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Supplement 7

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Subject: **Response to Portion of NRC Request for Additional Information Related To ESBWR Design Certification Application -- Acceptance Criteria for the Design and Qualification of the Gravity Driven Cooling System Squib Valves -- RAI 3.9-160 S01 (E-mail from Chandu Patel - NRC)**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to a portion of the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) sent by NRC e-mail dated June 16, 2007, Reference 1. The previous response was submitted via Reference 2 in response to NRC Letter No. 67, Reference 3. RAI 3.9-160 S01 is addressed in Enclosure 1.

If you have any questions or require additional information, please contact me.

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

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References:

1. E-mail from Chandu Patel (NRC), Supplement 1 to RAI 3.9-160 S01, dated June 16, 2007.

2. MFN 06-489, Letter from David Hinds to the U.S. Nuclear Regulatory Commission, *Response to Portion of NRC Request for Additional Information Letter No. 67 Related to ESBWR Design Certification Application Concerning Mechanical Systems and Components - RAI Numbers 3.9-3 through 3.9-175*, dated November 30, 2006.

3. MFN 06-378, Letter from the U.S. Nuclear Regulatory Commission to David H. Hinds, *Request for Additional Information Letter No. 67, Related To ESBWR Design Certification Application*, dated October 10, 2006.

Enclosure:

1. MFN 06-489 Supplement 7, Response to Portion of NRC Request for Additional Information Related to ESBWR Design Certification Application -- Acceptance Criteria for the Design and Qualification of the Gravity Driven Cooling System Squib Valves -- RAI Number 3.9-160 S01

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Enclosure 1

MFN 06-489 Supplement 7

Response to Portion of NRC Request for Additional Information

Related to ESBWR Design Certification Application

Acceptance Criteria for the Design and Qualification of the

Gravity Driven Cooling System Squib Valves

RAI Number 3.9-160 S01

NRC RAI 3.9-160

Describe the method for functional design and qualification including acceptance criteria for demonstrating that the squib valves will perform their function for a range of system pressure, pressure differential, temperature and ambient conditions from normal operating up to design basis conditions.

GE Response

Manufacturer before delivery to site will conduct mechanical testing of GDCS squib valves. Testing will include a full range of pressures and temperatures from ambient conditions to design-basis conditions. The GDCS squib valves will have a piston of sufficient length to drive the valve open. Opening stroke will be guided by guide ribs or other feature to provide an unobstructed flow path. See DCD Tier 2 Revision 2, Subsection 6.3.4.1.

DCD Impact

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

NRC RAI 3.9-160 S01

Comment on response to RAI 3.9-160 (MFN 06-489):
The applicant is requested to specify the acceptance criteria for the design and qualification of the gravity driven cooling system squib valves.

GEH Response

DCD Tier 2 discusses generic requirements for valve design and qualification (see Sections 3.9, 3.10 and 3.11). Additional requirements for the GDCS squib valves will be added to the DCD as shown in the DCD Impact section below. Detailed design requirements for these valves (e.g., pressures, flows and temperatures) will be specified in a valve specification (either specific to the GDCS squib valves or generic to the ESBWR) and in the purchase order. The vendor will be required to demonstrate that the valves are capable of performing their required functions under the conditions specified in the valve specification and/or purchase order.

DCD Impact

DCD Tier 2, Section 6.3.2.7.2 will be revised as shown in the attached mark-up.

6.3.2.7.2 System Description

Summary Description

The GDCS provides short-term post-LOCA water makeup to the annulus region of the reactor through eight injection line nozzles, by gravity-driven flow from three separate water pools located within the drywell at an elevation above the active core region. The system provides long-term post-LOCA water makeup to the annulus region of the reactor through four equalization nozzles and lines connecting the suppression pool to the RPV. During severe accidents the GDCS floods the lower drywell region directly via four GDCS injection drain lines (one each from two pools and two from the third pool) through deluge system, if the core melts through the RPV.

