NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

APR 25 1979

MEMORANDUM FOR: E. G. Case, Deputy Director, Office of Nuclear Reactor Regulation

FROM: D. F. Ross, Jr., Deputy Director, Division of Project Management, NRR

SUBJECT: SUMMARY OF MEETING WITH B&W REGARDING NATURAL CIRCULATION CONSIDERATIONS

On April 18, 1979 the NRC staff met with representatives of Babcock & Wilcox (B&W) Corporation in Bethesda, Maryland to discuss several considerations related to natural circulation in B&W reactors. A representative of Duke Power Company was also in attendance. A list of attendees is attached (Enclosure 1).

The meeting opened with a presentation of the proposed agenda. The following four (4) general areas were to be discussed:

1. Concerns raised by the ACRS in a recent letter.
2. A recent B&W precaution regarding subcooling, RCP operation and OTSG level while attempting to establish natural circulation in the RCS.
3. A report written by C. Michelson, a consultant to the ACRS, regarding potential difficulties in the removal of core decay heat for certain small break LOCAs in the 205 class B&W reactors.
4. Staff concerns related to the ICS and how it effects natural circulation in certain scenarios (loss of all RCPs, loss of off-site power).

1. ACRS Concerns

A. Greater Understanding of Natural Circulation

B&W explained the basic principles of natural circulation on the B&W system. There are three (3) basic criteria which must be met for natural circulation to be established in the RCS.

1. There must be an elevation head between the thermal centers of the system.
2. The RCS loops must be water solid without steam (the hot leg temperature, T_H, must be less than or equal to the saturation temperature for the pressure in the hot leg).

3. There must be no interruption of flow by bubble of non-condensib e gas (H_2). The partial pressure of hydrogen must be below the pressure in the RCS.

B&W stated that as long as these three criteria are met, then natural circulation will occur, and the relative elevation of the pressurizer is not important. Using a drawing showing the elevations of the RCS components (applicable to all B&W plants except Davis Besse-1 (raised loop design), B&W showed that the Auxiliary Feedwater inlet location (high on the OTSG) helps promote natural circulation flow would depend on the elevation difference and the system ΔT (which would depend on the heat input and removal).

The staff asked B&W to plot the temperature as a function of tube length along the OTSG, and B&W showed that under a natural circulation scheme, there would be a marked drop in primary temperature corresponding to the secondary fluid location, (water, steam interface).

B&W plants use an ICS which automatically raises OTSG level, to 50% using the Auxiliary Feedwater system if all four (4) RCPs are tripped. This feature is present on all B&W plants. During normal operations, when power is below 15%, OTSG level is maintained two feet above the tube sheet ([illegible] 26") for all plants.

The OTSG "operating" level is about 1/2 of the total tube bundle length, and a 50% level corresponds to roughly 1/4 of the total tube length. In the "operating" level range, 0% corresponds to about 96" above the tube sheet, and 100% corresponds to about 388" above the tube sheet. The indicated level is temperature compensated and represents a cross-section of varying density across the OTSG.

The staff noted that with respect to natural circulation criteria 3, hydrogen could come out if T_H approached T_{SAT} since the solubility of H_2 decreases markedly as temperature approaches the saturation value.

B&W noted that criteria #2 and #3 together should limit the amount of H_2 coming out of solution. The staff agreed with this, but noted that during a normal transient, structural components may keep local temperature up, and could the temperature approach the saturation value (as pressure decreases) thereby approaching a situation where H_2 could come out of solution?

B&W didn't believe enough H_2 could come out of solution to block the candy cane, but they would check with experts (chemists) in Lynchburg.

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The staff asked B&W if during the transients experienced, the structural components (pipes, upper vessel internals, etc.) kept system temperatures up.

B&W stated that the transients would have to be looked at individually, but temperatures may approach T_{SAT} momentarily, however the HPI is designed to replace lost volume due to flashing. Also, the HPI response time is adequate to prevent significant voiding (by flashing).

B&W has conducted tests to determine the amount of natural circulation. The tests are normally done during startup testing from an initial power level of about 20-25%. The reactor is scrammed, the RCPs are tripped, the emergency diesel generator comes on, the steam and motor driven AFW pumps start, the ICS raises OTSG level to the 50% value, and the plant is verified to be operating on natural circulation, without any operator action. The operator only has to monitor the systems to ensure their proper operation. The RCS temperature levels out at about 550-560°F, the ΔT across the core is about 30-40°F, the pressurizer level (L_p) steadies out at the normal value, and system pressure is 2000-2100 psig.

