SYSTEM 80

DOCKET STN-50-470F

ENCLOSURE 2-NP

TO

LD-82-039

CPC/CEAC PROTECTION ALGORITHM TEST PLAN

MARCH, 1982

Combustion Engineering, Inc.
Nuclear Power Systems
Power Systems Group
Windsor, Connecticut

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ARSTRACT

This document presents the approach that will be taken for testing and certifying the CPC/CEAC System Software for the System 80 plants. Sections in this document describe the purpose and scope for testing, types of testing to be performed, and documentation to support the algorithm changes and test results. The testing will be performed in accordance with the procedures of CEN-39(A)-P, Revision 2 and Supplement 1-P, Revision 00. Specific tests which are being performed because of the changes being made to the algorithms are specifically discussed.

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1.0 SPECIFICATION FOR TESTING PROTECTION ALGORITHM

1.1 PURPOSE

The purpose of this document is to outline the approach that will be taken for testing and certifying the CPC/CEAC System (CPCS) software for the System 80 plants. The testing outlined here is described in more detail in Reference 4.1. The implementation of the algorithm changes, the required testing, and the documentation will be performed and/or generated in accordance with the procedures of Reference 4.1.

1.2 SCOPE

The scope of the testing will include generation of a plant-specific data base and document, generation of appropriate test cases and acceptance criteria, and test reports. Testing of the CPCS software for each System 80 plant will be considered complete with the formal issuance of the following plant-specific documents:

1. CPC/CEAC Data Base Document
2. The Phase I Test Report
3. The Phase II Test Report

All documents will be generated and reviewed in accordance with the procedures given in Reference 4.2. In addition, all tests will be performed according to the procedures described in Reference 4.1, and the results documented in accordance with the procedures given in Reference 4.2. Together these steps will reflect the complete QA'd status of the CPCS software specification and implementation for System 80.

1.3 MODIFICATION REQUIREMENTS

The modifications being made to the System 80 CPCS software are to upgrade the CPCS capabilities to be compatible with the Reactor Power Cutback System (RPCS). The RPCS is designed to rapidly reduce the reactor power by dropping pre-selected CEA groups in response to

either a large load ejection or loss of one feedwater pump, without tripping the plant. These modifications consist of changes and additions to algorithms in the CEAC to detect the actuation of an RPC event, a flag in the CEAC penalty factor word to transmit to the CPCs the information that an RPC is in progress, and a more accurate down-power transient calculation in the event of an RPC. In addition, the positive range limit of the addressable constants for the DNBR and LPD penalty factor multipliers is being shifted toward zero to cover more completely the range of applicability. These modifications are described in more detail in Reference 4.3.

The modification process was initiated when details of the modification were established by the responsible C-E engineering group. The modifications will be incorporated into a revision to the CPC and CEAC Functional Design Specifications. Plant-specific constants will be generated for each System 80 plant, and a Data Base Document recording these constants will be generated. Since these modifications impact the CPC/CEAC FORTRAN code, the CPC/CEAC FORTRAN code certification document will be revised. All revisions to the Functional Design Specifications and to the FORTRAN code will be done in accordance with the requirements of Reference 4.2. Additional requirements for software functional design changes are described in more detail in Reference 4.1.

2.0 IMPLEMENTATION AND TESTING

2.1 SCOPE OF IMPLEMENTATION AND TESTING

This section covers the implementation of the algorithm changes and performance of Phase I and Phase II testing including test case selection and generation of acceptance criteria.

2.2 IMPLEMENTATION AND DISK GENERATION

All algorithm changes will be documented on Software Change Requests (SCR) and will be transmitted to the software implementation group. The procedures for filling out and processing ar SCR are covered in more detail in Reference 4.1. The most recent revisions of CPCS Software Specifications will be revised to reflect all software modifications indicated by the SCR's, and the resulting documents will be reviewed in accordance with Reference 4.2. The algorithm change will then be implemented, and all CPC/CEAC source files affected by the change will be updated. The updated CPC/CEAC source files will then be assembled to create object modules on the System 80 project disk. The object modules will then be fully debugged. Once debugged, the project disk will be used to generate two reference disks (Channels A/B and C/D). Phase I and Phase II testing will be performed on the Channel A/B reference disk.

2.3 PHASE I TESTING

Phase I testing will be performed to verify the correct implementation of modifications to the CPCS software and the generation of a new set of program constants. Phase I testing is performed on relatively small, single-entry/single-exit segments of code called modules as well as for integrated modules which constitute individual programs. Test cases will be generated for each and every module and for program-wide testing.