Detailed System Description

The GDCS is composed of four divisions designated as Divisions A, B, C, and D. Electrical separation and mechanical train separation between the divisions is provided. The mechanical trains A and D draw water from independent pools designated as A and D and trains B and C draw water from a common pool designated as B/C. Physical separation is ensured between divisions by locating each train in a different area of the reactor containment. A single division of the GDCS consists of three independent subsystems: a short-term cooling (injection) system, a long-term cooling (equalizing) system, and a deluge line. The short-term and long-term systems provide cooling water under force of gravity to replace RPV water inventory lost during a LOCA and subsequent decay heat boil-off. The deluge line connects the GDCS pool to the lower drywell. GDCS typical process flows are shown in Figure 6.3-1a.

Table 6.3-2 provides the design basis parameters for the GDCS, and includes:

- For GDCS pools, the minimum total drainable inventory;
- The minimum surface elevation of the GDCS pools above the RPV nozzle elevation;
- The minimum suppression pool available water inventory 1 meter above TAF; and
- The minimum GDCS equalizing line driving head, which is determined by the elevation differential between the top inside diameter of the first Suppression Pool (S/P) horizontal vent and the centerline of the GDCS equalizing line RPV nozzle.

The GDCS deluge lines provide a means of flooding the lower drywell region with GDCS pool water in the event of a core melt sequence which causes failure of the lower vessel head and allows the molten fuel to reach the lower drywell floor.

The core melt sequence results from a common mode failure of the short-term and long-term systems, which prevents them from performing their intended function. Deluge line flow is initiated by thermocouples, which sense high lower drywell region basemat temperature indicative of molten fuel on the lower drywell floor. Logic circuits actuate squib-type valves in the deluge lines upon detection of basemat temperatures exceeding setpoint values, provided another set of dedicated thermocouples also sense the drywell temperature to be higher than a preset value. The deluge lines do not require the actuation of squib-actuated valves on the injection lines of the GDCS piping to perform their function.

Each division of the GDCS injection system consists of one 200-mm (8-inch) pipe (with a temporary strainer[1] and a block valve) exiting from the GDCS pool. Just after the 200-mm (8-inch) block valve a 100-mm (4-inch) deluge line branches off and is terminated with three 50-mm (2-inch) squib valves and deluge line tailpipe to flood lower drywell. The 200-mm (8-inch) injection line continues after the 100-mm (4-inch) deluge line connection from the upper drywell region through the drywell annulus where the 200-mm (8-inch) line branches into two 150-mm (6-inch) branch lines each containing a check valve, squib valve, and block valve. Each division of the long-term system consists of one 150-mm (6-inch) equalizing line with two block valves, a check valve and a squib valve. All piping is stainless steel and rated for reactor pressure and temperature. Figure 6.3-1 illustrates the arrangement of GDCS piping configuration.

The RPV injection line nozzles and the equalizing line nozzles all contain integral flow limiters with a venturi shape for pressure recovery. The minimum throat diameter of the nozzles in the short-term system is 76.2 mm (3 in) and the minimum throat diameter of the nozzles in the long-term system is 50.8 mm (2 in.). Each injection line and equalizing line contains a locked open, manually-operated maintenance valve located near the vessel nozzle and another such valve located near the water source.

In the injection lines and the equalizing lines, there exists a check valve located upstream of the squib-actuated valve. Downstream of the squib-actuated injection valve is a test line, which can be used to back-flush. This operation is conducted during refueling and maintenance outages for the region of piping between the reactor and the squib valve.

The GDCS squib valves are gas propellant type shear valves that are normally closed and which open when a pyrotechnic booster charge is ignited. The squib valve is designed to withstand the drywell LOCA environment sufficiently long enough to perform its intended function. During normal reactor operation, the squib valve is designed to provide zero leakage. Once the squib valve is actuated it provides a permanent open flow path to the vessel.

The check valves close upon reverse impulse cuased by spurious GDCS squib valve operation to protect the lower pressure piping and minimize the loss of RPV inventory after the squib valves are actuated and the vessel pressure is still higher than the GDCS pool pressure plus its gravity head. Once the vessel has depressurized below GDCS pool surface pressure plus its gravity head, the differential pressure opens the check valve and allow water to begin flowing into the vessel.

