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Mr Kniel	one signed			XX	XX

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ENCLOSURES:

Responses to Questions concerning boron precipitation following LOCA..........

ACKNOWLEDGED
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PLANT NAME: Cook 1 & 2

FOR ACTION/INFORMATION 4-21-75 ehf

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INDIANA & MICHIGAN POWER COMPANY

P. O. BOX 18
BOWLING GREEN STATION
NEW YORK, N. Y. 10004

April 14, 1975

Docket No. 50-315
and 50-316
CPPR No. 61, DPR No. 58

Mr. Karl Kniel, Chief
Pressurized Water Reactors
Branch No. 2
Directorate of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Kniel:

In response to your letter dated March 14, 1975, the system capabilities and operating procedures with regard to boron precipitation following a postulated loss-of-coolant accident (LOCA) have been evaluated for the Donald C. Cook Nuclear Plant, Units 1 and 2. The results of this evaluation are discussed below.

The operating procedures for the Donald C. Cook Nuclear Plant require switchover of the emergency core cooling system (ECCS) from Reactor Coolant System cold leg to hot leg injection 24 hours after the accident. This procedure will preclude the possibility of exceeding boron solubility limits as is shown in the attached analysis. This analysis was also transmitted to Mr. T. M. Novak of the NRC staff in a letter from C. L. Caso of the Westinghouse Electric Corporation designated in CLC-NS-409 and dated April 1, 1975. Also enclosed is a copy of the Donald C. Cook Nuclear Plant operating procedure OHP 4022.008.002 titled "Initiation of ECC Recirculation Phase" which is the operating procedure calling for switchover from cold leg to hot leg injection.

With regard to system capability, redundancy in equipment is provided in both the high head and low head systems for hot leg recirculation. Each safety injection pump and low head (RHR) pump share a header which injects into two cold, or two hot legs. The switch-over from cold to hot leg injection is accomplished by

4250

closing the cold leg motor operated valve, and opening the hot leg motor operated valve. Thus with the worst single failure, at least one high head and one low head pump are available for hot leg recirculation. This system is described in the Donald C. Cook Nuclear Plant Final Safety Analysis Report, Section 6 and Appendix I.

There is a question on the environmental effects on the motor drives for the valves which are used to transfer from cold to hot leg injection which we are in the process of resolving. We are currently investigating this and will notify the Commission of our findings as soon as our investigation is completed.

Very truly yours,

John Tillinghast
Vice President

JT:ma

cc: Gerald Charnoff, Esq.
Richard Walsh, Esq.
Robert J. Vollen, Esq.
Robert C. Callen, Esq.
Peter W. Steketee, Esq.
R. S. Hunter
R. W. Jurgensen - Bridgman

ATTACHMENT TO AEW-6281

Wes_house Electric Corporation   Power Systems

PWR Systems Division
Box 355
Pittsburgh Pennsylvania 15230

April 1, 1975
CLC-NS-309

Mr. T. M. Novak
Chief, Reactor Systems Branch
U.S. Nuclear Regulatory Commission
7920 Norfolk Avenue
Bethesda, Maryland 20014

Dear Mr. Novak:

As we have discussed, enclosed is a discussion of some phenomena concerning the long term build up of boric acid in the core region following a postulated LOCA. This discussion is a generic document covering Westinghouse 2, 3 and 4 loop plants.

The discussion re-emphasizes the adequacy of the current Westinghouse ECCS design concept in addressing long term core cooling needs.

Very truly yours,

Carlo Caso

C. L. Caso, Manager
Safeguards Engineering

CLC:jmb

Enclosure

To Tom N[illegible] 4/1 w/ letter # [illegible]LC-NS-309

LONG TERM CORE COOLING-BORON CONSIDERATIONS

INTRODUCTION

Immediately after a hypothetical loss of coolant accident, LOCA, the safety injection system is supplied with borated water from the Refueling Water Storage Tank (RWST) and delivers to the reactor coolant system cold legs. When the low level signal from the RWST occurs, at approximately 20 minutes after the accident, the safety injection system is realigned to draw water from the containment sump. The safety injection system delivers to the cold legs of the reactor coolant system until 24 hours after the accident. This is commonly referred to as sump recirculation phase. At 24 hours the safety injection system is realigned to deliver to the RCS hot legs. This is commonly referred to as the hot-leg recirculation phase.

