July 20, 1979

Mr. Robert W. Reid, Chief
Operating Reactors Branch #4
Division of Operating Reactors
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Post-LOCA Procedural Guidelines

Reference: (A) Ltr., R. W. Reid to All Combustion Engineering Designed Operating Reactors, dated June 5, 1979

(B) Ltr., George Liebler to R. W. Reid, dated July 18, 1979

Enclosure: (1) Response to Question 16 of Reference (A) (Preliminary)

Dear Mr. Reid:

Enclosure (1) is forwarded in fulfillment of our agreement to provide post-LOCA procedural guidelines to the Nuclear Regulatory Commission by July 20. 1979. Enclosure (1) is a preliminary version of the Owners Group response to Question 16 of Reference (A). Those portions of the Owners Group response which are presently complete have been forwarded in Reference (B). Enclosure (1) was not forwarded at that time since this section was not available.

The preliminary nature of Enclosure (1) is due to the fact that not all of the analyses required to respond to Reference (A) are complete. The Owners Group reserves the right to modify the procedural guidelines as these analysis results become available. The final version of Enclosure (1) will be included in the July 30, 1979 submittal as Section 3.16.

Should you have any questions, please feel free to contact my office at (305) 552-3811 or Mr. Ken Morris of Omaha Public Power District at (402) 536-4504.

Sincerely,

P W Kruse for G. E. Liebler

G. E. Liebler, Chairman
C-E Owners Group

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3.16 RESPONSE TO QUESTION 16

3.16.1 Statement of Question 16

Provide guidelines for the preparation of operational procedures for the recovery of plants following small LOCA's. This should include both short-term and long-term situations and follow through to a stable condition. The guidelines should include recognition of the event, precautions, actions, and prohibited actions.

IF RC pump operation is assumed under two-phase conditions, a justification of pump operability should be provided. Discuss instrumentation available to the operator and any instrumentation that might not be relied upon during these events (e.g. pressurizer level). What would be the effect of this instrumentation on automatic protection actions?

3.16.2 Response to Question 16

In response to question (16), our bases for post-LOCA operating guidelines, and current guidelines for operating plants following LOCA's are provided below. The guidelines include symptoms, immediate actions, follow-up actions, and precautions. The material presented addresses both short-term and long-term situations, and follows through to a stable condition. Natural circulation guidelines are also included. Reactor coolant pump operation is addressed in sections 3.13 and 4.11.

This material is the current bases and guidelines for post-LOCA

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operation. These guidelines are written for a t ical operating plant with a C-E NSSS. While some of the specific information varies slightly from plant to plant, the overall functional processes apply to all operating plants with a C-E NSSS.

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BASES FOR POST LOCA OPERATING GUIDELINES

BASES

Provided below is a general description of plant responses to large and small break LOCA's. This is intended to supply background material for the information presented in the guidelines.

A small break LOCA is characterized by:

A slow loss of RCS pressure during the short term (10 to 30 minutes) and equilibrium pressure above* 300 psia in the long term (30 to 480 minutes) resulting from matching safety injection flow and flow from the break.

A loss of RCS inventory during the short term followed by a refilling of the RCS during the long term.

Core cooling is initially by the steam generator(s) and flow from the break and later by the shutdown cooling system. The break does not provide the necessary heat removal yet depletes RCS inventory. The steam generators provide cooling for either forced or natural circulation and, if the RCS inventory is depleted, in a boiloff and reflux mode. The shutdown cooling system is used after the RCS has been refilled and pressure control is provided by the HPSI pumps and the charging pumps.

A general description of small break LOCA operations follows:

Initially the plant is hot and pressurized. A small break LOCA results in a slow loss of RCS inventory and a decrease in pressure. (Small breaks located high in the system will result in faster RCS depressurization with less inventory loss than breaks located low in the system). Low pressurizer pressure initiates a SIAS which automatically actuates the SIS. The reactor is tripped. No operator action is required for 10 minutes. Auxiliary feedwater is established to the steam generators. Steam dump is provided manually using atmospheric dump valves or turbine bypass valves, or automatically by the steam generator dump and bypass system or by steam generator relief valves.

The reactor coolant pumps may be operable. Forced circulation, using one or more reactor coolant pumps, is possible for RCS conditions when natural circulation cannot occur. The steam generators are the main heat sink and it is desirable to operate reactor coolant pumps if they are effective. The reactor coolant pumps remain or are made operable, if possible, as long as they induce forced flow and are not in danger of incurring damage that would increase the severity of the accident.

The small break LOCA results in a partial loss of RCS inventory followed by a refilling. The time necessary to refill the RCS and regain control of pressure and inventory depends on break size, break location, and the number of HPSI pumps and charging pumps actuated. With only one HPSI pump activated, and a break located on the bottom of the cold leg, it may take as long as 8 hours to refill the RCS. With all injection pumps operable,

* This value is typical, it may vary for specific designs.

