	Inverse Boron Worth
ICES	INPO Consolidated Event System
ICI	In-Core Instrument
IFBA	Integral Fuel Burnable Absorber
INPO	Institute of Nuclear Power Operations
ITC	Isothermal Temperature Coefficient
LAR	License Amendment Request
LEF	Lower End Fitting
LER	Licensee Event Report
MTC	Moderator Temperature Coefficient
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
NUREG	NRC technical report designation
OE	Operating Experience
Optin	Zirconium Alloy - 4 with low tin level - Fuel cladding material
PARAGON/ANC	Core Design Software
pcm/°F	Percent mille/Fahrenheit
PHOENIX/ANC	Core Design Software
PPM	Parts Per Million
PSCEA	Part Strength CEA

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Acronym / Term	Definition
Pu	Plutonium
PVNGS	Palo Verde Nuclear Generation Station
PWR	Pressurized Water Reactor
QA	Quality Assurance
RCS	Reactor Coolant System
SDM	Shutdown Margin
SEN	Significant Event Notification
SER	Safety Evaluation Report
SFP	Spent Fuel Pool
SR	Surveillance Requirement
SRWM®[2]	Subcritical Rod Worth Measurement
STAR	Startup Test Activity Reduction Program
Tech Spec	Technical Specification
UEF	Upper End Fitting
UGS	Upper Guide Structure
UO_2	Uranium Dioxide
WCAP	Westinghouse Commercial Atomic Power
WOG	Westinghouse Owners Group
Zirc-4	Zirconium Alloy - 4 – Fuel cladding material
ZIRLO®[2]	Zirconium Alloy High Performance Fuel cladding material
ZrB_2	Zirconium Diboride – Absorber material

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1 INTRODUCTION

The Westinghouse Startup Test Activity Reduction Program (STAR Program[3], Reference 1) is a program that allows a significant simplification in the startup testing program by eliminating for most cycles the Beginning of Cycle (BOC) Zero Power CEA Worth and Isothermal Temperature Coefficient (ITC) measurements. These measurements in particular require the use of special test procedures that allow operation in Mode 2 outside the normal operating limits. In addition, the Control Element Assembly (CEA) Group Worth test requires temporary modifications to the CEA control and core protection systems in order to implement the special control rod insertion sequence and bank configuration required by the test. This situation increases the probability of errors during the test and places a burden on the operators. Furthermore, the tests are performed with the plant in an abnormal configuration. Implementation of the STAR Program at the Palo Verde Nuclear Generating Station (PVNGS) will enable the startup testing to be performed using normal plant operating practices instead of special operating procedures while maintaining checks on parameters that are important to safe plant operation. Additional operational benefits include a faster transition to the normal operating configuration.

The basis of the STAR Program is that all the purposes served by the BOC zero power CEA Group Worth and ITC startup measurements can be as or more effectively achieved by alternate means for cycles where there are no significant changes to the core or control rod configuration, core analysis methods, or startup procedures from previous cycles where these measurements have been performed. In order to satisfy the purposes of the eliminated tests, pre-operational activities and alternate checks, either performed off critical path or performed during startup employing data already being collected for other purposes, are performed. In addition, the STAR Program requires that all the conditions for elimination of the CEA Group Worth and ITC startup measurements have been satisfied for each cycle. These requirements related to Core Design, Fabrication, Refueling, Startup Testing and CEA Lifetime are given in the STAR Applicability Requirements shown in Table 3-4 of the STAR Topical Report.

The STAR Program was originally developed as part of a project sponsored by the Westinghouse Owners Group (WOG). Implementation of the STAR Program was approved by the NRC (Reference 1) for the original group of participating plants, which did not include PVNGS. In addition, the Combustion Engineering (CE) Standard Technical Specifications have been updated in Reference 7 to include Technical Specification (Tech Spec) changes that are consistent with STAR implementation. The program has since been successfully used for several cycles at SONGS 2&3, Waterford-3, Arkansas Nuclear One Unit 2, St. Lucie 1&2, Fort Calhoun, and Millstone Unit 2.

The purpose of this report is to justify application of the STAR Program to PVNGS. The PVNGS plants are of the Combustion Engineering System 80 design. With respect to reactor, core, and fuel design, these plants are very similar to those plants that have already been approved for STAR application. There are however some design differences and the impact of these differences on application of the STAR Program will be addressed herein. The STAR Topical Report, Reference 1, included guidelines (Attachment A of Appendix G) that provided a list of specific requirements and recommended activities to be performed to allow implementation of the STAR Program for non-participating plants. The justification contained within this report follows the general guidelines set forth in that Attachment to Reference 1.

Note that APS will also concurrently be eliminating the Near EOC MTC Measurement consistent with the approved methodology of Reference 8. Although the justification for this change is not explicitly addressed in this report, both the approved STAR Program of Reference 1 and the PVNGS STAR Program described herein does not preclude the elimination of the EOC MTC Measurement as described in Reference 8.

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[3] The original STAR Program of Reference 1 is identified within this report as the "STAR Program" while the program specific to the PVNGS plants is identified within this report as the "PVNGS STAR Program". Any references to sections, tables or figures within this report that do not explicitly identify them as coming from the STAR Topical Report are contained within in this report, with the following exception: Any references contained in direct quotes that are taken from the STAR Topical Report refer to the specified section, table or figure in the STAR Topical Report.

2 OVERVIEW OF THE STAR METHODOLOGY

2.1 BASIS FOR THE STAR PROGRAM

The STAR Program elimination of the Beginning of Cycle (BOC) Hot Zero Power (HZP) CEA Worth and ITC tests is based on the conclusions that:

1. For each "purpose" of the eliminated test there is an alternate method that is at least as effective in achieving the same objective.
2. The alternative method is at least as effective in achieving the purpose.
3. The accuracy and uncertainty of CEA Worth and ITC predictions by current core design methods is comparable to the accuracy of test methods for measurement of these parameters provided that the core, fuel, and control rod design remains similar to that contained in the Physics code uncertainty benchmark analysis.
4. The design margin of the values of CEA Worth and Moderator Temperature Coefficient (MTC) used in the nuclear safety is sufficient to accommodate the known uncertainties in predicted values in these parameters.

The procedure used in the STAR Topical Report for demonstrating that these conclusions are valid may be summarized as follows:

1. A set of standard or "Generic" startup Physics Tests is defined based on current practice for the participating plants and the ANSI/ANS 19.6.1 standard (Reference 5), (See Table 3-2). The Generic Test Program, hereafter referred to as the Generic Program, serves as a reference to which the effectiveness of the STAR Program was compared with regard to its effectiveness in detecting problems and anomalies.
2. For each startup test identified in the Generic Program all the safety related objectives of the test were defined. These safety related test objectives are the identification of "problems" which are essentially non-conforming core configurations that have not explicitly been accounted for in the safety analysis. These problems were divided into the following three general categories:
   a) Design Prediction problems related to the accuracy of core design methods
   b) As-Built Core problems related to core anomalies or errors in core design, fabrication, or reassembly
   c) Test Performance problems related to errors using test equipment, processes, or results

   The specific list of problems was developed from a list of general postulated problems from ANSI/ANS 19.6.1 1997 supplemented by historical information provided by the participating plants and by results of extensive search of the NRC and INPO Operational Experience (OE) industry databases (Appendix A).
3. The current Generic startup tests were evaluated (Good, Fair, Poor) for their ability to detect each of the "problems". Results from participating plant history, NRC, and INPO database, as well as engineering judgment, were used to perform this assessment.
4. A revised startup test program was defined (the STAR Program) that replaces the CEA Worth and HZP ITC test with alternate tests and checks.
5. For each of the "problems" the STAR Program was evaluated for its ability to detect the "problems".

a,c

2.2 APPLICABILITY OF STAR TO SPECIFIC CYCLE STARTUPS

The STAR Program requires that it be confirmed each cycle that all the conditions for elimination of the Zero Power CEA Group Worth and ITC startup measurements have been satisfied. These requirements, related to Core Design, Fabrication, Refueling, Startup Testing and CEA Lifetime, are given in the STAR Applicability Requirements shown in Table 3-4 of the STAR Topical Report. These requirements are summarized as:

a,c

2.3 APPLICATION OF STAR TO PVNGS

Attachment A of Appendix G of Reference 1 provides a recommended approach for application of the STAR Program to plants other than those included in the STAR Topical Report (i.e. non-participating plants). The process defined in that Appendix requires confirmation that the differences in design and startup procedures do not invalidate the conclusions with regard to ability of the STAR Program to detect non-conforming problems. This determination requires that there are no relevant unique design features that might introduce additional problems or would result in a degraded ability of the STAR Program to detect problems beyond those already considered in the STAR Topical Report.

PVNGS is a Combustion Engineering System 80 type plant. This plant type is a more recent design relative to the plants considered in the original STAR report. Because of this, there are some differences in the reactor internals, core components (including fuel design, CEAs, and ICIs), CEA drives, and refueling operations that need to be considered when evaluating applicability of the STAR Program to PVNGS. As will be demonstrated, none of these design differences have a significant impact on the STAR Program's acceptability as an alternative startup program for the PVNGS plants.

Note that the evaluation performed herein assumes that the full strength control rods are of the new Ag-In-Cd tipped System 80 design (Reference 2). This evaluation has not considered the older felt-metal encased B_4C tipped type System 80 control rods and thus applicability is limited to PVNGS cores having all Ag-In-Cd tipped System 80 full strength control rods. In addition, the part strength CEAs are not explicitly evaluated herein because they are not credited in the shutdown margin calculation and they are not included in the current CEA Worth reload startup test measurement. However, they are required to comply with the CEA Lifetime STAR Applicability Requirements.

The steps required to demonstrate applicability of the STAR Program to non-participating plants like PVNGS are defined in Attachment A of Appendix G as:

1. Identify and evaluate deviations between the current PVNGS startup tests and the STAR Generic Program to identify changes to the STAR Program startup tests or pre-operational activities that may be required. Note that deviations should only include those tests in the Generic Program that are not included in the current PVNGS Startup Test Program and those deviations in the STAR Program tests for PVNGS relative to the STAR Program defined in the STAR Topical Report.
2. Identify and evaluate relevant unique design features between PVNGS and the STAR participating plants that might cause significant increase in problems or the STAR program's ability to detect problems. In addition to evaluating the impact of relevant design differences, this effort should also include reviewing PVNGS operating history and recent additions to the NRC and INPO event databases to provide assurance that no new problems or PVNGS specific problems have occurred that might require additions to the problem evaluation matrix for the PVNGS STAR Program.
3. Modify or add to the STAR Program tests and pre-operational activities as necessary to address differences found in Step 2.
4. Verify that the PVNGS core design methods meet the requirements imposed by the STAR Program for current cycles.
5. Verify that all of the requirements in the STAR Applicability Requirements are applicable to PVNGS and modify as necessary to address the results of Step 3.

3 REVIEW OF STARTUP TEST PROGRAMS

This section compares the current PVNGS startup program with the Generic Program and the ANSI standards. The purpose of this comparison is to identify additional tests that might be necessary for STAR implementation at PVNGS in order to achieve the same effectiveness in detecting problems as was documented in the STAR Topical Report. Since justification of the STAR Program in the STAR Topical Report was based on the STAR Program having the same or better effectiveness of detecting problems as the Generic Tests, it is necessary to identify and evaluate gaps between the current PVNGS Startup Test program and the Generic Program in order to justify the acceptability of STAR implementation at PVNGS.

Table 3-1a shows a list of the typical Physics startup tests. Table 3-1b shows the major test objective commonly associated with each of these tests. Table 3-2 compares the current PVNGS startup test program to the Generic Program, the STAR Program, and ANSI/ANS standards. Note that the current PVNGS Startup Test Program contains all the tests currently recommended by the ANSI 2011 Standard. The major differences between the PVNGS Startup Program and the Generic Startup Program defined in the STAR Topical Report are:

- The current PVNGS startup test program does not include the CEA Drop Characteristics Tests.
- The current PVNGS startup test program includes a measurement of the Critical Boron Concentration and Inverse Boron Worth (IBW) with the CEA Exchange reference bank inserted. These tests are performed solely to support the CEA worth measurement using the CEA Exchange Method.
- The current PVNGS startup program has an additional Shutdown Margin (SDM) Surveillance Requirement (SR).

The additional tests, for example IBW, are not credited, and are not required, by the PVNGS STAR Program. Although the elimination of the CEA Drop Characteristics Tests is a deviation from the approved STAR Program, Section C.2.6.1.3 justifies the elimination of this test based on other means available at the PVNGS plants to confirm proper coupling between the CEAs and the extension shaft assemblies.

Table 3-3 lists the pre-operational startup activities at PVNGS that are relevant to the STAR program.

Table 3-1a Typical Physics Startup Test Descriptions

TEST	POWER	DESCRIPTION
CEA Drop Time (90% Insertion)	Shutdown	Determination of CEA drop time from measured trends of CEA position vs. time during CEA drops
CEA Drop Characteristics	Shutdown	Analysis of measured rod drop test characteristics such as trends of drop time by location, slowing in the dashpot, and normal rebound
CEA Flux Change	HZP	Measurements of reactivity or startup rate changes during CEA movement
CBC	HZP	Determination of CBC from chemical analysis of RCS samples
IBW	HZP	Determination of IBW from measurements of changes in reactivity and CBC
CEA Worth	HZP	Determination of CEA worth from measured change in reactivity during CEA motion
ITC	HZP	Determination of the ITC from measurements of changes in reactivity and moderator temperature when fuel and moderator temperature changes are isothermal
MTC Surveillance	HZP	Determination of the MTC for various operating conditions from the measured ITC, the predicted Fuel Temperature Coefficient, and the predicted MTC
MTC Alternate Surveillance	HZP	Determination of the MTC for various operating conditions by adjusting the predicted MTC using the measured CBC
SDM Surveillance	HZP	Determination of the SDM using parameters measured as part of startup testing at HZP
CEA Flux Symmetry	HZP	Determination of the degree of azimuthal asymmetry in the neutron flux from measurements of the variation in CEA Worth from symmetric CEAs
Incore Flux Symmetry	Low	Determination of the degree of azimuthal asymmetry in the neutron flux from measurements of the variation in incore detector signals from symmetric incore detectors
Incore Power Distribution	Intermediate	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at intermediate power levels in the 40-80% range.
ITC	Intermediate to HFP	Determination of the ITC from measurements of changes in reactivity and moderator temperature when fuel and moderator temperature changes are isothermal
MTC Surveillance	Intermediate to HFP	Determination of the MTC for various operating conditions from the measured ITC, the predicted Fuel Temperature Coefficient, and the predicted MTC
Incore Power Distribution	HFP	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at power levels greater than 90%
ΔCBC HZP-HFP	HFP	Determination of the change in measured CBC between HZP and HFP from chemical analysis of RCS samples

Table 3-1b Startup Test Objectives

TEST	POWER	Objective
CEA Drop Time (90% Insertion)	Shutdown	To determine if CEA drop times are within Technical Specification limits and verify proper reassembly of the reactor vessel and internal components
CEA Drop Characteristics	Shutdown	To determine if CEAs are coupled
CEA Flux Change	HZP	To determine if CEAs are coupled
CBC	HZP	To determine if the measured and predicted total core reactivity are consistent
IBW	HZP	To determine if the measured IBW is consistent with the predicted value
CEA Worth	HZP	To determine if the worth of selected rod groups is consistent with predictions
ITC	HZP	To determine if the measured ITC is consistent with the predicted value
MTC Surveillance	HZP	To determine if the calculated MTC derived using the measured ITC is within Technical Specification limits
MTC Alternate Surveillance	HZP	To determine if the calculated MTC derived using the measured CBC is within Technical Specification limits for various operating conditions
SDM Surveillance	HZP	To determine if the calculated shutdown margin derived using measured test values is within Technical Specification limits
CEA Flux Symmetry	HZP	To determine if the measured azimuthal flux symmetry is consistent
Incore Flux Symmetry	Low	To determine if the measured azimuthal flux symmetry is consistent
Incore Power Distribution	Intermediate	To determine if the measured and predicted core power distributions are consistent
ITC	Intermediate to HFP	To determine if the measured ITC is consistent with the predicted value
MTC Surveillance	Intermediate to HFP	To determine if the calculated MTC derived using the measured ITC is within Technical Specification limits for various operating conditions
Incore Power Distribution	HFP	To determine if the measured and predicted core power distributions are consistent
ΔCBC HZP-HFP	HFP	To determine if the reactivity difference between zero and full power conditions is consistent with design predictions

Table 3-2 Startup Test Programs

TEST	POWER	RODS	Palo Verde 1, 2 & 3	Generic Program	**STAR Program**	**1985** ANSI Standard (APS)	**1997** ANSI Standard (STAR)	**2011** ANSI Standard
CEA Drop Time	Shutdown	Moved	X	X	X			
CEA Drop Characteristics	Shutdown	Moved		X	X			
CEA Flux Change	HZP	Moved						
CBC	HZP	ARO	X	X	X	X	X	X
CBC	HZP	Rodded	X[1]			X		
IBW	HZP	Rodded	X[1]			X[2]	X	
CEA Worth	HZP	Moved	X	X		X	X	X
ITC	HZP	ARO	X	X		X	X	X
MTC Surveillance	HZP	ARO	X	X				
MTC Alternate Surveillance	HZP	ARO			X			
SDM Surveillance	HZP	ARO	X					
CEA Flux Symmetry	HZP	Moved						
Incore Flux Symmetry	Low	ARO	X	X	X	X[3]	X[3]	X[3]
Incore Power Distribution	Intermediate	ARO	X	X	X	X	X	X
ITC	Intermediate to HFP	ARO	X		X			
MTC Surveillance	Intermediate to HFP	ARO	X	X	X			
Incore Power Distribution	HFP	ARO	X	X	X	X	X	X
ΔCBC HZP-HFP	HFP	ARO	X[4]		X		X	X

1. The CBC and IBW calculated with Reference bank inserted are needed only to support the CEA Worth Measurement using the CEA Exchange procedure. The PVNGS STAR Program eliminates these tests.
2. Not explicitly recommended as a test but included in procedure for calculating rodded CBC (1% rho insertion). The PVNGS STAR Program eliminates this test.
3. The CEA Flux Symmetry test is an alternate to the Incore Flux Symmetry test in the ANSI 85 and 97 Standards but is not explicitly endorsed in 2011 Standard.
4. PVNGS procedures require that the measured HFP CBC, after adjustment of HZP CBC bias, to be within 50 ppm of prediction. This is equivalent to a ΔCBC HZP-HFP test.

Table 3-3 PVNGS Pre-Operational Activities

(Relevant to STAR Implementation)

a,c

4 EVALUATION OF PVNGS STAR PROGRAM EFFECTIVENESS

4.1 INTRODUCTION

The impact of changes to the Generic Program was considered acceptable in the STAR Topical Report if there were no significant adverse impact on safety analysis compliance. In this evaluation, core configurations that are not explicitly accounted for in the safety analysis are referred to as "problems." The word "problem" was selected to be consistent with the terminology used in the 1997 ANSI standard for reload physics testing. Startup tests can both detect and initiate problems. The evaluation consists of determining if the change in the ability to prevent problems is acceptable. The impact of the change on each problem is evaluated separately. This was found to be desirable because each problem identified for evaluation has many unique aspects that need to be considered in conjunction with all the changes to the Generic Program.

The problems are divided into the following three general categories:

- Design Prediction problems related to the accuracy of core design methods
- As-Built Core problems related to core anomalies or errors in core design, fabrication, or reassembly
- Test Performance problems related to errors using test equipment, processes, or results

The detection of design prediction and as-built core problems by startup tests can positively impact safety analysis compliance through corrective actions that ensure operation within the safety analysis. The occurrence of problems during the performance of startup tests can cause operation outside the assumptions of the safety analysis.

The STAR Topical Report concluded that:

> *The ability of the STAR Program to prevent operation with problems is essentially the same as, or better than, the Generic Program.*

Appendix A reports the result of a review of operational experience since the STAR Topical Report submittal. This was done in order to confirm that the conclusions from the STAR Topical Report regarding the effectiveness of the "Generic" startup tests remain valid since the Generic program is used as the reference. As stated in Appendix A, the general conclusion remains valid.

The purpose of this section is to evaluate the overall impact of PVNGS relevant unique design features, PVNGS tests, PVNGS pre-operational activities, and PVNGS STAR Applicability Requirements on the conclusions of Section 4.0 and Appendix E, "Problem Evaluations," of the STAR Topical Report. Specifically, this section will demonstrate that the net effect of these differences does not cause significant increases in design prediction problems, as-built problems and test performance problems using the STAR Program at PVNGS.

Specific evaluation criteria and processes are used for each problem category and are described in Sections 4.1, 4.2 and 4.3 of the STAR Topical Report for design prediction, as-built core, and test performance problems respectively.