I. COLD LEG BREAK

A. Basic Phenomena

Calculations were performed to determine the concentration of boric acid in the core region at 24 hours, following a cold leg break. For this analysis, both the core water volume and the water volume in the upper plenum, but below the lower lip of the hot leg nozzle were considered.

Figure 1 presents solubility data for boric acid. Table I summarizes the results for typical 2, 3 and 4 loop plants. The calculations were done assuming license core power and ANS finite decay heat.

It can be seen that these conservative calculations are close to the solubility limits for boric acid of 212°F. Several approximations in these calculations can be identified.

A. Basic Phenomena

Table I shows the effect of maximizing the steam boiloff rate (and consequently the boron build up rate) by assuming that the injected ECC water is at saturation temperature. This assumption ignores the heat capacity of the subcooled injection water. Table I also shows the effect on the weight percent boric acid at 24 hours assuming that the injected water is subcooled by 80 Btu/lbm (H_1 = 116 Btu/lbm). As another conservatism, the volatility of boric acid into steam is ignored. Although the distribution coefficient of boric acid between the vapor and liquid phases is small, the integrated effect would be appreciable, due to the large mass of vapor generated. For example, if it is conservatively assumed that the boric acid concentration is uniform at 10% of the initial 24 hours, and a distribution coefficient, D, of 0.005 is used, it can be calculated that 1500 lb_m of boric acid would be volatilized in the typical 4 loop case. This, in turn, would lead to a reduction of the boric acid in the core from 27.2% to 25.1% at 24 hours. More realistic calculations including temperature dependent D-values and time history core boric acid concentrations would be expected to increase this margin. This assumption of not including the volatility tends to maximize the boric acid build up rate. Another conservatism in these calculations is based on the specific gravity of boric acid solutions. As the concentration of H_3BO_3 increases, the specific gravity increases. Since the solution in the lower plenum is more dilute than that in the core, the heavier core solution would tend to migrate to the lower plenum. This would effectively increase the water volume available for the concentration of H_3BO_3.

A more realistic assumption to be considered is to include the effects of voids in the core region. These voids reduce the mass of water in the core region, even though the total amount of water above the lower core plate remains essentially the same in such a way that the elevation head in the core region equals the elevation head in the downcomer. If the mass in the core only is considered a smaller mass of boric acid would be necessary to bring this mass of water to the solubility limit.

