ARKANSAS POWER & LIGHT COMPANY
POST OFFICE BOX 551 LITTLE ROCK, ARKANSAS 72203 (501) 371-4000

January 31, 1980

2-010-25

Director of Nuclear Reactor Regulation
ATTN: Mr. R. W. Reid, Chief
Operating Reactor Branch #4
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Arkansas Nuclear One-Unit 2
Docket No. 50-368
License No. NPF-6
CPC/CEAC Software Modifications
(File: 2-1510)

Gentlemen:

The operating history of ANO-2 has indicated the need for a number of CPC/CEAC software modifications to (1) improve the unit availability and (2) enhance the overall operation of the CPC/CEAC system. We are presently reviewing a software revision to the CPC/CEAC software that will accomplish the above objectives by (1) reducing the probability of spurious trips and (2) providing additional diagnostic information to the plant staff. The purpose of this letter is to provide a description of the software modifications subsumed by this revision for your review.

The software modifications are delineated below and are fully described in the attached 'Description of Mod 2B/3 CPC/CEAC Software Modifications'.

1. Modification of the CPC DNBR update logic to include cold leg temperature difference bias algorithm for asymmetric steam generator transients to enhance CPC response to NSSS Transients.

2. Modification of 16-bit penality factor word to include the DNBR and LPD penalty factors and related operating flags which will improve the transfer of information between the CEACs and CPCs.

3. Addition of a pre-set LPD panalty factor to be used in the calculation of the LPD total CEA deviation penalty factor in the event both CEACs are flagged inoperable.

4. Calculation of an average of the hot channel power distribution for use in computing the integrated one pin radial peak which will improve computer efficiency.

5. Application of the CEAC deviation penalty factor to the core average heat flux rather than to the one pin radial peak to reduce the probability of spurious channel trips and increase reactor availability.

8002260 718 P

6. Calculation of the integrated one pin peak, hot pin heat flux distribution, hot pin axial shape index, and integrated hot pin heat flux during the STATIC DNBR program in order to improve computer efficiency and to ensure the most up-to-date values are used in the calculation of the STATIC DNBR.

7. Addition of a deadband at the low end of the excore detector signal range to reduce the sensitivity of the low end out-of-range alarm to signal noise.

8. Modification of the shape annealing correction logic to include checks and corrections to top and bottom detector responses.

9. Addition of CPC and CEAC sensors out-of-range status arrays and accessibility of this information via the operator's module and a teletype to increase the diagnostic capabilities.

10. Provision for a "snapshot" of CPC variables at the time of a CPC channel trip to increase the diagnostic information available to the operator and plant engineer to increase their ability to determine the cause of the trip.

11. Modification of logic to indicate which CEAC has failed to increase the availability of the operable CEAC to continue to provide computed deviation penalty factors and CEA positions.

12. Modification of the core average heat flux filter algorithm to reduce the sensitivity of the heat flux calculation to noise.

13. Modification of CEAC logic to compute both a DNBR and a LPD penalty factor to enhance the capabilities of the CPCs, to make the penalty factors subgroup-dependent, and to add flags to the 16-bit penalty factor word for CEAC failure and for multiple CEA deviations within a subgroup and large penalty factors.

14. Provisions for a "snapshot" of CEAC variables at the time of a CEAC penalty factor greater than one or when the larger PF flag is set.

15. Modification to CPCs to include a DNBR correction factor for rod deviation events.

Note that Item 12 above is the software change designated MOD 3, while the remaining items are part of the software change that had been designated MOD 2B. The separate designations arose from differences in time of origin, bases of origin, and other aspects. However, both MOD 2B and MOD 3 are being combined into one revision level of CPC/CEAC discs and documentation. For this reason, any reference to these modifications in this correspondence will be as MOD 2B/3, which better denotes the single revision level.

All the software modifications of MOD 2B/3 will be made in accordance with CEN-39(A), Rev. 2 and CEN-39(A), Supplement 1, Rev. 1. All modifications will be designed such that the CPC/CEAC system will automatically initiate shutdown of the reactor to assure that specified acceptable fuel design limits are not exceeded as a result of anticipated operational occurrences and to assist the Engineered Safety Features in limiting the consequences of certain postulated accidents. The comprehensive software modifications testing program will assure that the modified CPC/CEAC system has been implemented in accordance with the specified functional design.

