EVALUATION OF EMERGENCY PROCEDURE GUIDELINES

REVISION 2

BWR 1 THROUGH 6

OVERVIEW

The BWR Owners' Group, with the assistance of General Electric, has developed generic symptomatic emergency procedure guidelines (EPGs). The EPGs are generic to GE-BWR 1 through 6 designs in that they address all major systems which may be used to respond to the emergency. The guidelines are written for plants as they are currently configured; no attempt has been made to propose system modifications. Because no specific plant includes all of the systems in these guidelines, the EPGs are applied to individual plants by deleting statements which are not applicable or by substituting equivalent systems where appropriate. For example, plants with no low pressure injection system will delete statements referring to LPCI, and plants with low pressure core flooding will substitute LPCF for LPCI.

Although considerable effort has been expended by the BWR Owner's Group and General Electric in the development of the EPGs and the EPGs have been critically examined by several members of the staff, operating experience will almost certainly reveal situations which are not covered by the EPGs. However, the procedures which will be developed from the guidelines should be much more comprehensive and less voluminous than the procedures they replace. Also, because the operator using procedures based on the EPGs will be responding to symptoms rather than events, an incorrect event diagnosis will be of little consequence.

The entry conditions for the EPGs are symptomatic of both emergencies and events which may degrade into emergencies. The guidelines specify actions appropriate for both. Therefore, entry into procedures developed from these guidelines is not conclusive that an emergency has occurred. For example, a loss of drywell cooling while a plant is operating will result in a high drywell temperature and pressure with a resultant reactor scram and ECCS actuation but an emergency would not necessarily exist.

The EPGs are based upon maintaining core cooling and primary containment integrity. For the most degraded plant conditions, the integrity of the primary containment is given priority over core cooling. For example, step SP/L-3.4 of the containment control guidelines states that when the primary containment water level reaches the maximum safe primary containment water level at 0 psig or the highest containment vent elevation, the operator should terminate injection into the RPV from sources external to the primary containment irrespective of whether adequate core cooling is assured. The basis for this step is that flooding the primary containment above the level at which the hydrostatic head equals the yield stress of the containment at the limiting location may result in a breach of containment. Because of the extreme nature of this step, it is expected that onsite utility management, engineering staff and operations staff will make every effort, prior to reaching the Maximum Primary Containment Water Level Limit, to arrest the accumulation of water in the containment without terminating core cooling.

The EPGs are functionally divided into two guidelines (RPV control guideline and containment control guideline) and seven contingencies (Level Restoration, Emergency RPV Depressurization, Steam Cooling, Core Cooling Without Level Restoration, Alternate Shutdown Cooling, RPV Flooding, Level/Power Control) and are designed to cover all emergency situations including Anticipated Transients Without Scram (ATWS). Therefore, small-break LOCA, large-break LOCA, transients with multiple failures or no failures, and inadequate core cooling are all addressed by the EPGs. The guidelines address operator errors by checking the effects of directed operator actions and providing guidance for those cases where previous operator actions were unsuccessful. The guidelines do not address combustible gas control or secondary containment control but these will be addressed in future revision of the guidelines. In the meantime, there exist equipment procedures that could be used by operators, but they are not specifically treated in existing emergency procedures. The guidance provided for events with failure to scram is complicated and may result in core flow oscillations for ATWS events; however, core melt should be avoided if the ATWS guidance in the EPGs is followed. The ATWS guidance appears to be the only viable option (for ATWS conditions) for the systems that currently exist in the plants.

THE EPGs are organized to provide guidance for operator response to transients and accidents for the entire range of available systems. Guidance is provided for the use of all systems capable of performing a function. This "defense in depth" is discussed in evaluations of individual guidelines and contingencies.

The guidelines use a unique method to coordinate actions of different guidelines. This involves the evaluation of the necessity for an action in one guideline or contingency with the instructions for the action contained within another guideline or contingency. An example of this is emergency depressurization. Its need may result from containment control difficulties but its steps are in the Emergency RPV Depressurization Contingency #2. This organization is necessary to ensure all the considerations associated with this action are addressed for all situations. This method of coordinating these functions is acceptable; however it may be difficult to implement this mechanism in procedures using this organization. The procedures reviewed in the pilot monitoring program (TMI Action Plan Item I.C.8) were developed from an earlier version of the guidelines. Therefore, the Procedures and Systems Review Branch will scrutinize plan for the implementation of the guidelines.

SUMMARY OF LEVEL CONTROL

The purpose of the RPV control guideline is to restore and maintain RPV water level within a satisfactory range, shut down the reactor and control RPV pressure, and cool the RPV to cold shutdown conditions. The entry conditions are any of the following:

1) RPV water level below low level scram setpoint,
2) drywell pressure above the high drywell pressure scram setpoint,
3) an isolation which requires or initiates reactor scram, or
4) a condition which requires reactor scram and reactor power is above the APRM downscale trip or cannot be determined or

5) RPV pressure above the scram pressure.

For events in which scram occurs, either automatically or manually, the operator verifies scram and proceeds to control RPV water level and pressure with whatever systems are available. The systems used to inject water are listed in an approximate order of preference and both safety and non-safety systems are included. Where possible, water level is maintained in the normal control range; where this is not possible level is either controlled above the top of the active fuel or the operator attempts to verify sufficient injection (core spray flow rate) to assure adequate core cooling.