4.2 PVNGS RELEVANT UNIQUE DESIGN FEATURES

Section A.2.2 of Attachment A of Appendix G of the STAR Topical Report (Reference 1) requires that the relevant unique design features of PVNGS (relative to the plants evaluated in the STAR Topical Report) be evaluated to determine if these differences might result in a significant increase in problems or degrade the ability of the STAR Program to detect problems during startup testing at PVNGS. Appendix C provides a detailed description of the relevant design differences of PVNGS. The resulting relevant unique design features, determined in Appendix C and identified in Table C-1, are:

a,c

The impact of PVNGS relevant unique design features on the effectiveness of startup tests, pre-operational activities, and STAR Applicability Requirements in detecting as-built core problems for PVNGS is evaluated in Appendix B and summarized in Tables B-1 through B-3 for startup tests, pre-operational activities, and STAR Applicability Requirements respectively.

4.3 PROBLEM EVALUATIONS

This section evaluates the impact of PVNGS relevant unique design features on the overall effectiveness of the STAR program for detecting each of the design prediction, as-built core and test performance problems using the effective ratings from Appendix B.

4.3.1 Design Prediction Problem Evaluations for PVNGS

Section E.2.1 of the STAR Topical Report addressed four design prediction problems. These design prediction problems are based on the parameters measured in the Generic Program:

- CEA Worth Inaccuracy
- CBC Inaccuracy
- ITC Inaccuracy
- Power Distribution Inaccuracy

The evaluation process of the STAR Program for design prediction problems is described in Section 4.1 of the STAR Topical Report that used the following acceptance criterion:

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$]^{a,c}$

The purpose of this section is to evaluate the impact of (i) the PVNGS-specific CASMO-SIMULATE benchmark results discussed in Appendix D, and (ii) the PVNGS relevant unique design features discussed in Appendix C, on the conclusions of Section E.2.1, "Design Prediction Problem Evaluation," of the STAR Topical Report. Specifically, this section will demonstrate that there are no differences that could cause significant increases in design prediction problems or change the ability to detect design prediction problems using the STAR Program at PVNGS.

This is achieved, for each Design Prediction Problem, through the following steps:

1. Briefly describe the design prediction problem.
2. Summarize the conclusions of the STAR Topical Report and its SER (Reference 1) for this design prediction problem.
3. Identify which relevant unique design features are applicable to the design prediction problem.
4. Determine the impact of the relevant unique design features on the design prediction problem.
5. Determine the impact on the STAR Topical Report conclusions using the results of (4) above and Appendix D, PVNGS Core Design Methods and Uncertainties.

4.3.1.1 CEA Worth Inaccuracy

4.3.1.1.1 Problem Description – CEA Worth Inaccuracy

CEA worth inaccuracy is the uncertainty between the CEA worth predicted by core design methods and the CEA worth actually present in the core[4]. CEA worth inaccuracy is characterized by an uncertainty that is based on deviations between startup test measurements at HZP and core design predictions.

4.3.1.1.2 Conclusions of the STAR Topical Report - CEA Worth Inaccuracy

CEA worth inaccuracy was addressed in Section E.2.1.1 of the STAR Topical Report which concluded:

> *"The impact of the change on CEA worth inaccuracy is determined to be acceptable based on the evaluation criterion being satisfied. This result justifies the use of best estimate CEA worth predictions in lieu of measurements provided the Core Design Applicability Requirements are*

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[4] CEA Worth Inconsistency does not include errors in the procedures or execution of these procedures for specific calculations. Rather these types are covered under the CEA Worth Error problem evaluation in Section 4.3.2.1.

> *satisfied. A summary of the impacts on the ability to ensure uncertainties are bounded by the safety analysis is provided in Table 4-1. A summary of all the impacts associated with the changes to the Generic Program is provided in Table 5-1."*

The NRC concluded in Section 4.1 of the Safety Evaluation Report (SER) of the STAR Topical Report:

> *"the NRC staff concludes that as far as design prediction uncertainties are concerned. the STAR program is acceptable because the applicability requirements ensure that the design parameter uncertainty is bounded by the safety analyses."*

4.3.1.1.3 Relevant Unique Design Features Applicable to CEA Worth Inaccuracy

The following relevant unique design feature from Appendix C is relevant to CEA Worth Inaccuracy:

a,c

4.3.1.1.4 Impact of Relevant Unique Design Features on CEA Worth Inaccuracy

This relevant design feature does not invalidate the conclusions for application of the STAR Program to PVNGS because the following requirements from the PVNGS Core Design STAR Applicability Requirements in Table 5-2 ensure that the uncertainty is bounded by the safety analysis for PVNGS when using the STAR Program:

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]^{a,c}

4.3.1.1.5 Impact on STAR Topical Report Conclusion – CEA Worth Inaccuracy

The evaluation of CEA worth inaccuracy in the STAR Topical Report was reviewed above to confirm that there are no relevant unique design features for PVNGS that would invalidate the conclusions in Section E.2.1.1 of the STAR Topical Report. The results of the review confirmed that the relevant unique design features of PVNGS and the PVNGS-specific CEA Worth benchmark results provided in Appendix D have no impact on the conclusions relating to CEA worth inaccuracy associated with the DIT/ROCS or PHOENIX/ANC computer codes. In addition, Appendix D has demonstrated that the uncertainties of the PVNGS CASMO/SIMULATE physics methods meet the uncertainty requirements of the STAR Topical Report. Thus, these results conclude that use of predicted CEA Worth in lieu of measurements is justified for PVNGS provided the PVNGS Core Design STAR Applicability Requirements in Table 5-2 are satisfied.

4.3.1.2 CBC Inaccuracy

4.3.1.2.1 Problem Description – CBC Inaccuracy

CBC inaccuracy is the deviation between the Critical Boron Concentration (CBC) predicted by core design methods and the CBC actually present in the core. CBC inaccuracy is characterized by an uncertainty that is based on deviations between startup test measurements at HZP and core design predictions.

4.3.1.2.2 Conclusions of the STAR Topical Report - CBC Inaccuracy

CBC inaccuracy was addressed in Section E.2.1.2 of the STAR Topical Report which concluded:

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The NRC concluded in Section 4.1 of the Safety Evaluation Report (SER) of the STAR Topical Report:

> *"the NRC staff concludes that as far as design prediction uncertainties are concerned the STAR program is acceptable because the applicability requirements ensure that the design parameter uncertainty is bounded by the safety analyses."*

4.3.1.2.3 Relevant Unique Design Features Applicable to CBC Inaccuracy

The following relevant unique design feature from Appendix C is potentially relevant to CBC Inaccuracy:

a,c

[

]^{a,c}

4.3.1.2.4 Impact of Relevant Unique Design Features on CBC Inaccuracy

This relevant unique design feature has no impact on CBC inaccuracy. [

]^{a,c}

In addition, the following requirements from the PVNGS Core Design STAR Applicability Requirements in Table 5-2 ensure that the CBC uncertainty will be bounded by the safety analysis for PVNGS when using the STAR Program:

[ ] a,c

4.3.1.2.5 Impact on STAR Topical Report Conclusion – CBC Inaccuracy

The evaluation of CBC inaccuracy in the STAR Topical Report was reviewed above to confirm that there are no relevant unique design features for PVNGS that would invalidate the conclusions in Section E.2.1.2 of the STAR Topical Report. The results of the review confirmed that the relevant unique design features of PVNGS have no impact on the conclusions relating to CBC inaccuracy for the DIT/ROCS, PHOENIX (or PARAGON)/ANC, or CASMO/SIMULATE core physics methods.

4.3.1.3 ITC Inaccuracy

4.3.1.3.1 Problem Description – ITC Inaccuracy

ITC inaccuracy is the deviation between the ITC predicted by core design methods and the ITC actually present in the core. ITC inaccuracy is characterized by an uncertainty that is based on deviations between startup test measurements at HZP and core design predictions.

4.3.1.3.2 Conclusions of the STAR Topical Report - ITC Inaccuracy

ITC inaccuracy was addressed in Section E.2.1.3 of the STAR Topical Report which concluded:

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]a,c

The NRC concluded in Section 4.1 of the Safety Evaluation Report (SER) of the STAR Topical Report:

> *"the NRC staff concludes that as far as design prediction uncertainties are concerned. the STAR program is acceptable because the applicability requirements ensure that the design parameter uncertainty is bounded by the safety analyses."*

4.3.1.3.3 Relevant Unique Design Features Applicable to ITC Inaccuracy

There are no relevant unique design features relevant to ITC Inaccuracy.

4.3.1.3.4 Impact of Relevant Unique Design Features on ITC Inaccuracy

There is no impact of the relevant unique design features on ITC inaccuracy.

4.3.1.3.5 Impact on STAR Topical Report Conclusion – ITC Inaccuracy

The evaluation of ITC inaccuracy in the STAR Topical Report was reviewed above to confirm that there are no relevant unique design features for PVNGS that would invalidate the conclusions in Section E.2.1.3 of the STAR Topical Report. The results of the review confirmed that the relevant unique design features of PVNGS have no impact on the conclusions relating to ITC inaccuracy. [

]^{a,c} Therefore, the conclusions in Section E.2.1.3 of the STAR Topical Report remain applicable for application of the STAR Program at PVNGS.

4.3.1.4 Power Distribution Inaccuracy

4.3.1.4.1 Problem Description – Power Distribution Inaccuracy

Power distribution inaccuracy is the deviation between the power distribution predicted by core design methods and the power distribution actually present in the core. Power distribution inaccuracy is characterized by an uncertainty that is based on deviations between startup test measurements at power and core design predictions.

4.3.1.4.2 Conclusions of the STAR Topical Report - Power Distribution Inaccuracy

Power Distribution inaccuracy was addressed in Section E.2.1.4 of the STAR Topical Report which concluded:

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>]^{a,c}

The NRC concluded in Section 4.1 of the Safety Evaluation Report (SER) of the STAR Topical Report:

> *"the NRC staff concludes that as far as design prediction uncertainties are concerned the STAR program is acceptable because the applicability requirements ensure that the design parameter uncertainty is bounded by the safety analyses."*

4.3.1.4.3 Relevant Unique Design Features Applicable to Power Distribution Inaccuracy

The following relevant unique design features are relevant to Power Distribution Inaccuracy.

( )^{a,c}

4.3.1.4.4 Impact of Relevant Unique Design Features on Power Distribution Inaccuracy

Section B.4.1.2 demonstrates that these design features do not have an impact on the ability to predict or measure the core power distribution. [

]^{a,c}

4.3.1.4.5 Impact on STAR Topical Report Conclusion – Power Distribution Inaccuracy

The evaluation of Power Distribution inaccuracy in the STAR Topical Report was reviewed above to confirm that there are no relevant unique design features for PVNGS that would invalidate the conclusions in Section E.2.1.4 of the STAR Topical Report. The results of the review confirmed that the relevant unique design features of PVNGS have no impact on the conclusions relating to Power Distribution inaccuracy. In addition, Appendix D has demonstrated that the uncertainties for the PVNGS CASMO/SIMULATE physics methods meet the uncertainty requirements of the STAR Topical Report.

4.3.2 As-Built Core Problem Evaluation for PVNGS

Section E.2.2 of the STAR Topical Report addressed nineteen as-built core problems. As-built core problems are a result of either errors in the core design process or physical characteristics of the core that differ from the core design. The identification of as-built core problems is in part based on the kind of problems and their associated symptoms that have been identified in the past and documented by ANSI, and in part on a review of industry problems coupled with engineering judgment. The following are the as-built core problems that are identified for evaluation:

1. CEA Worth Error
2. CBC Error
3. ITC Error
4. Power Distribution Error
5. MTC Noncompliance
6. SDM Noncompliance
7. Fuel Fabrication Error
8. Fuel Misloading
9. Fuel Distortion
10. Fuel Poison Loss
11. Fuel Crudding
12. CEA Fabrication Error
13. CEA Misloading
14. CEA Uncoupling
15. CEA Distortion
16. CEA Absorber Loss
17. CEA Finger Loss
18. RCS Anomaly
19. RCS B-10 Depletion

The as-built core problems and their associated definitions are retained for evaluation of PVNGS relevant unique design features and deviations from the Generic Program.

The evaluation process for as-built core problems is described in Section 4.2 of the STAR Topical Report that used the following acceptance criterion:

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The purpose of this section is to demonstrate that the net effect of the PVNGS relevant unique design features, PVNGS tests, PVNGS pre-operational activities, and PVNGS STAR Applicability Requirements identified in Table 5-2 results in the PVNGS STAR Program being at least as effective as the current PVNGS startup program at detecting and preventing operation with these problems.

This is achieved, for each As-Built Core Problem, through the following steps:

1. Briefly describe the problem.
2. Summarize the conclusions of the STAR Topical Report and its SER (Reference 1).
3. Using the effectiveness matrices in Tables B-1, B-2 and B-3 of Appendix B, determine the net effect of the PVNGS relevant unique design features, PVNGS tests, PVNGS pre-operational activities, and PVNGS STAR Applicability Requirements on the effectiveness to detect problems compared with Tables C-5, C-6 and C-7 of the STAR Topical Report.
4. Summarize how the analysis in (3) above affects the conclusions of the STAR Topical Report.
    a. If the analysis in (3) indicates the PVNGS STAR Program is at least as effective at detecting the problem as the original STAR Program, then it can be concluded that the PVNGS STAR Program is at least as effective at detecting the problem as the Generic Program and the conclusions of the STAR Topical Report remain valid. This is because

the STAR Topical Report demonstrated that ability of the STAR Program to prevent operation with problems is essentially the same as or better than the Generic Program.

b. If the analysis in (3) indicates the PVNGS STAR Program is less effective at detecting the problem as the original STAR Program, it must be demonstrated that the PVNGS STAR Program is at least as effective as the current PVNGS startup program at detecting the problem.

4.3.2.1 CEA Worth Error (1)

4.3.2.1.1 Problem Description – CEA Worth Error

CEA worth error detection is the detection of CEA worth predictions that result from errors in the application of approved Pressurized Water Reactor (PWR) methods. This includes errors in procedures or errors in the execution of procedures for specific applications. The measured startup test parameters potentially affected when CEA worth prediction errors are present are CEA Worth, CBC, ITC and power distribution. CEA worth errors directly affect the CEA Worth and significant errors are expected to be detectable. Errors in CEA Worth that result from flux distribution errors also affect the power distribution. Related errors in the power distribution may be detectable even in the unrodded condition. Errors in CEA Worth that result from neutron absorber errors do not affect the power distribution unless CEAs are inserted. Analytical errors that affect the CEA Worth may also affect CBC and ITC although related errors are unlikely to be detectable. [

]^{a,c}

4.3.2.1.2 Conclusions of the STAR Topical Report - CEA Worth Error

CEA worth error detection was addressed in Section E.2.2.1 of the STAR Topical Report. The NRC SER concluded:

> *"CEA worth errors are those resulting from errors in the application of core design methods. A search of the database did not identify any such errors. However, the STAR method for CEA error detection is judged to be as effective as the generic program. This is due to the addition of the core design applicability requirements, which will flag core design errors which could impact CEA worth.*
>
> *The NRC staff concludes that the STAR CEA worth error effectiveness is as good as that of the generic program, and therefore, it is acceptable."*

4.3.2.1.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CEA Worth Error

There are no changes to the CEA worth error detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.1.4 Impact on STAR Topical Report Conclusion – CEA Worth Error

The overall effectiveness of detecting CEA worth errors using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.2 CBC Error (2)

4.3.2.2.1 Problem Description – CBC Error

CBC error detection is the detection of inaccurate CBC predictions that result from errors in the application of PWR methods (for example, use of an inappropriate code input value, the misreading of a code result, or the modeling of the incorrect reactor core conditions). The measured startup test parameters potentially affected when CBC errors are present are CEA Worth, CBC, ITC and power distribution. CBC prediction errors directly affect the CBC and significant errors are expected to be detectable. Errors in CBC also affect ITC. However, related errors in ITC are unlikely to be detectable because moderate changes in CBC result in only small changes in the ITC relative to test criteria. Analytical errors that affect the CBC may also affect the power distribution although related errors are unlikely to be detectable. The STAR program does not delete any CBC measurement and in fact adds a Tech Spec surveillance on HZP CBC as part of the alternate HZP MTC surveillance.

These observations on the ability to detect CBC errors using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, the core design QA program is effective in detecting CBC errors.

4.3.2.2.2 Conclusions of the STAR Topical Report - CBC Error

CBC prediction error detection was addressed in Section E.2.2.2 of the STAR Topical Report. The NRC SER concluded:

> *"CBC errors result from faulty application of core design methods. A review of the database did not reveal any instances of such errors. The STAR program retains the CBC measurement at HZP but removes the ITC and the CEA worth at HZP. Analytical errors affecting CBC are also likely to affect ITC and CEA worth. However, detecting CBC errors from CEA measured values of CEA worth, ITC, or power distribution is not effective because the CBC is more sensitive than the other three parameters.*
>
> *The NRC staff concludes that the STAR CBC error detection is at least as effective as the generic program, and therefore, it is acceptable."*

4.3.2.2.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CBC Error

There are no changes to the CBC error detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.2.4 Impact on the STAR Topical Report Conclusion – CBC Error

The overall effectiveness of detecting CBC errors using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.3 ITC Error (3)

4.3.2.3.1 Problem Description – ITC Error

ITC error detection is the detection of ITC predictions that result from errors in the application of PWR methods. The measured startup test parameters potentially affected when ITC errors are present are CEA Group Worth, CBC, ITC and power distribution. ITC errors directly affect the ITC and significant errors are expected to be detectable. Errors in ITC that result from reactivity errors also affect CBC. Related errors in CBC may be detectable. The test criteria for the MTC that is calculated from the measured ITC may also result in the detection of ITC errors but are less effective than the ITC test criteria. Analytical errors that affect ITC can also affect the CEA Group Worth and power distribution although related errors are unlikely to be detectable. [

]^{a,c}

These observations on the ability to detect ITC errors using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, the core design QA program is effective in detecting ITC errors.

4.3.2.3.2 Conclusions of the STAR Topical Report - ITC Error

ITC error detection was addressed in Section E.2.2.3 of the STAR Topical Report. The NRC SER concluded:

> *"ITC errors result from faulty application of core design methods. A review of the database did not reveal any instances of such errors. The STAR program replaces the ITC-at-HZP measurement with an ITC-at-HFP measurement. It is shown that the HFP measurement is just as effective as the HZP measurement because the added core design applicability requirements are effective in identifying ITC errors prior to reactor operation.*
>
> *The NRC staff concludes that the STAR program ITC error detection is as effective as the generic program, and therefore, it is acceptable."*

4.3.2.3.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - ITC Error

There are no changes to the ITC error detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.3.4 Impact on STAR Topical Report Conclusion – ITC Error

The overall effectiveness of detecting ITC errors using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.4 Power Distribution Error (4)

4.3.2.4.1 Problem Description – Power Distribution Error

Power distribution error detection is the detection of power distribution predictions that result from errors in the application of PWR methods. The measured startup test parameters potentially affected when power distribution errors are present are CEA Group Worth, CBC, ITC and power distribution. Power distribution errors directly affect the power distribution and significant errors are expected to be detectable. Errors in power distribution can also affect CEA Worth. Related errors in CEA Worth may be detectable but the measurements are limited to the locations involved in the CEA Worth test. Furthermore, the CEA Group test typically involves CEA groups with CEAs in different symmetric locations, which reduces the ability to resolve power distribution differences. Analytical errors that affect the power distribution can also affect CBC and ITC although they are unlikely to be detectable. These observations on the ability to detect power distribution errors using measured startup test parameters are used to assess the effectiveness of startup tests.

4.3.2.4.2 Conclusions of the STAR Topical Report - Power Distribution Error

Power distribution error detection was addressed in Section E.2.2.4 of the STAR Topical Report. The NRC SER concluded:

> *"Power distribution errors result from faulty application of core design methods. A review of the database revealed one case of a power distribution error. The error was detected by the Incore flux symmetry at power. This test is included in the STAR program. The NRC staff concludes that the ability of the STAR program to detect power distribution errors compared to the generic program is not affected, and therefore, it is acceptable."*

4.3.2.4.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - Power Distribution Error

There are no changes to the power distribution error detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.4.4 Impact on STAR Topical Report Conclusion – Power Distribution Error

The overall effectiveness of detecting power distribution errors using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.5 MTC Noncompliance (5)

4.3.2.5.1 Problem Description – MTC Noncompliance

MTC noncompliance detection is the detection of MTC values that are outside Tech Spec limits. The measured startup test parameters potentially affected when MTC is not in compliance are CBC and ITC. Factors causing MTC noncompliance are likely to be associated with CBC, ITC, and MTC prediction errors. The MTC value used in startup testing is calculated from the ITC using the predicted fuel temperature coefficient. MTC noncompliance is likely to be associated with changes in CBC that affect ITC. The test criteria for MTC are likely to result in the detection of MTC noncompliance because they are established using MTC Tech Spec limits for MTC. The test criteria for ITC may result in the detection of MTC noncompliance but are configured to detect deviations from predictions rather than noncompliance with Tech Specs. Reactivity changes that affect ITC and MTC also affect CBC and may be detectable. These observations on the ability to detect MTC noncompliance using measured startup test parameters are used to assess the effectiveness of startup tests.[

]^{a,c} It is noted that demonstrating Tech Spec compliance using MTC surveillance tests is only one of several methods that are capable of detecting MTC noncompliance.