Except for Phase I testing of the CPCS Executive software, all test cases will be transmitted to the functional design group which will

execute the test cases with the CPC/CEAC FORTRAN code. The results will then be returned to the software implementation group which will execute the test cases on the CPCS software and compare the results with those from the FORTRAN code. The CPCS executive software will be tested following any change made to it by comparing actual and expected hand-calculated results for selected test cases. These comparisons will be analyzed to ensure correct implementation of all modifications affecting the CPCS executive and application program software. The scope and results of this testing will be documented for each System 80 plant in the Phase I Test Report.

2.4 PHASE II TESTING

Phase II testing consists of the following tests:

(1) Input Sweep Test,
(2) Dynamic Software Verification Test, and
(3) Live Input Single Parameter Test.

These tests are performed on a single channel CPC/CEAC system with integrated software that has undergone successful Phase I testing.

The objectives of Phase II testing are described in Reference 4.1. The Phase II testing uses the CPC/CEAC FORTRAN code as a basis for comparison and for generating acceptance criteria. The results of the Phase II testing will be documented for each System 80 plant in the Phase II Test Report.

2.4.1 Input Sweep Test

The Input Sweep Test is a real-time exercise of the CPCS application program software and executive software with steady-state CPC input values read from a storage device. The objectives of the Input Sweep Test are described in Reference 4.1 and are summarized below:

(1) To determine the processing uncertainties resulting from differences in machine precision between the CPC/CEAC system

hardware and the CDC 7600 (on which the FORTRAN code is executed). The processing uncertainties will be factored into acceptance criteria for the other two Phase II tests and into CPC Data Base constants affected by these uncertainties.

(2) To verify the ability of the CPCS software algorithms to initialize to a steady state after an Auto-Restart for each test case.

(3) To complement Phase I individual module and program-wide testing by identifying any abnormalities which were not uncovered previously.

The Input Sweep Test will be performed in two segments. The CPC software and the CEAC software segments will be independently tested. Each segment will have its own test cases and acceptance criteria for processing uncertainties. Each segment will be first executed on the CPCS software by the software-implementation group. The test cases will be allowed to initialize by convergence of critical calculated parameters, after which calculated parameter values will be transferred to the functional design group. The functional design group will execute the same test cases on the CPC/CEAC FORTRAN code and will then perform a comparison between the two sets of calculated parameter values. Part of this comparison will be a statistical evaluation which will generate the processing uncertainties. The results of this comparison will be evaluated to ensure the test objectives have been met.

2.4.2 Dynamic Software Verification Test (DSVT)

The Dynamic Software Verification Test is a real-time exercise of the CPC application software and executive software with transient CPC input values read from a storage device. The objectives of the DSVT are described in Reference 4.1 and are summarized below:

(1) To verify that the dynamic response of the integrated CPC software is consistent with that predicted by design analyses, and

(2) To supplement other Phase I and Phase II tests in assuring correct implementation of the software modifications.

The DSVT cases will be executed on the CPC/CEAC FORTRAN code to generate the acceptance criteria. The DSVT cases will then be executed on the CPCS software. Input values for each test case will be read from a storage device. After initialization for each test case, DSVT will use time-variant test case input values to more thoroughly exercise "dynamic" portions of the CPCS software. The results of this test will be compared with the acceptance criteria and evaluated to ensure the test objectives have been met.

2.4.3 Live Input Single Parameter (LISP) Test

The LISP test is a real-time exercise of the CPCS application and executive software, with transient CPCS input values generated from an external signal generator and read through the CPCS input hardware. The objectives for the LISP test are described in Reference 4.1 and are summarized below:

(1) To verify the dynamic response of the integrated CPCS software and hardware.

(2) To supplement other Phase I and Phase II tests in assuring correct implementation of the software modifications.

(3) To evaluate the integrated hardware/software system during operational modes.

The LISP test cases will first be executed on the CPC/CEAC FORTRAN code to generate the acceptance criteria. The LISP test cases will then be executed using the CPCS software. Dynamic test case inputs will be generated by an external signal generator to produce "live"

analog and digital signals that are input to the CPCS input processing hardware. Each LISP test case will vary only one input parameter, holding the other inputs at constant values. The LISP test also exercises all dynamic portions of the CPCS software algorithms. The results of this test will be compared with the acceptance criteria and evaluated to ensure the test objectives have been met.