Both test and analysis have shown that maintaining water level above the top of the active fuel is sufficient to assure adequate core cooling, provided the reactor is tripped. The EPGs are designed to give preference to covering the core with water to cool it. Further, test and analysis have shown that injection with one or more core spray systems or flooding to 2/3 core height with low pressure systems is adequate to maintain core cooling if the reactor is tripped but the core cannot be completely covered. The EPGs recognize this mode of cooling as an alternate to the preferred mode of cooling.

If no injection systems are available to maintain inventory in the reactor vessel, the guidelines prescribe a combination of boiloff and depressurization to maintain core cooling while attempts are made to start inoperable systems to replenish inventory. Although this approach

only delays the eventual heatup of the fuel, it is the best that can be done with no available injection.

SUMMARY OF ATWS GUIDANCE

If scram does not occur when required, the EPGs call for several actions to be taken simultaneously. These include:

1) Start boron injection with standby liquid control system (SLCS) or other systems if SLCS is not operable, and
2) Manually insert control rods, reset scram, open breakers or remove fuses which deenergize scram solenoids, close scram air header supply valve and open scram air header vent valves, individually open scram test switches, and
3) lower water level until:
   a. power below APRM downscale trip (3% is typical), or
   b. containment heatup terminated, or
   c. level reaches the top of the active fuel in the downcomer.

Although the lowering of the water level is effective in reducing power, it may result in core flow oscillations. Neither the flow oscillations nor the consequences of the oscillations are amenable to analysis.

DEPENDANCE ON WATER LEVEL INDICATION

Because many of the actions in the EPGs are keyed to reactor vessel water level, the EPGs contain cautions which alert the operator to conditions which cause the water level indications to be unreliable.

These cautions are related to drywell temperature, indicated level and RPV pressure. The limits in the cautions are calculated conservatively.

If the vessel water level cannot be determined, the EPGs instruct the operator to depressurize the vessel and flood the vessel until water pours out of the safety/relief valves. This guidance assures that the fuel remains covered with water so that the fuel is adequately cooled.

SUMMARY OF CONTAINMENT CONTROL

The containment control guideline is concerned with primary containment temperature, pressure, and water level. It is executed concurrently with the RPV control guidelines. The entry conditions are any of the following:

1) suppression pool temperature above normal operating limit,
2) drywell temperature above normal operating limit,
3) containment temperature above normal operating limit,
4) drywell pressure above ECCS initiation pressure,
5) suppression pool water level above normal operating limit, or
6) suppression pool water level below normal operating limit.

The containment control guideline contains several limit curves such as a suppression pool spray limit and a pressure suppression limit. Beyond these limits, certain operator actions are required. Although the limits are conservative, they are derived from engineering analyses using best-estimate models. Consequently, these limits are not as conservative as the limits specified in a plant's technical specifications. This is not to imply that operation beyond the

technical specifications is recommended in an emergency. Rather, such operation may be required under certain degraded conditions. The limits specified in the guidelines establish the boundaries within which continued safe operation of the plant can be assured. Therefore, conformance with the guidelines under degraded conditions does not ensure strict conformance with a plant's technical specifications or other licensing bases. The licensing specifications will already have been exceeded in order to get into such a situation in the first place and the safe recovery of the plant becomes the matter of paramount importance.

SIMULTANEOUS ACTIONS

Although the operator could be using several procedures simultaneously, the simulator demonstrations of interim procedures for several plants that were based on the guidelines have demonstrated that containment parameters do not change rapidly enough to be beyond the operator's capability to respond.

DYNAMIC NATURE OF GUIDELINES AND OPEN ITEMS

Because the BWR Owners' Group may disband after these guidelines are approved, there is a need for a group consisting of BWR owners and General Electric to complete the development of the guidelines and to maintain the guidelines after development is complete. The development of the guidelines may be considered complete after combustible gas control and secondary containment control guidelines are reviewed and approved. Maintenance would include incorporation of operating

experience and new knowledge into the guidelines and modification of the guidelines to account for new equipment.

In addition, several steps in the guidelines require further work:

1) Criteria for defining containment venting pressure need to be determined. Interim values are given in this evaluation,
2) Conservatisms in the determination of drywell spray flowrate need to be reduced,
3) The RPV flooding contingency needs to be revised to make the depressurization step more explicit.

The actions specified in the EPGs are generally correct and appropriate and within the operator's capability. The combination of all emergency actions into two guidelines and seven contingencies greatly simplifies the emergency instructions. In addition, the use of symptoms rather than events as bases for actions eliminates errors resulting from incorrect diagnosis of events and addresses multiple failures and operator errors. A more detailed discussion of individual guidelines and contingencies follows.

RPV Control Guideline

The purpose of the RPV control guideline is to restore and maintain RPV water level within a satisfactory range, shut down the reactor, control pressure, and cool the RPV to cold shutdown conditions. The entry conditions are any of the following:

1) Reactor pressure vessel (RPV) water level below low level scram setpoint,
2) Drywell pressure above the high drywell pressure scram setpoint,
3) An isolation which requires or initiates reactor scram,
4) A condition which requires reactor scram and reactor power is above the APRM downscale trip or cannot be determined, or
5) RPV pressure above the scram pressure.