Our internal review of the MOD 2B/3 is incomplete at this time, but we expect that the software modifications will be found not to constitute an unreviewed safety question. Nonetheless, owing to the extent of the modifications, we are submitting this information for your review.

Sincerely yours,

David C. Trimble

David C. Trimble
Manager, Licensing

DCT:WBM:nak

Attachment

DESCRIPTION OF MOD 2B/3
CPC/CEAC SOFTWARE MODIFICATIONS

1. Change: Modify CPC DNBR update logic to include cold leg temperature difference bias algorithm for asymmetric steam generator transients.

Reason: This modification provides a CPC DNBR penalty based on the cold leg temperature difference caused by an asymmetric steam generator transient. The design basis event is the instantaneous closure of one MSIV. This modification ensures a reactor trip will occur when the DNBR margin is projected to a 1.3.

Description: CPC protection is provided by determining a penalty factor based on the difference between the two cold leg temperatures and then applying this factor to the calculation of the updated CPC-calculated DNBR. The computed temperature difference is compensated by a digital filter. The component temperature difference is used to determine a temperature-related PF component, and the core average power is used to determine a power-related PF component. These PF components are combined to yield the asymmetric SG transient penalty factor (PF_{ASGT}). Calculation of the updated DNBR is modified to include the PFASGT.

2a. Change: Modify 16-bit penalty factor word and associated logic to be consistent with the CEAC modifications.

Reason: Since modifications to the CEAC will now include calculation of a LPD penalty factor (separate from the DNBR penalty factor) and the setting of a flag indicating multiple CEA deviations in a subgroup, the 16-bit penalty factor word will have to be modified to transmit this information.

Description: The 16-bit penalty factor word will transmit to the CPCs the following information in bits location 0-15, respectively:

1. CEAC fail bit (1 bit)
2. DNBR PF minus 1.0 (7 bits)
3. Multiple CEA deviations in subgroup flag (1 bit)
4. LPD PF minus 1.0 (6 bits)
5. Scale flag (1 bit)

Logic will be added to the CEACs and CPCs to pack and unpack this information in the 16-bit penalty factor word.

2b. Change: Add scale type to processing of penalty factors and include scale flag in 16-bit penalty factor word.

Reason: For packing and unpacking the penalty factors in the 16-bit PF word, the highest resolution is obtained if the PF word processed falls within the range of 0 to 1. Therefore, where the adjusted PF (i.e., $PF_{adj.}$ = PF - 1.0) is greater than one, a pre-defined scaling factor is used to convert the adjusted PF to within the 0 to 1 range.

Description: In the CEACs, the adjusted PF, during processing, is compared with small-scale and large-scale limits. The small-scale limit designates the upper bound of the acceptable small-scale PF region. The large-scale limit designates the upper bound of the acceptable large-scale PF region. If the adjusted PF is less than the small-scale limit, it is adjusted by the small-scale scaling factor to fit the 0.0 to 1.0 range. If the adjusted PF lies between the small-scale and large-scale limits, the adjusted PF is scaled down by the large-scale scaling factor to fit the 0 to 1 range. The scaled PF is then processed for packing into the penalty factor word. If the adjusted PF is equal to or greater than the large-scale limit, the large PF flag is set; and a bit pattern indicating a large PF is set in the penalty factor word.

3. Change: Provide pre-set LPD penalty factor for CEAC inoperable mode.

   Reason: At present, if both CEACs are inoperable, a pre-set maximum penalty factor is used to calculate the total CEA deviation penalty factor. By modifying the CEAC-CPC logic to include a LPD penalty factor, a pre-set maximum LPD penalty factor must be added to ensure the logic for the LPD deviation penalty factor is consistent with that for the DNBR deviation penalty factor when both CEACs are inoperable.