4.3.2.5.2 Conclusions of the STAR Topical Report - MTC Noncompliance

MTC noncompliance detection was addressed in Section E.2.2.5 of the STAR Topical Report. The NRC SER concluded:

> *"MTC values which are outside technical specification limits are noncompliant, although a review of the database revealed many instances of MTC values outside the technical specification limits. In all cases corrective actions were implemented and no technical specification violations were recorded. Review of the database did not reveal any discrepancies in the calculated values of either MTC or ITC. The measured MTC values in the database were collected from HZP measurements. The STAR program substituted the MTC at HZP with an alternate surveillance test which adjusts the calculated MTC value at HZP using the CBC at HZP to produce a best-estimate MTC at HZP. The test criteria for MTC will result in the detection of MTC noncompliance, because the test criteria are based on technical specification limits for MTC.*
>
> *The NRC staff concludes that the STAR program uses the core design applicability requirements, which in combination with the core design quality assurance is as effective in the detection of MTC noncompliance as the generic program, and therefore, it is acceptable."*

4.3.2.5.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - MTC Noncompliance

There are no changes to the MTC noncompliance detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.5.4 Impact on STAR Topical Report Conclusion – MTC Noncompliance

The overall effectiveness of detecting MTC noncompliance using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.6 SDM Noncompliance (6)

4.3.2.6.1 Problem Description – SDM Noncompliance

SDM noncompliance detection is the detection of Shutdown Margin (SDM) values that are outside Tech Spec limits. This evaluation addresses SDM when the reactor is critical, which may not always be associated with an explicit Tech Spec requirement. The measured startup test parameters potentially affected when SDM is not in compliance are CEA Worth, CBC, and ITC. Factors causing SDM noncompliance are likely to be associated with CEA Worth, CBC, and ITC prediction errors. CEA Worth has the largest impact on SDM and is likely to be the cause of SDM noncompliance while CBC and ITC have lesser impacts that affect the power defect. A more negative MTC increases the likelihood of SDM noncompliance by resulting in the addition of more positive reactivity during the cooldown associated with a shutdown from power. The MTC that is calculated from the ITC and compared to Tech Spec limits may be affected. However, a more negative MTC would not exceed the positive MTC test criteria typically used for the MTC surveillance at HZP. The negative MTC test criteria typically used for the MTC surveillance at power may detect SDM problems. These observations on the ability to detect SDM noncompliance using measured startup test parameters are used to assess the effectiveness of startup tests. [

]^{a,c}

4.3.2.6.2 Conclusions of the STAR Topical Report - SDM Noncompliance

SDM noncompliance detection was addressed in Section E.2.2.6 of the STAR Topical Report. The NRC SER concluded:

> *"SDM values which are outside technical specification limits are noncompliant. A review of the database revealed one instance of SDM noncompliance involving shutdown CBC detected by core design quality assurance. The STAR program does not alter CBC or the quality assurance program. The addition of the core design applicability requirements enhances the core design error detection which impacts the SDM. SDM is not a technical specification requirement in the CE Standard Technical Specifications. However, verification of the SDM at HZP is a technical specification requirement in some plants.*
>
> *The NRC staff concludes that the addition of the core design applicability requirements in the STAR program and the core design quality assurance is more effective in identifying SDM errors than the generic program, and therefore, it is acceptable."*

4.3.2.6.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - SDM Noncompliance

There are no changes to the SDM noncompliance detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.6.4 Impact on STAR Topical Report Conclusion – SDM Noncompliance

The overall effectiveness of detecting SDM noncompliance using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.7 Fuel Fabrication Error (7)

4.3.2.7.1 Problem Description – Fuel Fabrication Error

Fuel fabrication error detection is the detection of as-built fuel characteristics that are different from the intended design. Potentially affected as-built fuel characteristics include enrichment, poison loading, fuel pellet placement and size, fuel rod placement, and poison rod placement. The measured startup test parameters potentially affected by fuel fabrication errors are CEA Worth, CBC, ITC and power distribution. Fuel fabrication errors affect the neutronic characteristics of the fresh fuel assemblies and therefore the power distribution in the core. Significant fuel fabrication errors are expected to be easily detectable in the power distribution. Changes in the power distribution can also affect CEA Worth. Related changes in CEA Worth may be detectable but the measurements are limited to the locations involved in the CEA Worth test. Furthermore, the measurements typically involve CEA groups with CEAs in different symmetric locations, which reduce the ability to resolve power distribution differences. Fuel fabrication errors can also affect core reactivity and related changes on CBC may be detectable. CBC related effects on ITC are not detectable because the predicted ITC is typically corrected for the measured CBC when calculating the deviation between measured and predicted ITC. The MTC that is calculated from the ITC and compared to Tech Spec limits would be affected but the effect is unlikely to be detectable. Fuel fabrication errors may be symmetric and thus may not affect core symmetry. These observations on the ability to detect fuel fabrication errors using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, the fuel fabrication QA is effective in detecting fuel fabrication errors.

4.3.2.7.2 Conclusions of the STAR Topical Report - Fuel Fabrication Error

Fuel fabrication error detection was addressed in Section E.2.2.7 of the STAR Topical Report. The NRC SER concluded:

> *"Fuel fabrication errors occur when the as-built fuel characteristics are different than those for the intended design. Fuel parameters which could contribute to fuel fabrication errors are enrichment, poison loading, fuel pellet size and location, fuel rod placement and poison rod placement. Review of the database revealed fourteen instances of fuel fabrication errors. Eight of these errors were detected before fuel shipment, three were identified by plant receipt inspection, and three were identified by incore power distribution tests at power.*
>
> *The NRC staff concludes that the STAR program does not affect fuel fabrication quality assurance, utility receipt inspection, or the core power distribution test at power, and therefore, the STAR fuel fabrication error detection is acceptable."*

4.3.2.7.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - Fuel Fabrication Error

There are no changes to the fuel fabrication error detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.7.4 Impact on STAR Topical Report Conclusion – Fuel Fabrication Error

The overall effectiveness of detecting fuel fabrication errors using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.8 Fuel Misloading (8)

4.3.2.8.1 Problem Description – Fuel Misloading

Fuel misloading detection is the detection of errors in the placement of fuel in the core during core loading. This could involve the placement of fuel in an incorrect location or orientation. The measured startup test parameters potentially affected by fuel misloadings are CEA Worth, CBC and power distribution. Fuel misloadings affect the power distribution in the vicinity of the misloading. The effect on the power distribution is more local than global and is likely to be asymmetric. Significant fuel misloadings are expected to be detectable in the power distribution during the core flux symmetry startup test. Changes in the power distribution can also affect CEA Worth. Related changes in CEA Worth are unlikely to be detectable because the effect is local. CEA Worth measurements involve the measurement of multiple locations simultaneously and are limited to the locations involved in the CEA Worth test. Fuel misloadings can also affect core reactivity although related CBC changes are unlikely to be detectable. Any CBC related effects on ITC are judged not to be detectable. These observations on the ability to detect fuel misloadings using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, core verification is effective in detecting fuel misloadings.

4.3.2.8.2 Conclusions of the STAR Topical Report - Fuel Misloading

Fuel misloading detection was addressed in Section E.2.2.8 of the STAR Topical Report. The NRC SER concluded:

> *"An error in the placement of fuel in the core is a misloading error. Review of the database revealed five instances of fuel misloading. One was detected by core quality assurance, two were detected by the core symmetry test at power, and two by the power distribution test at power. The STAR program does not affect the core design quality assurance, the core flux symmetry, or the core power*

> *distribution test. All of the effective fuel misloading detection methods are incorporated in the STAR program. Therefore, the NRC concludes that the STAR method fuel misloading detection program is acceptable."*

4.3.2.8.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - Fuel Misloading

There are no changes to the fuel misloading detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.8.4 Impact on STAR Topical Report Conclusion – Fuel Misloading

The overall effectiveness of detecting fuel misloading using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.9 Fuel Distortion (9)

4.3.2.9.1 Problem Description – Fuel Distortion

Fuel assembly distortion detection is the identification of changes in fuel assembly geometry that affect core operating characteristics. Fuel assembly distortions can be the result of operation in the reactor such as bowing or the result of damage incurred during fuel handling. The measured startup test parameters potentially affected by fuel distortion are CEA drop time and power distribution. Distortions of fuel assembly guide tubes can increase CEA drop time due to mechanical interference or result in the failure to fully insert due to mechanical binding. This is expected to be detectable should it occur, but may not always be a result of fuel distortion. Fuel distortion can also affect the power distribution if fuel rods are displaced or fuel pellets are lost from fuel rods. However, these effects are generally not easily detected because the effects are small and localized. Fuel distortion may be observed during the process of manipulating fuel or may be caused by fuel manipulation. In most instances, the events causing fuel damage or visual observations of apparent anomalies during fuel manipulations result in inspections that detect the actual degradation. The visual inspection of fuel is an effective means of detecting fuel damage but is not part of startup testing. Periodic fuel assembly inspections may be performed but are not a standard pre-operational activity. These observations on the ability to detect fuel distortion using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, if the fuel distortion results in fuel failure, fuel failure is detectable by Reactor Coolant System (RCS) chemistry monitoring and is accounted for in the safety analysis.

4.3.2.9.2 Conclusions of the STAR Topical Report - Fuel Distortion

Fuel distortion detection was addressed in Section E.2.2.9 of the STAR Topical Report. The NRC SER concluded:

> *"Fuel distortion occurs when changes due to operation or assembly result in operating characteristics different than the design assumptions. Reactor operation can result in fuel distortions such as bowing. Fuel handling or assembly can result in fuel distortions such as cracks or breaks. Review of the database revealed eight instances of fuel distortion. Three were detected by CEA drop time tests, two by CEA manipulations, two by CEA trips, and one by CEA inspection. The STAR program retains the CEA drop time test and the other methods used to identify fuel distortion. The changes from the generic program do not affect the CEA drop time test or other effective detection methods.*
>
> *Therefore, the NRC staff concludes that the STAR fuel distortion detection methods are acceptable."*

4.3.2.9.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - Fuel Distortion

There are no changes to the fuel distortion detection effectiveness ratings in Tables B-2 and B-3 compared with the STAR Topical Report Tables C-6 and C-7. [

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4.3.2.9.4 Impact on STAR Topical Report Conclusion – Fuel Distortion

The overall effectiveness of detecting fuel distortion using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.10 Fuel Poison Loss (10)

4.3.2.10.1 Problem Description – Fuel Poison Loss

Fuel poison loss detection is the detection of burnable poison degradation that results in the loss of neutron absorber material. The measured startup test parameters potentially affected by fuel poison loss are CEA Worth, CBC, ITC and power distribution. Fuel poison loss affects the power distribution. Significant fuel poison loss is expected to be detectable in the power distribution. Changes in the power distribution can also affect CEA Worth. Related changes in CEA Worth may be detectable but the measurements are limited to the locations involved in the CEA Worth test. Furthermore, the measurements typically involve CEA groups with CEAs in different symmetric locations, which reduce the ability to resolve power distribution differences. Fuel poison loss can also affect core reactivity and related changes on CBC may be detectable. CBC related effects on ITC are not detectable because the predicted ITC is typically corrected for the measured CBC when calculating the deviation between measured and predicted ITC. The MTC that is calculated from the ITC and compared to Tech Spec limits would be affected but the effect is unlikely to be detectable. The fuel poison may be asymmetric because the associated degradation may be somewhat random and core symmetry would also be affected. The PVNGS plants employ integral burnable absorbers (e.g., Erbia, ZrB2 IFBA) for the fuel poison. Thus, the loss of burnable absorber would be associated with fuel clad failure and the release of fission gasses to the coolant that would be easily detectable by RCS chemistry monitoring. These observations on the ability to detect fuel poison loss using measured startup test parameters are used to assess the effectiveness of startup tests.

4.3.2.10.2 Conclusions of the STAR Topical Report - Fuel Poison Loss

Fuel poison loss detection was addressed in Section E.2.2.10 of the STAR Topical Report. The NRC SER concluded:

> *"Fuel poison degradation occurs when burnable poison is degraded through burnup depletion or physical loss. Review of the database did not reveal any recorded instances of fuel poison loss. The STAR program retains the methods for fuel poison detection, and the changes from the generic program do not significantly affect the fuel poison loss detection.*
>
> *Therefore, the NRC staff concludes that the STAR fuel poison detection methods are acceptable."*

4.3.2.10.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - Fuel Poison Loss

There are no changes to the fuel poison loss detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.10.4 Impact on STAR Topical Report Conclusion – Fuel Poison Loss

The overall effectiveness of detecting fuel poison loss using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.11 Fuel Crudding (11)

4.3.2.11.1 Problem Description – Fuel Crudding

Fuel crudding detection is the detection of deposits of material from the coolant on the outside of fuel rods. The measured startup test parameters potentially affected by fuel crudding are CBC, CEA Worth, and power distribution. One potential effect of fuel crudding is on reactivity through temperature changes. Fuel crudding reduces heat transfer from the fuel rod and raises fuel temperature. The increase in fuel temperature reduces local reactivity and flux through fuel temperature coefficient feedback. This reactivity change affects CBC only during power operation and thus affects the change in CBC between HZP and HFP by causing an increase in fuel temperature at HFP.

A second potential effect of fuel crudding is on reactivity through neutron absorption in the crud. This is typically a result of depositing boron containing crud on the fuel during nucleate boiling. The increase in neutron absorption reduces local reactivity and can affect CBC at all power levels. The associated flux changes with both types of reactivity changes can affect CEA Worth and the power distribution. However, these effects are generally small and not easily detected. In some instances, reactivity changes associated with neutron absorption in the crud can be detected in axial flux distributions but is not likely to be detected using startup test criteria. This effect is referred to as crud induced power shift (CIPS).

These observations on the ability to detect fuel crudding using measured startup test parameters are used to assess the effectiveness of startup tests. All of the startup tests are ineffective in detecting this fuel crudding. Furthermore, fuel crudding usually develops slowly during operation and is thus not likely to be significant during startup. The effective methods for detecting this problem are the (a) monitoring of RCS pressure drop, flow, temperatures and chemistry during operation, (b) monitoring of the axial distribution for CIPS and (c) physical inspection of fuel. In addition, if the fuel crudding results in fuel failure, fuel failure is detectable by RCS chemistry monitoring and is accounted for in the safety analysis.

4.3.2.11.2 Conclusions of the STAR Topical Report - Fuel Crudding

Fuel crudding detection was addressed in Section E.2.2.11 of the STAR Topical Report. The NRC SER concluded:

> *"Fuel crudding occurs when deposits of foreign material accumulate outside the fuel cladding, distorting flow, heat transfer and poison distribution. Review of the data base identified five instances of crudding detected by incore flux mapping at power. The STAR program retains the fuel crudding detection program. The changes to the generic program do not significantly affect the crudding detection. Therefore, the NRC staff concludes that the STAR program crudding detection program is acceptable."*

4.3.2.11.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - Fuel Crudding

There are no changes to the fuel crudding detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.11.4 Impact on STAR Topical Report Conclusion – Fuel Crudding

The overall effectiveness of detecting fuel crudding using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.12 CEA Fabrication Error (12)

4.3.2.12.1 Problem Description – CEA Fabrication Error

CEA fabrication error detection is the detection of as-built CEA characteristics that are different from the intended design. The measured startup test parameters potentially affected by CEA fabrication errors are CEA drop time, CEA drop characteristics (such as trends of drop time by location, slowing in the dashpot, and normal rebound) and CEA Worth. Errors in CEA fabrication are unlikely to affect CEA drop time or drop characteristics because of the similar characteristics of CEA materials for different designs. It is unlikely that CEA fabrication errors would affect CEA Worth at detectable levels because credible errors in absorber material would result in a small change in CEA Worth. Most CEAs are of the similar design, which reduces the potential for interchanges of absorber material that could significantly affect CEA Worth. These observations on the ability to detect CEA fabrication errors using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, the CEA fabrication QA is effective in detecting fuel fabrication errors.

4.3.2.12.2 Conclusions of the STAR Topical Report - CEA Fabrication Error

CEA Fabrication Error detection was addressed in Section E.2.2.12 of the STAR Topical Report. The NRC SER concluded:

> *"CEA fabrication errors occur when the as-built CEA characteristics are different than the intended design. A review of the database revealed one instance of a CEA fabrication error, which was discovered by CEA fabrication quality assurance. The STAR program does not affect the CEA fabrication quality assurance program.*
>
> *Therefore, the NRC staff concludes that the STAR program fabrication assurance capability is acceptable."*

4.3.2.12.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CEA Fabrication Error

There are no changes to the CEA fabrication error detection effectiveness ratings in Tables B-2 and B-3 compared with the STAR Topical Report Tables C-6 and C-7. [

]^{a,c}

4.3.2.12.4 Impact on STAR Topical Report Conclusion – CEA Fabrication Error

The overall effectiveness of detecting CEA fabrication error using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.13 CEA Misloading (13)

4.3.2.13.1 Problem Description – CEA Misloading

CEA misloading detection is the detection of errors in the placement of CEAs in the core during core loading. This could involve the placement of a CEA in an incorrect location or orientation. In the PVNGS design, the CEAs are not shuffled with the fuel assemblies but instead are retained in the Upper Guide Structure during refueling. Therefore, once the correct initial position and orientation of each CEA is confirmed during CEA replacement, there is no possibility of subsequent inadvertent interchangeability of the CEAs throughout their lifetime. The measured startup test parameter potentially affected by CEA misloading is CEA Worth. Most CEAs are of a similar design, which reduces the potential for interchanges of CEAs during CEA replacement that could affect CEA Worth.

CEA misloadings also affect the power distribution in the vicinity of the misloading but this would not be detected by power distribution tests that are performed near ARO. These observations on the ability to detect CEA misloadings using measured startup test parameters are used to assess the effectiveness of startup tests.

4.3.2.13.2 Conclusions of the STAR Topical Report - CEA Misloading

CEA misloading detection was addressed in Section E.2.2.13 of the STAR Topical Report. The NRC SER concluded:

> *"Misloading would result if a CEA is placed in the wrong core location and/or orientation. A review of the database did not identify any CEA misloadings. However, the proposed changes do not significantly impact the CEA misloading program.*
>
> *Therefore, the NRC staff concludes that the STAR program CEA misloading detection capability is acceptable."*

4.3.2.13.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CEA Misloading

There are no changes to the CEA misloading detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7. [

]^{a,c}

4.3.2.13.4 Impact on STAR Topical Report Conclusion – CEA Misloading

The overall effectiveness of detecting CEA misloading using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.14 CEA Uncoupling (14)

4.3.2.14.1 Problem Description – CEA Uncoupling

CEA uncoupling detection is the detection of the failure to couple a CEA properly, which results in the CEA being inserted in a fuel assembly. As discussed in Appendix C, the PVNGS CEAs are normally not uncoupled during refueling, but remain attached to the CEA extension shaft which is latched to the UGS lift rig during refueling. Refueling procedures require that a visual check be made that all the CEAs are fully withdrawn into the UGS prior to reassembly of the reactor internals thereby confirming the CEAs remain coupled to the extension shaft assemblies. Thus, it is extremely unlikely that CEA uncoupling would occur at PVNGS.

However, if such an event occurred after re-assembly of the reactor internals following refueling, the measured startup test parameters potentially affected by CEA uncoupling are CEA drop characteristics, CEA Worth, CBC and power distribution. The analysis of CEA drop characteristics such as the drop time for a given location, slowing in the dashpot, and normal rebound is an effective method of detecting CEA uncoupling. CEA uncoupling has a significant effect on the power distribution and is likely to be asymmetric. The increases in power are likely to affect a broad area of the core and thus are likely to be detected using incore detectors. Thus, CEA uncoupling is likely to be detectable in the power distribution. Changes in the power distribution can also affect CEA Worth. Related changes in CEA Worth are also likely to be detectable because of the significant effect on the power distribution. CEA uncoupling also affects core reactivity and related changes in CBC may be detectable. CBC related affects on ITC are not detectable because the predicted ITC is typically corrected for the measured CBC when calculating the deviation between measured and predicted ITC. The related effects on the MTC that is calculated from the ITC are minor and unlikely to be detectable. These observations on the ability to detect CEA uncoupling using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, CEA coupling verification using acceptance criteria on [ ]^{a,c} and weights following CEA coupling are effective in detecting CEA uncoupling.