The first step in this guideline is to initiate reactor scram if it has not been initiated. The RPV control guideline then branches into three segments (level control, pressure control, and power control) which are executed concurrently.

o Level control

Level control attempts to control reactor water level between the low level scram setpoint and the high level trip setpoint. If water level cannot be maintained above the low level scram setpoint, then level control attempts to maintain the water level above the top of the active fuel. If level can be maintained above the top of the active fuel and the ADS timer has initiated, then the operator is instructed to reset the ADS timer; this may require frequent resetting of the Automatic Depressurization System (ADS) timer. Four of the seven contingencies

are called from level control. The conditions under which these are called are as follows:

1) Boron injection required, enter level/power control contingency
2) Reactor pressure vessel (RPV) water level cannot be determined, enter RPV flooding contingency
3) RPV flooding required (e.g., drywell or containment temperature near cold reference leg instrument vertical run reaches the RPV saturation temperature; suppression chamber pressure cannot be maintained below the primary containment design pressure), enter RPV flooding contingency
4) If RPV water level cannot be maintained above the top of the active fuel, enter the level restoration contingency
5) If alternate shutdown cooling is required, enter the alternate shutdown cooling contingency.

Each of the contingencies will be discussed separately. For a typical recovery from plant transients there will be no need to call upon any of the contingencies; the steps in the level control portion of the RPV control guidelines are simple and they are adequate to assure that the core is covered with water.

o Pressure Control

The RPV pressure control section of the RPV control guideline controls pressure such that safety relief valve (SRV) cycling is minimized and suppression pool heat capacity and load limits are not exceeded. The steps of the RPV pressure control section are adequate for normal recovery from plant transients and cooldown to shutdown cooling. If

emergency depressurization is anticipated (not yet required), the operator is instructed to rapidly depressurize the RPV with the main turbine bypass valves; this reduces the heat load on the suppression pool.

The heat capacity temperature limit is established such that, starting from any pressure, the suppression pool will accommodate rapid depressurization without exceeding the maximum allowable suppression pool temperature. The suppression pool load limit is established by a curve that defines where stress in the limiting submerged structural component equals yield stress for dynamic loads resulting from SRV discharge. A 10% load increase for each two foot water level increase was used to define the curve. If emergency depressurization, RPV flooding, alternate shutdown cooling or steam cooling is required, then pressure control switches to the corresponding contingency.

o Power Control

The reactor power control section of the RPV guideline verifies that rods are inserted and the reactor is shutdown. The operator is then directed to the scram procedure. The remainder of the power control section deals with those steps (other than water level control) to bring the reactor to a shutdown condition if the rods did not fully insert or if the reactor power is above the APRM downscale trip or cannot be determined. The reactor power control section includes such steps as place the reactor mode switch in shutdown (provides another scram signal), trip the recirculation pumps, inject boron before the suppression pool temperature reaches the boron injection initiation

temperature (typically 110°F) and insert control rods by various means. If these steps do not work, then contingency #7, level/power control, is used to control power by other means.

One step in the reactor power control section is impractical for failures to scram which result in vessel isolation and may not be practical for other failures to scram. Step RC/Q-4.1 states "If boron cannot be injected with SLC, inject boron into the RPV by one or more of the fo'' wing alternate methods:

- o CRD
- o HPCS
- o RWCU
- o Feedwater
- o HPCI
- o RCIC
- o Hydro pump.

Because the time required to add boron to the water source for these systems is large and because sufficient boron may not be available on site, the efficacy of this step is questionable. However, the probability of needing step RC/Q-4.1 is quite low. This step is a "last ditch" effort with a low probability of success. Our review has concluded that at least it is not detrimental to safety to try this approach despite the low probability of success.

Containment Control Guideline

The containment control guideline is executed concurrently with the RPV control guideline. Its purpose is to control primary containment temperature, pressure and level. Entry conditions are any of the following:

1) Suppression pool temperature above the most limiting suppression pool temperature limiting condition for operation (LCO),
2) Drywell temperature above drywell temperature LCO or maximum normal operating temperature, whichever is higher,
3) Containment temperature above its LCO,
4) Drywell pressure above high pressure scram setpoint,
5) Suppression pool water level above its maximum LCO, or
6) Suppression pool water level below its minimum LCO.

The containment control guideline has five sections which are executed concurrently; these are:

SP/T - suppression pool temperature,
DW/T - drywell temperature,
CM/T - containment temperature,
PC/P - primary containment pressure, and
SP/L - suppression pool level.

o SP/T

The SP/T section of the containment control guideline is quite simple. The operator is instructed to close all stuck open relief valves or scram the reactor if the valves cannot be closed. The operator is instructed to operate pool cooling when the pool temperature equals or

exceeds its LCO and to scram the reactor before the pool temperature reaches the boron injection temperature (temperature at which operator is instructed to inject boron). Also, the operator is instructed to control RPV pressure to maintain the pool temperature below the heat capacity temperature limit (locus at points for which stable condensation of discharge from SRVs is assured). If suppression pool temperature and RPV pressure cannot be restored and maintained below the heat capacity temperature limit, then emergency RPV depressurization is required. This latter step would permit the heat capacity temperature limit to be exceeded briefly without emergency depressurization provided a heat sink other than the suppression pool (e.g., main condenser or isolation condenser) is available.

o DW/T

The DW/T section of the containment control guideline is also simple. Its purpose is to monitor and control drywell temperature. The operator is instructed to operate available drywell cooling when drywell temperature exceeds the drywell temperature LCO or maximum normal operating temperature, whichever is higher. If drywell temperature near the cold reference leg instrument vertical runs reaches the RPV saturation temperature (a curve of saturation temperature versus pressure is provided), RPV flooding is required; this step is needed to assure that water level can be determined following flashing in the instrument lines.

