CPC/CEAC SOFTWARE MODIFICATIONS

FOR

SAN ONOFRE NUCLEAR GENERATING STATION UNITS No. 2 AND 3

JULY, 1984

POWER SYSTEMS

COMBUSTION ENGINEERING, INC.

LEGAL NOTICE

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1.0   INTRODUCTION

1.1   REPORT SCOPE

The Core Protection Calculator (CPC) System developed by Combustion
Engineering is a digital mini-computer system which calculates the
minimum Departure from Nucleate Boiling Ratio (DNBR) and the peak
Local Power Density (LPD) on-line and generates a reactor trip if
either the minimum DNBR or the peak LPD approaches the appropriate
Specified Acceptable Fuel Design Limit. The CPC System has been
reviewed by NRC and approved for operation in Arkansas Nuclear One
(ANO) Unit 2, Waterford-3, San Onofre Nuclear Generating Station
(SONGS) Units 2 and 3 and Palo Verde Nuclear Generation Station
(PVNGS) Units 1, 2 and 3. The CPC/CEAC software for SONGS Unit 2
and 3 is being modified for operation in Cycle 2. This modification
is being made using the PVNGS Cycle 1 CPC/CEAC software (Reference
1.3-3) as a basis since it is the latest NRC approved software. The
modification for SONGS Units 2 and 3 Cycle 2 includes algorithm
changes derived from the implementation of the PVNGS Cycle 1
software as well as other algorithm changes. These changes were
made to the CPC System in accordance with the NRC-approved CPC
software change procedure (References 1.3-1 and 1.3-2).

This report describes the changes to the SONGS software for Cycle 2.
Changes derived from the implementation of the PVNGS Cycle 1
software are described briefly since they have been approved and
implemented previously (Reference 1.3-3) while other changes are
described in detail.

1.2   REPORT SUMMARY

The modifications to the CPC/CEAC software which will be applicable
to Cycle 2 of SONGS Units 2 and 3 are:

1)   Modification of the temperature shadowing factor algorithm.

2)   Modification of the CPC core power bias algorithm.

3)   Improvement to the UPDATE algorithm.

4)   Modification of the heat flux distribution extrapolation in
     STATIC.

5)   Addition of [   ] new addressable constants.

6)   Modification of the four linear heat distributions in STATIC
     program to account for differences between the hot channel and
     hot pin relative powers.

7)   Upgrade of the non-uniform heating correction factors (FK) in
     the UPDATE program.

The general format used in describing each software modification
contained in this report is a statement of the change, the reason
for the change, and a detailed description of the change
including algorithm descriptions in symbolic algebra. This is the.
same format used in Reference 1.3-3.

1.3   REFERENCES FOR SECTION 1.0

1.   CEN-39(A)-NP, Revision 02, The CPC Protection Algorithm
      Software Change Procedure, December 21, 1978.

2.   CEN-39(A)-NP, Supplement 1-NP, Revision 01, January 5, 1979.

3.   Dockets STN-50-470F, Enclosure 1-NP to LD-82-039, CPC/CEAC
      Software Modifications for System 80, March, 1982.

2.0   SOFTWARE MODIFICATIONS

2.1   CHANGES DERIVED FROM IMPLEMENTATION OF PVNGS CYCLE 1 SOFTWARE

The changes in CPC software for SONGS Units 2 and 3 Cycle 2 that have been derived from implementation of the PVNGS Cycle 1 software are described in the following summaries. These changes were submitted previously to the NRC (Reference 2.5-1).

1. The non-uniform heating correction factor (F_K) in the UPDATE program was adjusted by the addition of [   ] constants based on the [   ] in quality margin.

2. The calculation of the four linear heat rate (LHR) distributions in the STATIC program was modified to account for the difference between the hot channel and hot pin relative powers.

3. The positive range limit on the CEAC penalty factor multipliers, [   ], was shifted from [   ] to [   ].

4. Algorithms were added to the CPC and CEAC (Control Element Assembly Calculator) for detecting the actuation of a Reactor Power Cutback (RPC) event, for using off-line calculated RPC penalty factors, and for allowing the CPC calculation to more closely model core conditions without generating an inadvertent trip in the event of a RPC. Since SONGS Units 2 and 3 do not have a RPC system, the effect of these algorithms will be nullified through the appropriate data base constants.