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the time is about 1 hour. Core cooling is maintained by flow from the break and by dumping steam from the steam generators until the shutdown cooling system is placed in operation. In the event that the condensate supply is exhausted and the shutdown cooling system is inoperable, the PORV's are opened to ensure that the flow from the injection system is sufficient to cool the core. The SIS may be realigned for cold leg injection only. Core flushing is from the cold legs through the core and out the PORV.

Simultaneous hot and cold leg injection is used for both small break and large break LOCA's so the operator does not have to distinguish between them at the time when simultaneous injection is required for large breaks. (For small breaks the boron concentration remains low due to dispersal throughout the RCS, so hot and cold leg injection is not essential.)

Reactor coolant system pressure is used to differentiate between small and large break LOCA's. However, the delineation between small and large breaks does not need to be precise since there is a range of intermediate breaks for which either response will produce satisfactory results. The guidelines take this into account with the decisions to be made after eitht hours.

The large break LOCA is characterized by:

A rapid loss of RCS pressure in 10 seconds to 3 minutes with equilibrium pressures below* 300 psia and, in the case of the largest breaks, the RCS pressure nearly equal to containment pressure.

Core cooling is provided for by large flow from the injection system due to low RCS pressure. The flow from the break provides sufficient heat removal. Simultanoeus hot and cold leg injection is required to prevent possible boric acid accumulation in the core.

A general description of large break LOCA operations follows:

Initially the plant is hot and pressurized. A large break LOCA results in a rapid loss of inventory and pressure. Low pressurizer pressure initiates a SIAS which automatically actuates the SIS. The reactor is tripped. Auxiliary feedwater is established to the steam generators. Steam dump is provided manually using atmospheric steam dump valves or turbine bypass valves. There may not be sufficient inventory in the RCS to run reactor coolant pumps. The major machanism for heat removal is the flow from the SIS through the core and out the break. Containment pressure may be high and containment isolation is likely. Containment spray may have been automatically activated.

The SIS is aligned to provide simultaneous hot and cold leg injection which is sufficicent to cool the core and flush the reactor vessel indefinitely.

For both large and small break LOCA's, continued monitoring of conditions in the RCS and performance of safety systems should be done. All available indications should be used to aid in diagnosing the event since the accident may cause irregularities in a particular instrument reading.

Regardless of the cause of actuation of a safety system, the automatic response should not be altered until it has been demonstrated that other systems and equipment are providing the functions that the safety system is intended to perform.

*This value is typical, it may vary for specific designs.

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GUIDELINES FOR OPERATING PLANTS FOLLOWING LOCA'S

SYMPTOMS

1. Reactor coolant system leak exceeds the capacity of the operable charging pumps.

2. A reactor trip may have occurred.

3. The Safety Injection System (SIS) may have automatically actuated.

4. Any one or more of the following indications or alarms may be present.

   a. Low pressurizer pressure
   b. High containment pressure
   c. High containment sump level
   d. High containment radiation
   e. Low pressurizer level
   f. High quench tank level
   g. High quench tank temperature
   h. Containment isolation

IMMEDIATE ACTIONS

1. Trip the reactor if not already tripped and carry out standard post trip actions.

2. Initiate safety injection if it has not already been actuated by the safety injection actuation signal.

3. Establish auxiliary feedwater flow to the steam generators within* 10 minutes.

4. If reactor coolant pumps are operating, leave one reactor coolant pump operating in each loop. If RCP's are not running, start one RCP in each loop.

5. If the containment isolation actuation signal (CIAS) is activated, ensure that the system has properly actuated. Manually unisolate those systems that remain operable and useful in regaining control of the plant.

6. After any SIAS, operate the SIS for at least 20 minutes and until RCS hot and cold temperatures are at least 50°F below the saturation temperature for the RCS pressure unless the cause of the SIAS has been verified to be an inadvertent actuation. If 50° subcooling cannot be maintained after the system has been stopped, the high pressure injection system must be restarted.

*This value is typical, it may vary for specific designs.

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FOLLOW-UP ACTIONS

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1. Operate atmospheric steam dump valves (or turbine bypass valves if the condenser is available) to maintain or reduce plant temperature. Within one hour, begin plant cooldown.

2. Manually align the safety inejction system to provide flow to the RCS hot and cold legs* two hours after the LOCA.

3. If pressure and inventory control cannot be established after*eight hours and RCS pressure is less than* 300 psig, continue the hot and cold leg injection.