4.3.2.14.2 Conclusions of the STAR Topical Report - CEA Uncoupling

CEA uncoupling detection was addressed in Section E.2.2.14 of the STAR Topical Report. The NRC SER concluded:

> *"An uncoupling error is a loss of connection of a CEA to the driving mechanism. A review of the database indicates that there have been eight recorded instances of CEA uncoupling. Four were detected by HZP flux symmetry tests, one was detected by flux symmetry at power, one by the incore power distribution at power, and two were detected by position indications.*
>
> *The uncoupling detection using incore flux symmetry and power distribution tests is not affected by the STAR program. In addition, the STAR program includes the flux symmetry test at power, which is effective at detecting CEA uncoupling. In general, the STAR program does not affect the CEA uncoupling detection. Therefore, the NRC staff concludes that the uncoupling detection capability of the STAR program is acceptable."*

4.3.2.14.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CEA Uncoupling

There are no changes to the CEA uncoupling detection effectiveness ratings in Tables B-2 and B-3 compared with the STAR Topical Report Tables C-6 and C-7. [

]^{a,c}

4.3.2.14.4 Impact on STAR Topical Report Conclusion – CEA Uncoupling

The overall effectiveness of detecting CEA Uncoupling using the PVNGS STAR Program is concluded to be better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.15 CEA Distortion (15)

4.3.2.15.1 Problem Description – CEA Distortion

CEA distortion detection is the detection of changes in CEA geometry that affect the ability of CEAs to move as designed. Of particular concern is the ability of CEAs to trip as designed. The measured startup test parameter potentially affected by CEA distortion is CEA drop time. Distortions of CEAs can increase CEA drop time due to mechanical interference or result in the failure to fully insert due to mechanical binding. Mechanical interference and significant impacts on CEA drop time are detectable. The inspection of CEAs using non-destructive examination techniques is an effective means of preventing and detecting CEA distortion but is not part of startup testing and, due to access restrictions during outages, is more difficult to perform at PVNGS. The most effective method of detecting CEA mechanical interference is by the manipulations of the CEA, including the insertion of the CEAs into the fuel assemblies, as well as the withdrawal and subsequent tripping of a CEA. These observations on the ability to detect CEA distortion are used to assess the effectiveness of startup tests.

4.3.2.15.2 Conclusions of the STAR Topical Report - CEA Distortion

CEA distortion was addressed in Section E.2.2.15 of the STAR Topical Report. The NRC SER concluded:

> *"CEA distortion due to neutron exposure can prevent normal insertion and/or result in absorber loss, either of which could affect the ability to trip. Review of the database identified 12 Instances of recorded CEA distortion. Ten were detected by CEA inspection, one was detected by CEA insertion, and one was detected by CEA manipulation.*

> *The STAR program does not impact the CEA distortion detection procedures. Therefore, the NRC staff concludes that the STAR CEA distortion detection is acceptable. The addition of the applicability requirements enhance the STAR's ability to detect CEA distortion."*

4.3.2.15.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CEA Distortion

There are no changes to the CEA distortion detection effectiveness ratings in Table B-3 compared with STAR Topical Report Table C-7. [

]^{a,c}

4.3.2.15.4 Impact on STAR Topical Report Conclusion – CEA Distortion

The overall effectiveness of detecting CEA distortion using the STAR Program at PVNGS is the same as the original STAR Program and the Generic Program, except [

]^{a,c} Therefore, the overall effectiveness of detecting CEA distortion using the PVNGS STAR Program is concluded to be better than the current PVNGS startup program.

4.3.2.16 CEA Absorber Loss (16)

4.3.2.16.1 Problem Description – CEA Absorber Loss

CEA absorber loss detection is the detection of CEA degradation that results in the loss of neutron absorber material. The measured startup test parameters potentially affected by CEA absorber loss are CEA drop time, CEA Worth and power distribution. Distortions of CEAs associated with CEA absorber loss can increase CEA drop time due to mechanical interference or result in the failure to fully insert due to mechanical binding. Significant impacts on CEA drop time are detectable. This aspect of CEA absorber loss (distortions and resulting impact on CEA drop time) is comparable to the CEA distortion discussion presented above.

In addition, to potential mechanical interaction implications, CEA absorber loss reduces CEA Worth and significant losses are expected to be detectable. However, the loss of absorber from a single finger in a CEA is unlikely to be detectable. The loss of absorber from multiple fingers in a CEA may be detectable. CEA absorber loss can affect the power distribution if the loss is in CEAs that are inserted during operation, but would likely not be detectable with typical CEA Bank insertions during startup testing. These observations on the ability to detect CEA absorber loss using measured startup test parameters are used to assess the effectiveness of startup tests.

4.3.2.16.2 Conclusions of the STAR Topical Report - CEA Absorber Loss

CEA absorber detector was addressed in Section E.2.2.16 of the STAR Topical Report. The NRC SER concluded:

> *"Absorber loss can result through leaching, loss of CEA physical integrity, and absorber transport. CEA absorber loss can result in degradation of CEA performance. Loss of absorber can coincide with CEA distortion and interference with CEA movement.*
>
> *A review of the database identified four recorded instances of absorber loss. Two were detected by CEA inspection, one by CEA manipulation, and one by EOC CEA insertion. The addition of the STAR applicability requirements makes the loss of the absorber detection method more effective than the standard program. Therefore, the NRC staff concludes that the STAR CEA absorber loss program is acceptable."*

4.3.2.16.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CEA Absorber Loss

The changes in Tables B-1, B-2, and B-3 for CEA absorber loss are identical to the changes described above for CEA distortion in Section 4.3.2.15.3 except [

]^{a,c} Therefore, the overall effectiveness rating for detecting the CEA Worth aspects of CE absorber loss is concluded to be the same or better at PVNGS with the STAR Program than with the current PVNGS startup program.

4.3.2.16.4 Impact on STAR Topical Report Conclusion – CEA Absorber Loss

The mechanical interaction aspects and the CEA Worth aspects of CEA absorber loss are evaluated above and the overall effectiveness of detecting CEA absorber loss using the PVNGS STAR Program is concluded to be the same as or better than the current PVNGS startup program.

4.3.2.17 CEA Finger Loss (17)

4.3.2.17.1 Problem Description – CEA Finger Loss

CEA finger loss detection is the detection of the physical separation of CEA fingers from CEAs. The separated finger subsequently remains in the fuel while the CEA is withdrawn. The simultaneous loss of a large number of fingers is unlikely. Further, the loss of a CEA finger, should it occur, would likely occur during the operating cycle. The measured startup test parameters potentially affected by CEA finger loss are CEA drop characteristics, CEA Worth, CBC and power distribution. The analysis of CEA drop characteristics is unlikely to detect the loss of a small number of fingers unless the lost finger is in an assembly that will be moved to another core location with a CEA. For PVNGS CEA Finger Loss, this type of detection is more probable than in the Standard 16x16 plants since most assembly locations receive a control rod (See Figure C-5). A small number of lost fingers have a minor effect on the power distribution that is likely to be asymmetric but unlikely to be detectable. Changes in the power distribution can also affect CEA Worth. Related changes in CEA Group Worth are also unlikely to be detectable. CEA finger loss also affects core reactivity but related changes in CBC are unlikely to be detectable. CBC related effects on ITC are not detectable because the predicted ITC is typically corrected for the measured CBC when calculating the deviation between measured and predicted ITC. The related effects on the MTC that is calculated from the ITC are likely to be minor and thus unlikely to be detectable. These observations on the ability to detect CEA finger loss using measured startup test parameters are used to assess the effectiveness of startup tests. In addition, CEA manipulation during refueling may detect CEA finger loss by either visual observation or mechanical interference.

4.3.2.17.2 Conclusions of the STAR Topical Report - CEA Finger Loss

CEA finger loss was addressed in Section E.2.2.17 of the STAR Topical Report. The NRC SER concluded:

> *"Finger loss refers to physical separation of CEA fingers from the CEA. The fingers remain in the fuel when the CEA is withdrawn. A review of the database identified four recorded instances of finger separation. Two were identified by CEA inspection, one by the power distribution test at power, and one by CEA manipulation.*
>
> *Although the STAR program eliminates the CEA worth test at HZP, its ability to detect CEA finger loss is not impaired because the most effective techniques are still part of the program and because of the addition of the applicability requirements. The NRC staff concludes that the STAR CEA finger loss detection capability is acceptable."*

4.3.2.17.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - CEA Finger Loss

There are no changes to the CEA finger loss detection effectiveness ratings in Tables B-2 and B-3 compared with the STAR Topical Report Tables C-6 and C-7. [

]^{a,c}

4.3.2.17.4 Impact on STAR Topical Report Conclusion – CEA Finger Loss

The overall effectiveness of detecting CEA finger loss using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.18 RCS Anomaly (18)

4.3.2.18.1 Problem Description – RCS Anomaly

RCS anomaly detection is the detection of anomalous changes in local RCS parameters such as temperature or flow. The measured startup test parameter potentially affected by RCS anomalies is the power distribution. RCS anomalies may cause core power distribution asymmetries. These observations on the ability to detect RCS anomalies using measured startup test parameters are used to assess the effectiveness of startup tests. Operational surveillances of RCS parameters such as flow, temperature, and pressure drop are more effective than startup tests in detecting RCS anomalies.

4.3.2.18.2 Conclusions of the STAR Topical Report - RCS Anomaly

RCS anomaly detection was addressed in Section E.2.2.18 of the STAR Topical Report. The NRC SER concluded:

> *"RCS anomalies are changes in the local RCS temperature and flow. A review of the database (limited to CE design plants) did not identify any instances of RCS anomalies.*

> *The STAR program does not change anything which could impact its ability to detect RCS anomalies. Therefore, the NRC staff concludes that the STAR RCS anomaly detection program is acceptable."*

4.3.2.18.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - RCS Anomaly

There are no changes to the RCS Anomaly detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7.

4.3.2.18.4 Impact on STAR Topical Report Conclusion – RCS Anomaly

The overall effectiveness of detecting RCS anomalies using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.2.19 RCS B-10 Depletion (19)

4.3.2.19.1 Problem Description – RCS B-10 Depletion

RCS B-10 depletion detection is the detection of the reduced abundance of the isotope B-10 in the RCS boron relative to its natural value. B-10 depletion is caused by burnup of the high absorption component of RCS boron. Isotopic boron depletion could bring the core to conditions outside those calculated as safe in core analysis if only boron concentration is monitored. However a review of the database did not reveal any recorded instances of boron depletion with safety significance. The measured startup test parameter potentially affected by RCS B-10 depletion is the CBC. The depletion of B-10 in the RCS requires a higher CBC for a particular set of core conditions and significant depletions are detectable. This observation on the ability to detect RCS B-10 depletion using measured startup test parameters is used to assess the effectiveness of startup tests.

4.3.2.19.2 Conclusions of the STAR Topical Report - RCS B-10 Depletion

RCS B-10 Depletion detection was addressed in Section E.2.2.19 of the STAR Topical Report. The NRC SER concluded:

> *The STAR program does not impact the B-10 isotopic composition detection method. Therefore, the NRC staff concludes that the STAR program is acceptable for B-10 depletion detection capability.*

4.3.2.19.3 Net Effectiveness of PVNGS STAR Program versus STAR Program - RCS B-10 Depletion

There are no changes to the RCS B-10 depletion detection effectiveness ratings in Tables B-1, B-2 and B-3 compared with the STAR Topical Report Tables C-5, C-6 and C-7. The most effective way of detecting B-10 Depletion is by regular isotopic analysis of the RCS water samples that directly yields the B-10 abundance. The plant procedure that requires this sampling will not be changed with STAR implementation.

4.3.2.19.4 Impact on STAR Topical Report Conclusion – RCS B-10 Depletion

The overall effectiveness of detecting RCS B-10 Depletion using the PVNGS STAR Program is concluded to be the same as or better than the original STAR Program, the Generic Program, and the current PVNGS startup program.

4.3.3 Test Performance Problem Evaluation

This section evaluates the impact of PVNGS relevant unique design features and deviations from the Generic Program on the three test performance problems identified in Section E.2.3 of the STAR Topical Report:

- Test equipment errors
- Test process errors
- Test result errors

Test performance problems are test initiated errors that have the potential for significantly impacting the operation of the core. The identification of test performance problems was based on a review of startup test performance activities to determine associated practices that have the potential for causing errors that impact core operation. Tests that involve unique operating practices or reactivity maneuvers to support the testing are judged to have a credible likelihood of initiating operation outside the safety analysis. Unique operating practices involving equipment and processes necessary to support testing may cause errors that impact operation. Unique operating practices include the use of a reactivity computer, unique CEA configurations, and the frequent interaction between operations and test personnel on plant operating maneuvers. Normal operating practices involving reactivity maneuvers as part of the test process may also cause errors that impact operation. Normal operating practices include reactivity maneuvers that require changes in CEA position, boron concentration, and temperature. Finally, errors in test results have the potential of impacting plant operation through the substitution of measured values for predicted values in operating instructions. Although, such errors have a minimal likelihood of initiating operation outside the safety analysis because the test result error would have to involve a significant nonconservative measurement error and be within acceptance criteria for the test. In addition, predicted values rather than measured values are typically used in operating instructions when the test result is less conservative.

The evaluation process for the STAR Program used for test performance problems is described in Section 4.3 the STAR Topical Report that used the following acceptance criterion:

[

]^{a,c}

As discussed in Section 1, the STAR Program eliminates tests where the potential for problems with the tests themselves is significant (See Table A-3). The zero power CEA Worth and ITC Test are being replaced with alternate means of problem detection. Where tests are added in the STAR Program, normal operating practices are used rather than invoking special core conditions or procedures. In addition, the test equipment, processes and results are essentially the same for PVNGS as the participating plants. Thus the implementation of the PVNGS STAR Program does not alter the test problem initiation matrix in Table D-1 of Appendix D of the STAR Topical Report.

Therefore, using the STAR Program at PVNGS is at least as effective as the original STAR Program and the Generic Program, and better than the current PVNGS startup program at avoiding problems related to startup test equipment, processes and results. Thus the STAR acceptance criterion applicable to startup test problems is satisfied for STAR application at PVNGS.

4.4 CONCLUSIONS OF EVALUATION OF PVNGS STAR PROGRAM EFFECTIVENESS

4.4.1 PVNGS STAR Effectiveness Versus STAR Program and Generic Program

Sections 4.3.1, 4.3.2 and 4.3.3 evaluated the overall impact of PVNGS relevant unique design features identified in Section 4.2, PVNGS tests, PVNGS pre-operational activities, and additional PVNGS STAR Applicability Requirements on the conclusions of Section 4.0 and Appendix E, "Problem Evaluations," of the STAR Topical Report. Based on the conclusions of these sections it is concluded that the PVNGS STAR Program is at least as effective at detecting the following general categories of problems as the original STAR Program and the Generic Program:

- Design Prediction problems related to the accuracy of core design methods.

- As-Built Core problems related to core anomalies or errors in core design, fabrication, or reassembly (except for the as-built core problems of CEA Distortion and CEA Absorber Loss).
- Test Performance problems related to errors using test equipment, processes, or results do not cause significant increases in design prediction problems, as-built problems and test performance problems using the STAR Program at PVNGS.

The conclusion regarding the two identified as-built core problems is that the PVNGS STAR Program is at least as effective as the current PVNGS startup test program (included in the discussion of Section 4.4.2 below).

4.4.2 PVNGS STAR Effectiveness Versus Current PVNGS Startup Test Program

Section 4.4.1 above concluded that the PVNGS STAR Program is at least as effective at detecting problems as both the original STAR Program and the Generic Program except for the as-built problems of CEA Distortion and CEA Absorber Loss. Since the differences in effectiveness of the as-built problems of CEA Distortion and CEA Absorber Loss are associated with (a) PVNGS relevant unique design features, most notably:

a,c

and (b) the absence of CEA shuffling in the SFP and core associated with this unique design feature, it is concluded that the PVNGS STAR Program is at least as effective at detecting problems as the current PVNGS startup program. It should also be noted that the PVNGS STAR Program is more effective than the ANSI 2011 Standard Test Program for detecting all the problems since [

]^{a,c} Therefore, the PVNGS STAR Program is an acceptable alternate to the current PVNGS startup test program.

5 CONCLUSIONS

This report has performed an evaluation of the applicability of the STAR Program (Reference 1) to the PVNGS plants. The conclusions are:

1. None of the relevant unique design features of the PVNGS reactor internals, core components (fuel assemblies, CEAs, and ICIs), and CEA Drives (extension shafts and CEDMs) have an overall adverse impact on the ability of the STAR Program for detecting problems at PVNGS with the changes to the startup tests and STAR Applicability Requirements identified in Tables C-2 and C-3, respectively.
2. The PVNGS STAR Program is at least as effective at detecting problems as both the original STAR Program and the Generic Program except for the as-built problems of CEA Distortion and CEA Absorber Loss. However, the differences with these two as-built problems are due to inherent design and hardware differences between the PVNGS plants and the Standard 16x16 plants and are not directly related to the startup operations, so they do not change the effectiveness for detecting these two as-built core problems at PVNGS with or without the STAR Program. In addition, the PVNGS STAR Program is at least as effective at detecting these problems as the current PVNGS startup program and is better than the ANSI 2011 Standard. Therefore, the PVNGS STAR Program is an acceptable alternate to the current PVNGS startup test program.
3. Table 5-1 compares the startup tests associated with the original STAR Program and the PVNGS STAR Program, and indicates which of those tests are included in the current PVNGS startup program. Note that other startup tests not listed here are not affected by the PVNGS STAR Program.
4. Applicability of STAR to PVNGS is acceptable for all cycle startups that [

]^{a,c}

6. APS should implement Tech Spec changes consistent with the following:
    - Change SR 3.1.4.1 to be consistent with SR 3.1.3.1 of Reference 7
    - Change to Tech Spec Bases for SR 3.1.4.1 to be consistent with Section B.3.1.3.1 of Reference 7
7. APS should review the guidelines given in Section A.2.1 of Attachment A to Appendix G of the STAR Topical Report and this report to determine any additional actions that are necessary for STAR implementation. (Note that the additional guidance given in Section A.2.2 of the STAR

Topical Report relating to application to nonparticipating plants will not be necessary upon approval of this report.)

Note that this report is applicable to future changes in fuel and future PVNGS core designs provided that [

]^{a,c}

Note that the evaluation performed herein assumed that the full strength control rods have all been replaced with the new Ag-In-Cd tipped System 80 design (Reference 2). This evaluation has not considered the older felt-metal encased B_4C tipped type System 80 CEAs. Therefore, applicability of the PVNGS STAR Program is limited to cores having all Ag-In-Cd tipped System 80 full strength CEAs (Reference 2). Application of the PVNGS STAR Program to cores containing CEAs with feltmetal encased B_4C tips will require further evaluation.

Other than [ ]^{a,c}, there are no STAR related requirements on the part strength CEAs since they currently are not credited in the shutdown margin calculation and they are not included in the current CEA group worth reload startup test measurement. However, additional evaluations may be necessary if the PSCEAs will be credited in the shutdown margin calculation for reload safety analysis.

Table 5-1 Comparison of Pertinent Startup Tests

TEST (POWER)	DESCRIPTION	Current PVNGS Program	Original STAR Program	PVNGS STAR Program
CEA Worth (HZP)	Determination of CEA worth from measured change in reactivity during CEA motion. The eliminated measurement includes the CEA Exchange measurements as well as its supporting measurements of IBW and CBC at HZP with the reference bank inserted.	X		
ITC (BOC HZP)	Determination of the ITC from measurements of changes in reactivity and moderator temperature when fuel and moderator temperature changes are isothermal	X		
CEA Drop Time (Shutdown)	Determination of CEA drop time from measured trends of CEA position vs. time during CEA drops	X	X	X
CEA Drop Characteristics (Shutdown)	Verification of CEA coupling from analysis of measured rod drop test characteristics such as trends of drop time by location, slowing in the dashpot, and normal rebound.		X	
CBC (HZP)	Determination of CBC from chemical analysis	X	X	X
MTC Surveillance (HZP)	Determination of the MTC for various operating conditions from the measured ITC, the predicted Fuel Temperature Coefficient, and the predicted MTC	X		
MTC Alternate Surveillance[2] (HZP)	Determination of the MTC for various operating conditions by adjusting the predicted MTC for various operating conditions using the measured CBC		X	X
Incore Flux Symmetry (Low)	Determination of the degree of azimuthal asymmetry in the measured power between rotationally symmetric fuel assemblies	X	X	X
Incore Power Distribution (Intermediate)	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at intermediate power levels in the 40-80% range.	X	X	X
ITC (Intermediate to HFP)	Determination of the ITC from measurements of changes in reactivity and moderator temperature when fuel and moderator temperature are at non-zero power conditions	X	X	X
MTC Surveillance (Intermediate to HFP)	Determination of the MTC for various operating conditions from the measured ITC, the predicted Fuel Temperature Coefficient, and the predicted MTC	X	X	X
Incore Power Distribution (HFP)	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at power levels greater than 90%	X	X	X
ΔCBC HZP-HFP (HZP and HFP)	Determination of the change in CBC between HZP and HFP from chemical analysis	X	X	X

Note that other tests not shown above currently being performed on PVNGS are not affected by STAR implementation.