   Description: This modification to the CPCs adds logic to compare and select the larger of the two LPD penalty factors received from the CEACs in order to complete the LPD total CEA deviation penalty factor. If one CEAC is failed or in-test, this modification includes logic to compare and select the larger of the penalty factors between (1) the operable CEAC and (2) the previously stored penalty factor from the failed CEAC. It also provides a pre-determined maximum penalty factor to be used in the event both CEACs are inoperable due to being in-test or failed.

4. Change: Calculate an average of the hot channel power distribution and use this variable in calculating the integrated one pin radial peak.

   Reason: At present, the pseudo hot pin axial power distribution is calculated during the power distribution up-date, and this 20-mode power distribution is transferred to the "POWER" program output buffer. It is then used in the calculation of the hot pin heat flux distribution and the integrated one pid radial peak. A nodal summation is performed for each calculation of the one pin peak. Since the pseudo hot pin axial power distribution does not change with each calculation of the one pin peak and updated CPC-calculated DNBR, elimination of this additional summation will improve computer efficiency.

Description: As part of the calculation of the pseudo hot pin axial power distribution, the average of the hot channel power distribution will also be determined. This factor will be transferred to the output buffer for use in the calculation of the integrated one pin radial peak.

5a. Change: Apply the CEAC deviation penalty factor to the core average heat flux rather than to the one pin radial peak.

Reason: CEA deviations currently cause overly conservative DNBR calculations because the penalty factor is applied to the one pin radial peak. This modification applies the deviation penalty factor to the heat flux as an overpower margin correction rather than to the one pin peak.

Description: The CEA deviation penalty factor is deleted form the calculation of the hot pin heat flux distribution and the integrated one pin radial peak in the UPDATE program and is added to the calculation of the adjusted compensated core average power (core average heat flux) in the STATIC program. In addition, the calculation of the integrated one pin radial peak is modified to replace the nodal summation of the pseudo hot pin axial power distribution with the average of the hot channel power distribution.

5b. Change: Modify CEA deviation penalty factor in the calculation of the local power density.

Reason: Present operating limits yield a much greater local power density (LPD) margin than DNBR margin. At present, the same CEA deviation penalty factor is applied to both the DNBR and LPD margin calculations. As a result, a DNBR-initiated reactor trip will always occur before a LPD-initiated trip. To conserve the same relationship between DNBR and LPD, a separate LPD penalty factor is calculated and applied to the calculation of the uncompensated local power density in te UPDATE program.

Description: In the UPDATE program, the equation for the uncompensated local power density is modified by substituting the CEA deviation LPD penalty factor for the CEA deviation DNB penalty factor.

6. Change: Perform calculation for integrated one pin peak, hot pin heat flux distribution, hot pin axial shape index, and integrated hot pin heat flux in the STATIC program.

Reason: The calculation of the STATIC DNBR is initiated immediately after the power distribution calculation. However, the heat flux data used in the STATIC DNBR calculation are obtained from the UPDATE program, which uses power distribution data from the last execution of the POWER program. This could result in these data being as much as 1.0 seconds old, and, therefore, inappropriate for use in the STATIC DNBR calculation. This modification ensures the most up-to-date power distribution data are used in the calculation of the STATIC DNBR.

Description: This modification calculates the integrated one pin peak, hot pin heat flux distribution, hot pin axial shape index, and integrated hot pin heat flux in the STATIC program prior to the calculation of the revised STATIC DNBR. Output buffer storage space is conserved by not transferring these values to the output buffer of the UPDATE program.

7. Change: Add deadband at low end of excore neutron flux detector signal range.

Reason: The low end of the excore detector signal range is equivalent to a hot standby operating condition. If the raw excore detector signal is less than the raw excore detector signal lower limit, the detector signal is set equal to the scaled detector signal lower limit and a sensor failure alarm is initiated. This format is sensitive to signal noise and results in unnecessary spurious sensor failure alarms at zero power. This modification adds a deadband to the low end of the excore detector signal range, which reduces the probability of spurious alarms.

Description: A raw excore neutron flux signal low limit alarm setpoint value has been added to the sensor failure logic in the CPCs. The alarm setpoint is less than the signal lower limit. If the raw signal lies between the signal lower limit and the low limit alarm setpoint, the signal is set equal to the lower limit. If the raw signal is equal to or less than the low limit alarm setpoint, the signal is set equal to the lower limit and a sensor failure alarm is initiated.