4. If pressure and inventory control are established and RCS pressure is greater than* 300 psig, conduct one of the following activities. The activities are listed in order of decreasing preference.

   a) Initiate shutdown cooling. If RCS pressure is above the initiating pressure for shutdown cooling system operations, reduce it by reducing the flow delivered by the high pressure injection and charging pumps and by venting or isolating the safety injection tanks as necessary. After shutdown cooling is initiated, maintain RCS pressure with the charging pumps and/or the HPSI pumps to attain at least 50^{o} subcooling.

   or b) Continue to remove decay heat using emergency feed and steam dump if adequate condensate is available and (a) cannot be implemented.

   or c) Open pressurizer power operated releif valves and align the SIS for cold leg injection if (a) or (b) cannot be implemented.

*This value is typical, it may vary for specific designs.

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PRECAUTIONS

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1. If a loss of services(i.e. cooling water) to the RCP's occurs, and they cannot be restored, the operator should consider stopping the pumps. If possible, one RCP per loop must remain in operation until conditions for natural circulation have been established. If the operating reactor coolant pumps are not providing forced flow or are in danger of incurring damage that will increase the severity of the event, stop these pumps.

2. When establishing auxiliary feedwater flow to the steam generators, monitor primary system temperature and pressure to avoid overcooling.

3. Feedwater is normally provided to both steam generators. Isolation of a steam generator is desirable if a steam generator tube rupture is detected to prevent lifting the safety valves or reseat them if they have lifted. This action will also reduce the amount of radioactivity released.

4. Continued lengthy operation of the containment spray may jeopardize the operation of equipment which would be desirable or necessary to mitigate the consequences of the event. Early consideration should be given to termination of spray operation. If the containment pressure has returned to below the actuation setpoint, the system may be stopped, provided that the operation of the containment atmosphere clean-up system and containment hydrogen control system are not compromised. The spray system should be realigned for automatic actuation.

5. If a recirculation actuation signal (RAS) occurs, the operator must prevent the HPSI pumps from operating at less than minimum flow conditions. If all HPSI pumps and charging pumps are operating and the HPSI pumps are delivering less than 30 gpm per pump, turn off the charging pumps one at a time and then one HPSI pump at a time until only one HPSI pump remains operating.

6. If there is a high radioactivity level in the reactor coolant system, circulation of this fluid in the SCS may result in high area radioactivity readings in the auxiliary building. The activity level of the RCS should be determined prior to initiating SCS flow.

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BASES FOR NATURAL CIRCULATION GUIDELINES

1. Reactor coolant pump forced circulation and heat transfer to the steam generators is the preferred mode of operation for residual heat removal whenever plant temperatures and pressures are above the Shutdown Cooling System entry conditions. The natural circulation capability of all CE plants provides an emergency means for core cooling using the steam generators, if the reactor coolant pumps (RCPs) are unavailable.

2. Emergency Procedures which could involve operation in a natural circulation mode include, but are not limited to, the following:

   Loss of Flow Procedures

   - Loss of offsite power.
   - Loss of RCPs.
   - Reactor Trip.
   - Turbine Trip
   - Emergency Shutdown
   - Shutdown Outside the Control Room.
   - Loss of Coolant Accident

   RCP Emergency Procedures

   - Loss of Component Cooling Water.
   - Reactor Coolant Pump and Motor Emergencies.
   - Inadvertant Containment Isolation.
   - RCP Off Normal Operation.

3. Natural circulation is governed by decay heat, component elevations, primary to secondary heat transfer, loop flow resistance, and voiding. Component elevations on CE plants are such that satisfactory natural circulation decay heat removal is obtained by density differences between the bottom of the core and the top of the steam generator tube sheet. An additional contribution to natural circulation flow rate is the density difference obtained as the coolant passes through the steam generator U-tubes, but this is not required for satisfactory natural circulation. Natural circulation is assured even if the U-tubes are partially uncovered on the steam generator secondary. Because of the temperature distribution in the steam generator U-tubes, there is no degradation in primary to secondary heat transfer as long as the secondary level covers at least 1/3 of the tube height. By ensuring that the loop ΔT is less than the full power ΔT, the power-to-flow ratio is assured to be less than one during natural circulation.

4. Satisfactory natural circulation heat removal can be obtained with either one or two steam generators. Unequal auxiliary feedwater flow to the steam generators will not lead to unsatisfactory natural circulation as long as all of the decay heat is being removed through the steam generators.

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- Continuation -

5. Although plant safety analysis does not take credit for reactor coolant pump operation under two-phase flow conditions, a significant degree of forced circulation cooling can be maintained under these conditions. Continued reactor coolant pump operation with cavitation will result in increased impeller, bearing, and seal wear, but catastrophic failure is highly unlikely.

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GUIDELINES FOR OPERATING PLANTS FOR NATURAL CIRCULATION OPERATION

SYMPTOMS

1. A reactor trip may have occurred.

2. All reactor coolant pumps (RCPs) have been automatically, or manually tripped, or are operating abnormally enough to consider manually tripping.

