**Enclosure 1**

**MFN 08-641, Supplement 1**

**Response to Portion of NRC Request for**

**Additional Information Letter No. 278**

**Related to ESBWR Design Certification Application**

**DCD Tier 2, Sction 3.9**

**Mechanical Systems and Components**

**RAI Numbers 3.9-200 S01**

**For historical purposes, the original text of RAI 3.9-200 and the GEH response are included. The attachments (if any) are not included from the original response to avoid confusion.**

**NRC RAI 3.9-200**

*NRC Summary:*
*GDCS check valve design and orientation*

*NRC Full Text:*
*Discuss the evaluation of potential impact of vertical orientation of check valves in the ESBWR Gravity-Driven Cooling System (GDCS). As described in Section 6.3, "Emergency Core Cooling Systems," of the ESBWR Design Control Document (DCD) Tier 2, Revision 4, the GDCS is required to inject cooling water into the reactor by gravity flow following a loss of coolant accident (LOCA). In a presentation to the Advisory Committee on Reactor Safeguards (ACRS) on May 8, 2008, GEH indicated that the GDCS might include vertically mounted check valves. In a letter dated March 27, 2008 (MFN 08-084), GEH had indicated that the GDCS check valves might be horizontally or vertically mounted. Under specific LOCA depressurization scenarios, there could be significant reactor coolant pressure present when the GDCS squib valve actuates and reverse flow through the GDCS line might occur until the flow closes the check valve. In light of these possible GDCS design features, please provide the following information:*

*a) Discuss the design and analysis of applicable components for waterhammer loading due to the reverse acceleration and stoppage of the GDCS water column from the check valve closure, including performance of tests and analysis of affected pressure boundary and active system components.*

*b) Discuss the design and analysis of applicable components for loading due to the formation of steam in the GDCS piping during depressurization of hot reactor coolant following a LOCA and the subsequent condensation-induced waterhammer during GDCS injection, including performance of tests and analysis of affected pressure boundary and active system components.*

*c) Discuss the consideration of the force on the valve disk necessary for closure of the check valve in the vertically-mounted position under all conditions of reverse flow.*

*d) Discuss the provisions to provide assurance that for all conditions of GDCS injection, the valve disk of the vertically mounted check valve will be stable and in the fully open position, without damage or wear caused by chatter or flutter of the disk.*

*e) Discuss the potential for the GDCS check valves in vertical flow lines to remain partially open under slow pressure increase conditions of the reactor coolant system that could allow backflow to the cooling water pools.*

*f) Discuss the specifications for the inservice testing program for the GDCS check valves in vertical flow lines to provide reasonable assurance of their operational readiness based on their application and performance requirements.*

**GEH Response**

The GDCS check valves will either be installed in a horizontal piping run and be held normally open by a spring, or in a vertical piping run and be held normally open by gravity. In either case, the net force keeping the valve open will be minimized to a value sufficient to ensure the valve is open with no differential pressure (DP). One conceptual configuration is a nozzle check valve in a vertical pipe, oriented such that gravity opens the valve. To minimize the reverse flow/DP required to close the valve, valve opening would be resisted by a light spring, sized such that the valve is fully open with no DP (disk weight is equal to the spring force at fully open). Discussions with a valve vendor determined that this type of valve in this configuration would close with a fraction of 1 psi DP in the reverse direction.

The GDCS squib valves are actuated 150 seconds after a confirmed Level 1 signal. ADS actuation begins 50 seconds after a confirmed Level 1 signal. Therefore, when the GDCS squib valves actuate, reactor pressure is significantly below the normal operating pressure. For the accident cases analyzed, the range of reactor pressures at squib valve actuation is 58 to 218 psig. Based on the safety analyses, up to 130 seconds may pass before reactor pressure drops below the GDCS injection pressure. The GDCS check valves will remain closed during this time and will reopen as reactor pressure reaches the GDCS injection pressure (with a fraction of 1 psi reverse DP). GDCS injection will begin at a low flow rate and gradually increase as the reactor further depressurizes.