These tests have been conducted at Davis-Besse and Oconee. Also, Arkansas-1 suffered a loss of offsite power (LOOP) from 100%, on 7/25/75 and natural circulation was established, without any operator action. TMI-2 also had, two (2) unscheduled events in their startup testing program (LOOP test) which resulted in natural circulation.

The staff requested as much detail and description as possible on all the natural circulation tests and events.

The staff asked B&W to explain how system pressure is controlled if the LOOP results in a loss of pressurizer heaters. B&W stated that the system pressure is mainly determined by the bulk system temperature which is a function of the energy input/removal. If temps are constant, the pressurizer level is constant, and pressure is steady. Also, the makeup system, which shouldn't be lost in the LOOP, acts to maintain pressurizer level, which helps maintain pressure. (B&W noted that during the ANO-1 event, the makeup pump was lost for an unknown reason.)

The staff asked B&W what analysis had been conducted regarding the system response to natural circulation, and had the various tests and unplanned events been compared to these analyses?

B&W stated that no formal report regarding natural circulation had ever been generated or submitted to the staff, but significant in-house knowledge based on analog and digital computer studies exists.

The staff asked B&W if these analyses included off-normal situations, FMEAs, or sensitivity studies. B&W noted that some sensitivity studies

had been done (Auxiliary Feedwater initiation times, RCP inertial effects, and possibly initial pressurizer level effects), but no extensive sensitivity studies had been done. For example, during the course of analyzing a loss of feedwater transient (the normal safety analysis) various single failures are considered, and the worst is assumed for the analysis. The transient is analyzed for DNB considerations, but natural circulation is not analyzed in this analysis.

Regarding the sensitivity studies of natural circulation, the staff asked if the PORV is manually opened to control pressure during a LOFW? B&W stated that during the ANO-1 event, the PORV was not opened, and in general, the PORV should not be challenged during a LOOP (or LOFW).

The staff noted that the plant response may be quite dependent on initial parameters, and asked if the B&W transient code, POWERTRAIN, has been checked against the ANO-1 event. B&W stated this had not yet been done since they didn't yet have all the data.

The staff asked if any B&W reactor operator has any instructions on what to do if something failed during an attempt to establish natural circulation?

B&W noted that the operator requalification program covers many instrument failures, but they don't know the details of the requalification program (training expert couldn't attend the meeting).

The plant operators have general instructions in the procedures to ensure that the automatic actions have occurred as designed, and this implies that if the automatic action has not occurred, to take corrective action. However, there are generally not statements in the procedures such as "...if the AFW pump has not started within _____ minutes, do..."

The staff asked B&W if there is an iteration between plant operators and designers to ensure the procedures are adequate with respect to the design. Duke Power Company representative stated that B&W design engineers reviewed all their procedures and made meaningful comments, and it is the policy of Duke to ask all equipment vendors to review procedures (generated by Duke) for the operation of that equipment.

B. More Analyses and Experiments

The staff noted that this agenda item has been discussed under Item A, and that we will probably request more detailed analyses. This item will be discussed at the end of the meeting.

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C. Better Procedures

The staff noted that when at the TMI-2 site, many procedures for the situations occurring there had to be developed on the spot. And the staff wonders if other plants must also develop these procedures in a like manner.

B&W recognizes the concern regarding the detail to which the "what if" type analysis has been incorporated into the plant procedures. The plant procedures are specific to each plant, and the individual most knowledgeable in this area could not attend, (training coordinator).

The staff noted that this item may be addressed in a bulletin.

D. Information to Tell the Operator if Natural Circulation is Working

The staff noted that this item is included in item C, above, and may be included in a bulletin. B&W stated that they do not have a document which could be used to tell the operator if natural circulation has been successfully achieved.

Duke Power Company stated they had looked at natural circulation with respect to plant security scenarios, and they have personnel who have thought through the details of natural circulation in the Oconee units.

E. Role of Pressurizer Heaters (and pressurizer spray)

B&W stated that the pressurizer heaters are not essential within the first 10-15 minutes following a LOOP, and they can be transferred manually to an energized power supply thereafter. They have calculated that there are about 1.5 MW of ambient heat loss at 532°F, and in an hour, pressure would decay about 40 psi. The staff noted that TMI-2 estimated the heat losses from the pressurizer alone would be about 20 kw.

If B&W deemed it was necessary to have the pressurizer heaters powered by a vital power supply, they would issue a "site instruction".