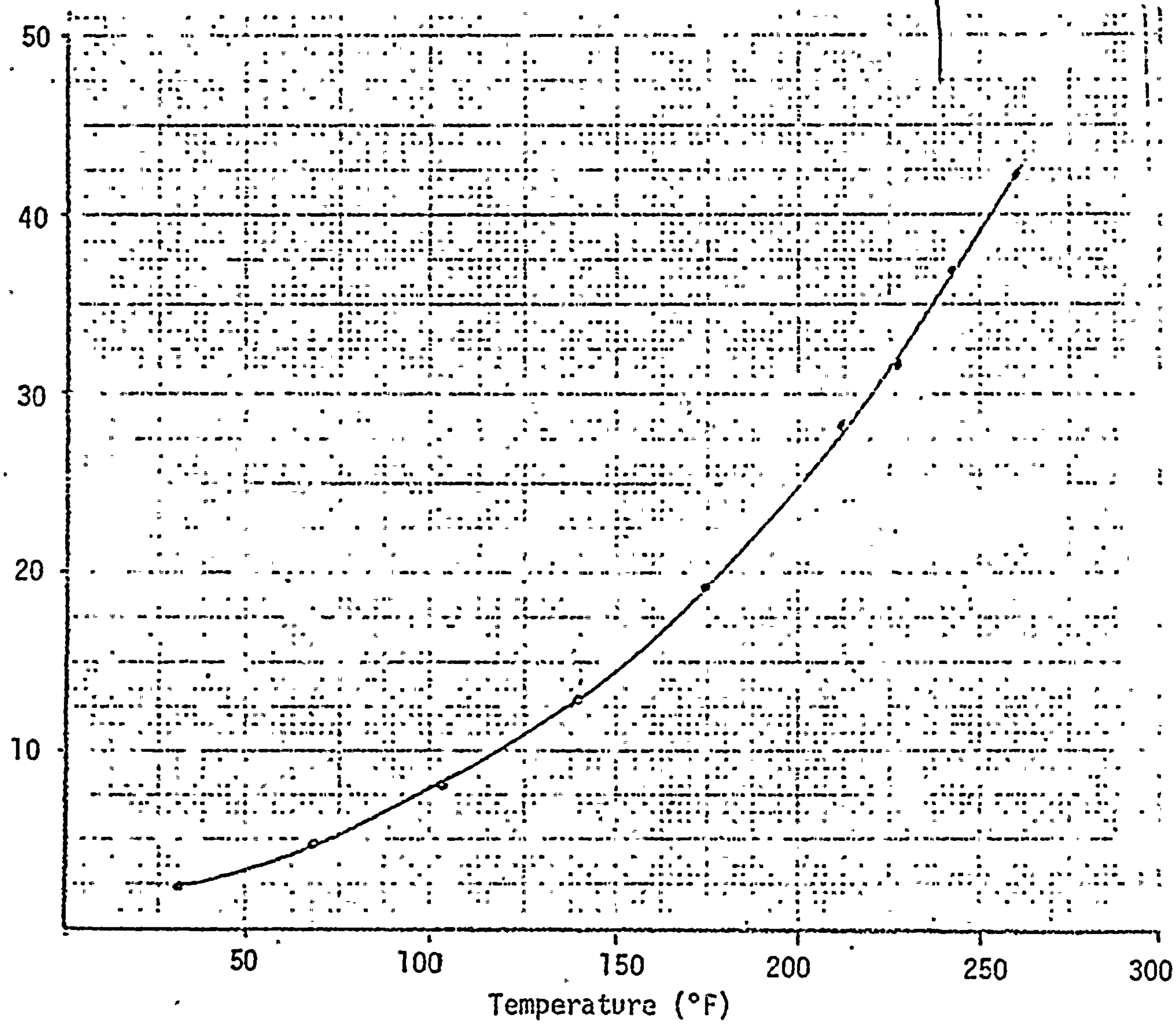
In order to assess some effects of the above considerations, it was decided to perform calculations including the voids in the core and the specific gravity. The results are discussed in the following section.

TABLE I

	2 Loop	3 Loop	4 Loop
NSSS Power (MWt)	1650	2785	3425
Total Sump Inventory (lbm)	2.5×10^6	3.3×10^6	3.6×10^6
Initial ppm Boron in System	2000	2000	2000
Effective Vessel Volume (ft^3)	590	854	1154
Weight Percent Boric Acid in Vessel at 24 hours Using $(h_g - h_f)_{sat}$	27.8	30.6	27.2
Weight Percent Boric Acid in Vessel at 24 hours Using $(h_g - h_{inj})$ where $h_{inj} = h_f - 80 \frac{btu}{lbm}$	26.7	29.0	25.8

FIGURE I

SOLUBILITY LIMIT OF BORIC ACID SOLUTIONS



(Encyclopedia of Chemical Technology, Page 612, Table 2)

B. <u>The Effects of Voids in the Core and Solution Density Changes</u>

Since the concentration build up takes place in the core, there will be an increase in the density of the solution. Since the water in the lower plenum is at a lower concentration of boron than that in the core, under isothermal conditions, the fluid in the core would migrate to the lower plenum.