Step DW/T-3 states "Before drywell temperature reaches maximum ADS qualification temperature or drywell design temperature, whichever is

lower, but only if suppression chamber temperature and drywell pressure are below the drywell spray initiation pressure limit, shutdown recirculation pumps and drywell cooling fans and initiate drywell sprays restricting flow rate to less than maximum drywell spray flow rate limit" (720 gpm typical). The drywell spray initiation pressure limit is defined to protect against containment collapse due to negative differential pressures (containment to reactor building and drywell to suppression pool) caused by condensation of steam in the containment. This limit applies only to Mark I and Mark II containments. The drywell spray flow rate limit is very low (approximately 10% of flow capability) and is probably very conservative. More work is needed to obtain a more realistic spray flow limit.

If the drywell temperature cannot be maintained below the ADS qualification temperature or drywell design temperature, then emergency depressurization is required. This step is necessary because the high drywell temperature may cause the ADS to become inoperable and the capability to rapidly depressurize, if needed, would be lost.

o CN/T

The CN/T section of the containment control guideline applies to Mark III containments and is very similar to the DW/T section for Mark I and Mark II containments. The operator uses available containment cooling when the containment temperature exceeds its temperature LCO. Before containment temperature reaches the design value, but only if suppression chamber pressure is above the Mark III containment spray initiation pressure limit, the operator initiates suppression pool

sprays. A single value of 1.7 psig was chosen to bound plants with and without vacuum breakers. If the containment temperature cannot be maintained below the design temperature, emergency RPV depressurization is required. If containment temperature near the cold reference leg instrument vertical run reaches the RPV saturation temperature, RPV flooding is required.

o PC/P

The PC/P section of the containment control guideline monitors and controls primary containment pressure. The first step should be sufficient for recovery from most plant transients. The logic for the remaining steps is somewhat complex. In the case of containment venting, there is no well defined basis for a limit. After much discussion among GE, the owners, and various elements of the staff, we have settled on twice the design pressure of the containment as an interim value for venting provided containment integrity can be demonstrated.

The first step of PC/P merely states: Operate the following systems as required:

- o Containment pressure control systems.
- o SBGT and drywell purge, only when the temperature in the space being evacuated is below 212°F.

This step should be sufficient for most situations. The remaining steps are for progressively degraded situations.

Step PC/P-2 states: Before suppression chamber pressure reaches the suppression chamber spray initiation pressure (typically 17.4 psig for

Mark I) but only if suppression chamber pressure is above 1.7 psig (Mark III spray initiation pressure limit) or suppression pool water level is below the elevation of suppression pool spray nozzles, initiate suppression pool sprays. The purpose of the Mark I and II suppression chamber spray initiation pressure limit is to reduce pressure before drywell spray is needed (drywell sprays may damage electrical equipment). The Mark III containment spray initiation pressure limit has already been discussed in the DW/T section. The pool water level limit assures that the sprays can condense steam in the airspace; if the nozzles are submerged, the spray is not effective.

The next step calls for drywell spray, taking cognizance of suppression chamber spray initiation pressure and drywell spray initiation pressure limits discussed previously. Again, there is the limit on drywell spray flow rate which is probably too conservative.

If suppression chamber pressure cannot be maintained below the pressure suppression pressure curve, emergency depressurization is required. The pressure suppression pressure curve serves to limit pressure to a design pressure for blowdown along the heat capacity temperature limit and minimizes excessive bypass leakage.

If suppression chamber pressure cannot be maintained below the primary containment design pressure, RPV flooding is required. Flooding of the RPV should result in subcooled water rather than steam blowing into the containment (the vessel should already be depressurized from the previous step). This should terminate the containment pressurization.

Step PC/P-6 states that, "If suppression chamber pressure cannot be maintained below the primary containment pressure limit, then irrespective of whether adequate core cooling is assured:

- o If suppression pool water level is below elevation of suppression pool spray nozzles, initiate suppression pool sprays.
- o If suppression chamber temperature and drywell pressure are below the drywell spray initiation pressure limit, initiate drywell sprays."

This step elects to preserve containment integrity over core cooling. This is acceptable. It recognizes the value of preserving the last barrier to release of radioactivity and it recognizes that if containment integrity is lost, then core cooling may ultimately fail for such overpressurization events due to loss of heat sink . Because of the extreme nature of this step, it is expected that onsite utility management, engineering staff and operations staff will make every effort, prior to reaching the Primary Containment Pressure Limit, to reduce the containment pressure or to arrest the pressurization. Also, the length of time that flow will be diverted from core cooling should be short; i.e., if the spray is effective in reducing containment pressure, the flow can be immediately returned to core cooling and the RPV control guideline or the level restoration contingency would instruct the operator to do so. The major problem with this step is that the Primary Containment Pressure Limit is not well defined.

The Primary Containment Pressure Limit is supposed to be the best estimate of the pressure at which the containment ruptures. It is well

o SP/L

Section SP/L of the Containment Control Guideline monitors and controls suppression pool water level. The first step merely maintains the water level between the high level and low level LCOs; this should be adequate for most events.

The second step gives a heat capacity level limit based on absorbing energy from a RPV blowdown and states that if suppression pool water level cannot be maintained above that limit, emergency RPV depressurization is required.

