GE-Hitachi Nuclear Energy Americas LLC

James C. Kinsey
Project Manager, ESBWR Licensing

PO Box 780 M/C A-55
Wilmington, NC 28402-0780
USA

T 910 675 5057
F 910 362 5057
jim.kinsey@ge.com

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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 70 – Related to ESBWR Design Certification Application – RAI Number 14.2-44**

Enclosure 1 contains GEH's response to the subject NRC RAI transmitted via the Reference 1 letter.

If you have any questions or require additional information regarding the information provided here, please contact me.

Sincerely,

Kathy Sedney for

James C. Kinsey
Project Manager, ESBWR Licensing

D068

NRO

Reference:

1. MFN 06-382, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 70 Related to the ESBWR Design Certification Application*, October 10, 2006

Enclosures:

1. MFN 07-425 – Response to Portion of NRC Request for Additional Information Letter No. 97 – Related to ESBWR Design Certification Application –Initial Test Program – RAI Number 14.2-44

cc:	AE Cubbage	USNRC (with enclosures)
	DH Hinds	GHNEA Wilmington (with enclosures)
	BE Brown	GHNEA Wilmington (with enclosures)
	eDRF	0000-0070-1747

Enclosure 1

MFN 07-425

Response to Portion of NRC Request for

Additional Information Letter No. 70

Related to ESBWR Design Certification Application

Initial Test Program

RAI Number 14.2-44

NRC RAI 14.2-44

As stated in DCD Tier 2, Revision 1, Section 14.2.8.2.7, the purpose of Core Performance tests are to demonstrate that the various core and reactor performance characteristics such as power and flow, core power distributions, and those parameters used to demonstrate compliance with core thermal limits and plant license conditions are in accordance with design limits and expectations. This section also states "Core flow is calculated from a heat and mass-flow balance on the downcomer. Core power is calculated from a heat and mass-flow balance on the nuclear boiler".

Please provide specific methods on how you will calculate core flows and core power. What variables will be obtained from the in-vessel measurement to calculate core flows and core power? Please provide a detailed test plan for testing vessel natural circulation at various power levels after fuel loading during startup testing.

GEH Response

The request is broken down into distinct items for clarity.

1. Please provide specific methods on how you will calculate:
   (a.) core flow, and
   (b.) core power.
2. What variables will be obtained from in-vessel measurements to calculate core flow and core power?
3. Provide a detailed test plan for testing natural circulation at various power levels after fuel loading during startup testing.

Response Part 1(a.) - Description of heat and mass balance method for calculating core flow

Under normal operation condition, a control volume (CV) is established or defined as the liquid volume of the downcomer region and lower plenum region as shown in the following schematic figure. In the figure, key flow paths are identified to keep track of the mass and energy across the boundaries (entering or leaving) the CV. The basic idea of heat balance method is to use the steady-state conservation of mass and energy equations for the CV to derive an equation for the core flow.

The following equation can be obtained from mass conservation of CV

$$M_{cf} + M_{rwcu,out} = M_{dc}(1+f_{cu}) + M_{fw} + M_{rwcu,in} + M_{crd} \quad (1)$$

where

M_{dc} = mass flow rate of the saturated liquid from the separators into the CV [kg/s]

f_{cu} = steam carryunder fraction

M_{fw} = mass flow rate of the feedwater flow into the reactor vessel or the CV [kg/s]

$M_{rwcu,in}$ = mass flow rate of the RWCU/SDC (Reactor Water Cleanup/Shutdown Cooling System) return flow into the CV [kg/s]

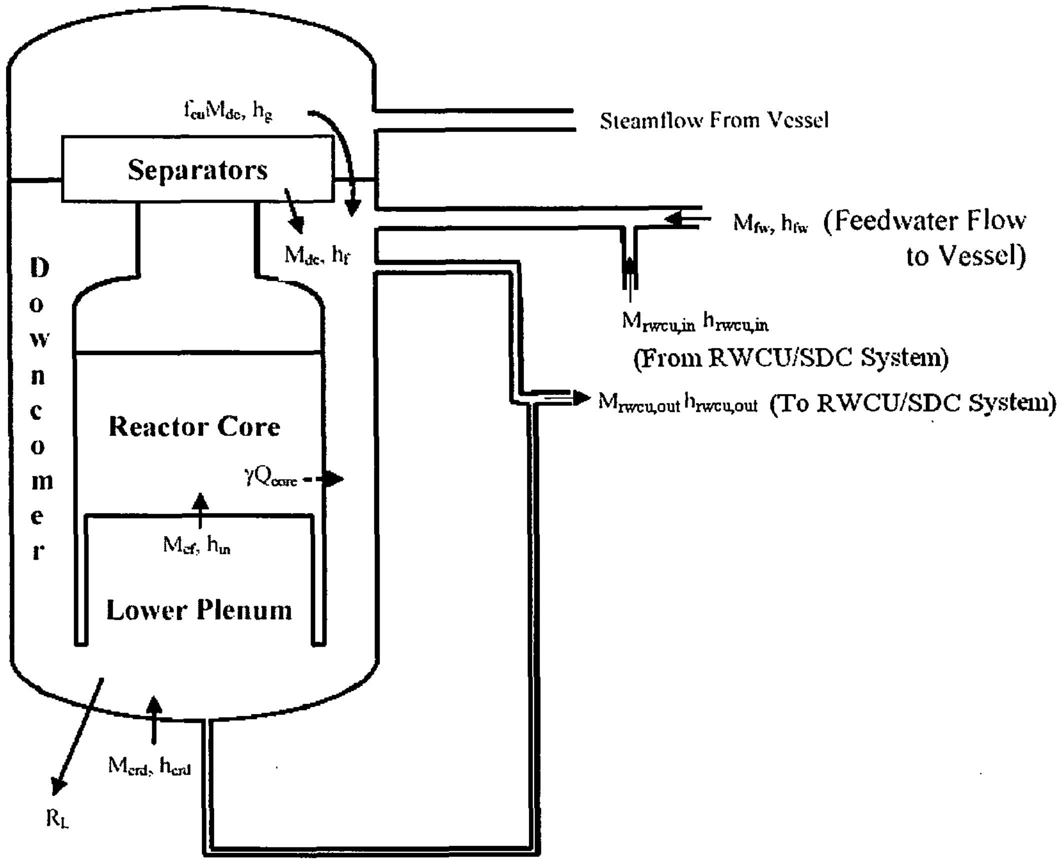
$M_{rwcu,out}$ = mass flow rate of the RWCU/SDC suction flow leaving the CV [kg/s]