As part of the LISP test, major aspects of the operator's module operation will be tested. The CPC and CEAC Point ID tables will be checked to ensure that the Point IDs displayed on the operator's module are the same as those listed in the Point ID tables. The lower and upper range limits for all addressable constants will be tested and verified as having been correctly implemented. Finally, all aspects of automated reentry of addressable constants will be tested and verified to be correctly implemented.

2.5 PHASE I TEST CASE SELECTION AND ACCEPTANCE CRITERIA

For Phase I testing, test cases will be generated for all modules. These test cases will include cases to exercise all modifications, including those related to RPC. The selection of test cases will ensure that each functional branch and each instruction in all modules will be exercised. Program wide test cases will then be run to assure correct transfer of information between modules of the same program and compatibility of the RPC modifications.

The acceptance criteria will be [ ] allowable difference between the expected results and the actual results. However, all differences greater than [ ] shall be investigated, and their causes verified as not being due to software errors or corrected.

2.6 PHASE II TEST CASE SELECTION

THE CPC Input Sweep Test cases are selected to cover the region of CPC operation. Approximately [ ] test cases will be generated. Test

case parameters will be varied over the range of CPC inputs with the following additional variations applied over certain test case ranges:

The CEAC Input Sweep Test cases are selected to cover various CEA configurations. Approximately [ ] test cases will be generated. The majority of these test cases will encompass the CEA configurations expected during normal operation. The test cases in this first group

] Test cases in the second group will cover the following conditions:

[ ]

Because of the static nature of the CEAC Input Sweep Test, no RPC-related test cases are included in this test.

The DSVT cases are selected to adequately exercise dynamic portions of the CPCS application software. The test cases that will be generated for this test are listed in Table 2.6-1. This list includes test cases to evaluate the CPCS software response to a RPC. These test cases will verify that the CPCs respond correctly during a RPC event and that the CPCs will not generate a reactor trip for RPC events which are progressing normally and do not require a trip.

The LISP test cases are selected to demonstrate that the integrated CPCS hardware/software system functions as designed in response to externally-generated transient input signals in a real time environment. The test cases will consist of variations of single variables encompassing cases 17 through 21 of Table 2.6-1. Since the LISP test evaluates trip time based on transient input signals, no RPC-related test cases are included in this test.

TABLE 2.6-1

Dynamic Software Verification Test Cases

[ ]

TABLE 2.6-1 (Cont.)

SINGLE VARIABLE

[ ]

2.7 GENERATION OF PHASE II ACCEPTANCE CRITERIA

The acceptance criteria for the CPC Input Sweep test are that:

(1) The processing uncertainties fall within the guidelines described in Reference 4.1,

(2) Initialization capability is demonstrated, and

(3) No software errors are detected.

This test will be performed on the CPC software and the CDC 7600. The CDC 7600 will then compare the results from both executions, case by case, evaluate the magnitude of the difference between calculated DNBRs and LPDs, and generate processing uncertainties.

The acceptance criteria for the CEAC Input Sweep test are similar to those for the CPC Input Sweep Test. The test will be performed on the CEAC software and the CDC 7600. Comparison and evaluation of results will be performed in a manner similar to that for the CPC Input Sweep Test.

The DSVT acceptance criteria are based on [ ]. The acceptance criteria for [ ] will be determined by applying the processing uncertainties determined during CPC Input Sweep Testing to [ ] calculated with the CPC/CEAC FORTRAN code. To determine acceptance criteria for [ ]. The dynamic cases will then be run on the CPC/CEAC FORTRAN code to produce [ ] acceptance criteria.

The acceptance criteria for the LISP test will consist of [ ]

[ ] will be factored into the acceptance criteria. Each case will be executed several times on the CPC/CEAC FORTRAN code to generate the acceptance criteria.

3.0 GENERATION OF MASTER DISK AND SOFTWARE DESIGN DOCUMENTATION

The generation of a reference disk for Phase I and Phase II testing was described in Section 2.2. Once the testing is satisfactorily completed, the two reference disks described in Section 2.2 will become the new reference disks for the software system. Additionally, several steps will be taken in generating various software disks which will produce individual channel System Load Disks and System Test Disks. Four System Load Disks and four System Test Disks will be transmitted to each plant.