The third step of SP/L has several substeps based on progressive increases in water level in the containment above the maximum suppression pool water level LCO. Thus, SP/L.3.1 states "If adequate core cooling is assured, terminate injection into the RPV from sources external to the primary containment." If that cannot be accomplished, SP/L-3.2 states that if suppression pool water level and RPV pressure cannot be restored and maintained below the suppression pool load limit (discussed earlier), emergency RPV depressurization is required. Step SP/L-3.3 calls for drywell spray to reduce containment pressure before the water level reaches the elevation of the vacuum breakers; above that level, the vacuum breakers are ineffective. Step SP/L-3.4 calls for continued operation of the drywell sprays after the vacuum breakers are covered. If the containment pressure and temperature were allowed to increase after the vacuum breakers are covered with water, drywell spray should not be reactivated because the caccum breakers would not be effective in limiting the pressure differential between the drywell and suppresion chamber. Finally, if the water level reaches the Maximum Primary Containment Water Level limit, the operator is instructed to terminate injection into the RPV from sources external to

the primary containment irrespective of whether adequate core cooling is assured. This step is based on preserving containment integrity against failure due to weight of water in the containment even if it causes loss of core cooling and fuel damage. This is a very drastic step which would be required in only the most degraded circumstances. Because of the extreme nature of this step, it is expected that onsite utility management, engineering staff and operations staff will make every effort, prior to reaching the Maximum Primary Containment Water Level Limit, to arrest the accumulation of water in the containment without terminating core cooling.

Contingency #1, Level Restoration

This contingency is entered from the level control portion of the RPV Control Guideline when the operator determines that water level cannot be maintained above the top of the active fuel; however, the water level may still be above the top of active fuel. Once water level is restored to above the top of the active fuel, control is returned to the RPV Control Guideline. If while executing this contingency boron injection is required, RPV water level cannot be determined, or RPV flooding is required, control switches to the appropriate contingency.

The first step in this contingency is to initiate core cooling using the isolation condenser and line up pumps for injection from two or more of the ECCS subsystems or condensate system. If less than two of the normal injection subsystems can be lined up, the operator is instructed to line up as many of the following alternate injection subsystems as possible:

- o RHR service water crosstie,
- o Fire system,
- o Interconnections with other units,
- o ECCS keep-full systems,
- o SLC (test tank),
- o SLC (boron tank).

The operator then monitors RPV pressure and water level and continues at the step indicated in the following logic table:

RPV PRESSURE REGION

[425 psig][1] [100 psig][2]

RPV LEVEL	HIGH	INTERMEDIATE	LOW
INCREASING	C1-4	C1-5	C1-6
DECREASING	C1-7		C1-8

[1](RPV pressure at which LPCS shutoff head is reached)

[2](HPCI or RCIC low pressure isolation setpoint, whichever is higher)

C1-3 MONITOR RPV PRESSURE AND WATER LEVEL. CONTINUE IN THIS PROCEDURE AT THE STEP INDICATED IN THE FOLLOWING TABLE:

RPV PRESSURE REGION

1025 PSIG (*) | 1100 PSIG (+)

RPV WATER LEVEL	HIGH	INTERMEDIATE	LOW
INCREASING	C1-4 ENTER [PROCEDURE DEVELOPED FROM THE RPV CONTROL GUIDELINE] AT [STEP RC/L].	C1-5 IF HPCI AND RCIC ARE NOT AVAILABLE AND RPV PRESSURE IS INCREASING, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED. WHEN RPV PRESSURE IS DECREASING, ENTER [PROCEDURE DEVELOPED FROM THE RPV CONTROL GUIDELINE] AT [STEP RC/L]. IF HPCI AND RCIC ARE NOT AVAILABLE AND RPV PRESSURE IS NOT INCREASING, ENTER [PROCEDURE DEVELOPED FROM THE RPV CONTROL GUIDELINE] AT [STEP RC/L]. OTHERWISE, WHEN RPV WATER LEVEL REACHES [+12 IN. (LOW LEVEL SCRAM SETPOINT)], ENTER [PROCEDURE DEVELOPED FROM THE RPV CONTROL GUIDELINE] AT [STEP RC/L].	C1-6 IF RPV PRESSURE IS INCREASING, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED. WHEN RPV PRESSURE IS DECREASING, ENTER [PROCEDURE DEVELOPED FROM THE RPV CONTROL GUIDELINE] AT [STEP RC/L]. OTHERWISE, ENTER [PROCEDURE DEVELOPED FROM THE RPV CONTROL GUIDELINE] AT [STEP RC/L].
DECREASING	C1-7 IF HPCI OR RCIC IS NOT OPERATING, RESTART WHICHEVER IS NOT OPERATING. IF NO CRD PUMP IS OPERATING BUT AT LEAST 2 INJECTION SUBSYSTEMS ARE LINED UP FOR INJECTION WITH PUMPS RUNNING, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED. WHEN RPV WATER LEVEL IS INCREASING OR RPV PRESSURE DROPS BELOW [1100 PSIG (HPCI OR RCIC LOW PRESSURE ISOLATION SETPOINT, WHICHEVER IS HIGHER)], RETURN TO [STEP C1-3]. IF NO CRD PUMP IS OPERATING AND NO INJECTION SUBSYSTEM IS LINED UP FOR INJECTION WITH AT LEAST ONE PUMP RUNNING, START PUMPS IN ALTERNATE INJECTION SUBSYSTEMS WHICH ARE LINED UP FOR INJECTION. WHEN RPV WATER LEVEL DROPS TO [-161 IN. (TOP OF ACTIVE FUEL)]: ○ IF NO SYSTEM, INJECTION SUBSYSTEM OR ALTERNATE INJECTION SUBSYSTEM IS LINED UP WITH AT LEAST ONE PUMP RUNNING, STEAM COOLING IS REQUIRED. WHEN ANY SYSTEM, INJECTION SUBSYSTEM OR ALTERNATE INJECTION SUBSYSTEM IS LINED UP WITH AT LEAST ONE PUMP RUNNING, RETURN TO [STEP C1-3]. ○ OTHERWISE, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED. WHEN RPV WATER LEVEL IS INCREASING OR RPV PRESSURE DROPS BELOW [1100 PSIG (HPCI OR RCIC LOW PRESSURE ISOLATION SETPOINT, WHICHEVER IS HIGHER)], RETURN TO [STEP C1-3].		C1-8 [IF NO LPCS OR LPCS SUBSYSTEM IS OPERATING,] START PUMPS IN ALTERNATE INJECTION SUBSYSTEMS WHICH ARE LINED UP FOR INJECTION. IF RPV PRESSURE IS INCREASING, EMERGENCY RPV DEPRESSURIZATION IS REQUIRED. WHEN RPV WATER LEVEL DROPS TO [-161 IN. (TOP OF ACTIVE FUEL)] ENTER [PROCEDURE DEVELOPED FROM CONTINGENCY #4].