3. Any one or more of the following indications or alarms may be present.

   a. Low Reactor Coolant Flow.
   b. Low Bus Voltages.
   c. Reactor Coolant Pump breaker overload or trip.
   d. Any Reactor Coolant Pump Alarm.
   e. Any Component Cooling Water System Alarm.

4. Any of the following plant emergency procedures may have been implemented:

   a. Loss of Offsite Power.
   b. Loss of Reactor Coolant Flow.
   c. Loss of Reactor Coolant Accident.
   d. Reactor Trip.
   e. Turbine Trip.
   f. Emergency Shutdown.
   g. Loss of Component Cooling Water.
   h. Reactor Coolant Pump and Motor Emergencies.
   i. Inadvertent Containment Isolation.

IMMEDIATE ACTIONS

1. Trip the reactor if not already tripped and carry out standard post-trip actions.

2. If all RCPs have tripped, attempt to restart at least one RCP and if possible, a second pump, preferably in the opposite loop.

3. If no RCP can be restarted, a natural circulation mode of operation for residual heat removal must be established. Take the following actions to establish and maintain the conditions for natural circulation.

   - Operate the atmospheric dump valves or turbine bypass valves to maintain plant temperature by removing decay heat and to prevent lifting of secondary safety valves.

   - Restore and maintain steam generator water level within the indicating range. Actuate the Auxiliary Feedwater System, if required. Monitor primary system temperature and pressure to avoid overcooling.

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3. ----------continued

- Establish and maintain the hot leg temperature at least 20°F below the saturation temperature corresponding to reactor coolant system pressure by: (see precaution 2)

  (a) operating pressurizer heaters and auxiliary spray as required to increase or maintain plant pressure,

  (b) reducing plant temperature by increasing dump or bypass valve steam flow.

- Restore primary system inventory and maintain normal pressurizer level.

4. Verify that natural circulation has been established from the following indications: (approximately 10 minutes after tripping reactor coolant pumps)

- Loop ΔT (T_h - T_c) less than normal full power ΔT.

- T_c constant or decreasing,

- T_h stable (i.e., not steadily increasing),

- No abnormal differences between T_h RTDs and core exit thermocouples.

5. If a loss of services to the reactor coolant pumps occurs, the operator should consider stopping reactor coolant pumps. The following actions should be taken in order to ensure continued core cooling if services can not be restored.

- Continue to operate two reactor coolant pumps (one each loop). Stop the other running reactor coolant pumps to prevent possible damage to those pumps.

- Establish the conditions for natural circulation as outlined above.

- If conditions for natural circulation (see Action 3 above) cannot be established, continue to operate two reactor coolant pumps (one each loop).

- After conditions for natural circulation are established, if it appears that pump damage is imminent, stop the remaining two reactor coolant pumps.

- Verify natural circulation as above.

- If natural circulation cannot be maintained, restart two reactor coolant pumps (one each loop) and maintain forced circulation.

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6. During plant recovery from an unplanned transient or accident, low system pressure may result in reactor coolant pump cavitation. Under these conditions, continue to operate two reactor coolant pumps (one each loop). Stop the other running pumps to prevent possible pump damage.

   - Since cavitation may be indicative of a temporary saturation condition in the loop, no attempt should be made to enter a natural circulation mode.

   - Establish the hot leg temperature at least 20°F below the saturation temperature corresponding to reactor coolant system pressure as outlined above. (See precaution 2)

FOLLOW UP ACTIONS

1. Maintain the hot leg temperature at least 20°F below the saturation temperature corresponding to reactor coolant system pressure. Operate pressurizer heaters and auxiliary spray as required. Increase dump valve flow if necessary to reduce plant temperature. (See precaution 2).

2. Maintain pressurizer level within normal range.

3. Maintain steam generator level within the visible range. Actuate the Auxiliary Feedwater System if required. Monitor primary system temperature and pressure to prevent overcooling.

4. Maintain reactor coolant total gas concentration within specification. Initiate degassification procedures if required.

5. Monitor the following parameters:

   - Loop ΔT ($T_h - T_c$), less than normal full power ΔT.

   - T_c, controllable (constant or decreasing) by steam dump or bypass.

   - T_h not steadily increasing.

   - Core exit thermocouples following T_h RTDs.

6. As soon as possible after the reason for loss of forced circulation has been corrected, start at least one reactor coolant pump and reestablish forced circulation. When possible start a second pump in the opposite loop.

7. Monitor condensate storage tank level and replenish from alternate sources as required.

PRECAUTIONS

1. When establishing auxiliary feedwater flow to the steam generators, monitor primary system temperature, pressure, and pressurizer level to avoid overcooling and potentially draining the pressurizer.

2. In determining that 20°F subcooling exists, appropriate allowances must be made for instrument location and instrument error.

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