8. Change: Modify shape annealing correction logic to include checks and corrections to top and bottom detector responses.

Reason: At present, the logic indicates that if the detector segment response for the upper third of the core is less than 3%, then the peak is in the bottom of the core; and the detector segment response for the lower third of the core is not checked. This modification ensures that both the upper and lower detector responses are checked.

Description: The shape annealing correction logic has been adjusted to ensure that both the upper and lower detector responses are checked.

9. Change: Add CPC and CEAC sensors out-of-range status arrays and make accessible for display via the operator's module and a teletype.

Reason: Sensor status information is provided so the operator is aware of which sensor has failed and to aid the plant engineer in compiling a history of sensor out-of-range failures.

Description: Both a CPC and a CEAC failed sensor stack will be implemented. Each stack will contain a maximum of six failed sensors, the failed sensor ID, a sensor status and failure type indicator, and a time associated with the failure. New failed sensors will be added at the top of the stacks, and excess failed sensors (in excess of six) will be deleted from the bottom of the stacks. The sensor failure stacks will be accessible for display through the operator's module and a teletype.

10. Change: Provide a "snapshot" of CPC variables at the time of a CPC channel trip.

Reason: There is currently no CPC/CEAC information retained to determine the inputs and calculated variables at the time of trip. As a result, determining the cause of trip is sometimes difficult, particularly if caused by spurious, momentary causes external to the CPC/CEAC system. Providing a list of variables at the time of channel trip will increase the ability of the operator and plant engineer to determine the precise cause of the trip.

Description: When a trip signal is generated in a CPC channel, a "snapshot" of specified variables will be transferred to a buffer that is accessible by teletype. These specified variables will include the following:

1. All CPC inputs (Pump Speeds in Fraction, not counts)

2. From Trip Sequence Program:
MINDNB - Minimum DNBR with uncertainty factor.

3. From Flow
MC - calibrated CPC mass flow rate
MCS - past value of calibrated CPC mass flow rate
X1 - flow projected DNBR

4. From UPDATE
BDT - CPC Static Thermal Power
BDTD - Total Thermal Power
PHICAL - Neutron Flux Power
PF - DNBR Penalty Factor
PFLPD - Local Power Density Penalty Factor
LPDDC - Compensated Local Power Density
FCALC - Core Average Heat Flux
P1 - One Pin Radial Peak
D - Maximum Value of FR^4FZ
QASI - Hot Pin Axial Shape Index
DXMIN - Updated Minimum Quality
X2 - Updated DNBR
X3 - Pressure-Projected DNBR
TCMAX - Maximum Cold Leg Temperature

5. From POWER
   ASI - Axial Shape Index

6. From STATIC

DST	-	Static Maximum of FR^4FZ
MCST	-	Static Mass Flow Rate
PRST	-	Static Pressure
TCMST	-	Static Cold Leg Temperature
FCALCST	-	Static Heat Flux (Compensated Core Average Power)
HMAX	-	Maximum Core Exit Enthalpy
HF	-	Enthalpy of Saturated Fluid
PFST	-	Static DNBR Penalty Factor

7. The addressable constants

8. The time of the trip.

An addressable constant will be provided to reset (clear) the buffer. The "snapshot" will be of the first channel trip after the buffer is cleared. In addition, an auto-restart will not clear the buffer, but a software reload will.

11. Change: Modify logic to indicate which CEAC has failed.

Reason: At present when operating in the CEA INOP mode, if one CEAC is indicated inoperable, then both CEACs are considered inoperable. This modification expands the CEAC INOP status in the CPCs to indicate which CEAC is inoperable and to specify the DNBR and LPD penalty factors to be used. In this manner, if one CEAC is inoperable, the penalty factors from the operable CEAC will continue to be used.

Description: The addressable constant CEANOP, which indicates to the CPC which CEAC has failed, will have four allowable values: CEANOP = 0, 1, 2, 3. The following listing summarizes the steps the CPC will take for each value of CEANOP.

0 - Both CEACs operable. Use DNBR and LPD penalty factors determined by the CEAC's.