However, if it is assumed that the lower plenum is at a lower temperature than the core, it becomes necessary to establish the point at which temperature effects on density are balanced by the concentration effects. For example, if it is assumed that the core is at 212° and the lower plenum is at 130°, the difference in specific gravity is 0.9581 - 0.9860 = 0.0279. From Figure 2, it can be seen that a difference in concentration of 8.5% will balance that effect. The boric acid concentration in the lower plenum is at a maximum of 1.144 Wt% Boric Acid initially if Boron of 2000 ppm concentration (equal to that used in the RWST) is assumed to exist at the initialization of the boric acid concentration calculation. This would require approximately an upperbound of 9.6 Wt% Boric Acid concentration in the core to initiate migration to the lower plenum. In this calculation, the ΔT was conservatively maximized. The mixture flowing to the lower plenum will not precipitate boron since concentration @ 130°F = 11.5% > 9.6%. Thus mixing starts before precipitation threshold.

Hence, in the worst case, when the concentration in the core exceeds the concentration in the lower plenum by 8.5%, downward migration would be expected. The Davis curves[3] show that at low pressures the critical steam velocity for carry-over is about 10 ft/sec. After about 3 hours the average steam velocities in the core are less than 10 ft/sec and therefore the migration of fluid to the lower plenum is not prevented Furthermore, a continuous supply of water to the core is insured due to the available driving force of a full downcomer. One of the effects of this migration would be to increase the temperature of the lower

plenum. A natural circulation pattern would be established which will result in subsequent dilution of boric acid in the lower plenum. In summary, when the volume of the lower plenum is included in the inventory available for storage of the concentrated boron solution, the results shown in Table 2 are obtained. These results do not consider boron volatility which will redistribute boron in all the water mass above the core thus further reducing the boron concentration.

TABLE 2

Parameters used to Calculate Boric Acid Concentration in Vessel at 24 Hours

NSSS Power (Mwt)	1650	2785	3425
Total Inventory in Sump	2.5×10^6 lbm	3.3×10^6 lbm	3.6×10^6 lbm
Initial ppm B in System	2000	2000	2000
Effective* Vessel Volume	819.0 ft^3	1284.0 ft^3	1637.7 ft^3
Containment Pressure (psia)	20.0	20.0	20.0
Wt. % Boric Acid	21.7	22.0	20.5

*Effective Vessel Volume includes lower plenum volume and core volume with a void fraction of 30% in the core.

The above analyses were performed assuming $\alpha = 0.3$ in the core and mixing with the lower plenum volume. A void fraction in the core of 30% was used as it corresponds to the void fraction in the core at 24 hours. The boric acid concentration in the core at 24 hours depends on the void fraction at that time. Varying the void fraction in the core during the transient has little effect on the calculation of the boric acid concentration at 24 hours. The reduction of void fraction in the core caused by a reduction in decay heat results in an increase of water mass in the core. This additional water mass dilutes boron since it is supplied by sump, downcomer, and lower plenum liquid which has a lower boric acid concentration.

Clearly, these results show considerable margin to the solubility limits at 212°F.