The deluge valve is a squib-actuated valve that is initiated by a high temperature in the lower drywell region. This temperature is sensed by thermocouples located on the basemat protective layer. The deluge valve is designed to survive the severe accident environment of a core melt and still perform its intended function. The pyrotechnic material of the squib charge used in the deluge valve is different than what is used in the other GDCS squib valves to prevent common mode failure. The deluge valve is designed to withstand the water hammer expected as a result of an inadvertent GDCS squib valve opening while the reactor is at normal operating pressure and temperature. Once the deluge valve is actuated it provides a permanent open flow path from the GDCS pools to the lower drywell region. Flow then drains to the lower drywell via permanently open drywell lines.

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[1] Temporary strainer will be removed after initial flushing of GDCS injection lines.

The GDCS check valves remain fully open when zero differential pressure exists across the valve. A test connection line downstream of the check valve allows the check valve to be tested during refueling outages. This provides a means for testing the operation of the check valve.

All system block valves are normally locked open and are used for maintenance during a plant refueling or maintenance outage.

Suppression pool equalization lines have an intake strainer to prevent the entry of debris material into the system that might be carried into the pool during a large break LOCA. The GDCS pool airspace opening to the DW will be covered by a perforated steel plate to prevent debris from entering pool and potentially blocking the coolant flow through the fuel. Protection against the dynamic effects associated with postulated pipe ruptures is described Section 3.6. The maximum hole diameters in the perforated steel plate are are 38 mm (1.5 inch) A splash guard is provided at the opening to minimize any sloshing of GDCS pool water into the drywell following dynamic event.

The GDCS is designed to operate from safety-related power. The system instrumentation and the GDCS squibs are powered by divisionally separated safety-related power. The deluge valve initiation circuitry is powered nonsafety-related, 250 V DC.

System Operation

During normal plant operation, GDCS is in a standby condition. It can be actuated simply by transmitting a firing signal to the squib valves. The firing signal can be initiated automatically or manually from switches in the main control room. The design basis for the system during normal plant operation is to maintain RPV backflow leak-tight. Each GDCS injection line positively prevents unnecessary heating of the GDCS pools and transport of radioactive contamination to the GDCS pools and/or suppression pool.

When the reactor is shutdown, the GDCS is normally in a standby condition. Deactivating and isolating GDCS divisions are governed by plant Technical Specifications.

During a LOCA, GDCS is initiated following a confirmed ECCS initiation signal from NBS. The signal starts two sets of timers in each division; two injection valve timers for initiation of the short-term water injection lines and two longer equalization timers which create a permissive signal (in combination with RPV water level below Level 0.5 or 1 meter above TAF) for initiation of the long-term injection lines. After the injection valve timer expires after a confirmed ECCS initiation signal, the short-term injection squib valves open to allow water to flow from the GDCS pools to the RPV. Once the reactor becomes adequately depressurized the water flow refills the RPV thereby ensuring core coverage and decay heat removal.

The long-term portion of GDCS can begin operation following a longer equalization valve time delay initiated by a confirmed ECCS initiation signal and when RPV level reaches Level 0.5, which is 1 m (3.28 ft.) above the TAF. Flow is initiated with the opening of the squib valve on each GDCS equalizing line. The GDCS equalizing lines perform the RPV inventory control function in the long term and makeup for the following inventory losses:

- For any LOCA above the core the equalizing lines provide for coolant boil-off losses to the drywell (Most coolant boil-off is returned to the RPV as condensate from the isolation condensers or the Passive Containment Cooling System heat exchangers).

- For a vessel bottom line break, the equalizing line provides inventory for coolant boil-off losses to the drywell and break flow losses in the mid-term. In the long term the equalizing lines provide for evaporation losses to the drywell.

The GDCS is designed to mitigate the consequences of a hypothetical severe accident with molten core material on the lower drywell floor. The lower drywell basemat is divided into 30 cells, with two thermocouples (channel A and B) installed in each cell, to sense the presence of molten fuel on the lower drywell floor. Temperature greater than setpoint sensed by channel A thermocouples in any two adjacent cells, coincident with channel B thermocouples also sensing temperature greater than setpoint in any two adjacent cells, initiates deluge line flow. Inadvertent actuation is prevented by the presence of an inhibit signal if another set of dedicated safety-related thermocouples monitoring the lower drywell temperature do not sense the temperature to be greater than a preset value. The initiation signal opens the deluge valve on each separate deluge line to allow GDCS pool water to drain to the lower drywell. This water aids in cooling the molten core.