During the software development and testing, documentation will be generated to document the changes, verify quality assurance of the CPCS software, and document the results of the testing. These documents will include:

(1) CPC/CEAC Data Base Document

(2) Phase I and Phase II Test Reports

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4.0 REFERENCES

4.1 CPC Protection Algorithm Software Change Procedure, CEN-39(A)-P, Revision 02, and Supplement 1-P, Revision 00.

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4.3 CPC/CEAC Software Modifications for System 80, Enclosure 1-P of this submittal.

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The modification process was initiated when details of the modification were established by the responsible C-E engineering group. The modifications will be incorporated into a revision to the CPC and CEAC Functional Design Specifications. Plant-specific constants will be generated for each System 80 plant, and a Data Base Document recording these constants will be generated. Since these modifications impact the CPC/CEAC FORTRAN code, the CPC/CEAC FORTRAN code certification document will be revised. All revisions to the Functional Design Specifications and to the FORTRAN code will be done in accordance with the requirements of Reference 4.2. Additional requirements for software functional design changes are described in more detail in Reference 4.1.

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Phase I testing will be performed to verify the correct implementation of modifications to the CPCS software and the generation of a new set of program constants. Phase I testing is performed on relatively small, single-entry/single-exit segments of code called modules as well as for integrated modules which constitute individual programs. Test cases will be generated for each and every module and for program-wide testing.

Except for Phase I testing of the CPCS Executive software, all test cases will be transmitted to the functional design group which will

execute the test cases with the CPC/CEAC FORTRAN code. The results will then be returned to the software implementation group which will execute the test cases on the CPCS software and compare the results with those from the FORTRAN code. The CPCS executive software will be tested following any change made to it by comparing actual and expected hand-calculated results for selected test cases. These comparisons will be analyzed to ensure correct implementation of all modifications affecting the CPCS executive and application program software. The scope and results of this testing will be documented for each System 80 plant in the Phase I Test Report.

2.4 PHASE II TESTING

Phase II testing consists of the following tests:

(1) Input Sweep Test,
(2) Dynamic Software Verification Test, and
(3) Live Input Single Parameter Test.

These tests are performed on a single channel CPC/CEAC system with integrated software that has undergone successful Phase I testing.

The objectives of Phase II testing are described in Reference 4.1. The Phase II testing uses the CPC/CEAC FORTRAN code as a basis for comparison and for generating acceptance criteria. The results of the Phase II testing will be documented for each System 80 plant in the Phase II Test Report.

2.4.1 Input Sweep Test

The Input Sweep Test is a real-time exercise of the CPCS application program software and executive software with steady-state CPC input values read from a storage device. The objectives of the Input Sweep Test are described in Reference 4.1 and are summarized below:

(1) To determine the processing uncertainties resulting from differences in machine precision between the CPC/CEAC system

hardware and the CDC 7600 (on which the FORTRAN code is executed). The processing uncertainties will be factored into acceptance criteria for the other two Phase II tests and into CPC Data Base constants affected by these uncertainties.

(2) To verify the ability of the CPCS software algorithms to initialize to a steady state after an Auto-Restart for each test case.

(3) To complement Phase I individual module and program-wide testing by identifying any abnormalities which were not uncovered previously.

The Input Sweep Test will be performed in two segments. The CPC software and the CEAC software segments will be independently tested. Each segment will have its own test cases and acceptance criteria for processing uncertainties. Each segment will be first executed on the CPCS software by the software implementation group. The test cases will be allowed to initialize by convergence of critical calculated parameters, after which calculated parameter values will be transferred to the functional design group. The functional design group will execute the same test cases on the CPC/CEAC FORTRAN code and will then perform a comparison between the two sets of calculated parameter values. Part of this comparison will be a statistical evaluation which will generate the processing uncertainties. The results of this comparison will be evaluated to ensure the test objectives have been met.

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The Dynamic Software Verification Test is a real-time exercise of the CPC application software and executive software with transient CPC input values read from a storage device. The objectives of the DSVT are described in Reference 4.1 and are summarized below:

(1) To verify that the dynamic response of the integrated CPC software is consistent with that predicted by design analyses, and

(2) To supplement other Phase I and Phase II tests in assuring correct implementation of the software modifications.

The DSVT cases will be executed on the CPC/CEAC FORTRAN code to generate the acceptance criteria. The DSVT cases will then be executed on the CPCS software. Input values for each test case will be read from a storage device. After initialization for each test case, DSVT will use time-variant test case input values to more thoroughly exercise "dynamic" portions of the CPCS software. The results of this test will be compared with the acceptance criteria and evaluated to ensure the test objectives have been met.