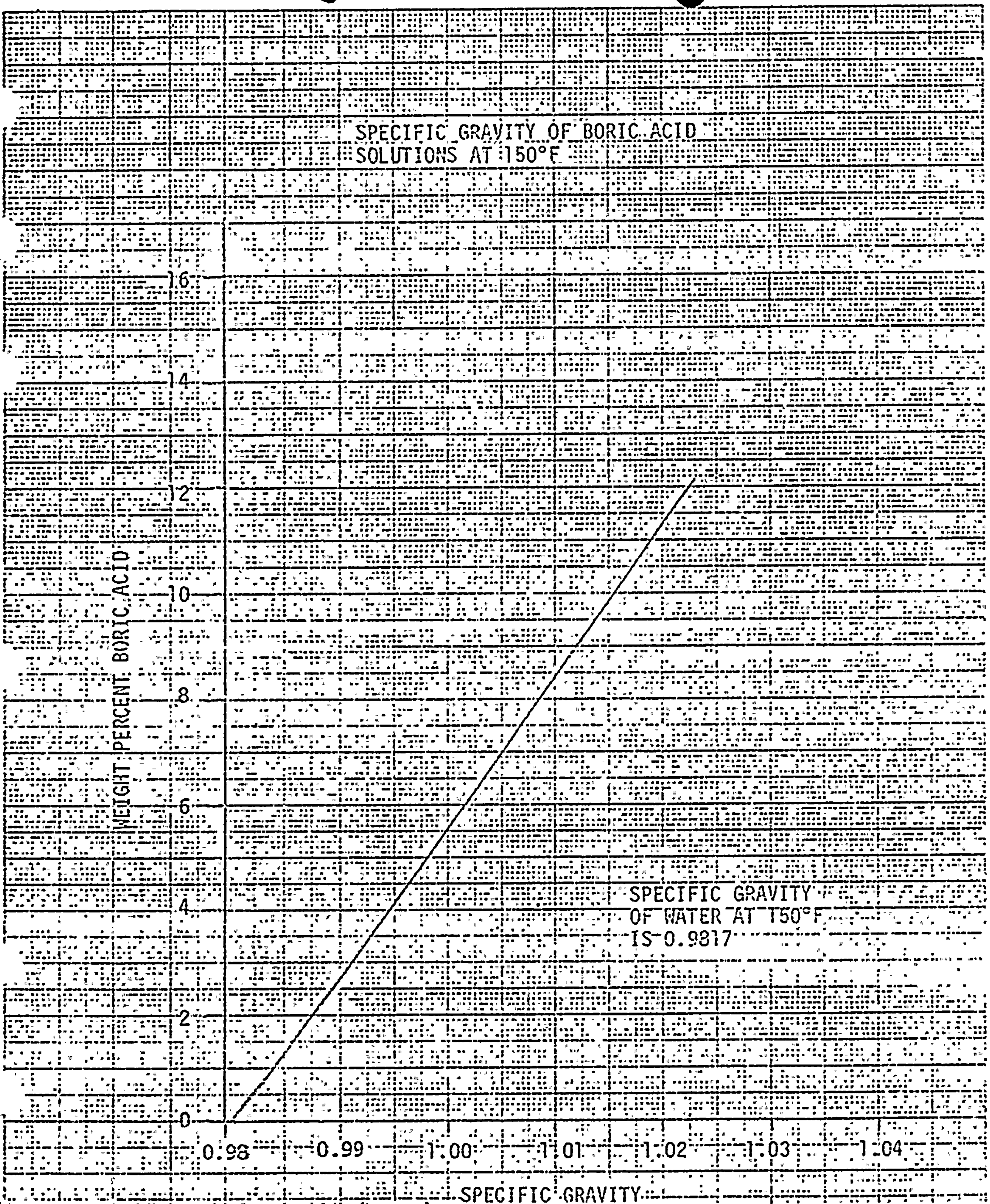

SPECIFIC GRAVITY OF BORIC ACID
SOLUTIONS AT 150°F
WEIGHT PERCENT BORIC ACID
16
14
12
10
8
6
4
2
0
0.98
0.99
1.00
1.01
1.02
1.03
1.04
SPECIFIC GRAVITY
OF WATER AT 150°F
IS 0.9817
SPECIFIC GRAVITY

FIGURE 2

II. HOT LEG BREAK

For the large break LOCA in the RCS hot leg, the safety injection flow delivered to the RCS cold legs during the first 24 hours will flow through the core and spill to the containment sump via the broken hot leg. This flow will facilitate sub-cooling of the core at the time when decay heat energy addition can be matched by the safety injection water. The time at which the core becomes sub-cooled depends on safety injection flow rates, the containment pressure transient, core stored and metal heat energy dissipation, and the decay heat energy.