1 - CEAC1 inoperable. Use last good DNBR and LPD penalty factors from CEAC1. Auctioneer with penalty factors from CEAC2. Record failure in failed sensor stack.

2 - CEAC2 inoperable. Use last good DNBR and LPD penalty factors from CEAC2. Auctioneer with penalty factors from CEAC1. Record failure in failed sensor stack.

3 - Both CEAC's inoperable. Use predetermined DNBR and LPD penalty factors.

12. Change: Modify core average heat flux filter algorithm

Reason: In the calculation of the core average heat flux, the adjustment of the static component of thermal power by the dynamic component can result in increases in the total thermal power that are highly sensitive to noise. This modification reduces the step increases and decreases due to the biases and, therefore, reduces the sensitivity to noise. It includes the addition of a second digital filter to optimize for increasing power.

Description: Up until now the static thermal power has been biased with the dynamic component to yield the total thermal power. The larger of the thermal power and the calibrated neutron flux power is returned as the core average power, which is compensated by two digital filters to yield the core average heat flux. Because of the wide swings in power due to the dynamic bias and the filter compensation, this method has been sensitive to noise.

This modification to the CPCs separates the application of uncertainty terms and filter compensation to the calibrated neutron flux power and thermal power. The calibrated neutron flux power is biased for uncertainties and compensated by a digital filter to optimize for increasing power. The static component of thermal power is increased by the dynamic component. The resulting total thermal power is biased for uncertainties and compensated by two digital filters to optimize for increasing and decreasing power. The larger of the optimized thermal power values and the optimized calibrated neutron flux power is returned as the core average heat flux. This modification also includes changes to the data base constants to account for the additional digital filter and for the functional change in the application of the original two digital filters.

This modification provides for:

a) reduced workload requirement for the dynamic component,

b) compensation of the calibrated neutron flux power with the uncertainty bias and digital filter to optimize for increasing power,

c) computation of a value of core average heat flux with a reduced value of the dynamic compensation,

d) compensation of the total thermal power with an uncertainty bias and two digital filters to optimize for increasing and decreasing power,

e) selection from the optimized calibrated neutron flux power and optimized total thermal power the maximum value as the core average heat flux.

13a. Change: Modify CEAC logic to compute both a DNBR and a LPD deviation penalty factor.

Reason: At present, the same CEA deviation penalty factor is applied to both the DNBR and the LPD margin calculations. As a result, the limiting value of two penalty factors must be used by the CEAC in its data base for calculating a penalty factor to be passed to the CPC. Since the limiting value is the LPD penalty factor, which is significantly higher than the DNBR penalty factor, an excessively conservative penalty factor is applied to DNBR calculations. This modification adds a separate LPD penalty factor, which is processed for output to the CEAC-CPC data link.

Description: In computing the DNBR and LPD penalty factors, the CEAC determines the lowest and highest CEA position in each subgroup and then computes the deviation magnitude between these two positions. If the deviation magnitude is less than a deviation deadband, then no penalty factor is required for that subgroup. Otherwise, the penalty factors are determined based on the amount of the deviation magnitude. With this method, the penalty factors are group-dependent.

13b. Change: Modify CEAC logic to compute a dynamic Xenon PF component and apply component to the calculation of the DNBR and LPD subgroup penalty factors.

Reason: Any excessive CEA deviation will result in Xenon redistribution within the core. The impact and magnitude of the Xenon redistribution is directly dependent on the length of time of the deviation. For a case where a CEA is withdrawn from the core, the power in the region of the withdrawn CEA is increased which burns off the Xenon in that region. With less Xenon in that region than in the remainder of the core, the radial peak will increase. For a case where a CEA in inserted into the core, the power in the region of the inserted CEA is decreased which causes a buildup of Xenon in that region. As a result, the core will have relatively less Xenon than the region of the inserted CEA and the core average radial peak will increase. The impact of Xenon redistribution occurs over a period of hours. To account for this phenomenon, a dynamic component is determined and applied to the calculation of the DNBR and LPD subgroup penalty factors.

Description: A Xenon PF component is applied by maintaining an elapsed time counter for each subgroup. The counter is started when excess deviation in the subgroup is first detected, is frozen at a maximum elapsed time, and is reset to zero when the excess deviation is removed. The Xenon PF component is computed as a function of elapsed time.