Equipment and Component Description

The following describes the GDCS squib valve, deluge valve and biased-open check valve, which are unique system components that are not used in previous BWR designs.

Squib Valve

The function of the squib valve is to open upon an externally applied signal and to remain in its full open position without any continuing external power source in order to admit reactor coolant makeup into the reactor pressure vessel in the event of a LOCA. The valves also function in the closed position to maintain RPV backflow leaktight and maintain reactor coolant pressure boundary during normal plant operation. The GDCS squib valves have a C_v that will permit development of full GDCS flow. The valve is a horizontally mounted, straight through, long duration submersible, pyrotechnic actuated, non-reclosing valve with metal diaphragm seals and flanged ends. The valve design is such that no leakage is possible across the diaphragm seals throughout the 60-year life of the valve. The squib valve is classified as Quality Group A, Seismic Category I, and ASME Section III Class 1. The valve diaphragm forms part of the reactor pressure boundary and as such is designed for RPV service level conditions.

Illustrated in Figure 6.3-2 is a typical squib valve design that satisfies GDCS system requirements. This valve has similar design features to the ADS depressurization valve.

Valve actuation initiates upon the actuation of either of two squib valve initiators, a pyrotechnic booster charge is ignited, and hot gasses are produced. To minimize the probability of common mode failure, the injection line squib valve pyrotechnic booster charge is from a different batch than from the batch used in equalizing line squib valves. When these gasses reach a designed pressure, a tension bolt holding a piston breaks allowing the piston to travel downward until it impacts the ram and nipple shear caps. Once the piston impacts the ram and nipple shear caps, the nipples are sheared. The ram and shear caps are then driven forward and are locked in place at the end of stroke by an interference fit with the nipple retainer. This lock ensures that the nipples cannot block the flow stream and provides a simple means of refurbishment by simply unthreading the plug. A switch located on the bottom of the valve provides a method of indication to the control room of an actuated valve. The shear nipple sections are designed to produce clean shear planes.

The piston is allowed to backup after shearing the nipples. Standard metal seals are installed on the piston to reduce the potential of ballistic products from entering the flow stream.

The squib valve can be completely refurbished once fired. The squib valve housing, nipples, adapter flanges, actuator housing, indicator switch body, indicator plunger, head cap, coupling, collar and adapter are machined. The piston, ram, and tension bolt are made from heat treated material for necessary strength.

The squib valve will be designed to meet the following requirements:

- The valve shall be designed such that, in the event of squib actuation, no internal fragments (not inherently trapped within the valve) are produced of a size that if transported downstream could, by themselves or collectively, credibly represent a threat of blockage at the venturi throat.
- The valve shall be designed such that, in the event of squib actuation, no missiles are generated that could impact the operation of any system valves, components or instrumentation within the drywell.
- The valve shall provide remote indication of "valve opened" and "valve closed" status.
- The valve shall have a C_V greater than 1095 gpm/psi$^{1/2}$ at full GDCS flow. The valve manufacturer shall perform a full flow test and provide test data to verify the minimum required C_V.
- Once the valve is open, it shall remain permanently open.

GDCS Check Valve

The GDCS check valves are designed such that the check valve is fully open when zero differential pressure is applied across the check valve. The full open position is accomplished by valve design and installation. The check valve is a long duration submersible valve. The valve meets the minimum flow requirements for a valve stuck in the open position. 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.

Deluge Valve

The deluge valve is a 50 mm (2 inch) squib valve similar in design to the SLC squib valves or ADS depressurization valves. To minimize the probability of common mode failure, the deluge valve pyrotechnic booster material is different from the booster material in the other GDCS squib valves. The pyrotechnic charge for the deluge valve is qualified for the severe accident environment in which it must operate.

The deluge valve will be designed to meet the following requirements:

- The valve shall remain closed with zero leakage under all normal and anticipated operational occurrences, including a LOCA and the water hammer associated with the inadvertent opening of a GDCS injection line squib valve while the RPV is at normal operating pressure.

- The valve shall be designed to survive the severe accident environment and still perform its intended function.
- The valve shall provide remote indication of "valve opened" and "valve closed" status.
- The valve shall have a C_v greater than 130 gpm/psi$^{1/2}$ at full flow. The valve manufacturer shall perform a full flow test and provide test data to verify the minimum required valve C_v.