After the safety injection system is realigned at 24 hours to deliver to the RCS hot legs, the cold safety injection flow enters the core and will absorb decay heat energy.* The safety injection flow rates into the core needed to keep the core below saturated conditions are given in Table 3. The values presented are based on a thermodynamic equilibrium calculation at 14.7 psia and an RHR heat exchanger outlet temperature of 130°F. The amount of water needed to keep the core below saturated conditions depends on the decay heat energy addition, containment pressure, and the temperature of the safety injection water drawn from the sump and passed through the Residual Heat Removal (RHR) heat exchangers.

* Decay heat energy addition at 24 hours for the 2, 3, and 4 loop plants is given in Table 2.

For a hot leg break, there would be no excessive boric acid concentration buildup in the core for the first 24 hours due to the direct flow path going from the cold leg injection point, directly through the core, and out the break. After switchover to hot leg recirculation at 24 hours, there would be no significn-t buildup of boric acid in the core since the hot leg injection will condense or prevent boiloff from core. Whether boiloff will re-occur @ 24 hours depends on the Safety Injection System flow delivery capability of each specific plant.

For a plant design where the safety injection flow rate at 24 hours is not adequate to keep the core below saturated conditions, it is necessary to determine the time at which the decay heat energy addition will decrease to a level that matches safety injection capabilities. Table 4 gives the decay heat energy addition and safety injection flowrate needed to keep the core below saturated conditions at various times. Then it is necessary to determine the increase of boric acid concentration in the core due to decay heat mass boiloff after 24 hours. However, it should be noted that because of the reduction in decay heat with time and the absorption of the decay heat by the sensible heat of the injected water negligible or no boil-off will result in this phase.

After the switchover to hot leg recirculation, flow patterns are established in the core, primarily to the density differences between the injected water and the heated water leaving the core. Calculations of these circulation flows in the core are presently underway, and will be reported in the near future.

TABLE 3

	2 Loop	3 Loop	4 Loop
Core Power (MWt)	1650	2786	3425
Safety Injection Enthalpy (Btu/lbm)	98	98	98
Sensible Heat ($h_{sat}-h_{inj}$) (Btu/lbm)	82	82	82
Decay Heat Energy Addition at 24 hours (Btu/sec)	8600	14520	17850
Safety Injection Flowrate needed to keep core below saturated conditions at 24 hours (lbm/sec)	106	178	218

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TABLE 4

	86400 sec (24 hrs)	10^5 sec	$2x10^5$ sec	$4x10^5$ sec	$6x10^5$ sec
Decay Heat Energy Addition* (Btu/sec)	17850	17100	13440	10270	8530
Safety Injection Flowrate** needed to keep the core below saturated conditions (lb_m/sec)	218	209	164	125	104

* Decay Heat Energy Addition is based on a 3425 MWt power. To obtain Decay Heat Energy Addition for another power level divide by 3425 MWt and multiply by appropriate power level in MWt.

** SI Flowrate is based on Decay Heat Energy Addition at 3425 MWt, 14.7 psia containment pressure and a SI temperature of 130°F. To obtain SI flowrate for different conditions divide the Decay Heat Energy Addition by $(h_{sat}-h_{inj})$.

III. SMALL AND INTERMEDIATE BREAKS

For small breaks, an analysis similar to that performed for large breaks was performed to determine the boric acid concentration in the core (0-24 hrs). The major difference between a small break and a large break analysis is that for the small break analysis the average core pressure (from 0-24 hrs) will be somewhat higher than for a large break. This has 3 main effects on the calculation. Higher core pressures result in lower void fractions in the core and would tend to increase the core water inventory. On the other hand, a higher core pressure yields lower saturation water densities and this tends to reduce water inventory per unit core volume. The third effect of increased pressure is to decrease steam boiloff from the top of the core because of the higher subcooling of the injection water.