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[2] Not required if a MTC Surveillance test is performed at HZP.

Table 5-2 PVNGS STAR Program Applicability Requirements

a,c

Table 5-2 PVNGS STAR Program Applicability Requirements (continued)

a,c

Table 5-2 PVNGS STAR Program Applicability Requirements (continued)

a,c

Table 5-2 PVNGS STAR Program Applicability Requirements (continued)

a,c

6 REFERENCES

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5. ANSI/ANS-19.6.1-1997, “American National Standard Reload Startup Physics Tests for Pressurized Water Reactors,” August 22, 1997.
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APPENDIX A REVIEW OF OPERATIONAL EXPERIENCE SINCE STAR TOPICAL REPORT (REFERENCE 1) SUBMITTAL

A.1 INTRODUCTION

A.1.1 Background

Appendix A of the STAR Topical Report (Reference 1) provided the results of a review of past industry problems of relevance to the STAR Program. The purpose of that review was to aid in identifying the types of problems affecting safe core operation and to provide an empirical measure of the efficacy of the Generic Program tests, pre-operational activities and other activities in identifying and preventing operation with each problem. This Appendix updates the results in the STAR Topical Report to reflect more recent data to confirm that the original STAR conclusions in Section A.3 of the STAR Topical Report remain valid. The review also demonstrates the effectiveness of the STAR Program, had the program been in place when each problem was detected.

The results for recent past industry relevant problems were obtained from searches of NRC and INPO databases. The methods that detected the problems were identified where possible. In addition, other information that was relevant to the impact of the STAR Program on problems was summarized. Included were the causes of the problems and corrective actions to prevent recurrence.

The NRC and INPO databases were chosen since the problems of interest are limited to significant problems that remained uncorrected prior to the beginning of Startup Tests. Such problems are, in general, expected to be reportable under NRC Regulations and likely reported to INPO because of the potential impact on the industry. Although a search of Westinghouse's and/or licensees' corrective action program databases would have identified additional problems, most of these would not be relevant to the STAR Program for the following reasons:

- The problem was not significant, i.e., small compared to parameter uncertainties and other margins in the safety analysis.
- The problem was detected and corrected prior to the initiation of startup testing.
- The problem was not relevant to the STAR Program changes.

Therefore, many of the errors and other problem associated with analyses and measurements reported in Westinghouse's and/or licensees' corrective action program databases, that may otherwise be expected to be identified, are not identified since they are, in general, inconsequential.

A.1.2 Purpose

The purpose of this appendix is to provide an update of past industry experience, since submittal of the STAR Topical Report, i.e., since approximately 2002. This will be used to confirm the conclusion in Section A.3 of the STAR Topical Report assessment of the effectiveness of the STAR Program.

A.2 SEARCH STRATEGY

The principal sampling of industry experience included searches of

1. Nuclear Regulatory Commission (NRC) Agencywide Documents Access and Management System (ADAMS) including:

    - Licensee Event Reports (LERs)
    - Reportable Occurrence Reports
    - Abnormal Occurrence Reports
    - Deficiency Reports
    - Notices of Violation
    - NUREG Reports

- Part 21 Correspondence
- Generic Letters

2. Institute for Nuclear Power Operations (INPO) Global Search database which included, among other areas:

   - Operational Experience (OE) Documents
   - Significant Event Notifications (SENs)
   - INPO Consolidated Event System (ICES) Records
   - NRC Regulatory Reports

The NRC and INPO searches essentially used the same keywords as in the STAR Topical Report Tables A-1 and A-3 respectively. In the INPO search, the Google-like capability meant other combinations of words and phrases in the STAR Topical Report Table A-3 could be used to narrow the search results to more relevant issues.

As in the STAR Topical Report, the searches focused on design prediction, as-built core and test performance problems relevant to the STAR Program.

A.3 SEARCH RESULTS

By exercising the keywords, phrases and strings in the NRC and INPO databases, many thousands of documents were identified, most of which had no applicability to problems relevant to the STAR Program. A review of the raw search results by document title and "abstract" was the principal method employed to pare down the extensive lists of search results to likely candidates for document retrieval and subsequent review (i.e., a 'hit'). These 'hits' were then retrieved from their respective source (NRC, INPO or Westinghouse) and reviewed to determine their applicability to STAR problems. The review of these selected documents resulted in further paring down of the 'hits' since the actual review, most times, revealed that they were not applicable to the STAR Program.

Tables A-1, A-2 and A-3 reproduce the Reference 1 Tables A-7, A-8 and A-9 problem frequency tables. Tables A-4, A-5 and A-6 show the total problem occurrence frequencies updated to include the recent searches described above. Note that some specific problems have been generic in nature, e.g., issues[5] with Subcritical Rod Worth Measurement, and have manifested themselves in multiple instances across numerous plants.

The difference between "prediction inaccuracies" or "prediction errors" as applied to CEA Worth, ITC, CBC and power distribution issues, is that inaccuracies refer to the ability of the code, whereas "errors" relate to inappropriate use of inputs to and/or outputs of the code. Where an event has multiple causes including both these elements, judgment is used to categorize the event. When consideration is given to how an event rated an "inaccuracy" would manifest itself under the PVNGS STAR Program, many "inaccuracy" events would be eliminated due to the fact that the STAR Applicability Requirements require benchmarking of similar core designs and fuel types, and the establishment of biases and uncertainties be applied to the predicted values. These requirements nullify the adverse effects of many of the contributing factors, such as systematic use of approximations, or deficiencies in code modeling capabilities. Nevertheless, such "inaccuracy" related events are retained here even thought they would be precluded due to the imposition of the STAR Applicability Requirements.

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[5] The subcritical rod worth measurement error is an example of a test performance problem described in Section 4.3.3. The cause was a methodology error specific to the processing of source range detector signals collected during the CEA Worth test, which affected the inferred CEA worth results. Note that this error is not related to any of the core design activities required by the STAR Program.

A.4 CONCLUSIONS

The following is concluded based on the results of a review of recent past industry problems obtained from searches of various industry databases summarized in Tables A-1 through A-3:

1. The incidence of significant problems associated with predictions of CEA Worth and MTC has remained very low. This conclusion is based on the observation that only three CEA Worth prediction problems and no ITC or MTC prediction problems were identified in total in both the original STAR Topical Report industry experience search and the updated search combined. The updated searches over the time period since the STAR Topical Report searches suggest that improvements in predictions, plant procedures, and in-core fuel management practices, related to MTC Tech Spec limit compliance, have improved significantly since only one instance has occurred in the update period versus 30 instances reported in the STAR Topical Report.
2. The eliminated CEA Worth test at HZP has not been effective in detecting as-built core problems. The one instance[6] where a CEA group worth measurement identified a CEA Worth error is very unlikely to have occurred had the Core Design STAR Applicability Requirements been in place. None of the other as-built core problems in the updated sample search results were detected by the CEA Worth test. The industry reviews have not identified any instance in which a CEA Worth test or prediction has subsequently been found to invalidate the assumptions used in the safety analysis.
3. Problems related to tests that involve CEA Worth measurements and the reactivity computer at HZP have continued to result in operational problems and test delays. This conclusion is based on the observation that test performance errors involving CEA Worth measurements or the reactivity computer have persisted since the issuance of the STAR Topical Report. In addition, many problems with the tests themselves were "common cause" related to measurement methodology or measurement signal noise.

Thus the conclusions given in Section A.3 of the STAR Topical Report remain valid and continue to support the STAR Topical Report assessment of effectiveness of the STAR Program.

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[6] The error was due to a discrepancy in how the fully-inserted CEA position was modeled and the actual fully-inserted position used in the CEA group worth measurements. The error was caused by the use of an incorrect fully-inserted position in the CEA Worth test itself. For the STAR Program, the difference in predicted and measured worth would have resulted in the CEA worth bias used in design calculations (since this discrepancy had existed for many cycles) and so the difference in CEA position would have been implicitly accounted for in the code benchmarking (bias and uncertainty determination) in the STAR Applicability Requirements.

Table A-1 Methods That Have Detected Past Industry Design Prediction Problems

(Table A-7 from Reference 1) (Number of Events Identified)[1]

PROBLEM	SECTION[1]	DETECTION METHOD																						Total by Problem
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests	Core Design QA	Fuel Fabrication QA	CEA Fabrication QA	Receipt Inspection	EOC CEA Insertion	CEA Manipulation	CEA Inspections	CEA Position Indication	CEA Trip	
CEA Worth Inaccuracy	4.1.2.1						3																	3
CBC Inaccuracy	4.1.2.2				1																			1
ITC Inaccuracy	4.1.2.3																							-
Power Distribution Inaccuracy	4.1.2.4																							-
Total by Detection Method	All	-	-	-	1	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4

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[1] Definitions and discussions of these problems are provided in the indicated report sections.

Table A-2 Methods That Have Detected Past Industry As-Built Core Problems

(Table A-8 from Reference 1) (Number of Events Identified)[1]

PROBLEM	SECTION[1]	DETECTION METHOD																						Total by Problem
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests	Core Design QA	Fuel Fabrication QA	CEA Fabrication QA	Receipt Inspection	EOC CEA Insertion	CEA Manipulation	CEA Position Indication	CEA Inspections	CEA Trip	
CEA Worth Error	4.2.2.1																							-
CBC Error	4.2.2.2																							-
ITC Error	4.2.2.3																							-
Power Distribution Error	4.2.2.4											1												1
MTC Noncompliance	4.2.2.5								30															30
SDM Noncompliance	4.2.2.6														1									1
Fuel Fabrication Error	4.2.2.7												3			8		3						14
Fuel Misloading	4.2.2.8											2	2		1									5
Fuel Distortion	4.2.2.9	3																		2		1	2	8
Fuel Poison Loss	4.2.2.10																							-
Fuel Crudding	4.2.2.11												5											5
CEA Fabrication Error	4..2.12																1							1
CEA Misloading	4.2.2.13																							-
CEA Uncoupling	4.2.2.14										4	1	1								2			8
CEA Distortion	4.2.2.15																		1	1		10		12

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[1] Definitions and discussions of these problems are provided in the indicated report sections.

Table A-2 Methods That Have Detected Past Industry As-Built Core Problems (continued)

(Table A-8 from Reference 1) (Number of Events Identified)[1]

PROBLEM	SECTION[1]	DETECTION METHOD																						
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests	Core Design QA	Fuel Fabrication QA	CEA Fabrication QA	Receipt Inspection	EOC CEA Insertion	CEA Manipulation	CEA Position Indication	CEA Inspections	CEA Trip	Total by Problem
CEA Absorber Loss	4.2.2.16																		1	1		2		4
CEA Finger Loss	4.2.2.17												1							1		2		4
RCS Anomaly	4.2.2.18																							-
RCS B-10 Depletion	4.2.2.19																							-
Total by Detection Method	All	3	-	-	-	-	-	-	30	-	4	4	12	-	2	8	1	3	2	5	2	15	2	93

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[1] Definitions and discussions of these problems are provided in the indicated report sections.

Table A-3 Tests That Have Initiated Past Test Performance Problems

(Table A-9 from Reference 1) (Number of Events Identified)[1]

PROBLEM	SECTION[1]	TEST													
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests[2]	Power Ascension Tests	Total by Problem
Test Equipment Error	4.3.2.1						6				1			5		12
Test Process Error	4.3.2.2						6	1						3		10
Test Result Error	4.3.2.3								3							3
Total by Test		-	-	-	-	-	12	1	3	-	1	-	-	8	-	25

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[1] Definitions and discussions of these problems are provided in the indicated report sections.

[2] These occurred during startup tests but an individual test was not identified.

Table A-4 Methods That Have Detected Past Industry Design Prediction Problems – UPDATED[1]

(Number of Events Identified)[2]

PROBLEM	SECTION[2]	DETECTION METHOD																						
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests	Core Design QA	Fuel Fabrication QA	CEA Fabrication QA	Receipt Inspection	EOC CEA Insertion	CEA Manipulation	CEA Inspections	CEA Position Indication	CEA Trip	Total by Problem
CEA Worth Inaccuracy	4.3.1.1						3																	3
CBC Inaccuracy	4.3.1.2				3																			3
ITC Inaccuracy	4.3.1.3																							-
Power Distribution Inaccuracy	4.3.1.4																							-
Total by Detection Method	All	-	-	-	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6

1. Fields with updated information are shaded
2. Definitions and discussions of these problems are provided in the indicated report sections

Table A-5 Methods That Have Detected Past Industry As-Built Core Problems – UPDATED[1]

(Number of Events Identified)[2]

PROBLEM	SECTION[2]	DETECTION METHOD																						
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	* MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests	Core Design QA	Fuel Fabrication QA	CEA Fabrication QA	Receipt Inspection	EOC CEA Insertion	CEA Manipulation	CEA Position Indication	CEA Inspections	CEA Trip	Total by Problem
CEA Worth Error	4.3.2.1						1																	1
CBC Error	4.3.2.2				2																			2
ITC Error	4.3.2.3																							-
Power Distribution Error	4.3.2.4											1												1
MTC Noncompliance	4.3.2.5								31															31
SDM Noncompliance	4.3.2.6				1										1									2
Fuel Fabrication Error	4.3.2.7												3		1	9		4						17
Fuel Misloading	4.3.2.8											2	2		1									5
Fuel Distortion	4.3.2.9	3																		3		1	2	9
Fuel Poison Loss	4.3.2.10																							-
Fuel Crudding	4.3.2.11												6											6
CEA Fabrication Error	4.3.2.12																1							1
CEA Misloading	4.3.2.13																							-
CEA Uncoupling	4.3.2.14										4	1	2								4			11
CEA Distortion	4.3.2.15																		1	5		10		16
CEA Absorber Loss	4.3.2.16																		1	1		3		5
CEA Finger Loss	4.3.2.17												1							1		3		5

Table A-5 Methods That Have Detected Past Industry As-Built Core Problems – UPDATED[1] (continued)

(Number of Events Identified)[2]

PROBLEM	SECTION[2]	DETECTION METHOD																						Total by Problem
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests	Core Design QA	Fuel Fabrication QA	CEA Fabrication QA	Receipt Inspection	EOC CEA Insertion	CEA Manipulation	CEA Position Indication	CEA Inspections	CEA Trip	
RCS Anomaly	4.3.2.18																							-
RCS B-10 Depletion	4.3.2.19																							-
Total by Detection Method	All	3	-	-	3	-	1	-	31	-	4	4	14	-	3	9	1	4	2	10	4	17	2	112

1. Fields with updated information are shaded
2. Definitions and discussions of these problems are provided in the indicated report sections

Table A-6 Tests That Have Initiated Past Test Performance Problems – UPDATED[1]

(Number of Events Identified)[2]

PROBLEM	SECTION[2]	TEST														
		CEA Drop Time	CEA Drop Characteristics	CEA Flux Change	CBC	IBW	CEA Worth	ITC	MTC Surveillance	SDM Surveillance	CEA Flux Symmetry	Incore Flux Symmetry	Incore Power Distribution	Low Power Physics Tests[2]	Power Ascension Tests	Total by Problem
Test Equipment Error	4.3.3						9				1			5		15
Test Process Error	4.3.3						13	1						3		17
Test Result Error	4.3.3						1†		3				1			5†
Total by Test		-	-	-	-	-	23†	1	3	-	1	-	1	8	-	37†

1. Fields with updated information are shaded
2. Definitions and discussions of these problems are provided in the indicated report sections

†Note – Subcritical Rod Worth Measurement methodology issue affected the CEA Worth test results of several cycles of numerous plants.

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[2] These occurred during startup tests but an individual test was not identified.

APPENDIX B AS-BUILT CORE PROBLEM DETECTION FOR PVNGS

B.1 INTRODUCTION

B.1.1 Background

Appendix C of the STAR Topical Report, Reference 1, describes the development of matrices that provided the effectiveness of various methods of detecting as-built core problems by startup tests, pre-operational activities, and STAR Applicability Requirements. The development of the matrices started with the information in the ANSI standard for startup tests, Reference 5, that addresses the likelihood of a particular problem being detected by a given test.

The information in the ANSI standard was expanded to include the full set of tests and problems addressed in the evaluations in the STAR Topical Report. Included were addition of tests (including pre-operational activities and STAR Applicability Requirements) and problems that were not within the scope of the ANSI standard. In addition, the descriptions of problems were changed from those in the ANSI standard to provide more comprehensive categories of problems. Furthermore, the two level rating system in the ANSI problem detection matrix representing the likelihood of a problem causing an unexpected result for the test was expanded to use a three level rating system because of the wide variations in the ability to detect problems. Specifically, tests were rated as “Good,” “Fair,” or “Poor” in effectiveness in detecting the problem. In Appendix C of the STAR Topical Report, the likelihood of detecting an as-built problem is based on an analysis of the operational experience in Appendix A, as well as engineering judgment by individuals experienced in safety analysis, startup testing, and plant operation. Finally, the problem detection matrix was divided into the following three as-built problem detection matrices:

STAR Problem Detection Matrix	STAR Topical Report Table
Startup Test	C-5
Pre-operational Activities	C-6
STAR Applicability Requirements	C-7

Information in the problem detection matrices above was used in the as-built core problem evaluations in Section 4.2 and Appendix E of the STAR Topical Report to determine changes in the ability to detect problems between the Generic and STAR Programs. The information was also used in the evaluation of deviations from the Generic Program by Participating Plants in Appendix F of the STAR Topical Report.

B.1.2 Purpose

The purpose of this appendix is to determine the effectiveness of startup tests, pre-operational activities, and STAR Applicability Requirements in detecting as-built core problems for PVNGS. This information is used in Section 4 of this report to evaluate changes in the ability to detect problems between the current PVNGS startup program, the STAR Program, the Generic Program, and the PVNGS STAR Program.

B.2 DISCUSSION

The following were reviewed to determine whether changes to the current PVNGS startup testing (identified in Table 3-2) were necessary to implement the STAR Program at PVNGS:

- The as-built core problem detection matrices for startup tests, pre-operational activities and STAR Applicability Requirements in Tables C-5, C-6, and C-7 of the STAR Topical Report.
- The Startup Test Description, Startup Test Purposes, STAR Tests, and STAR Applicability Requirements in Tables 1-1, 1-2, 3-3, and 3-4 of the STAR Topical Report.
- The PVNGS relevant unique design features identified in Appendix C (Table C-1).
- The change to the STAR startup tests for PVNGS identified in Appendix C (Table C-2).

- The changes to the STAR Applicability Requirements for PVNGS identified in Appendix C (Table C-3).

Included in the review was the consideration of the following types of changes to the STAR Program for implementation at the PVNGS plants:

- Changes to startup tests, pre-operational activities, and STAR Applicability Requirements
- Addition of any new problems due to PVNGS relevant unique design features
- Changes to the effectiveness rating of tests, pre-operational activities, and STAR Applicability Requirements

Appendix C evaluates design differences between the PVNGS plants and the Standard 16x16 plants. Table C-1 identifies the four relevant unique design features that require consideration in the implementation of the STAR Program at PVNGS. Appendix C also evaluates the effect of the relevant unique design features on the STAR startup tests, pre-operational activities, and STAR Applicability Requirements. The differences in the STAR startup tests are summarized in Table C-2 while the differences in the STAR Applicability Requirements are summarized in Table C-3. [

]^{a,c}

B.3 RESULTS

The as-built core problem detection matrices for startup tests, pre-operational activities, and STAR Applicability Requirements from Tables C-5, C-6, and C-7 of the STAR Topical Report, with changes associated with the PVNGS Startup Test Program and relevant unique design features, are identified in Tables B-1, B-2, and B-3, respectively. Table B-8 summarizes the changes to the effectiveness ratings of the STAR Topical Report for implementation of STAR at the PVNGS plants. In addition, the Startup Test Descriptions, Startup Test Purposes, STAR Tests and STAR Applicability Requirements from Tables 1-1, 1-2, 3-3, and 3-4 of the STAR Topical Report, with changes associated with PVNGS Startup Test Program and relevant unique design features, are identified in Tables B-4, B-5, B-6, and B-7, respectively.