5. Addressable constants have been added to the CPC and CEAC to define the duration that the RPC flags can remain set. (For SONGS these addressable constants will be set to [ ]).

6. An algorithm was added to the FLOW Program to account for
forward flow through a reactor coolant (RC) pump at or near
zero revolution per minute (RPM). Since SONGS Units 2 and 3 do
not have a very rapid occurrence of negative head across an RC
pump with a locked rotor, the effect of this algorithm will be
nullified through the appropriate data base constants.

2.2   ADDITIONAL CORE PROTECTION CALCULATOR (CPC) ALGORITHM CHANGES

2.2.1   <u>Modification of the Temperature Shadowing Factor Algorithm</u>

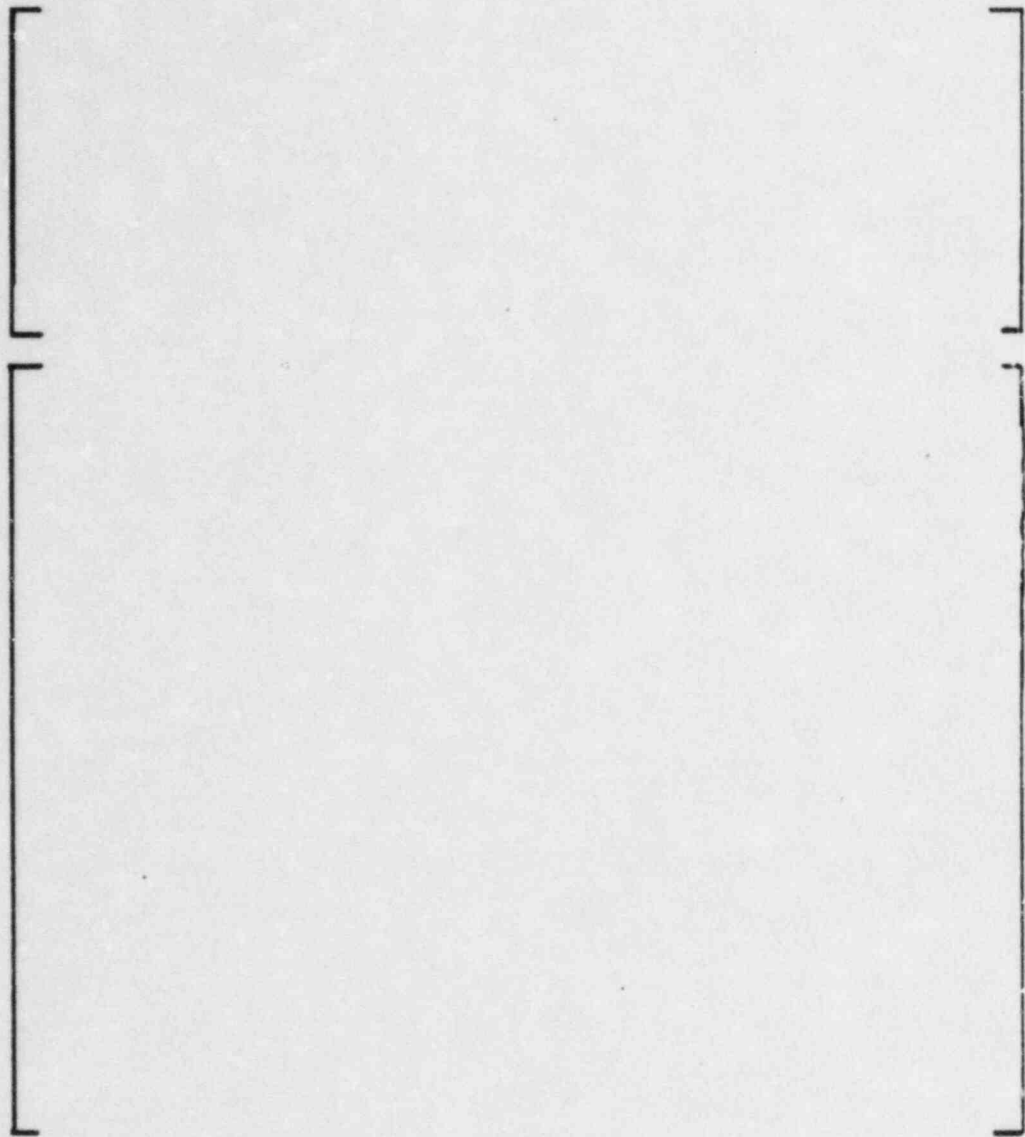Change:

Implement for cycle 2 a[   ]the
Temperature Shadowing Factor (TSF) on moderator temperature using a
[   ]inlet moderator temperature. The slope of the
correction for temperatures[   ]
                    [   ]will be chosen to bound all expected TSF data,
including uncertainties. A[.]will be used
for temperatures[   ]. The excore
detector calibration procedures will be modified to be consistent
with this determination of the TSF and its use in adjusting the
neutron flux power.

Reason:

The temperature shadowing factor (TSF) is used to correct the CPC
neutron flux power for decalibration effects resulting from changes
in inlet coolant density. A moderator temperature-dependent
multiplier is applied to the neutron flux power calculation to
correct excore detector response. In the current algorithm, the TSF
is a[   ]of the change in moderator temperature
the slope of which is measured at start-up. The uncertainty in the
measurement of the TSF is currently accommodated in the CPC
Departure from Nucleate Boiling (DNB) and Linear Heat Rate (LHR)
overall uncertainty terms[   ].

This change will allow the TSF uncertainty to be included directly
in the factor itself. This insures a conservative correction for
temperature at moderator temperatures above or below the inlet
moderator temperature at which the neutron flux power was calibrated
(calibration temperature) while removing unnecessary penalties for
uncertainty at the calibration temperature (which is anticipated to
be near nominal conditions).

Description:

[   ]

[

                                                                    ]

2.2.2   Modification of the CPC Core Power Bias Algorithm

Change:

Implement [   ] to adjust the thermal power
and neutron flux power level in the CPCs.

2-4

Reason:

[   ]

Description (See Figure 1):

[   ]

FIGURE 1

[   ]

2-6

where:

2-7

[

]