The calculations presented in Table 1 neglected the effects of subcooling of the injected water. The conservatism in neglecting the subcooling effects is greater for a higher pressure case because the saturation liquid enthalpy increases with increasing pressure. This, in turn, increases the sensible heat of the injected water available to remove decay heat. If the benefit of the subcooling of the injected water is completely neglected and the assumptions used to generate the number presented in Table 2 are used, the calculated boron concentration at 24 hours for a 200 psia case is 23.2%.

Also it is significant to note that for a small break where the pressure remains higher than atmospheric pressure, the solubility limit of boric acid solution will be much greater because the saturation temperature is higher. For example, at 200 psia (TSAT=381°F) the solubility limit is > 42%. Thus for a 200 psia case, the margin between the calculated boric acid concentration and the solubility limit has actually increased.

For a small break that completely depressurizes by 24 hours the analysis of boric acid concentration approaches that of the large break analysis and the 200 psia case presented earlier is expected to be overly conservative.

Hot Leg Recirculation

After hot leg injection is initiated (@ 24 hours) a small break can offer a benefit in terms of steam condensation. For example, in a 4 loop plant, at a pressure of 200 psia and a SI water temperature of 130°F only 66 lbm/sec of SI water is needed to keep the core below saturated conditions at 24 hours instead of 218 lbm/sec at 14.7 psia.

DONALD C. COOK NUCLEAR PLANT

PROCEDURE COVER SHEET

Procedure No.	OHP 4022.008.002
Revision No.	0

TITLE INITIATION OF ECC RECIRCULATION PHASE

SCOPE OF REVISION

SIGNATURES

	ORIGINAL	Rev. 1	REV. 2	Rev. 3
PREPARED BY	[signature]			
QUALITY ASSURANCE REVIEW	[signature]			
INTERFACING DEPARTMENT HEAD CONCURRENCE	N/A			
DEPARTMENT HEAD APPROVAL	[signature]			
PLANT NUCLEAR SAFETY COMMITTEE	[signature]			
AEPSC NUCLEAR SAFETY & DESIGN REVIEW COMMITTEE	N/A			
PLANT MANAGER APPROVAL	[signature]			
DATE OF ISSUE	9-27-74			

INITIATION OF ECC RECIRCULATION PHASE

1.0 OBJECTIVES

1.1 This procedure outlines the steps necessary to terminate the "Injection Phase" of Safety Injection and to initiate the various modes of the "Recirculation Phase" and the "Residual Spray" operation.

2.0 DISCUSSION

2.1 The "Recirculation Phase" is necessary when the water level in the RWST reaches the low level alarm point. The purpose of the recirculation phase is to provide sufficient water to the reactor vessel to prevent any further core damage and to maintain the core in a subcooled condition following the LOCA. After approximately twenty four (24) hours the recirculation is switched from the cold leg injection mode to the hot leg injection mode.

If spray in addition to that provided by the spray pumps is desired "Residual Spray" may be initiated by using one of the RHR pumps.

3.0 SYMPTOMS

3.1 Not Applicable.

4.0 IMMEDIATE ACTION

4.1 Automatic

4.1.1 None

4.2 Manual

4.2.1 Cold Leg Injection Recirculation

4.2.1-1 Bef... starting the Cold Leg Injection, check that the recirculation sump level is adequate to provide the required NPSH for the RHR pumps. (100 inch level light on control panel)

4.2.1-2 Block the automatic Safety Injection Initiation signals at the Control Board. Verify them blocked by the following indications on the Permissive and Interlock Annunciators:

a) Pressurizer SI Blocked LIGHT ON

b) Steamline Isolation SI Blocked LIGHT ON

c) Pressurizer SI Permissive P-11 both LIGHTS ON

d) Lo-LO Tavg Permissive P-12 LIGHT ON

4.2.1-3 Close the "E" and "W" RHR Pump Discharge Cross-Connect Valve IMO-314 & IMO-324.

4.2.1-4 Stop the "W" RHR Pump.

4.2.1-5 Close the "W" RHR Pump Suction Valve IMO-320.