F. Awareness of Impending Saturation

To warn the operator that system temperatures are approaching the saturation temperatures for the system pressure, Duke Power utilizes the plant process computer and a curve (Pressure vs. Temp with 50°F subcooling line). An explicit warning or alarm is not presently used.

B&W is considering the need for an extra alarm or warning. Now, they conclude that the operator should definitely be aware of the status of plant subcooling, but they do not yet know if extra instrumentation is necessary.

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The staff expressed concern over the validity of temperature readings due to lag time in a natural circulation mode. That is, the temperature being sensed is physically far from the core temperatures. During the Davis Besse-1 event, the 70°F subcooling was lost over a 5-minute span without operator intervention.

G. Role of Exit Thermocouples

B&W stated that all B&W plants have core exit T/Cs. The staff asked what the plant operators should be told today regarding the T/C readings as they relate to natural circulation.

B&W responded that the core exit T/Cs may be important, but they're not yet ready to make a recommendation regarding their use in decisions. For example, if during natural circulation 80% of the T/Cs are above T_{SAT}, this does not necessarily mean natural circulation has been lost. We agreed, but noted that the T/Cs are certainly a sign that natural circulation may not be adequately established. The staff also noted that this item may be further addressed in a bulletin.

H. Simulator Training

The staff expressed its desire to observe the training taking place on the B&W simulator, and the degree to which "what if" type scenarios are investigated during natural circulation simulation on the machine. However, the staff does not want to interfere with operator training nor impact on any TMI-2 simulation. (No more than 5 NRC people would observe the simulator.)

B&W said they would investigate the availability of the simulator for observation.

2. B&W Precaution

B&W explained that the origin of the B&W precaution was from remarks taken from Dr. Etherington, of the ACRS. The concern related to the TMI-2 operator tripping the RCPs because he expected the plant to go into natural circulation. If this is true, then how might he have known beforehand that natural circulation was not achievable?

Based on these comments, B&W decided it prudent to issue guidance to the operators regarding tripping of the RCPs. B&W has this guidance under review. For concurrence, a site bulletin must be reviewed by the design organization and the nuclear services organization.

The staff asked Duke Power what their actions would be if they received guidance like the one proposed by B&W. Duke stated that they would immediately brief their operators, since the guidance is only procedural and not a hardware change (otherwise their plant safety committee would be involved).

The staff asked B&W to explain what happened at TMI-2 with respect to OTSG level.

Apparently, the ICS was controlling A OTSG level at its startup level ($\approx$ 26") up until the time the RCPs were all lost. Then the ICS raised A OTSG level to the 50% value, but B OTSG was isolated (manually beforehand) so its level was later manually raised.

The staff noted that the B&W guidance says to ignore what the ICS will do to OTSG level, and take manual control before tripping RCPs.

B&W agreed and pointed out that the bulletin said to observe all temperature and pressure limits while raising OTSG level, so no limits should be violated. This action just is earlier than the ICS automatic action (the ICS would raise OTSG level at about 15"/min).

B&W stated that both guidances (paragraph 1 and 2) are prudent actions, but are not necessary actions since the ICS does the same thing.

The staff asked if it would also be prudent to initiate HPI along with raising OTSG level prior to RCP stopping to increase the subcooling. B&W said they would consider this.

B. Role of ICS - Does it Need Changing?

B&W stated that the ICS does not require hardware changes, and that the guidance being suggested is best carried out with procedural modifications.

C. Existing Guidelines or Criteria Provided to Customer

B&W is researching the guidelines associated with natural circulation and they'll inform us.

3. Michelson Report

It was B&W's initial assessment that the phenomena discussed in the Michelson report have no real bearing on the B&W reactors, and that the B&W reactors for the break size of interest do not suffer a loss of natural circulation (intermittent or sustained) as the report suggests is possible. Also, for the range of break sizes discussed in the report, the core is not uncovered.

The effect of non-condensible gasses coming out of solution is not appreciable, and would not effect natural circulation.

The only aspect of concern associated with the stuck open PORV is the misleading L_p indication. Natural circulation for this event (small break) would not be lost. When asked by the staff if it is good or bad to shut the PORV MOV if the operator notices the stuck open PORV, B&W stated that as long as HPI remains on, it wouldn't matter since natural circulation wouldn't be lost.

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Another PWR vendor stated that for a 2 1/2" steam space break, if AFW is unavailable, and HPSI is available, the core remains covered, but if the HPSI is not available (and the AFW unavailable) the core uncovers. B&W stated this was probably true in their reactors also. They note that a key piece of information regarding the TMI-2 event is the times when the HPI was unavailable.