IF WHILE EXECUTING THE FOLLOWING STEPS THE RPV WATER LEVEL TREND REVERSES OR RPV PRESSURE CHANGES REGION, RETURN TO (STEP C1-3).

*RPV PRESSURE AT WHICH LPCS SHUTOFF HEAD IS REACHED. +HPCI OR RCIC LOW PRESSURE ISOLATION SETPOINT, WHICHEVER IS HIGHER.

Figure I ALTERNATE FORMAT FOR STEPS C1-3 THROUGH C1-8

Where C1-4 through C1-8 refer to steps in contingency #1. There are two criteria to be considered: 1) Is water level increasing or decreasing, and 2) Is RPV pressure high, intermediate or low. If while executing one of the steps indicated, the RPV water level trend reverses or RPV pressure region changes a return to the logic table directs the operator to the correct step. Also, if RPV water level drops below the ADS initiation setpoint, the operator prevents automatic initiation of ADS in order to maintain flexibility in coping with the event. The actions in steps C1-4 through C1-8 are summarized in Figure 1 and are discussed below:

o C1-4 RPV Water Level Increasing, RPV Pressure High.
This step merely tells the operator to return to the procedure developed from the RPV control guideline. If the pressure is high and water level is increasing, the high pressure system(s) is providing sufficient inventory makeup and the operator will soon have to start controlling makeup flow to prevent his high pressure systems(s) from tripping off on high water level.

o C1-5 RPV Water Level Increasing, RPV Pressure Intermediate
If HPCI and RCIC are not available and RPV pressure is increasing, emergency RPV depressurization is required. This is because no high pressure systems are available and the pressure will probably get above the shutoff head for whatever system is providing the makeup if the vessel is not depressurized. If the RPV pressure is decreasing and no HPCI nor RCIC are available, then makeup is being provided by a low pressure system and a decrease in pressure will improve the makeup

capability. Therefore, the operator returns to the procedure developed from the RPV control Guideline.

Even if HPCI or RCIC are not available and RPV pressure is not increasing, but water level is increasing the operator again returns to the procedure developed from the RPV Control Guidelines.

If HPCI or RCIC are available, the operator permits the water level to return to the low level scram setpoint and then returns to the procedure developed from the RPV Control Guideline to control water level in the normal range.

o C1-6 RPV Water Level Increasing, RPV Pressure Low

If RPV pressure is increasing, emergency RPV depressurization is required. This is because low pressure systems are providing the makeup which is causing water level to increase. When their shutoff head is reached, injection ceases and the level will start to drop. If RPV pressure is steady or decreasing, adequate makeup will continue and the operator returns to the procedure developed from the RPV Control Guideline.

o C1-7 RPV Water Level Decreasing, RPV Pressure High or Intermediate

If HPCI or RCIC are not operating, the operator restarts them. These systems may reverse the decrease in water level.

If no CRD pump is operating but at least two normal injection subsystems are lined up for injection with pumps running, emergency RPV

depressurization is required to allow them to inject. If a CRD were running, there is a possibility that the CRD pump would reverse the level decrease before the level reaches the top of the active fuel in which case emergency RPV depressurization would not be required (This was the case during the Browns Ferry fire). However, if no CRD pump is operating, there is no reason to delay emergency depressurization until the water level reaches the top of the active fuel.