a) As discussed above, the reactor pressure when the GDCS squib valves actuate will be significantly less than normal reactor pressure (up to about 218 psig). The GDCS check valves will be designed to minimize the impact loads due to valve closure. For example, a fast-acting design with a lightweight disk, such as a nozzle check valve, will be used, such that damage from deceleration of GDCS system fluid will not occur. Valve qualification will also address these closing conditions and verify acceptable valve performance.

b) The piping between the GDCS pools and the reactor pressure vessel (RPV) is a continuous loop seal and is therefore expected to remain full of water (i.e., no steam voids should exist). In addition, as discussed above, GDCS injection begins at a low flow rate and gradually increases as the reactor depressurizes. Therefore, no rapid pressure changes that could lead to waterhammer are expected during GDCS injection.

c) See the discussion above on check valve operation. The check valve will be designed and qualified to ensure it remains open under normal operating conditions (zero DP) and closes under low reverse DP/flow conditions.

d) As discussed above, after squib valve initiation but before reactor pressure falls below GDCS injection pressure, the check valves will be closed by the reverse flow/DP. The GDCS check valves will begin to open with a fraction of 1 psi reverse DP across the valves and will be fully open when reactor pressure drops to the GDCS injection pressure and forward flow begins, such that no chatter or flutter will occur. Valve qualification will verify check valve performance under these conditions.

e) There are no “slow pressure increase conditions of the reactor coolant system” under either normal or design basis conditions following actuation of the GDCS injection valves (during which time reverse flow through the check valves could occur). During normal operating conditions, there is no DP across the check valves, and the pressures are not changing on either side of the check valves. When the injection squib valves actuate, the pressure on the downstream side of the check valves is decreasing.

f) As shown in DCD, Revision 5, Table 3.9-8 for the GDCS system, the GDCS check valves will be IST tested during refueling outages. Open/close exercise testing, leakage testing and position indication verification testing will be performed. Exercise testing will verify that the valves are held open with no DP or flow and that the valves close on low reverse flow/DP.

**DCD Impact**

No DCD changes will be made in response to this RAI.

**NRC RAI 3.9-200 S01**

*Summary: GDCS check valve design attributes*

*RAI Text:*
*A) In response to RAIs 3.9-200, 201, and 203, GEH specified design attributes for the Gravity Driven Cooling System (GDCS) check valves and valves in other plant systems in MFN 08-641 (dated August 18, 2008) and MFN 08-652 (dated August 26, 2008). The NRC staff will rely on those design attributes in reaching a safety finding on the ESBWR Design Certification application. Therefore, the staff requests that GEH include the design attributes for the GDCS check valves and other valves specified in its response to RAIs 3.9-200, 201, and 203 in Section 6.3 of the ESBWR Design Control Document (DCD) Tier 2.*

*B) In RAI 3.9-200, the NRC staff requested that GEH provide information related to the evaluation of the potential impact of vertical orientation of GDCS check valves. The staff has reviewed the GEH responses to the individual paragraphs in RAI 3.9-200 and need the following information:*

*1) In paragraph (a) in RAI 3.9-200, the NRC staff requested that GEH confirm that potential waterhammer loads from the reverse flow of water in the GDCS line closing the check valve following squib valve actuation will be evaluated. In its response to this RAI (MFN 08-641), GEH did not confirm that the design process for the GDCS piping will include this evaluation. In its RAI response, GEH stated that the open check valve will have a spring force that will exactly balance the weight of the disk to minimize the reverse flow and differential pressure to close it. However, the disk will be required to travel its stroke distance to close. The motion of the water column in the GDCS line will be equivalent to at least the swept volume of the disk, and additional water column displacement will result from drag force on the disk and uncertainties in the check valve performance. Significant loads could result from check valve closure following a water column displacement of only one pipe diameter. In addition, GEH stated that the reactor pressure during squib valve actuation following an accident is in the range of 58 to 218 psig; however, the ESBWR DCD specifies that the check valves and GDCS piping must be capable of stopping the reverse flow with full reactor pressure conditions following a spurious squib valve actuation. GEH is requested to verify that the design process will include an evaluation of the GDCS check valve closure loads.*