B&W stated that their analyses (small break LOCA) assume the availability of Auxiliary FW at about 40 sec, and the OTSG level goes to that set by the ICS (for loss of RCPs), about 17 ft.

B&W noted, in response to several questions regarding the ICS, that there are three (3) power supplies to the ICS: (1) battery pack, (2) offsite power and (3) emergency diesel generator.

The staff asked B&W to discuss the sensitivity of AFW initiation time on the results of a PORV stuck open LOCA. B&W said that even without AFW, and the OTSG boiling dry, the core goes into pool boiling, and, as long as HPI is available, the core remains covered. Voids would occur in the system and the safety valves would open and pass water.

The staff summarized the B&W response: although not specifically analyzed, if there were a loss of fer water w/a small LOCA (2 1/2-3" or $\simeq$ 0.04 ft^2), if both HPI pumps are available, the results are satisfactory, (based on B&Ws judgment). B&W agreed with this summary.

- In response to a previous concern on the H_2 coming out of solution, B&W reported that the normal hydrogen concentration in the system is about 40 cc/kg, as set by the makeup tank cover gas pressure. This corresponds to about 440 standard ft^3 of hydrogen, or about 20 ft^3 at 300 psia if all evolved. At a concentration of 40 cc/kg, at a temperature of 410°F at 300 psia, significant H_2 would be released from the system. If the concentration were 68 cc/kg, then at a temperature of 405°F at 300 psia, significant H_2 would evolve.

4. Staff Concerns

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The staff noted that many of the questions were already answered in the discussion of the preceding items, and that only a few remain.

6. Thermal Shock Considerations

The staff is concerned for the potential for thermal shock of the reactor vessel from relatively cold HPI water entering the downcomer, during a loss of natural circulation. What would be the minimum RCS temperature with the pressure being maintained by the RCS code safeties.

B&W said they would look at giving the operator more instructions regarding the closing of the PORV MOV since the thermal shock problems depend on the HPI flow into the system (as well as system pressure).

A 1-hour break was taken for the staff to discuss the necessity (and content) of a bulletin to B&W reactors, and other information/analyses required from B&W.

The staff concluded that, based on the information presented at the meeting a bulletin to all B&W reactors would be issued by cob Thursday, 4/19/79. The bulletin would have four (4) ingredients:

1. Operating plants must reduce the likelihood of opening the PORV in the event of an anticipated transient.

2. Operating plants should incorporate a scram feature sensing a loss of heat sink (loss of load or loss of feedwater). (The scram may be manually performed.)

3. General guidance to operators regarding the necessity of determining the degree of subcooling before attempting to initiate natural circulation.

4. General guidance to operators regarding the OTSG level during an attempt to establish natural circulation.

The staff noted that with respect to item 1, reducing the overpressure scram setpoint to below the PORV setpoint may result in the necessity for steady state operation at reduced pressure. B&W should carefully study the possibility with respect to the continued validity of the ECCS analyses.

B&W agreed to look at this aspect, and suggested the possibility of an automatic scram on loss of feedwater. Such a scram signal, however, may originate from "unqualified" instruments which might violate the GDC (regarding mixture of safety/non-safety grade systems). B&W said they would contact the staff in the morning of 4/19/79 to discuss the most preferable means of achieving the goals of items 1 and 2 above. Also, B&W agreed to submit the following items within the times indicated.

ITEM	TIME
A. Perform calculations, worst-case break without AFW for 30 min.	2-3 days
B. Document natural circulation tests conducted at Davis Besse & Oconee	2 1/2 weeks
C. Document all occurrences of natural circulation which happened inadvertently; include a description of unexpected behavior	2 1/2 weeks
D. Document natural circulation analytical methods	4 weeks
E. Summarize and document sensitivity in key parameters (definition and agreement with staff in two weeks regarding scope)	8 weeks
F. Deleted	
G. Define and document thermal shock criteria for operation at low temperature with HPI pumps running and no natural circulation	2 weeks

The staff agreed with these items and schedule, and requested that items A-D go to Dr. Michelson, and that items E and G not be started until the report being generated by R. Tedesco is complete, around May 1, 1979 since this report will define the scope of work desired.

Also, the staff requests an additional item, called H, to be an assessment of the safety concerns raised in the report of Dr. Michelson, and that this assessment be submitted within 2 1/2 weeks. B&W agreed to our requests.