If no CRD pump is operating and no normal injection subsystems are lined up for injection with at least one pump running,-the operator starts pumps in alternate injection subsystems which are lined up for injection. When RPV water drops to the top of the active fuel:

1) If no system, injection subsystem or alternate injection subsystem is lined up with at least one pump running, steam cooling is required (contingency #3). Steam cooling is only a temporary measure to gain time to start an injection system. Therefore, when any system, injection subsystem or alternate injection subsystem is lined up with at least one pump running, the operator returns to the logic diagram to determine the appropriate step.
2) Otherwise, emergency RPV depressurization is required. This allows injection by low pressure pumps.

o C1-8 RPV Water Level Decreasing, RPV Low

If no core spray subsystem is operating, the operator start pumps in alternate injection subsystems which are lined up for injection. If RPV pressure is increasing, emergency RPV depressurization is required to

keep the pressure low so that low pressure systems may inject. If water level drops to the top of active fuel, then core cooling without level restoration (contingency #4) is required.

Contingency #2. Emergency RPV Depressurization

Emergency RPV Depressurization is identified as being required at several steps in the Containment Control Guideline, at several steps in Contingency #1, and at two steps in Contingency #7. Whenever Emergency RPV Depressurization is required, pressure control switches to Contingency #2.

Whether boron injection is not required or boron injection is required with all injection into the RPV except from boron injection systems and CRD blocked, several steps are taken which quickly depressurize the reactor pressure vessel. If an isolation condenser is available, it is initiated. If suppression pool water level is above the elevation of top of the SRV discharge device, the operator opens all ADS valves. If any ADS valve cannot be opened, the operator opens other SRVs until the same number of SRVs used for ADS (typically 7) are open. This step should depressurize the RPV to pressures within the range of low head pumps within three to five minutes.

Further, if less than the minimum number of SRVs required for emergency depressurization (typically 3) are open and RPV pressure is at least the minimum SRV re-opening pressure (typically 50 psig) above suppression chamber pressure, the operator rapidly depressurizes the RPV using one or more of the following systems (used in order which will minimize radioactive release to the environment):

- o Main condenser,
- o RHR (steam condensing mode),
- o Other steam driven equipment,

- o Main steam line drains,
- o HPCI steam line,
- o RCIC steam line;
- o Head vent,
- o Isolation condenser tube side vent.

For a typical BWR/4, the reactor can be depressurized quickly with as few as three SRVs. If only one SRV is available, it will still depressurize the RPV but the time to depressurize will be much longer (on the order of 20 to 30 minutes). Therefore additional vent paths will be needed. The main condenser, if available is very effective; most of the other systems listed are low capacity but in combination may be helpful.

If RPV flooding is required, the operator switches to procedures developed from Contingency #6, RPV Flooding once the reactor pressure vessel is depressurized. Otherwise, the operator returns to procedures developed from the RPV Control Guideline once depressurization is complete.

Contingency #3. Steam Cooling

Steam cooling is called out in Contingency #1 if while attempting to restore RPV water level,

1) RPV water level is decreasing and
2) RPV pressure is high or intermediate and,
3) No system, injection subsystem or alternate injection subsystem is lined up with at least one pump running and,
4) RPV water level drops to the top of the active fuel.

Stated simply, steam cooling is used when there are no systems injecting into the vessel. This contingency provides cooling for an interim period while the plant staff attempts to start an injection system, and as soon as a system is injecting, the operator returns to the level restoration contingency.

For steam cooling, the water level is allowed to decrease to the level which corresponds to a maximum fuel cladding temperature of 2000°F. One SRV is then opened to obtain steam cooling. This one valve is held open until pressure drops below 700 psig; this limits peak cladding temperature to 2200°F. When RPV pressure drops below 700 psig, all ADS valves are opened to provide additional steam cooling. Once the vessel is depressurized, no additional steam cooling is possible. These actions are based upon best estimate analyses.

If no systems are injecting into the vessel, steam cooling is the only option available. A slight increase in core cooling time can be achieved by opening the SRVs one at a time, but the additional complication in procedures is unwarranted. Opening of the SRVs one at a

time extends the steam cooling period a few minutes but requires the operator to remain at the SRV control panel during the steam cooling phase.

Contingency #4, Core Cooling Without Level Restoration

Contingency #4 is entered only from step C1-8, RPV water level decreasing, RPV pressure low, of contingency #1. The spray mode of core cooling is established if RPV water level decreases below the top of the active fuel when the vessel is depressurized. In this lineup, a spray subsystem draws suction from the suppression pool and sprays water over the fuel from spargers mounted inside the core shroud. The water then drains back to the suppression pool through the break (if no break, the core spray system will flood the core). In this manner, long term cooling can be provided even though the core cannot be flooded.

When conditions have improved such that RPV water level can be restored to the top of the active fuel, the operator will terminate core spray and return to procedures developed from the RPV control Guideline to control level above the top of the active fuel.

Contingency #5, Alternate Shutdown Cooling

Contingency #5 is entered from the RPV Pressure control section of the RPV Control Guideline if, after stabilization of RPV water level, RPV cooldown is required but cannot be accomplished using normal shutdown cooling or other pressure control systems and all control rods are inserted beyond position 06. The alternate shutdown cooling mode is impractical for the case of a plant shutdown by boron because suppression pool water is circulated through the reactor and boration of the suppression pool would be required to prevent dilution of the boron in the core.

The alternate shutdown cooling procedure removes heat from the RPV by slowly flooding the vessel until the water level is above the level of the main steam lines and the RPV is slightly pressurized; the minimum number of SRVs required (typically one) are opened to establish a flow path to the suppression pool. Low pressure core spray or low pressure coolant injection is used to inject into the vessel and suction is from the suppression pool.