2.4.3 Live Input Single Parameter (LISP) Test

The LISP test is a real-time exercise of the CPCS application and executive software, with transient CPCS input values generated from an external signal generator and read through the CPCS input hardware. The objectives for the LISP test are described in Reference 4.1 and are summarized below:

(1) To verify the dynamic response of the integrated CPCS software and hardware.

(2) To supplement other Phase I and Phase II tests in assuring correct implementation of the software modifications.

(3) To evaluate the integrated hardware/software system during operational modes.

The LISP test cases will first be executed on the CPC/CEAC FORTRAN code to generate the acceptance criteria. The LISP test cases will then be executed using the CPCS software. Dynamic test case inputs will be generated by an external signal generator to produce "live"

analog and digital signals that are input to the CPCS input processing hardware. Each LISP test case will vary only one input parameter, holding the other inputs at constant values. The LISP test also exercises all dynamic portions of the CPCS software algorithms. The results of this test will be compared with the acceptance criteria and evaluated to ensure the test objectives have been met.

As part of the LISP test, major aspects of the operator's module operation will be tested. The CPC and CEAC Point ID tables will be checked to ensure that the Point IDs displayed on the operator's module are the same as those listed in the Point ID tables. The lower and upper range limits for all addressable constants will be tested and verified as having been correctly implemented. Finally, all aspects of automated reentry of addressable constants will be tested and verified to be correctly implemented.

2.5 PHASE I TEST CASE SELECTION AND ACCEPTANCE CRITERIA

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The acceptance criteria will be [ ] allowable difference between the expected results and the actual results. However, all differences greater than [ ] shall be investigated, and their causes verified as not being due to software errors or corrected.

2.6 PHASE II TEST CASE SELECTION

THE CPC Input Sweep Test cases are selected to cover the region of CPC operation. Approximately [ ] test cases will be generated. Test

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[

]

The CEAC Input Sweep Test cases are selected to cover various CEA configurations. Approximately [ ] test cases will be generated. The majority of these test cases will encompass the CEA configurations expected during normal operation. The test cases in this first group

[

] Test cases in the second group will cover the following conditions:

[

]

Because of the static nature of the CEAC Input Sweep Test, no RPC-related test cases are included in this test.

The DSVT cases are selected to adequately exercise dynamic portions of the CPCS application software. The test cases that will be generated for this test are listed in Table 2.6-1. This list includes test cases to evaluate the CPCS software response to a RPC. These test cases will verify that the CPCs respond correctly during a RPC event and that the CPCs will not generate a reactor trip for RPC events which are progressing normally and do not require a trip.

The LISP test cases are selected to demonstrate that the integrated CPCS hardware/software system functions as designed in response to externally-generated transient input signals in a real time environment. The test cases will consist of variations of single variables encompassing cases 17 through 21 of Table 2.6-1. Since the LISP test evaluates trip time based on transient input signals, no RPC-related test cases are included in this test.