B.4 EVALUATION

The purpose of this section is to determine if any changes to the effectiveness ratings of Table C-5 (startup tests), C-6 (pre-operational activities), and C-7 (STAR Applicability Requirements) of the STAR Topical Report are required for the PVNGS STAR Program due to the changes identified in Tables C-1 (PVNGS relevant unique design features), C-2 (change to STAR startup tests), and C-3 (change to STAR Applicability Requirements). For each of the three types of tables (startup tests, pre-operational activities, and STAR Applicability Requirements), the changes and their impact on the effectiveness ratings of the STAR Topical Report for PVNGS are discussed with any resulting effectiveness rating changes identified in Tables B-1, B-2, and B-3.

B.4.1 Changes to As-Built Core Problem Matrix for Startup Tests

B.4.1.1 Changes to STAR Startup Tests

The change to the STAR startup tests for implementation at the PVNGS plants is summarized in Table C-2 of Appendix C. The one change specified in Table C-2 is:

- Deletion of the CEA Drop Characteristics test (or the CEA Flux Change test which is an acceptable alternate test).

The requirement to perform the CEA Drop Characteristics test (or its alternate, the CEA Flux Change test) was included in the STAR Program to retain the assurance of proper CEA coupling previously provided by the CEA Worth test that was being eliminated with the implementation of the STAR Program. The need for the assurance of proper CEA coupling to the extension shaft assembly arose from the inability to obtain visual confirmation of the proper engagement of the CEA and extension shaft assembly in the Standard 16x16 plants. As discussed in Section C.2.6.1.3, the design of the PVNGS plants allows visual confirmation of the proper engagement, as well as visual confirmation that the attachment mechanism (plunger) is in the proper (engaged) position. In addition, the PVNGS CEAs typically remain coupled to the extension shaft assemblies during refueling outages and a visual check of the CEA axial positions can confirm the CEAs remain coupled during the outage. Modifications of the STAR Applicability Requirements discussed in Section B.4.3 provide assurance of proper CEA coupling thereby eliminating the need for the CEA Drop Characteristics test to confirm CEA coupling. Therefore, the CEA Drop Characteristics test is not included in the PVNGS STAR Startup Tests in Table 5-1.

B.4.1.2 Changes to Effectiveness Ratings of Startup Tests

B.4.1.2.1 Changes Associated with Startup Test Differences

The only startup test difference identified in Table C-2 associated with the implementation of the STAR Program at PVNGS is the elimination of the CEA Drop Characteristics test. Therefore, the CEA Drop Characteristics test is shown in Table B-1 as being eliminated for the PVNGS STAR Program. The effectiveness ratings of this test from Table C-5 of the STAR Topical Report are shown in Table B-1 for use in the evaluation of impacts associated with the test's elimination.

B.4.1.2.2 Changes Associated with PVNGS Relevant Unique Design Features

The effectiveness ratings for the as-built core problem detection matrix for startup tests in the STAR Program are included as Table C-5 of the STAR Topical Report. Appendix C of this report identified relevant unique design features that could influence the evaluations in the STAR Topical Report and are included in Table C-1. Any changes to the startup testing effectiveness ratings associated with these relevant unique design features are discussed below and shown in Table B-1.

B.4.1.2.2.1 Changes Associated with PVNGS Relevant Unique Design Feature #1

[

]^{a,c}

B.4.1.2.2.2 Changes Associated with PVNGS Relevant Unique Design Feature #2

[

]^{a,c}

[

]^{a,c}

The effectiveness ratings discussed above are identified in Table B-1.

B.4.1.2.2.3 Changes Associated with PVNGS Relevant Unique Design Feature #3

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Therefore, the effectiveness ratings in Table C-5 of the STAR Topical Report are not affected for the PVNGS STAR Program by relevant unique design feature #3 of Table C-1, as shown in Table B-1.

B.4.1.2.2.4 Changes Associated with Relevant Unique Design Feature #4

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B.4.1.3 Conclusions Regarding Effectiveness Ratings for Startup Tests

The effectiveness ratings of Table C-5 of the STAR Topical Report are evaluated in Section B.4.1.1 and Section B.4.1.2 for application to the PVNGS STAR Program. The evaluation addressed the relevant unique design features identified in Table C-1 and the change to the startup test for PVNGS identified in Table C-2. The resulting effectiveness ratings for the PVNGS startup tests are shown in Table B-2.

B.4.2 Changes to As-Built Core Problem Matrix for Pre-Operational Activities

B.4.2.1 Changes to Pre-Operational Activities

The as-built core problem detection matrix for pre-operational activities in the STAR Program is included as Table C-6 of the STAR Topical Report. Section C.3 concludes that some of the PVNGS relevant unique design features influenced pre-operational activities and that the modifications to the PVNGS STAR Applicability Requirements identified in Table C-3 are sufficient to ensure the verifications of pre-operational activities required for the PVNGS STAR Program are performed. Section C.3 also determined that no new pre-operational activity categories were needed relative to those in Table C-6 of the STAR Topical Report.

B.4.2.2 Changes to Effectiveness Ratings for Pre-Operational Activities

The effectiveness ratings for the as-built core problem detection matrix for pre-operational activities in the STAR Program are included as Table C-6 of the STAR Topical Report. Section C.2.6 discussed how the relevant unique design features influence the following pre-operational activities for PVNGS:

- CEA fabrication QA,
- CEA manipulation,
- Core verification (for CEAs), and
- CEA coupling verification.

The effectiveness ratings associated with these pre-operational activities are discussed individually in Section B.4.2.2.1 through Section B.4.2.2.4 below while the remainder of the pre-operational activities are discussed in Section B.4.3.2.5.

B.4.2.2.1 CEA Fabrication QA

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]a,c the effectiveness ratings of the CEA fabrication QA for the PVNGS STAR Program are concluded to be equivalent to those of the STAR Program (Table C-6 of the STAR Topical Report), as shown in Table B-2.

B.4.2.2.2 CEA Manipulation

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]^{a,c} it is concluded the CEA manipulation pre-operational activity at the PVNGS plants with STAR has the same overall detectability for as-built problems as the current PVNGS startup program.

B.4.2.2.3 Core Verification (for CEAs)

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]^{a,c} Therefore, it is concluded that the core verification pre-operational activity for CEAs at the PVNGS plants with STAR has the same overall detectability for as-built problems as the current PVNGS startup program.

B.4.2.2.4 CEA Coupling Verification

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]^{a,c} the detectability of the CEA Coupling Verification for the PVNGS STAR Program is concluded to be better than that of the Standard 16x16 plants [ ]^{a,c}

B.4.2.2.5 Remaining Pre-Operational Activities

There are no additional changes in Table B-2 to the effectiveness ratings of Table C-6 of the STAR Topical Report for pre-operational activities due to PVNGS Startup Test Program or relevant unique design features. The remaining pre-operational activities performed by PVNGS (Core Design QA, Fuel Fabrication QA, EOC CEA Insertion, Fuel Manipulation, and CEA Position Indication) were judged equally effective for detecting as-built problems for the following reasons:

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B.4.2.3 Conclusion Regarding Effectiveness Ratings for Pre-Operational Activities

The effectiveness ratings for the pre-operational activities of the PVNGS STAR Program are included in Table B-2. Based on the above discussions, it is concluded the effectiveness ratings of the pre-operational activities are assured by the modifications in Table C-3 to the STAR Applicability Requirements for PVNGS.

B.4.3 Changes to As-Built Core Problem Matrix for STAR Applicability Requirements

B.4.3.1 Changes to STAR Applicability Requirements

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The remaining PVNGS STAR Applicability Requirements are unchanged from those in Table 3-4 of the STAR Topical Report. The complete listing of the PVNGS STAR Applicability Requirements is contained in Table B-7 of this report.

B.4.3.2 Changes to Effectiveness Ratings for STAR Applicability Requirements

The effectiveness ratings for the as-built core problem detection matrix for the STAR Applicability Requirements in the STAR Program are included as Table C-7 of the STAR Topical Report. A review of those effectiveness ratings in combination with the PVNGS STAR Applicability Requirements discussed above concluded that any reduction in effectiveness of the STAR Applicability Requirements for the PVNGS plants was compensated for by the additions and modifications to the PVNGS STAR Applicability Requirements. Therefore, none of the effectiveness ratings for the PVNGS STAR Applicability Requirements in Table B-3 are changed relative to the STAR Applicability Requirements in Table C-7 of the STAR Topical Report.

B.4.3.3 Conclusions Regarding Effectiveness Ratings for STAR Applicability Requirements

The effectiveness ratings of Table C-7 of the STAR Topical Report are evaluated in Section B.4.3.1 and Section B.4.3.2 for application to the PVNGS STAR Program. The evaluation addressed the impact of the PVNGS STAR Applicability Requirements identified in Table C-3 and concluded that no changes to the effectiveness ratings of Table C-7 of the STAR Topical Report. These resulting effectiveness ratings for the PVNGS STAR Applicability Requirements are shown in Table B-3.

B.5 CONCLUSIONS REGARDING AS-BUILT PROBLEM DETECTION FOR THE PVNGS STAR PROGRAM

Based on the discussion presented in this appendix it is concluded that the effectiveness ratings in the as-built problem detection matrices in Table B-1, B-2, and B-3 are appropriate for the PVNGS STAR Program. Table B-8 summarizes the changes to the effectiveness ratings of the STAR Topical Report for implementation of STAR at the PVNGS plants.

Table B-1 STAR Topical Report As-Built Core Problem Detection Matrix for Startup Tests With Changes for PVNGS[1]

(Effectiveness of test in detecting problem: 1=Good 2=Fair 3=Poor)

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Table B-2 STAR Topical Report As-Built Core Problem Detection Matrix for Pre-Operational Activities With Changes for PVNGS

(Effectiveness of pre-operational activity in detecting problem: 1=Good 2=Fair 3=Poor)

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Table B-3 STAR Topical Report As-Built Core Problem Detection Matrix for STAR Applicability Requirements With Changes for PVNGS

(Effectiveness of STAR Applicability Requirements in detecting problem: 1=Good 2=Fair 3=Poor)

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Table B-4 Startup Test Descriptions

TEST	POWER	DESCRIPTION
CEA Drop Time	Shutdown	Determination of CEA drop time from measured trends of CEA position vs. time during CEA drops
CEA Drop Characteristics	Shutdown	Verification of CEA coupling from analysis of measured rod drop test characteristics such as trends of drop time by location, slowing in the dashpot, and normal rebound (and acceptable clearances between the dashpot and CEAs in System 80 Plants)
CEA Flux Change	HZP	Verification of CEA coupling from measurements of reactivity or startup rate changes during CEA movement
CBC	HZP	Determination of CBC from chemical analysis of RCS samples
IBW	HZP	Determination of IBW from measurements of changes in reactivity and CBC
CEA Worth	HZP	Determination of CEA worth from measured change in reactivity during CEA motion
ITC	HZP	Determination of the ITC from measurements of changes in reactivity and moderator temperature when fuel and moderator temperature changes are isothermal
MTC Surveillance	HZP	Determination of the MTC for various operating conditions from the measured ITC, the predicted Fuel Temperature Coefficient, and the predicted MTC
MTC Alternate Surveillance	HZP	Determination of the MTC for various operating conditions by adjusting the predicted MTC using the measured CBC
SDM Surveillance	HZP	Determination of the SDM using parameters measured as part of startup testing at HZP
CEA Flux Symmetry	HZP	Determination of the degree of azimuthal asymmetry in the neutron flux from measurements of the variation in CEA Worth from symmetric CEAs
Incore Flux Symmetry	Low	Determination of the degree of azimuthal asymmetry in the neutron flux from measurements of the variation in incore detector signals from symmetric incore detectors
Incore Power Distribution	Intermediate	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at intermediate power levels in the 40-80% range.

Table B-4 Startup Test Descriptions (continued)

TEST	POWER	DESCRIPTION
ITC	Intermediate to HFP	Determination of the ITC from measurements of changes in reactivity and moderator temperature when fuel and moderator temperature changes are isothermal
MTC Surveillance	Intermediate to HFP	Determination of the MTC for various operating conditions from the measured ITC, the predicted Fuel Temperature Coefficient, and the predicted MTC
Incore Power Distribution	HFP	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at power levels greater than 90%
ΔCBC HZP-HFP	HFP	Determination of the change in measured CBC between HZP and HFP from chemical analysis of RCS samples

Table B-5 Startup Test Purposes

TEST	POWER	PURPOSE
CEA Drop Time	Shutdown	To determine if CEA drop times are within Technical Specification limits and verify proper reassembly of the reactor vessel and internal components
CEA Drop Characteristics	Shutdown	To determine if CEAs are coupled
CEA Flux Change	HZP	To determine if CEAs are coupled
CBC	HZP	To determine if the measured and predicted total core reactivity are consistent
IBW	HZP	To determine if the measured IBW is consistent with the predicted value
CEA Worth	HZP	To determine if the worth of selected rod groups is consistent with predictions
ITC	HZP	To determine if the measured ITC is consistent with the predicted value
MTC Surveillance	HZP	To determine if the calculated MTC derived using the measured ITC is within Technical Specification limits
MTC Alternate Surveillance	HZP	To determine if the calculated MTC derived using the measured CBC is within Technical Specification limits for various operating conditions
SDM Surveillance	HZP	To determine if the calculated shutdown margin derived using measured test values is within Technical Specification limits
CEA Flux Symmetry	HZP	To determine if the measured azimuthal flux symmetry is consistent
Incore Flux Symmetry	Low	To determine if the measured azimuthal flux symmetry is consistent
Incore Power Distribution	Intermediate	To determine if the measured and predicted core power distributions are consistent
ITC	Intermediate to HFP	To determine if the measured ITC is consistent with the predicted value
MTC Surveillance	Intermediate to HFP	To determine if the calculated MTC derived using the measured ITC is within Technical Specification limits for various operating conditions
Incore Power Distribution	HFP	To determine if the measured and predicted core power distributions are consistent
ΔCBC HZP-HFP	HFP	To determine if the reactivity difference between zero and full power conditions is consistent with design predictions

Table B-6 PVNGS STAR Program Tests

TEST[1]	POWER	DESCRIPTION
CEA Drop Time	Shutdown	Determination of CEA drop time from measured trends of CEA position vs. time during CEA drops
CBC	HZP	Determination of CBC from chemical analysis
MTC Alternate Surveillance[2]	HZP	Determination of the MTC for various operating conditions by adjusting the predicted MTC for various operating conditions using the measured CBC
Incore Flux Symmetry	Low	Determination of the degree of azimuthal asymmetry in the neutron flux from measurements of the variation in incore detector signals from symmetric incore detectors
Incore Power Distribution	Intermediate	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at intermediate power levels in the 40-80% range.
ITC	Intermediate to HFP	Determination of the ITC from measurements of changes in reactivity and moderator temperature when fuel and moderator temperature changes are isothermal
MTC Surveillance	Intermediate to HFP	Determination of the MTC for various operating conditions from the measured ITC, the predicted Fuel Temperature Coefficient, and the predicted MTC
Incore Power Distribution	HFP	Determination of the relative power distribution from the measurement of incore detector signals. Tests are typically performed at power levels greater than 90%
ΔCBC HZP-HFP	HFP	Determination of the change in CBC between HZP and HFP from chemical analysis

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[1] Table 1-2 of STAR topical report provides purposes of the tests discussed in this report.

[2] Not required if a MTC Surveillance test is performed at HZP.

Table B-7 PVNGS STAR Program Applicability Requirements

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Table B-7 PVNGS STAR Program Applicability Requirements (continued)

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Table B-7 PVNGS STAR Program Applicability Requirements (continued)

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Table B-7 PVNGS STAR Program Applicability Requirements (continued)

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Table B-8 Summary of Changes to Detection Matrices for the PVNGS STAR Program

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APPENDIX C PVNGS RELEVANT UNIQUE DESIGN FEATURES

C.1 INTRODUCTION

C.1.1 Background

Section 5.2.2 of the STAR Topical Report (Reference 1) discusses the applicability of the STAR Program for non-participating PWR plants and identifies the following conclusion:

> Implementation of the STAR Program in the non-participating PWR plants[7] is acceptable provided there are no relevant unique design features that require additional startup testing. This conclusion is based on the evaluations summarized in Table 5-1 that demonstrate acceptable results for the impact of the STAR Program on safety analysis conformance. These results are demonstrated for the changes to the Generic Program but not for the elimination of additional tests that deviate from the Generic Program. Any changes to deviations from Generic Program by non-Participating Plants would have to be evaluated on an individual basis.

Therefore, the implementation of the STAR Program at PVNGS requires the identification and the evaluation of any relevant unique design features that could require additional startup testing at PVNGS relative to the requirements of the STAR Program.

C.1.2 Purpose

The purpose of this appendix is to identify any relevant unique design features that could require additional startup testing, pre-operational activities, or STAR Applicability Requirements at PVNGS relative to the requirements of the STAR Program. Relevant unique design features that impact the pre-operational activities and the STAR Applicability Requirements are identified. The changes to the startup testing, pre-operational activities, and STAR Applicability Requirements of the STAR Program necessary to implement the STAR Program at the PVNGS plants are also identified. The implications of these changes on the effectiveness of identifying problems with the implementation of the STAR Program at the PVNGS plants are evaluated in Appendix B.

C.2 EVALUATION OF DESIGN DIFFERENCES

This appendix identifies relevant unique design features associated with PVNGS by comparing the

- reactor internals,
- core components (fuel assemblies, CEAs, and ICIs),
- CEA drives (extension shafts and CEDMS),
- and refueling operations

of PVNGS relative to those of the STAR Topical Report Participating Plants. The Participating Plants evaluated in the STAR Topical Report are a subset of the CE-NSSS Plants and include Arkansas Nuclear One Unit 2, Waterford Unit 3, St. Lucie Units 1 & 2, Millstone Unit 2, San Onofre Nuclear Generating Station Units 2 & 3, Calvert Cliffs Units 1 & 2, and Fort Calhoun. These plants represent both CE 14x14 plants and CE Standard (non-System 80) 16x16 plants. The PVNGS plants are CE System 80 16x16 plants with many similarities to the CE Standard 16x16 plants (Arkansas Nuclear One Unit 2, Waterford Unit 3, St. Lucie Unit 2, and San Onofre Nuclear Generating Station Units 2 & 3), along with some distinct differences.

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[7] This includes CE Plants, Westinghouse Plants and B&W Plants.

The PVNGS plant information is described and compared to the corresponding CE Standard 16x16 plant information for each of the topics identified above to identify any relevant unique design features of PVNGS. Relevant unique design features are summarized in Section C.3 and Table C-1.

C.2.1 Reactor Internal Designs

The overall reactor internal designs of the Standard 16x16 plants and PVNGS are similar, but there are some significant design differences that require evaluation relative to any impact on the implementation of STAR for PVNGS. The pertinent aspects of the reactor internal designs are discussed below and associated PVNGS unique design features are identified.

C.2.1.1 Standard 16x16 Reactor Internals[8]

There are several variations of reactor internals included within the classification of Standard 16x16 plants. The major differences are associated with the number of fuel assemblies the core contains (either 177 or 217) and the active fuel length of the core (136.7" or 150"). A representative vertical arrangement of the reactor internals for the Standard 16x16 plants is shown in Figure C-1 (arrangement shown for typical plant with 217 fuel assemblies and 150" active length). The pertinent aspects of the Standard 16x16 reactor internals regarding startup testing, pre-operational activities, or STAR Applicability Requirements are discussed below.

The lower portion of the reactor internals support the fuel assemblies and direct flow up into the fuel assemblies. The upper portion of the internals contains the ICIs and their guide thimbles, the CEDMs (which are attached to the reactor head and shown in Figure C-1), and the UGS. The UGS has CEA shrouds that generally encircle each CEA to shield against cross flow and the associated extension shaft assembly extends through the top of the CEA shroud up into the CEDM. Prior to installing the UGS during a refueling outage, the fuel assemblies are loaded into the core with the returning (or replacement) CEAs installed in the appropriate fuel assemblies. At that point the core verification of the proper location and orientation of the fuel assemblies and the CEAs is performed. Afterwards, the UGS is lowered into position with the extension shaft assemblies contained within the UGS. Once the UGS is in position, the ICI plate containing the ICI guide thimbles and ICIs is lowered into the core and the extension shaft assemblies are coupled to the CEAs. When the head is lowered into position, the upper portion of the extension shaft assemblies enters the CEDMs and upon completion of the head installation can be withdrawn and/or inserted into the fuel assembly by the jacking mechanism of the CEDMs.