The staff met with B&W on 4/13 to discuss alternative means of reducing PORV actuations in the event of the type of transients that have been experienced at B&W designed plants.

B&W considered four alternative means of achieving the above objective.

1. Restrict Initial (operating) Power

   Experience shows PORV would lift even at low power level ($< 9\%$) and thus this alternative would be ineffective.

2. Lowering High Pressure Reactor Trip Setpoint

   In order to minimize or eliminate PORV opening following feedwater transients, the reactor trip setpoint would have to be lowered to

2215 psig which would result in only 60 psig margin in pressure between the nominal reactor operating pressure and the high pressure scram setpoint. Because of uncertainties in these parameters; increased spurious reactor scrams would be expected.

3. Plant Operation with Reduced Operating Pressure

To eliminate lifting the PORV during transients, the normal operating pressure would have to be reduced to about 1900 psig with a comparable reduction in high reactor pressure trip to 2100 psig. A reduction in system operating temperatures would also be required to preserve margins to departure from nucleate boiling (DNB) in the core. These changes would necessitate an extensive reanalysis of all transients and accidents.

4. Reduction of High Pressure Trip Setpoint and Increase of Pilot-Operated Electromatic Pressurizer Relief Valve Setpoint

By lowering the reactor coolant system high pressure trip setpoint and raising the setpoint of the pilot-operated relief valve, B&W stated that it is possible to eliminate the lifting of the PORV following transients which have occurred on B&W plants. They had performed analyses to support this conclusion.

The pressure trip set points for this alternative are:

Present		Proposed
2500 psig	safety valve	2500 psig
2355 psig	reactor trip	2300 psig
2255 psig	PORV setpoint	2450 psig
2155 psig	operating pressure	2155 psig

A tabulation of the pros and cons of this alternative is attached. B&W recommended the approval of this alternative since it covers essentially all transients and maintains the safety analysis of the plants.

The staff reviewed each alternative and concurred with the B&W recommendation.

D. F. Ross, Jr., Deputy Director
Division of Project Management

Enclosure:
As stated

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ENCLOSURE 1

LIST OF ATTENDEES
B&W MEETING
4/18/79

Name	Organization
L. B. Marsh	NRC/NRR/DOR
S. Newberry	NRC/NRR/DSS
C. Graves	NRC/NRR/DSS
R. C. Jones	B&W/ECCS Analysis
D. F. Hallman	B&W/Plant Performance Svs.
J. H. Taylor	B&W/Licensing
E. A. Womack	B&W/Engineering
R. E. Ham	B&W/Customer Service
A. Thadani	NRC/DSS
D. F. Ross	NRC/DPM
W. A. Smith	Bechtel
F. Odar	NRC/DSS/AB
H. A. Wilber	NRC/I&E
S. Israel	NRC
W. Minners	NRC
E. V. Imbro	NRC
J. A. Castanes	B&W/C&I Engineering
R. W. Winks	B&W/Plant Design
D. H. Beckham	NRC/DPM
L. Beltracchi	NRC/ICSB
M. Fairtile	NRC/DOR
L. R. Cartin	B&W/Plant Design
G. N. Lauben	NRC/DSS
C. Berlinger	NRC/NRR/DOR/RSB
S. Carody	Duke Power
E. Case	NRC/NRR
R. Mattson	NRC/DSS
F. Schroeder	NRC/DSS
A. Szukiewicz	NRC/DSS
A. Schwencer	NRC/DOR
A. Oxfurth	NRC/I&E
B. Clayton	NRC/NRR/DPM
J. Calvo	NRC/NRR/DSS

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ASSESSMENT OF ALTERNATIVE 4

PRO

1. Eliminate PORV actuation following essentially all anticipated transients.
2. Preserves validity of analyses serving as basis for current operating licenses.
3. Reduces (relative to current setpoints) probability of PORV and PSV actuation (PORV is isolatable).
4. Preserves venting capacity for high pressure transients (e.g., ATWS)
5. Can be implemented immediately with setpoint change in control room.
6. Lessens probability of actuating PORV for infrequent AT's (e.g., rod withdrawal)
7. More forgiving of delay in auxiliary feedwater supply. (Longer time to OTSG dryout.)

CON

1. Somewhat potential for spurious reactor trips
2. Eliminates runback capability on lo load. Turbine trip (i.e., increases number of trips by design).
3. May still open on some infrequent AT's (i.e., its still in the system)
4. PORV may open spuriously (i.e., its still in the system).