*2) In RAI 3.9-200(b), the NRC staff requested that GEH discuss the design and analysis of applicable components for loading due to the formation of steam in the GDCS piping during depressurization of the reactor coolant following a postulated accident. In its response to this RAI (MFN 08-641), GEH stated that the GDCS piping is a continuous loop seal that is expected to remain full of water without steam voids following a reactor depressurization. However, unless the water in the GDCS line is maintained below a* *temperature of 212 .F, some water will flash to steam when the reactor depressurizes. GEH did not provide information addressing the control of water temperature, or the loads resulting from the formation of steam. Steam that forms will tend to rise in vertically sloping piping or might mix with cooler liquid in the line, resulting in condensation-induced phenomena such as chugging flow and waterhammer. Further, if the loop seal section of the piping is not full of water, steam from the vessel will enter the GDCS piping and this countercurrent steam flow could result in flow instability, condensation-induced water hammer, and restriction of necessary GDCS cooling flow until the loop seal is refilled. Therefore, the NRC staff requests that GEH discuss the control of the water temperature in the GDCS line to prevent steam formation when the reactor depressurizes, or provide assurance that the steam that forms will not result in excessive loading to the GDCS or reduction in the necessary GDCS injection flow.*

*3) In RAI 3.9-200(c), the NRC staff requested that GEH discuss the force necessary for closure of the GDCS check valves. In its response to this RAI (MFN 08-861), GEH indicated that the GDCS check valves will be designed and qualified to ensure that they will remain open under normal operating conditions with no differential pressure, and will close under low reverse flow and differential pressure conditions. However, GEH did not provide information to provide assurance that the actual expected loads on the check valve and piping will be considered in the qualification process. Therefore, the NRC staff requests that GEH verify that the design process will include consideration of the expected reverse check valve closure loads in the qualification of the GDCS check valves, piping, and other components.*

*4) In RAI 3.9-200(e), the NRC staff requested that GEH discuss the potential for the GDCS check valves to remain partially open under slow pressure increase conditions of the reactor coolant system that could allow backflow to the cooling water pools. In its response to this RAI (MFN-08-641), GEH stated that there are no slow pressure increase conditions of the reactor coolant system under either normal or design basis conditions following actuation of the GDCS injection valves. GEH indicated that when the injection squib valves actuate, the pressure on the downstream side of the check valves will be decreasing. The NRC staff requests that GEH discuss the potential for a slow pressure increase to occur later during a postulated event that might cause the GDCS check valves to remain partially open.*

**GEH Response**

A. Key design attributes of the GDCS check valves described in the responses to RAIs 3.9-200, 3.9-201 and 3.9-203 will be added to Section 6.3 of the DCD. Verification that these design attributes are met in the design and qualification of the GDCS check valves is covered by ITAAC 10a and 10b in Table 2.4.2-3 of DCD Revision 5 Tier 1.

B. Responses are below.

(1) Section 6.3 of the DCD will be revised to indicate that the design process will include an evaluation of the GDCS check valve closure loads.

(2) As discussed in the response to RAI 21.6-112 (MFN 08-692, 9/17/08), steam and noncondensable gases cannot flow from the reactor pressure vessel (RPV) into and up the GDCS line. For the GDCS Line Break bounding LOCA case, the GDCS flow initiates when the downcomer two-phase level is still above the elevation of GDCS line entry to the RPV. When the downcomer water level recedes below the GDCS nozzle elevation, steam flows towards the cold water in the GDCS line and condenses. The steam condensing capacity of the flow from the intact GDCS lines exceeds the rate at which steam flows towards the cold water, by a factor of two to three.

(3) Section 6.3 of the DCD will be revised to indicate that the design process will include consideration of the expected reverse check valve closure loads in the qualification of the GDCS check valves, piping and other components.

(4) Following GDCS squib valve actuation and initial GDCS injection, which occur after the automatic depressurization system (ADS) has actuated, the RPV pressure increases, as shown in DCD Tier 2 Figures 6.2-9a1, 6.2-10a1, 6.2-11a1, 6.2-12a1, 6.2-13a1 and 6.2-14a1, as the drywell pressure increases. At this point in the accident scenarios, the DPVs are open, and the pressures in the RPV steam dome and in the GDCS pool gas space are essentially the same. Any slow change in the RPV pressure (downstream of the check valves) will also reflect in the GDCS pool gas space and eventually in the piping upstream of the check valves. Note that the bottom of the GDCS pools (~ 18 m elevation) is about 10.5 m above the top of active fuel (TAF, ~7.5 m).