M_{crd} = mass flow rate of the FMCRD purge flow into the CV [kg/s]

M_{cf} = mass flow rate of the core inlet flow (in kg/s) leaving the CV and going into the core

Conservation of CV energy gives a second equation

$$M_{cf}h_{in} + M_{rwcu,out}h_{rwcu,out} + R_L = \gamma Q_{core} + M_{dc}(h_f + f_{cu}h_g) + M_{fw}h_{fw} + M_{rwcu,in}h_{rwcu,in} + M_{crd}h_{crd} \quad (2)$$



where

h_{in} = enthalpy of the core inlet flow [kJ/kg]

$h_{rwcu,out}$ = enthalpy of the subcooled RWCU/SDC suction flow [kJ/kg]

R_L = heat loss from the CV [kW]

γ = fraction of the core thermal power that corresponds to gamma/neutron heat addition into the CV

Q_{core} = core thermal power [kW]

h_f = enthalpy of the saturated liquid flow at dome pressure [kJ/kg]

h_g = enthalpy of the saturated vapor flow (carryunder flow) at dome pressure [kJ/kg]

h_{fw} = enthalpy of the subcooled feedwater [kJ/kg]

$h_{rwcu,in}$ = enthalpy of the subcooled RWCU/SDC return flow [kJ/kg]

h_{crd} = enthalpy of the subcooled FMCRD purge flow [kJ/kg]

Thus, equations (1) and (2) form a linear system in terms of unknowns M_{cf} and M_{dc}, where the remaining terms in equations (1) and (2) can be either measured or evaluated based on measurement. Therefore, M_{cf} can be solved by eliminating M_{dc} and the solution can be summarized in a single equation as a function of all the following terms

$$M_{cf} = f(M_{fw}, M_{rwcu,in}, M_{rwcu,out}, M_{crd}, f_{cu}, h_{in}, R_L, \gamma, Q_{core}, h_f, h_g, h_{fw}, h_{rwcu,in}, h_{rwcu,out}, h_{crd}) \quad (3)$$

Response Part 1(b.) - Description of heat and mass balance method for calculating core thermal power

Define the reactor pressure vessel (RPV) as the boundary of a second CV, core thermal power can be calculated through the conservation of the CV energy as the following

$$Q_{core} + M_{fw}h_{fw} + M_{rwcu,in}h_{rwcu,in} + M_{crd}h_{crd} = R_L + M_sh_s + M_{rwcu,out}h_{rwcu,out} \quad (4)$$

where

M_s = mass flow rate of steam flow to turbine [kg/s]

h_s = enthalpy of steam flow to turbine [kJ/kg]

Equation (4) can be rearranged to solve for Q_{core} as

$$Q_{core} = R_L + M_sh_s + M_{rwcu,out}h_{rwcu,out} - M_{fw}h_{fw} - M_{rwcu,in}h_{rwcu,in} - M_{crd}h_{crd} \quad (5)$$

Response Part 2 - Description of variables obtained from the in-vessel measurement to calculate core flow and core power

For calculation of core flow, M_{cf}, by equation (3), the enthalpy of coolant at core inlet location, h_{in}, is the key plant parameter which needs to be obtained through in-vessel measurement. Other parameters on the RHS of equation (3) are either measured on the reactor connected coolant systems or evaluated based on correlations (i.e. f_{cu}).

In order to establish h_{in}, both the temperature and pressure in the lower bottom plenum need to be measured. For ESBWR, two K-type thermocouples are placed inside each LPRM string. These thermocouples are located at an elevation well below the core plate to avoid the effect of the neutron flux and gamma rays on the temperature elements. Lower plenum pressure is calculated based on measured dome pressure plus the static pressure increase over downcomer region, which is obtained through water level measurements.

For calculation of core power, Q_{core}, no in-vessel measurements are needed, because all values are external.

Response Part 3 – Provide a detailed test plan for testing natural circulation at various power levels after fuel loading during startup testing.

The ESBWR has no method of creating forced core flow and relies completely on natural circulation flow conditions. Therefore all startup testing will be conducted using natural circulation. A detailed startup test procedure will be written during the procedure preparation phase in accordance with the description in DCD Chapter 14 Subsection 14.2.8.2.7 "Core Performance Test". This testing will require collection of data to be taken with the reactor in steady state operation at numerous discrete intervals from the start of heatup to 100% power. The data taken will be used to obtain values of total core power, core flow, and core power distribution in both axial and radial directions using data taken from the neutron monitoring system. This data will be used to confirm that the predicted power to flow relationship (Power to Flow Map) is accurate and that core thermal limits are being met.

Creating a detailed test plan at this time is beyond the scope of DCD creation or preparation of supporting information for the COLA. The startup test procedures will be written and presented to the NRC for formal review in accordance with the Startup Administration Manual preparation scheduling.

DCD Impact

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