TABLE 2.6-1

Dynamic Software Verification Test Cases

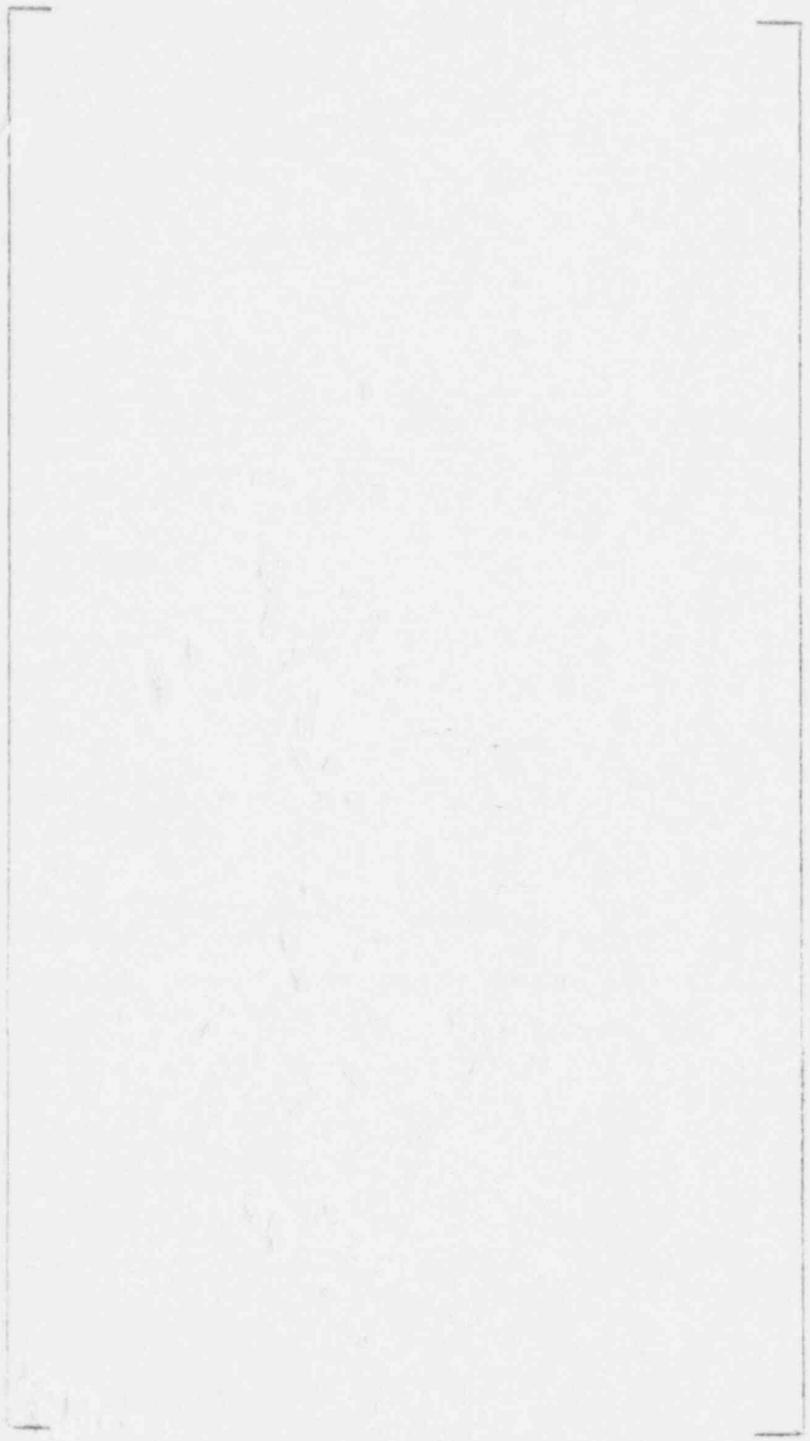

TABLE 2.6-1 (Cont.)

SINGLE VARIABLE

2.7 GENERATION OF PHASE II ACCEPTANCE CRITERIA

The acceptance criteria for the CPC Input Sweep test are that:

(1) The processing uncertainties fall within the guidelines described in Reference 4.1,

(2) Initialization capability is demonstrated, and

(3) No software errors are detected.

This test will be performed on the CPC software and the CDC 7600. The CDC 7600 will then compare the results from both executions, case by case, evaluate the magnitude of the difference between calculated DNBRs and LPDs, and generate processing uncertainties.

The acceptance criteria for the CEAC Input Sweep test are similar to those for the CPC Input Sweep Test. The test will be performed on the CEAC software and the CDC 7600. Comparison and evaluation of results will be performed in a manner similar to that for the CPC Input Sweep Test.

The DSVT acceptance criteria are based on [ ]. The acceptance criteria for [ ] will be determined by applying the processing uncertainties determined during CPC Input Sweep Testing to [ ] calculated with the CPC/CEAC FORTRAN code. To determine acceptance criteria for [ ]. The dynamic cases will then be run on the CPC/CEAC FORTRAN code to produce [ ] acceptance criteria.

The acceptance criteria for the LISP test will consist of [ ]

[ ] will be factored into the acceptance criteria. Each case will be executed several times on the CPC/CEAC FORTRAN code to generate the acceptance criteria.

3.0 GENERATION OF MASTER DISK AND SOFTWARE DESIGN DOCUMENTATION

The generation of a reference disk for Phase I and Phase II testing was described in Section 2.2. Once the testing is satisfactorily completed, the two reference disks described in Section 2.2 will become the new reference disks for the software system. Additionally, several steps will be taken in generating various software disks which will produce individual channel System Load Disks and System Test Disks. Four System Load Disks and four System Test Disks will be transmitted to each plant.

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(3) CPC/CEAC Software Modifications Document (Reference 4.3)

4.0 REFERENCES

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4.2 Quality Assurance of Design Manual for C-E Nuclear Power Systems.

4.3 CPC/CEAC Software Modifications for System 80, Enclosure 1-P of this submittal.