Since the CEAs remain with the fuel when the UGS is removed during an outage, the CEAs can easily be shuffled between fuel assemblies either in the reactor or in the spent fuel pool. In addition, the CEAs can be easily inspected visually for damage, they can be inserted into or withdrawn from fuel assemblies to assess any potential for drag or binding, their orientation and serial numbers can be viewed for the core verification, and, with the proper equipment, they can be inspected with ECT or UT for cracks, swelling, ovality, and wear.

C.2.1.2 PVNGS Reactor Internals

The PVNGS reactor internals are generally similar to the Standard 16x16 reactor internals. The PVNGS reactor internals hold 241 fuel assemblies which have an active fuel length of 150". The assembly pitch and guide tube pitch within the assembly of the PVNGS plants is the same as the Standard 16x16 plants. A vertical arrangement of the reactor internals for the PVNGS plants is shown in Figure C-2.

One significant difference in the PVNGS reactor internals design that is readily apparent by comparing Figures C-1 and C-2 is that the ICIs enter the lower head of the PVNGS reactor rather than entering the upper head of the Standard 16x16 reactor. Another design difference apparent between Figures C-1 and C-2 is that the PVNGS UGS includes a bank of tubes immediately above the fuel assemblies. These

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[8] CEAs addressed in this section are of the Standard 16x16 5-finger design with Ag-In-Cd tips. Some Standard 16x16 plants have four CEAs of a 4-finger design with Ag-In-Cd tips (Section C.2.3.1). These 4-finger CEAs remain secured within the reactor internals during refueling outages.

tubes isolate and protect the CEA fingers from coolant cross flow exiting the reactor vessel. The pertinent aspects of the PVNGS reactor internals regarding startup testing requirements, pre-operational activities, and STAR Applicability Requirements are discussed below.

The lower portion of the reactor internals support the fuel assembly, direct flow up into the fuel assembly, and provide for the guidance and insertion of the ICIs into the lower end of the appropriate fuel assemblies. The top of the upper internals interfaces with guide funnels attached to the bottom of the reactor head. The funnels guide the extension shafts up into the CEDMs which are attached to the top of the reactor head. The upper portion of the UGS assembly has CEA shrouds that encircle each CEA with the associated extension shaft assembly extending through the top of the CEA shroud up into the CEDM. The lower portion of the UGS assembly has a bank of tubes that begin in the UGS base plate, extend a short distance through the fuel alignment plate, and position the upper end fitting outer posts of the fuel assembly. This UGS to CEA interface is shown in Figure C-4. Within this region of the UGS, each individual CEA finger tube is contained within a separate tube of the bank of tubes. The coolant flow comes upwards through the fuel alignment plate and then turns 90 degrees between that plate and the UGS base plate in order to exit horizontally out the reactor vessel outlets. Since the CEA fingers are fully encapsulated within the bank of tubes in this region, the design effectively isolates the CEA fingers from the coolant cross flow through this region of turbulent flow.

The CEAs are located in the reactor such that the spiders are always above the UGS base plate shown in Figure C-4 with the CEA fingers extending down through the UGS tube bank into the fuel assemblies. As a result, the CEAs cannot remain in the fuel assemblies and be shuffled between fuel assemblies during refueling outages. Instead, they remain coupled to the extension shaft assemblies and stay with the UGS. In addition, the CEA spider impacts the UGS base plate at the end of a scram in the PVNGS plants rather than impacting the top of the center post of the fuel assembly's upper end fitting for the Standard 16x16 plants.

Prior to the removal of the UGS from the reactor vessel during a refueling outage, all the extension shaft assemblies with the attached CEAs are latched to mechanisms secured to the CEA Support Plate. Lifting of the CEA Support Plate by the UGS lift rig simultaneously withdraws all the CEAs from the fuel assemblies until the tips of the CEA fingers do not extend below the UGS (see Figure C-3 for additional details of these configurations). The extension shaft assemblies and CEAs typically remain secured in this condition within the UGS during the refueling outage. Prior to installing the UGS following a refueling outage, the fuel assemblies are loaded into the core (obviously without any CEAs) and the core verification for the fuel (location and orientation) is performed. The verification of each CEA's location and orientation is performed once when the CEA is initially installed in the UGS. Subsequently the UGS is lowered into the reactor vessel with the extension shaft assemblies still latched to the CEA Support Plate in its raised position within the UGS lift rig. Once the UGS is in position, all the extension shaft assemblies with their coupled CEAs are lowered simultaneously by the lowering of the CEA Support Plate with the CEA fingers inserting into their respective fuel assembly's outer guide tubes. When the head is lowered into position, the upper portions of the extension shaft assemblies enter the CEDMs. Upon completion of the head installation, the extension shaft assemblies and CEAs can be withdrawn and/or inserted into the fuel assemblies by the stepping mechanism of the CEDMs. Note that during this entire refueling operation and throughout the life of the CEAs, all the full strength CEAs (FSCEAs) and part strength CEAs (PSCEAs) typically remain coupled to the extension shaft assemblies in the same CEA shroud location within the UGS.

Confirmation that a CEA is oriented properly and in the desired location at the PVNGS plants and the Standard 16x16 plants is ensured by visual inspections performed during the initial installation of a CEA (within a fuel assembly for Standard 16x16 CEAs and within the UGS for PVNGS CEAs). During subsequent refueling outages, the PVNGS CEAs remain in the same location within the UGS while the Standard 16x16 CEAs are shuffled within the appropriate fuel assemblies. Although mis-orienting or mis-locating the CEAs could occur during the shuffling at the Standard 16x16 plants, the PVNGS remain secured within the same location of the UGS during the outage, thereby eliminating any potential for mis-orienting or mis-locating the CEAs in subsequent cycles.

The CEAs remaining within the UGS during refueling outages makes it difficult to inspect the CEAs if necessary. Normally the CEA fingers are positioned so the tips are above the bottom of the UGS during refueling, although the CEAs can be lowered approximately a foot to the floor of the UGS laydown area. This allows visual inspections to be performed over this region of the CEA fingers, which has historically been the most limiting for design life and where most CEA finger problems have occurred (cladding cracking, drag within the guide tube dashpot, etc.). In addition, the CEAs remaining within the UGS eliminates the CEA shuffling between fuel assemblies that is performed during refueling outages at Standard 16x16 plants, thereby eliminating those opportunities for detecting anomalous CEA drag or binding within the fuel assemblies.

C.2.1.3 PVNGS Reactor Internals Relevant Unique Design Features

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C.2.2 Fuel Assembly Designs

C.2.2.1 Fuel Assembly Design Comparison

The PVNGS standard fuel design is very similar to the Standard 16x16 fuel designs with 150" cores except for the details of the upper and lower end fittings. These similarities include the designs having the same fuel rod pitch, approximately the same fuel rod length and guide tube length, common spacer grid designs, and the same basic outer guide tube design and spacing. Design differences include the following:

- Lower end fitting (LEF): Main differences of the PVNGS design are
  1. the core alignment pins are at the corner of the assembly versus inboard on the Standard 16x16 design so the engagement features are at the corners of the LEF,
  2. the ICIs are bottom mounted so they enter the fuel assembly through a funnel shaped feature in the center of the LEF rather than entering the center guide tube from above, and

3. the LEFs are taller than the Standard 16x16 LEFs by about an inch.

- Upper end fitting (UEF): Main differences of the PVNGS design are
  1. the center post is short with a blind hole from the bottom to receive the bottom mounted, instrumentation and associated thermocouple rather than a center post with a through-hole of a diameter to receive a CEA finger,
  2. the holddown plate is a different shape due to its interface with the UGS.

- Center guide tube or instrument tube: Main differences of the PVNGS design are
  1. tube is dimpled periodically to aid in locating the ICI within the tube, and
  2. it is not attached to the LEF since the attachment screw would prohibit the ICI from entering the bottom of the fuel assembly.

- Outer guide tubes: Main differences of the PVNGS design are
  1. upper region of the tubes are expanded approximately 0.042 inches relative to the Standard 16x16 guide tubes (this particular design difference only applies to the Standard PVNGS fuel design since the new PVNGS fuel design discussed below does not have the expanded region of the outer guide tubes), and
  2. flow area associated with cooling hole(s) and bleed hole reduced to minimize CEA vibration caused by bypass flow in the guide tubes.

- Overall fuel assembly length: PVNGS fuel assembly is longer than the Standard 16x16 fuel due primarily to the longer PVNGS end fittings resulting from their interfacing with the reactor internals.

There are two Westinghouse fuel designs currently operating in the PVNGS plants; the standard design which has been operating for many years and eight lead fuel assemblies of a new fuel design. The main differences between the standard design and the new design are 1) the fuel rod diameters (nominally 0.382" outside diameter for the standard design versus 0.374" outside diameter for the new design), 2) the intermediate spacer grid designs (wavy straps with cantilevered springs for the standard design and straight straps with I-springs and mixing vanes on the new design), and 3) the outer guide tubes do not have the enlarged diameter region discussed above. None of the new fuel design features including the change to the fuel rod diameter have any impact on the functioning of the CEAs or startup testing and thus have no impact on implementation of the STAR Program at PVNGS. However, the PVNGS STAR Applicability Requirement #4 (Table 5-2) would prevent the extrapolation of a previous cycle measurement to be used as the Reconciliation method for the first cycle of the new fuel design's implementation because the change in water to fuel metal ratio due to the change in fuel rod diameter is greater than the ±2% criterion in the STAR Applicability Requirement. Comparison to an independent qualified core physics method would be acceptable for the Reconciliation. Thus, although the preceding discussion regarding relevant unique design features is based on the standard assembly, it is applicable to PVNGS cores with partial or full regions of the new fuel assembly design as well.

C.2.2.2 PVNGS Fuel Assembly Relevant Unique Design Features

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C.2.3 CEA Designs

C.2.3.1 CEA Design Comparison

The PVNGS plants have two basic geometric CEA designs; 12-finger CEAs and 4-finger CEAs. All the 12-finger CEAs contain full strength fingers (FSCEAs) while the 4-finger CEAs contain either full strength fingers (FSCEAs) or part strength fingers (PSCEAs). The fingers of a 12-finger CEA insert into five separate fuel assemblies with the four central inboard fingers inserted in the four guide tubes of the fuel assembly directly under the CEA and two fingers inserted in each of the four fuel assemblies adjacent to the central fuel assembly. For all the 4-finger CEAs (FSCEAs and PSCEAs), all the fingers insert into the four guide tubes within the fuel assembly directly under the CEA. Figure C-5 shows the arrangement of the CEAs within the PVNGS cores. All Standard 16x16 plants have 5-finger CEAs where the fingers insert into the outer and center guide tubes within the fuel assembly directly under the CEA. Some standard 16x16 plants employ, or have employed, 4-finger CEAs where two fingers insert into outer guide tubes of an assembly on the short outer rows of the core (core flats) and the other two fingers insert into outer guide tubes of the adjacent assembly on the core flats.

The fingers of the PVNGS PSCEAs contain Alloy (Inconel) 625 slugs over the entire absorber region. None of the Standard 16x16 plants utilize a similar design, so the PSCEAs are a unique design feature of the PVNGS plants. However, the PSCEAs are not relevant to the implementation of the STAR program since they are not credited in the shutdown margin calculation and are not included in the current CEA Group Worth test. Therefore, all other discussions within this report related to PVNGS CEAs refer to the full strength 12-finger and full strength 4-finger CEAs. [

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Until the more recent CEA replacements at the PVNGS plants, the full strength fingers contained B_4C pellets as the absorber over the entire absorber length with the lower 12 ½ inch end of the column containing reduced diameter pellets wrapped with feltmetal (a compressible stainless steel sponge-like material). The design for the latest CEAs (Reference 2) replaces the feltmetal encased B_4C at the tips of the fingers with Ag-In-Cd slugs and increases the length of the Ag-In-Cd region relative to the B_4C/feltmetal region. These redesigned CEAs are more resistant to cracking and hence absorber loss than the older feltmetal encased B_4C CEAs. The scope of the STAR implementation evaluation for the PVNGS plants is limited to operation of the plants with the Ag-In-Cd tipped CEA designs; it does not include the older CEA design that employed B_4C encased in feltmetal in the tips of the CEAs. Therefore, application of the STAR Program discussed herein for the startup of any PVNGS plants containing CEAs with the feltmetal encased B_4C fingers will require further evaluation.

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The absorber region of the PVNGS CEAs is very similar to that of the Standard 16x16 CEAs, yet the overall length of the PVNGS CEAs is approximately 6 feet longer than that of the Standard 16x16 CEAs. The additional length of the PVNGS fingers is associated with an inert extension piece (predominantly tubular stainless steel) between the spider and the absorber region to accommodate the length of the bank of tubes discussed in Section C.2.1.2. The longer length of the PVNGS fingers by itself does not affect startup testing, but some implications of the underlying need for the longer length (the tube bank portion of the UGS resulting in the CEAs remaining coupled to the extension shaft assemblies during refueling outages) do affect startup testing, as discussed in Section C.2.6.1.3.

C.2.3.2 PVNGS CEA Relevant Unique Design Features

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C.2.4 ICI Designs

C.2.4.1 ICI Design Comparison

The ICIs in the Standard 16x16 plants enter the fuel from the top (Figure C-1) while the PVNGS ICIs enter the fuel from the bottom (Figure C-2). Top mounted ICIs are located within ICI guide thimbles which are raised and lowered vertically into the fuel assemblies' center guide tube each outage. Conversely, bottom mounted ICIs are retracted and inserted individually through their stationary guide paths into the fuel assemblies' center guide tube during each outage. Although the use of bottom mounted ICIs results in some fuel assembly design differences, the basic design, functioning, and operation of the individual ICIs are comparable between top and bottom mounted designs. Therefore, although the PVNGS ICIs being bottom mounted rather than top mounted as in the Standard 16x16 plants is a design difference of the PVNGS ICIs, the design difference is not relevant to the STAR implementation at the PVNGS plants since the basic design, functioning, and operation of the ICI designs are comparable.

Because none of the CEAs insert a control rod finger in the center guide tube of the PVNGS fuel assemblies, some of the PVNGS ICIs are positioned in locations containing control rods. This eliminates the constraint on the PVNGS ICI pattern from the limitation imposed on the Standard 16x16 plants of positioning the ICI's in only non-CEA locations. The PVNGS ICI pattern was chosen with the goal of having every quadrant location instrumented when the full core is folded back into the quadrant. This approach allows a more accurate measurement of the overall core power distribution since ICIs are present in both rodded and unrodded fuel assemblies. However, since the total number of ICI penetrations is limited by other considerations, this approach had the downside that it reduced the number of quadrant symmetric ICI groups compared to the more symmetric checkerboard ICI pattern of the Standard 16x16 plants. [

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C.2.4.2 PVNGS ICI Relevant Unique Design Features

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C.2.5 CEA Drives Design (Extension Shaft Assemblies and CEDMs)

C.2.5.1 Extension Shaft Assembly Design Comparison

A review of the extension shaft designs for the PVNGS plants and the Standard 16x16 plants revealed that the designs are fundamentally the same with some minor design differences but with the same overall functionality due to similar gripper and plunger designs, drive shaft designs (the stepped portion of the shaft that engages the CEDM latches), and overall lengths. The PVNGS CEAs are much longer than the Standard 16x16 CEAs due to the extension piece between the absorber region and the spider, but the extension shaft assemblies themselves are comparable in length because the travel of the CEAs is the same basic 150 inches stroke (i.e., the extension piece of the PVNGS CEAs merely accounts for the additional length necessary to extend through the tube sheets in the UGS but does not affect the stroke or travel of the CEA). [

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Although the designs of the extension shaft assemblies are comparable and their functioning during reactor operation is comparable, there are differences in the handling of the extension shaft assemblies during refueling outages. These differences result from the fact that the CEAs remain coupled to the extension shaft assemblies during outages at the PVNGS plants rather than having the CEAs uncoupled from the extension shaft assemblies during each outage at the Standard 16x16 plants.

C.2.5.2 CEDM Design Comparison

A review of the CEDM designs for the PVNGS plants and the Standard 16x16 plants revealed that the designs are fundamentally the same with the energizing of coils controlling the stepping action of latches in the CEDM that engage grooves on the drive shaft portion of the extension shaft assembly. The only pertinent design difference is that the Standard 16x16 CEDMs are capable of driving the CEA/extension shaft assembly downward on an insertion step while the PVNGS CEDMs cannot (the PVNGS CEA/extensions shaft assembly inserts by gravity only). Therefore, the detectability of drive line drag of the PVNGS CEDMs exceeds that of the Standard 16x16 CEDMs since the driving capability of the Standard 16x16 CEDMs could overpower friction that could be identified with the PVNGS CEDMs. [

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C.2.5.3 PVNGS CEA Drives Relevant Unique Design Features

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C.2.6 Refueling Operations

C.2.6.1 Refueling Operation Comparisons

Sections C.2.1 through C.2.5 have identified aspects of the PVNGS plant design that could affect the PVNGS refueling operations in such a manner as to require evaluation regarding the PVNGS STAR implementation with respect to startup testing, pre-operational activities, and STAR Applicability Requirements. The resulting relevant unique design features (Features #1 through #4) are summarized in Table C-1. The effects of these relevant unique design features on refueling operations are identified and discussed below relative to their effect on the implementation of the STAR Program for the PVNGS plants.

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C.2.6.1.5 *Detectability of the Loss of Entire CEA Finger*

The STAR Topical Report identified the loss of CEA fingers as a potential as-built problem. The neutronics effect of dropping one finger during normal operation (i.e., basically all rods out) would be comparable for both the PVNGS plants and the Standard 16x16 plants. However, since the CEAs remain within the UGS during refueling outages at PVNGS, there are differences during refueling that need to be addressed.

Although loss of an entire CEA finger is a very unlikely situation in any of the CE-NSSS plants (no known instances), the more likely point of separation for the PVNGS CEAs is between the top of the finger and the spider rather than between the absorber region and the extension piece due to the differences in the joint configurations and their stepping loads. With the PVNGS CEAs, if the entire finger separates from the spider, the finger would fall to the bottom of the guide tube and, due to the extension piece in the upper portion of the CEA finger, the top of the finger would extend well up into the UGS (~6 feet). During refueling, the finger loss would be easily identified following the removal of the UGS because of the distance which the finger would be sticking out of the fuel assembly. Conversely, if the finger separated between the absorber region and the extension piece, the top of the absorber region would be slightly recessed within the fuel assembly (~2 inches). In the case of the Standard 16x16 CEAs, a separated finger would extend a short distance above the top of the fuel assembly (~4 inches).

Missing fingers may be identified visually during CEA manipulations, core verification, or fuel handling. In addition, if the lost finger is in a guide tube that will receive a CEA finger in the upcoming cycle, it would result in an interference condition that would be identified and need to be resolved when lowering the CEAs into the fuel assembly during the CEA shuffle. In PVNGS plants, there are fewer opportunities to detect the missing finger during refueling outages than in the Standard 16x16 plants. However, if the portion of the finger is in a guide tube that will receive a CEA finger in the upcoming cycle, it would result in an interference condition that would need to be resolved when lowering the CEAs into the core after UGS reinstallation. If the portion of the finger is in a non-CEA location, it could go undetected during refueling and reactor startup. However, over 75% of the guide tube locations in the PVNGS cores contain CEA fingers so it is likely the lost finger would be detected. Therefore, with the most likely scenario for the PVNGS CEAs being separation at the spider connection (making the loss finger very obvious during refueling) and with over 75% of the guide tube locations containing CEA fingers, it is concluded that the overall likelihood of detecting a loss of an entire finger in PVNGS is comparable to that in a Standard 16x16 plant. Regardless, even if loss of an entire finger were to occur, there would be no violation of any design criteria, since one dropped finger is bounded by the PVNGS safety analysis that demonstrates that no fuel failure occurs for a drop of any 4-fingered CEA under any allowed operating condition.

C.2.6.2 PVNGS Relevant Unique Design Features Related to Refueling Operations

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C.3 SUMMARY OF PVNGS RELEVANT UNIQUE DESIGN FEATURES

The design differences between the PVNGS plants and the Standard 16x16 plants were evaluated in Section C.2 to identify any relevant unique design features of the PVNGS reactor internals, fuel assemblies, CEAs, ICIs, extension shaft assemblies, CEDMs. and reactor refueling operations that could cause a significant increase in problems with the implementation of the STAR program at the PVNGS plants. Four relevant unique design features were identified and are listed in Table C-1.