[

]
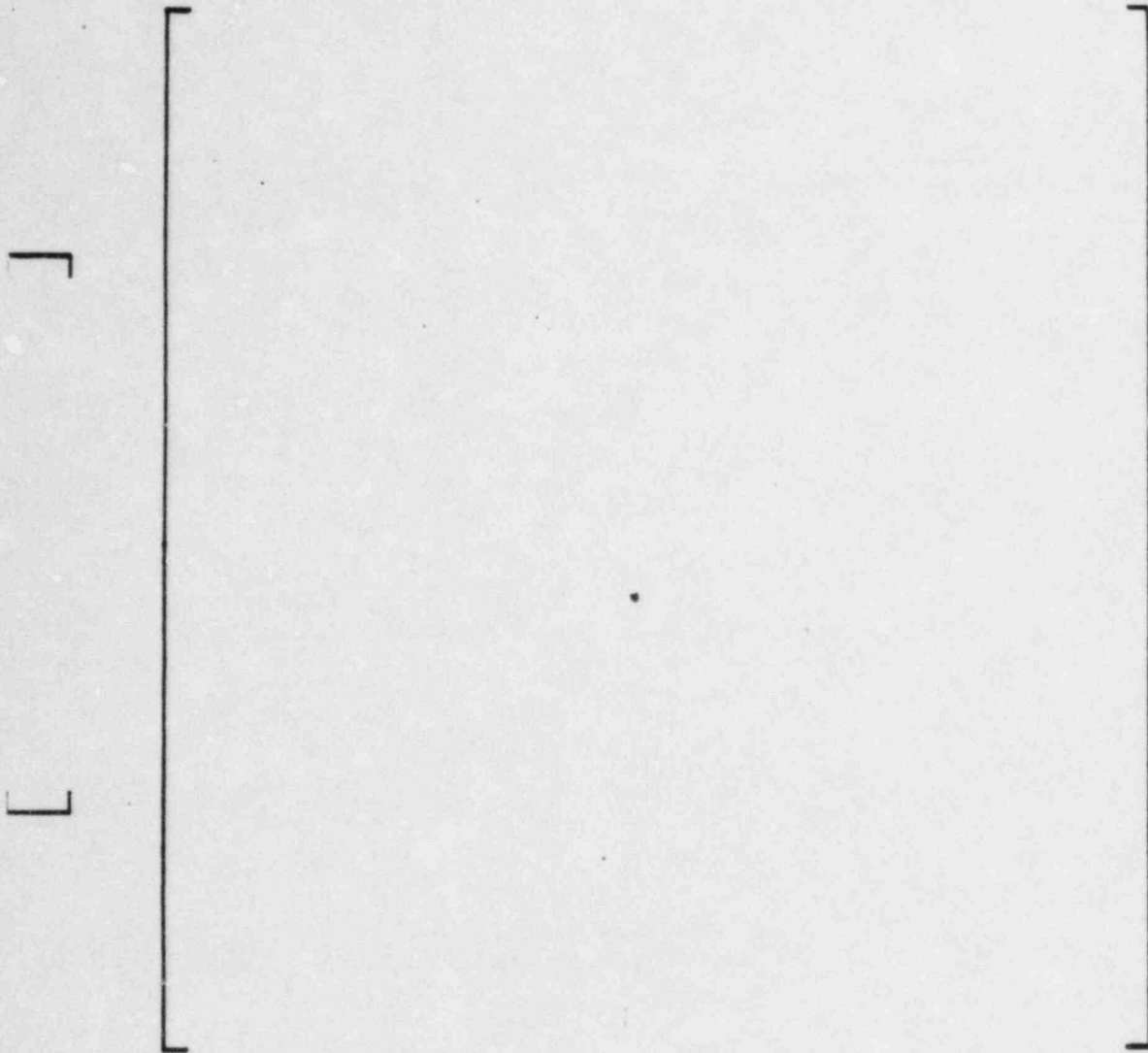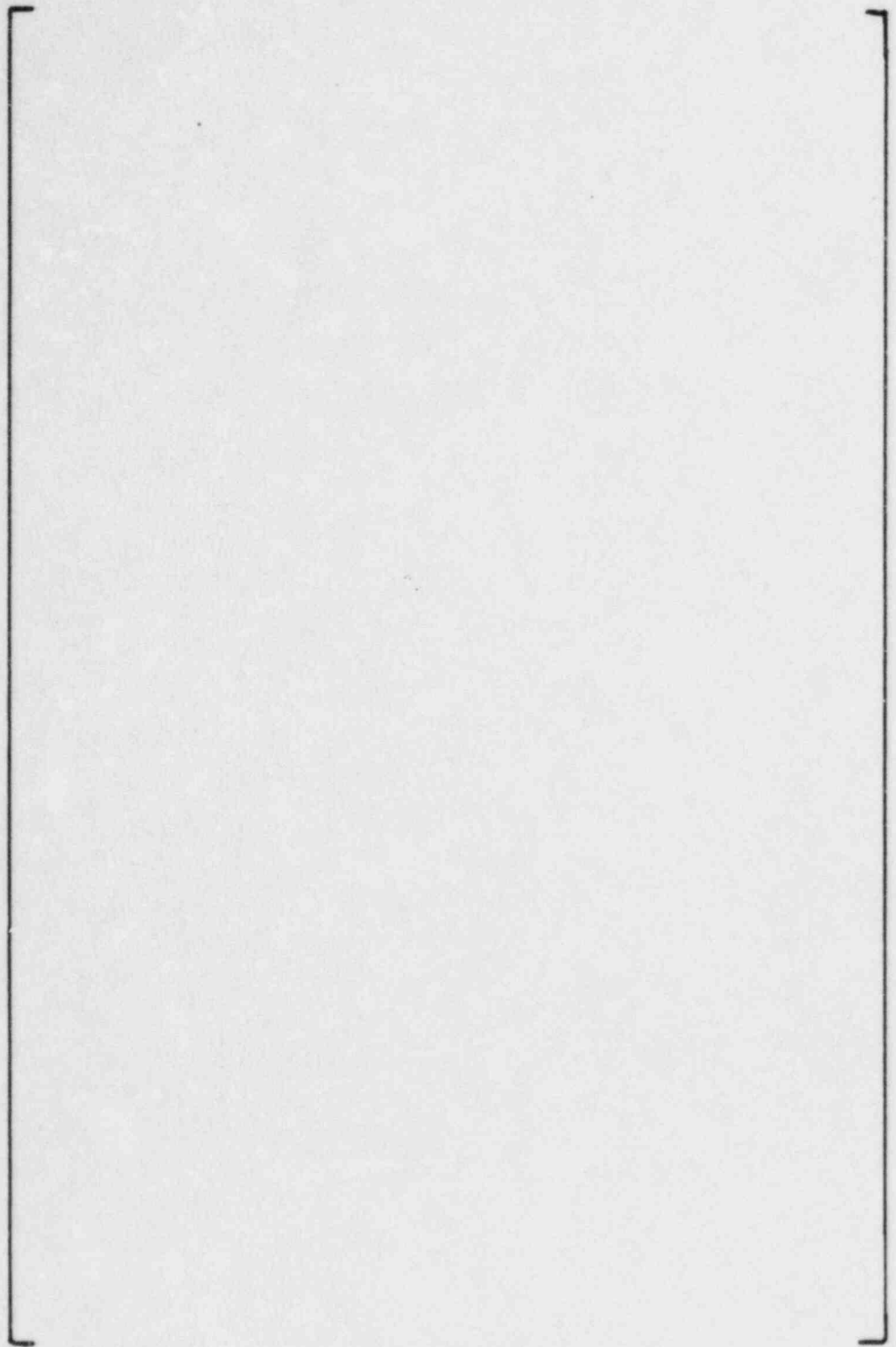
Where [