For high elevation breaks (e.g., a main steam line break), the GDCS pool long-term (equilibrium) water level is at about the same elevation as the DPVs, which is approximately 21 m from the RPV bottom or 13.5 m above the TAF. In these cases, some backflow into the GDCS pools could occur if there are brief pressure transients that result in the RPV pressure slightly exceeding the GDCS injection pressure, such that the check valves do not fully reseat. However, this backflow is not a concern because the RPV water level is 13.5 m above the TAF.

For low elevation breaks, such as a feedwater line break, GDCS line break, or bottom drain line break, the break elevations are below the GDCS pool bottom. For these cases, the long-term GDCS pool water level drops to the pool bottom (~18 m), and the RPV level drops below 18 m (but ~2 m above the TAF). In these cases, there may be some backflow into the GDCS injection lines if there are brief pressure transients that result in the RPV pressure slightly exceeding the GDCS injection pressure, such that the check valves do not fully reseat. This backflow is not a concern because it has a small effect on RPV level since the cross-sectional area of the reactor vessel is much greater than for the injection lines.

**DCD Impact**

DCD Tier 2, Subsection 6.3.2.7.2 will be revised in DCD Revision 6 as noted in the attached markup.

**GDCS Check Valve**

The GDCS check valves are ~~designed and installed such that the valves are fully open with zero differential pressure across the valve and fully closed with a low reverse differential pressure to prevent back flow. The check valve is a~~ long duration submersible, piston check valves ~~(of suitable pattern such as Y-pattern or axial flow) installed in a horizontal or vertical piping run~~. The valves meet~~s~~ the requirements for minimum fully open flow coefficient in the forward flow direction and maximum fully open flow coefficient in the reverse flow direction. The reverse flow coefficient addresses the case in which a check valve sticks in the fully open position following a LOCA. Type testing is performed to verify the valve meets the reverse flow coefficient requirement. The results of the testing and a comparison of the measured flow coefficient to the maximum value is documented in a report. The check valve is classified as Quality Group A, Seismic Category I, and ASME Section III Class 1.

Remote check valve position indication is provided in the main control room by position-indication instrumentation.

The check valves will either be installed in a horizontal piping run and held normally open by a spring or installed in a vertical piping run and held normally open by gravity. In either case, the net force keeping the valve open will be minimized to a value sufficient to ensure the valve is open with no differential pressure. One possible configuration is a nozzle check valve in a vertical pipe, oriented such that gravity opens the valve. To minimize the reverse flow/differential pressure required to close the valve, valve opening would be resisted by a light spring, sized such that the valve is fully open with no differential pressure (disk weight is equal to the spring force at fully open).

When the GDCS squib valves actuate, reactor pressure is significantly below the normal operating pressure but above the GDCS injection pressure. The GDCS check valves will remain closed until the reactor pressure is just above the GDCS injection pressure. As reactor pressure drops further, GDCS injection will begin at a low flow rate and gradually increase, such that chatter is not expected to occur.

The GDCS check valves are located upstream of the GDCS injection squib valves, which are located at the bottom of a U-shaped pipe loop, and open block valves downstream of the squib valves. During normal operation, the injection line squib valves are closed and pipe legs on both sides of the squib valves are filled with water. The water solid pipe legs from the squib valves to the reactor pressure vessel inlet nozzles prevent non-condensable gases from entering into the injection lines. The GDCS injection lines from the squib valves to the GDCS pools are self-venting back to the pools, which are at the highest elevation of the system. Test lines in the system stay filled with liquid up to the test line isolation valves.

The design process for the GDCS check valves will evaluate the loads on the valve disk during normal and design basis conditions to ensure the valves remain open under normal operating conditions (zero differential pressure) and will close under low reverse differential pressure/flow conditions. The design process will also include an evaluation of the closure loads on the valve, piping and other applicable components under design basis conditions and following an inadvertent actuation of the GDCS squib valves, to ensure damage from deceleration of GDCS fluid will not occur. Valve qualification will verify applicable design requirements are met and will also address the effect of the installed orientation on valve performance.