In addition to the identification of the relevant unique design features, their effects on startup testing, pre-operational activities, and the STAR Applicability Requirements were identified. A modification to the startup testing is shown in Table C-2 while modifications to the STAR Applicability Requirements are shown in Table C-3. Although there are no additional categories of pre-operational activities compared to those shown in Table C-7 of the STAR Topical Report, some of the modifications to the STAR Applicability Requirements are to address differences in the PVNGS pre-operational activities. The modification of the STAR Applicability Requirements in Table C-3 for PVNGS are concluded to be sufficient to capture the necessary verifications to ensure the performance of the pre-operational activities required for the PVNGS STAR Program. Table C-4 provides relational information related to the modifications of the STAR Applicability Requirements for PVNGS. Specifically, the table identifies the applicable relevant unique design feature associated with the modified requirement, as well as the applicable sections that discuss the modified requirement and its impact.

Table C-1 Relevant Unique Design Features to the PVNGS STAR Implementation

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Table C-2 Modifications of Startup Testing Due to PVNGS Relevant Unique Design Features

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Table C-3 Modifications of STAR Applicability Requirements Due to PVNGS Relevant Unique Design Features

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Table C-3 Modifications of STAR Applicability Requirements Due to PVNGS Relevant Unique Design Features (continued)

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Table C-4 Relational Information for Modified STAR Applicability Requirements for PVNGS

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Table C-4 Relational Information for Modified STAR Applicability Requirements for PVNGS (continued)

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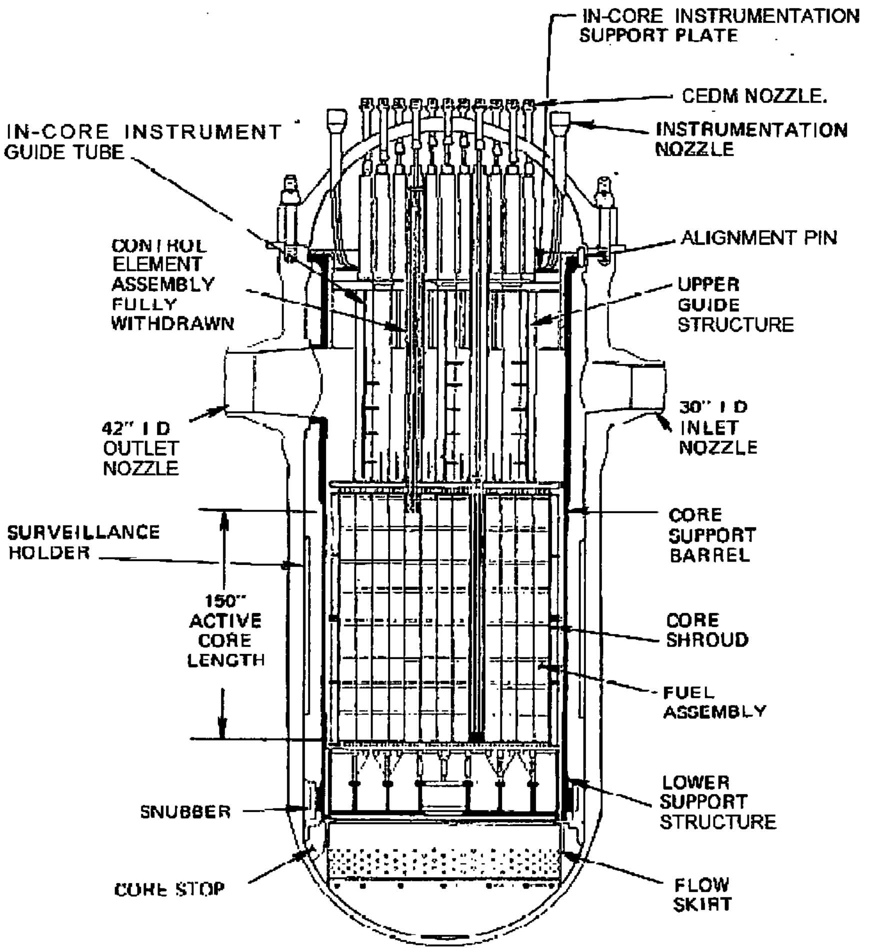


Figure C-1 Representative Reactor Internals Vertical Arrangement for Standard 16x16 Plants

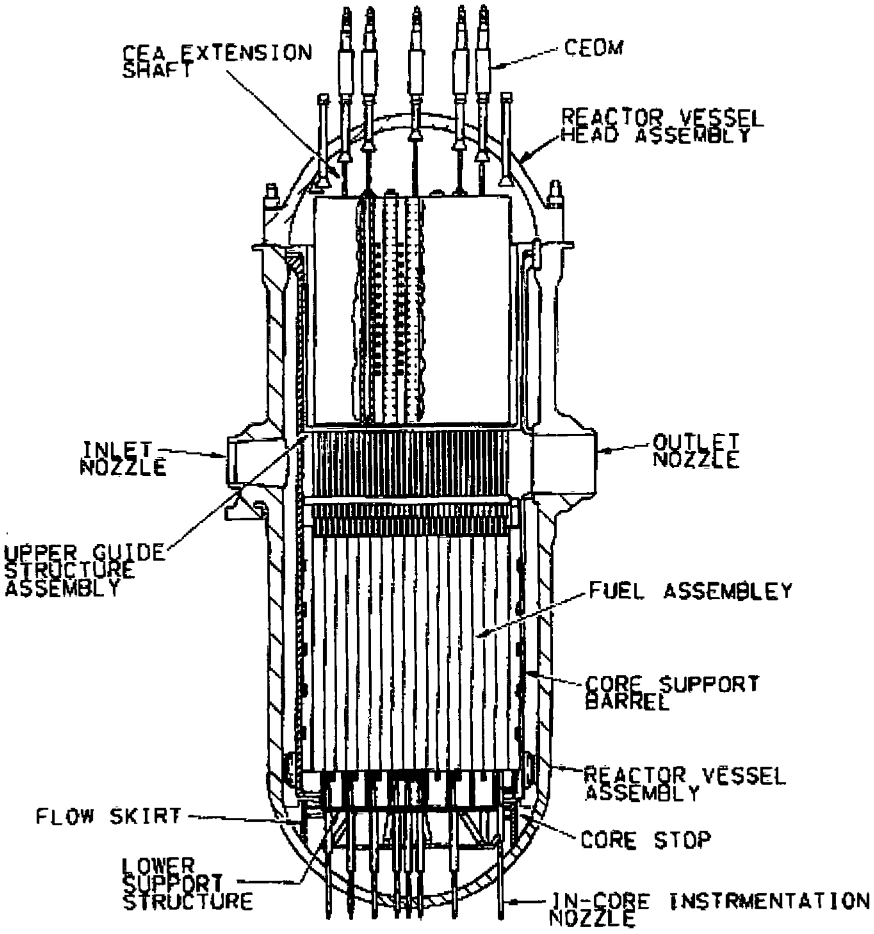
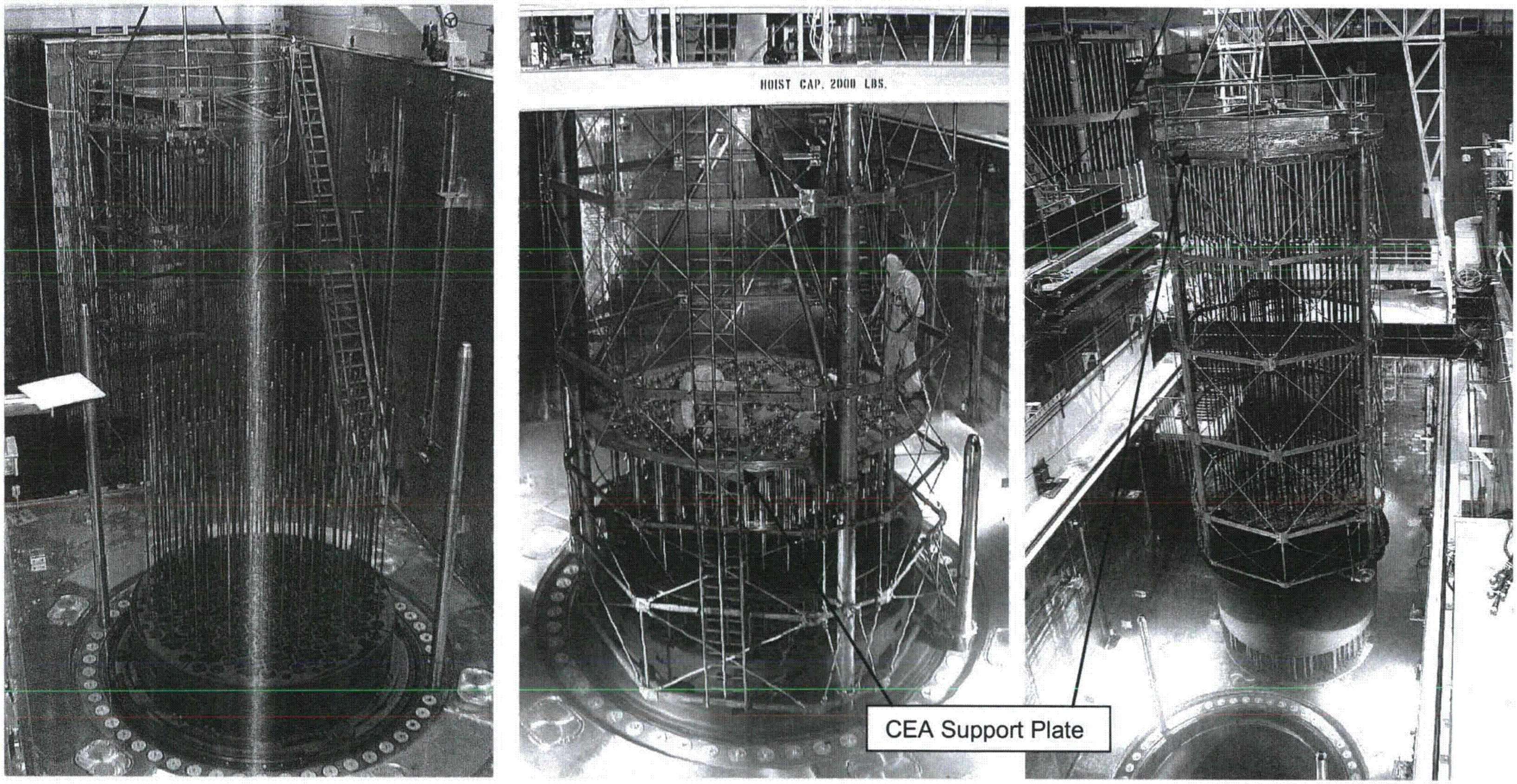


Figure C-2 Reactor Internals Vertical Arrangement for PVNGS Plants



Reactor vessel with head removed and UGS still in place. Shows extension shafts extending up from UGS. UGS lift rig in background. CEAs with extension shafts attached are seated on UGS base plate down within the reactor vessel.

UGS lift rig has been attached to UGS. CEA Support Plate with mechanisms that latch onto extension shafts has been lowered to receive shafts. Workers are latching mechanisms to extension shafts. CEAs with extension shafts still seated on UGS base plate.

CEA Support Plate with latching mechanisms engaged to extension shafts has been raised, drawing all CEAs into the UGS. UGS was lifted from reactor vessel and is being transported to laydown area where it remains in this configuration for the outage with extension shafts latched and CEAs drawn up into UGS.

Figure C-3 PVNGS Reactor Internals Configurations During Refueling

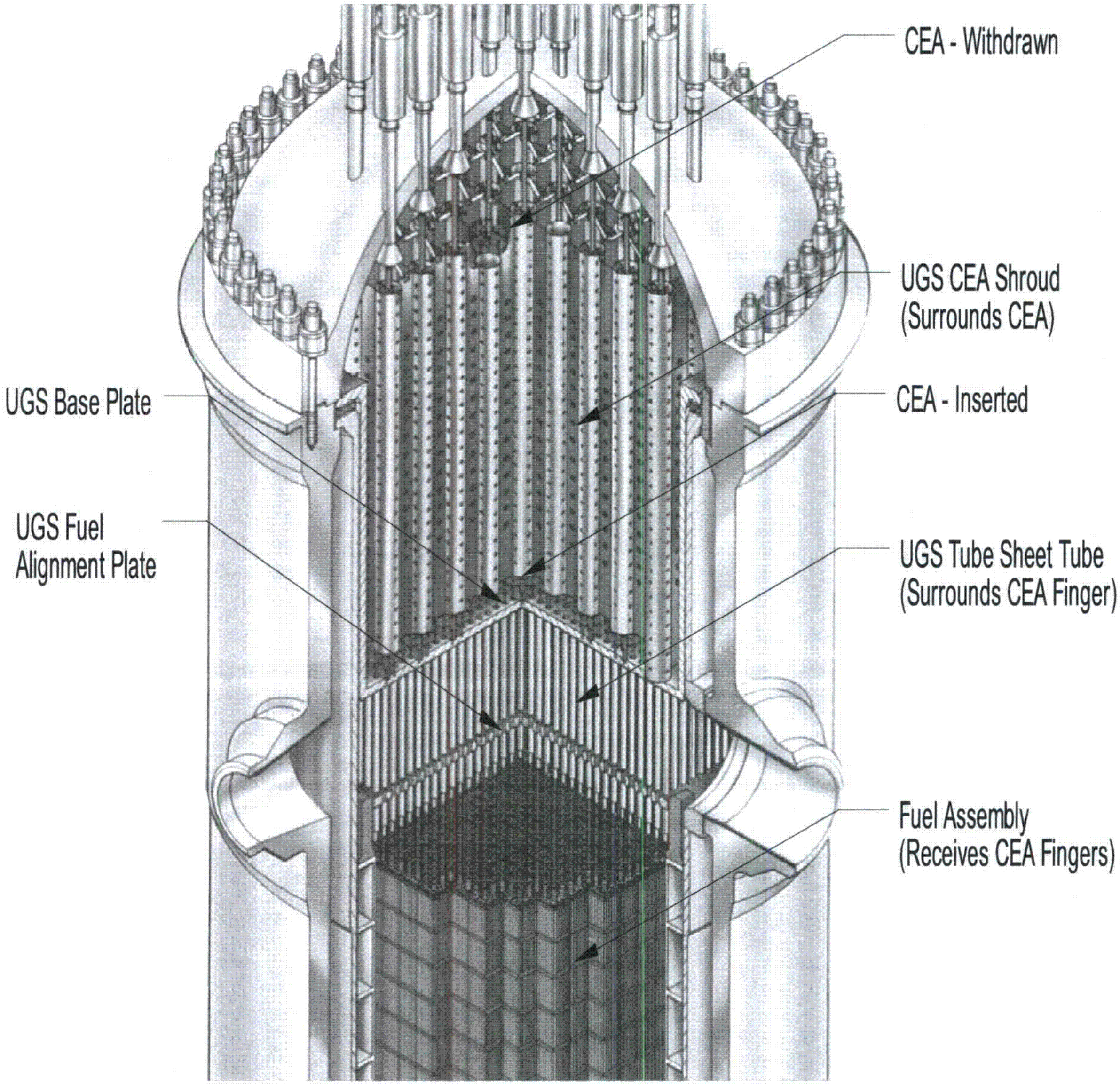
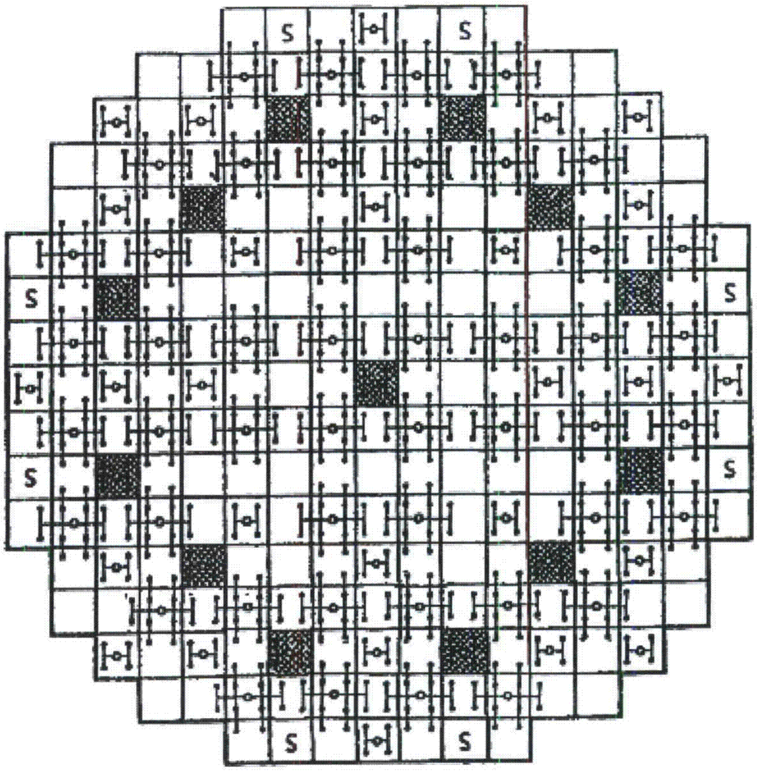


Figure C-4 PVNGS UGS to CEA Interface



	12-Finger FSCEAs	48
	4-Finger FSCEAs	28
▨	4-Finger PSCEAs	13
	Total	89

Figure C-5 CEA Locations for PVNGS Plants

APPENDIX D PVNGS Core Design Methods and Uncertainties

D.1 INTRODUCTION

D.1.1 Background

The STAR Program imposes specific requirements regarding the benchmarking of the Core Physics Methodology used to provide the CEA Worth and ITC/MTC predictions for the core reload safety analysis. This is required since the STAR Program removes the requirement for cycle specific low power experimental confirmation of CEA Worth and ITC predictions.

Application of the STAR Program requires that the core design methodology satisfy the following requirements summarized from the STAR Core Design Applicability Requirements in Table 3-4 of the STAR Topical Report:

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The STAR Topical Report demonstrated that these requirements are satisfied for the DIT/ROCS, PHOENIX/ANC[9], and CASMO/SIMULATE core physics methodology for the original group of participating plants.

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[9] Note that the SER in Reference 4 has indicated that the PARAGON code is a suitable replacement for PHOENIX and benchmarking has indicated that the PARAGON/ANC package also satisfies the STAR Core Design Applicability requirements and thus this is also an acceptable core physics methodology for application of the STAR Program.

D.1.2 PURPOSE

The purpose of this appendix is to demonstrate that the APS PVNGS CASMO/SIMULATE models satisfy all the STAR Core Design Applicability Requirements for elimination of the CEA Group Worth and HZP ITC tests for all cycles that satisfy the STAR Applicability requirements in Table 3-4 of the STAR Topical Report, and reproduced in, Table 5-2.

D.2 EVALUATION OF PVNGS CORE DESIGN METHODS AND UNCERTAINTIES

The PVNGS safety analysis of record is based on the standard Combustion Engineering safety analysis methodology. APS currently uses CASMO/SIMULATE (Reference 3) as the primary core physics predictive tool for core reload design analysis. Although the STAR Topical Report did include benchmark results for the CASMO/SIMULATE package for various plants, it did not include any CASMO/SIMULATE benchmark results for the PVNGS plants. Although there is no reason to believe that the CASMO/SIMULATE models would not also meet the STAR Core Design Applicability Requirements for PVNGS, this section provides quantitative proof that these requirements are satisfied, based on the results of extensive benchmarking of the CASMO/SIMULATE models to PVNGS plant measurements.

APS has performed extensive benchmarking of the PVNGS CASMO/SIMULATE models to past and recent PVNGS cycles. This benchmarking is used to determine the bias and uncertainty factors for use in the reload safety analysis. Reference 3 documents the benchmarking for older cycles. Benchmarking to more recent PVNGS cycles has validated the uncertainties used in the safety analysis[10]. The results from these more recent benchmarks are used here to demonstrate that the PVNGS CASMO/SIMULATE models satisfy the STAR Core Design Applicability Requirements:

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[10] The biases and uncertainties shown here have been updated based on more recent PVNGS measurements. Arizona Public Service maintains a continuing core follow program, comparing core physics models with plant operation and surveillance tests. When appropriate, Arizona Public Service updates biases and uncertainties to reflect current core designs using the methods of Reference 3. If necessary the uncertainty allowances in the safety analysis are adjusted to assure that the safety analysis remains conservative.

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D.3 CONCLUSIONS

Based on these facts, it is concluded that the APS PVNGS CASMO/SIMULATE models satisfy all the STAR Core Design Applicability Requirements for elimination of the CEA Group Worth and HZP ITC tests for all cycles that satisfy the STAR Applicability Requirements in Table 5-2. Note that this also demonstrates that the APS PVNGS CASMO/SIMULATE models also satisfy the requirements for EOC MTC test elimination defined in Reference 8.

Figure D-1 CEA Bank Worth Error For Recent PVNGS Cycles

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Figure D-2 CEA Total Worth Error For Recent PVNGS Cycles

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Figure D-3 ITC Error For Recent PVNGS Cycles

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Table D-1: PVNGS CASMO/SIMULATE Uncertainties (95/95 uncertainty limits)

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