13c. Change: Add a flag to indicate CEA failure to the 16-bit penalty factor word.

Reason: An excessive number of deviations in a core quadrant or an excessive number of failed CEA sensors throughout the core could be indications of power supply problems. If the number of deviated CEAs per core quadrant or the number of failed CEA sensors exceed pre-set values, the CEAC failure flag is set.

Description: Up until now, the left-most bit in the 16-bit penalty factor word has been used to indicate a CEAC in-test mode of operation. This modification to the CEAC program expands the use of this bit to indicate CEAC failure. This indicator or flag may be set as a result of failure summations in two sections of the CEAC program. When the raw CEA positions are interrogated, if the CEA position exceeds the out-of-range or rate-of-change checks, the sensor failed flag is set for that CEA and the failure is added to a running sum. In the next section of the program, the deviation magnitude and deviation type are determined. During this process, the number of subgroups containing excessive deviations is summed per core quadrant. During the calculation of the penalty factors, the total number of sensor failures and the total number of deviated CEAs per core quadrant are checked. If either of these sums exceed pre-set values, the CEAC failure flag is set.

13d. Change: Add a flag to the penalty factor word to indicate 2 or more deviated CEAs within a subgroup.

Reason: Two or more deviations within a subgroup could indicate excessive RSPT failures or power supply problems Therefore, if this condition exists, the 16-bit penalty factor word should be set to a multiple deviation indicator and the operator alerted to the condition.

Description: The processed CEA positions are manipulated on the subgroup level to determine the deviation magnitude, deviation type (CEA withdrawal or CEA insertion), and overall group configuration. These quantities are found by first sorting the CEAs in the subgroup by relative position. The deviation magnitude is calculated from the most and least withdrawn CEAs. The definitions for the deviation types are the following:

0 - subgroup lies totally within the upper or lower core deadband (i.e., no CEA deviation).

± 1 - single CEA withdrawal (+1) or insertion (-1).

± 11 - 5 CEA subgroup to distinguish deviations of center CEA.

2 - multiple CEA deviation within a subgroup.

During determination of the deviation types, if multiple CEA deviations are detected in a subgroup, the deviation type is set to 2. As a result, the large PF flag is set and processed for output to the CEAC-CPC data link as one bit of the 16-bit penalty factor word; and the deviation alarm is initiated. The large PF flag is also set if the adjusted DNBR and LPD penalty factors equal or exceed the large-scale PF region limits.

14. Change: Provide a "snapshot" of CEAC variables at the time of a CEAC penalty factor greater than one or when the large PF flag is determined.

    Reason: There is currently no CPC/CEAC information retained to determine the CEA position inputs and calculated penalty factors at the time a large penalty factor is calculated or the large PF flag is set. As a result, determining the cause of failure is sometimes difficult, particularly if caused by spurious, momentary causes external to the CPC/CEAC system. Providing a list of variables at the time of either of the aforementioned occurrences will increase the ability of the operator and plant engineer to determine the precise cause of the trip.

    Description: A "snapshot" of CEA positions, penalty factors, and time of deviation occurrence shall be stored when initiated by a CEAC penalty factor greater than one or by the large PF flag. This "snapshot" shall be accessible by teletype. In addition, the CRT display will exhibit an indicator over each subgroup with a deviation to indicate whether the deviation initiated an alarm or a penalty factor.

15. Change: Add DNBR correction factor algorithm to CPC UPDATE program.

    Reason: In the past, a red insertion event would-in all likelihood-cause a reactor trip because the penalty factors generated as a result of the rod deviation would be conservative. This process did not fully take into consideration available overpower margin. These changes, which incorporate a DNBR correction factor into the CPCs, take credit for available overpower margin.

    Description: The DNBR penalty factor is saved in a PF array for 35 executions of the UPDATE program. After updating for DNBR and quality changes, the power margin loss is computed using the most recent and the oldest DNBR penalty factors from the PF array. If the power margin loss violates minimum acceptable conditions, a DNBR correction factor is selected and applied to the calculation of the updated CPC calculated DNBR (X2).