The minimum number of SRVs is selected to maximize the driving head for water flow through the SRVs yet maintain RPV pressure below the point at which a single LPCS or LPCI can deliver sufficient flow to remove decay heat via liquid flow through the open SRVs. Adequate flow is defined to be the flow rate which limits the temperature rise within the core to 100°F for decay heat generated ten minutes after a scram from full power; this is a conservative assumption for shutdown cooling. The

alternate shutdown cooling mode is an acceptable means of cooling the system if normal methods are not available.

Contingency #6, RPV Flooding

Reactor pressure vessel flooding is required when:

1) RPV water level cannot be determined,

2) Drywell temperature reaches the RPV saturation temperature,

3) Containment temperature reaches the RPV saturation temperature, or

4) Suppression chamber pressure cannot be maintained below the primary containment design pressure.

The flooding procedure depressurizes the RPV and slowly fills the vessel using any of a number of specified makeup systems. If water level cannot be determined, flooding may be verified by monitoring the response of RPV pressure. As in alternate shutdown, SRVs provide a return path for flow to the suppression pool.

Three separate flooding methods are used in contingency #6. If flooding is necessary when all control rods are not fully inserted, Step C6-2 is followed. If flooding is required because RPV water level cannot be determined, Step C6-3 is used. If water level can be determined and all rods are fully inserted, Step C6-4 is used.

For Step C6-2, all injection into the RPV except from boron injection systems and CRD, is blocked to avoid large power excursions due to cold water addition from ECC system, and boron dilution. Once RPV pressure is below the minimum alternate RPV flooding pressure, injection is commenced and slowly increased to maintain pressure above the minimum alternate RPV flooding pressure. The minimum alternate RPV flooding

In step C6-4, if suppression chamber pressure exceeds the primary containment design pressure, flooding is required to quench the source of steam which is pressurizing the containment. This is the only situation in the guidelines which requires flooding when water level can be determined. In this case, the operator floods the vessel and continues flooding until primary containment pressure is reduced.

Contingency #7, Level/Power Control

Contingency #7 is entered from Guideline RC/L or Contingency #1 if boron injection is required following a failure to scram. The objective of Contingency #7 is to minimize heatup of the suppression pool during boron injection. If a reactor isolation does not accompany a failure to scram, it is unlikely that Contingency #7 will be entered. Steam will simply be discharged to the condenser and no containment heatup will occur. If a reactor isolation does occur, relief valves will discharge steam to the suppression pool at a rate equivalent to the reactor power level. Unless power is reduced, the suppression pool heatup during the boron injection will be excessive. Tripping the recirculation pumps to reduce power to natural circulation levels is not sufficient. Therefore, the operator decreases power by reducing the core flow by lowering the water level and thus reducing the natural circulation driving head.

The operator lowers RPV water level by terminating and preventing all injection into the RPV except from boron injection systems and CRD until either:

1) Reactor power drops below the APRM downscale trip, or
2) RPV water level reaches the top of active fuel, or
3) All SRVs remain closed and drywell pressure remains below the high drywell pressure scram setpoint.

This minimizes the suppression pool heatup but also reduces the flow below that required to mix the boron with the water in the vessel.

If flow is decreased sufficiently to reduce reactor power to the desired level, boron mixing efficiency is so low that the boron stagnates in the lower plenum. Once the required amount of boron has been injected, core flow must be increased to rapidly distribute the boron throughout the core. This is accomplished by raising RPV water level until natural circulation flow is reestablished (recirculation pumps cannot be used because of the low RPV water level interlock, designed to prevent cav[illegible]n). Test data indicate that sufficient boron mixing will occur as the water level increases.

Decreasing the water level to the top of the active fuel may result in large flow oscillations accompanied by power oscillations and water level oscillations. The effects of these oscillations on the fuel rods is unknown. However, lowering the water level to reduce power is necessary to minimize pool heatup because: 1) If HPCI (or HPCS) and RCIC are used to keep the water level above the top of the active fuel, emergency RPV depressurization will be required to prevent exceeding the heat capacity temperature limit of the suppression pool, 2) HPCI and RCIC take suction from the condensate storage tank initially but have to switch to suction from the suppression pool after about 20 minutes. As the pool heats up, HPCI and RCIC will possibly be lost due to bearing failure and low pressure systems will be required to inject.

The steps outlined in Contingency #7 to reduce power by dropping water level to the top of the active fuel are contrary to normal operator response and have the potential to produce some cladding failure as a

Conclusions

We have reviewed the BWR Emergency Procedure Guidelines and find them to be conditionally acceptable: There are two situations, combustible gas control and secondary containment control which have not yet been covered. These must be covered in subsequent revisions to the guidelines. There are also a few sections in the guidelines which require more work. These include:

1) Criteria for defining containment venting pressure need to be determined,

2) Conservatisms in the determination of drywell spray flow rate need to be reduced,

3) The RPV flooding contingency needs to be revised to make the depressurization step more explicit.

With these exceptions, we find the guidelines to be acceptable. Implementation of procedures based on the guidelines may proceed before these concerns are corrected.

Because the BWR Owners' Group may disband after these guidelines are approved, there is a need for a group consisting of BWR owners and General Electric to complete the development of the guidelines and to maintain the guidelines after development is complete. The development of the guidelines may be considered complete after combustible gas control and secondary containment control guidelines are reviewed and approved. Maintenance would include incorporation of operating experience and new knowledge into the guidelines and modification of the guidelines to account for new equipment.