4.2.1-6 Stop the "W" Cont. Spray Pump.

4.2.1-7 Close the "W" Cont. Spray Pump Suction Valve IMO-225.

4.2.1-8 Close the SI Pump Mini-Flow Line Isolation Valves IMO-262 & IMO-263.

4.2.1-9 Open "W" Recirculating Sump Isolation Valve ICM-306.

4.2.1-10 Start the "W" RHR Pump.

4.2.1-11 Open SI Pump Suction from "W" RHR Hx Valve IMO-350.

4.2.1-12 Start the "W" Containment Spray Pump.

4.2.1-13 Close the two SI Pump Discharge Cross-Connect Valves IMO- 270 and IMO- 275.

4.2.1-14 Close the SI Pump Suction from RWST IMO-261.

4.2.1-15 Open SI Pump Suction Cross-Tie to charging pump suction valve IMO-361 & IMO-362.

4.2.1-16 When the RWST Lo-Lo level alarm point is reached, stop the "E" RHR pump.

4.2.1-17 Close the "E" RHR pump suction valve IMO-310.

4.2.1-18 Stop the "E" Containment spray pump.

4.2.1-19 Close the "E" Containment spray pump suction valve IMO-215.

4.2.1-20 Open "E" Recirculating sump isolation valve ICM-305.

4.2.1-21 Start the "E" RHR Pump.

4.2.1-22 Start the "E" Containment spray pump.

4.2.1-23 Open "E" RHR Hx to Charging Pump Suction Valve IMO-340.

4.2.1-24 Close Charging Pump Suction from RWST Valves IMO-910 and IMO-911.

5.0 SUBSEQUENT ACTION

5.1 Switching from Cold Leg Recirculation to Hot Leg Recirculation Mode.

5.1.1 Close the Cold Leg Injection Isolation IMO-315.

5.1.2 Open Hot Leg Injection Isolation, Loop 1 & 4, IMO-315.

5.1.3 Verify Hot Leg Injection Flow to Loops 1 & 4 on IFI-310 and IFI-311.

5.1.4 Close the Cold Leg Injection Isolation Valve IMO-326.

5.1.5 Open Hot Leg Injection Isolation, Loops 2 & 3, Valve IMO-325.

5.1.6 Verify Hot Leg Injection Flow to Loops 2 & 3 on IFI-320 & IFI-321.

5.2 To align the "E" RHR Pump for Residual Spray Operation.

<u>CAUTION</u>: The flow directly to the core from the RHR pump must be terminated before initiating residual spray. Allowing flow from the pump directly to the core, to the high head pumps and to spray may result in a runout flow greater than design for the RHR pump.

5.2.1 If on Hot Leg Injection, close the Hot Leg Injection Isolation Valve IMO-315.

5.2.2 If on Cold Leg Injection, close the Cold Leg Injection Isolation Valve IMO-316.

5.2.3 Open "E" RHR Hx to Upper Spray Header IMO-330.

5.2.4 Verify flow to the Spray Header on IFI-330.

Intermediate Break

The analysis for intermediate breaks are expected to approach that of the large break analysis but should be bounded by the large and small break analysis because the pressure transient is bounded.

Docket Nos. ~~50-315~~
50-316

APR 1 1975

American Electric Power Service Corporation
ATTN: Mr. John E. Dolan
Executive Vice President
2 Broadway
New York, New York 10004

Gentlemen:

Thank you for your letter dated January 21, 1975, which forwarded a report pursuant to 10 CFR 50.55(e) describing the safety implications of the welding deficiency that occurred at Donald C. Cook Nuclear Plant, which had been inadvertently omitted from your report dated October 23, 1974. Your report will be reviewed and evaluated. Should we require additional information concerning this matter, we will contact you.

Your cooperation concerning this matter is appreciated.

Sincerely,

Original signed by
J. G. Davis

John G. Davis
Deputy Director for
Field Operations
Office of Inspection
and Enforcement

bcc: PDR
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