]

2.2.3 Improvement to UPDATE Algorithm

Change:

The penalty on DNBR in UPDATE will be modelled more realistically.
When the [

]

[

]

Reason:

The UPDATE algorithm of CPC provides rapid and conservative
recalculation of DNBR based upon the detailed DNBR calculation
contained in the STATIC algorithm and updated state parameters.
During the CPC overall DNB uncertainty analysis, off-line
comparisons of UPDATE and STATIC-predicted DNBRs based on

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period are used to quantify the conservatism. Presently, the UPDATE
algorithm of CPC applies a penalty to the updated DNBR at all times.
This change provides greater margin to pre-trip alarms during steady
state operation and is justified by the high accuracy of the UPDATE
algorithm for small changes in conditions. The safety margin of the
CPC's during transients is preserved by the larger conservative
penalty factors which are applied when the UPDATE DNBR changes
significantly from the STATIC value.

Description:

where

[

]

2.2.4   Modification of Heat Flux Distribution Extrapolation in STATIC

Change:

Modify the heat flux distribution extrapolation in STATIC[   ]
[   ] nodal heat flux distribution values.

Reason:

For certain CEA configurations, radial peaking factor assignments,
and/or radial peaking factor multipliers, it is possible to
[

]

Description:

This change is applied in the section of the STATIC program where
[   ].

A check is performed for [   ]. If any are
detected, [   ].

2-11

[   ]

Where:

$\phi_c(i)$ = [ ] node hot pin normalized heat flux distribution

2.3   CPC ADDRESSABLE CONSTANT CHANGES

1. Change·

    Addressable constant [   ]
    replaces [   ].

    Reason:

    Consistent with TSF algorithm change described in section
    2.2.1.

    Description:

    [

                                                                    ]

2. Change

    Addressable constant [   ] has been
    added to the CPC in relation to the core power level.

    Reason:

    To implement new algorithm using [   ]
    and [   ] bias terms described in section 2.2.2.

    Description:
    [   ]

2.4   TYPICAL DATA BASE CONSTANTS CHANGES FOR SONGS UNIT 2

2.4.1   <u>Data Base Constants for the Temperature Shadowing Factor Algorithm</u>
         <u>Constants.</u>

[

]

2.4.2   <u>Data Base Constants for Power Dependent Biases</u>

[

]

[

]

2.4.3   Data Base Constants for DNBR Penalty in UPDATE

[

]

2.4.4   Change in UPDATE DNBR Uncertainty and Threshold Constants

[   ]

[ ]

2.4.5   Data Base Constants for RPC Algorithm

[ ]

2.5   REFERENCES FOR SECTION 2.0

1. Dockets STN-50-470F, Enclosure 1-NP to LD-82-039, CPC/CEAC Software Modifications for System 80, March, 1982.

2. CEN-147(S)-NP, Functional Design Specification for a Core Protection Calculator, January 1981.

3. CEN-148(S)-NP, Functional Design Specification for a Control Element Assembly Calculator, January 1981.

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