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August 15, 1985

United States Nuclear Regulatory Commission
Washington, D.C. 20555

Attention: Mr. John A. Zwolinski, Chief
Operating Reactors Branch No. 5
Division of Licensing

References:
(a) License No. DPR-3 (Docket No. 50-29)
(b) License No. DPR-28 (Docket No. 50-271)
(c) License No. DPR-36 (Docket No. 50-309)
(d) USNRC Letter to YAEC and MYAPCO, dated May 11, 1984
(e) Topical Report: "RELAP5YA - A Computer Program for Light Water Reactor System Thermal-Hydraulic Analysis," Yankee Atomic Electric Company, YAEC-1300P, October 1982
(f) MYAPCO Letter to USNRC, dated January 31, 1985
(g) YAEC Letter to USNRC, dated February 26, 1985
(h) YAEC Letter to USNRC, dated July 1, 1985

Subject: Response to the NRC Questions on RELAP5YA

Dear Sir:

Reference (d) requested answers to 197 questions on YAEC's Topical Report on RELAP5YA [Reference (e)]. Our schedule called for the submittal of responses to 20 RELAP5YA questions by August 15, 1985. Responses to 12 of these questions have already been submitted to you in Reference (h). Responses to the remaining 8 questions are provided as an attachment to this letter. The attachment contains 7 extra responses belonging to the next group of questions. These are provided to you in advance to facilitate the review process.

Our schedule called for the submittal of the responses to the remaining 43 questions on September 30, 1985. However, due to the unexpectedly high volume of work in our LOCA Analysis Group, these responses will instead be submitted to you by November 1, 1985.

We trust this information is satisfactory. However, if you have any questions please contact us.

Very truly yours,

YANKEE ATOMIC ELECTRIC COMPANY

George Papanic Jr.

G. Papanic
Senior Project Engineer - Licensing

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RESPONSE TO 15 QUESTIONS ON

RELAP5YA

AUGUST 15, 1985

I. CONDENSATION HEAT TRANSFER AND NONCONDENSABLE GASES

Q.I.11

Clarify the assessment of the vaporization model given in Equation 2.1-20 on Page 34 of Reference 10 for cases with noncondensable gas present.

A.I.11

Justification is provided in the answer to Question Q.I.3 and Appendix A.I-3 to exclude noncondensable gases in our small break LOCA analyses. However, the presence of a noncondensable gas will tend to reduce the vaporization rate given by the current model in RELAP5YA. This is further explained below.

The current vaporization model in RELAP5YA is given on page 34 of Reference I.18-1 as follows:

$$\Gamma_g = C_g^1 (G_m + G_o)^2 \sqrt{P}\,(X - X_n - X_o)(X_e - X)/\rho_v \qquad (1)$$

Where:

C_g^1 = 6.4517175 x 10^{-3} (sec m^{-2} $Pa^{-1/2}$), empirical constant
G_m = mixture mass flux (Kg m^{-2} sec^{-1})
G_o = 3500.0 (Kg m^{-2} sec^{-1}), empirical constant
P = total pressure (Pa)
X = gas phase static quality
X_e = equilibrium static quality
X_n = noncondensable gas static quality
X_o = 1.0 x 10^{-5}, empirical constant
ρ_v = vapor density (Kg m^{-3})

Let us examine the variation of Γ_g with an increase of X_n for the case where G_m, P and X are held constant. From the Gibbs-Dalton model for a gas mixture, the vapor density, ρ_v, is given by:

$$\rho_v = M_{TOT} X_v / V_{gas} = M_{TOT} (X - X_n) / V_{gas} \quad (2)$$

Since X_o is a very small constant, then the quotient given by $(X - X_n - X_o)/\rho_v$ in Equation (1) is nearly constant. Therefore, the variation of Γ_g with an increase in X_n depends primarily upon the static quality difference $(X_e - X)$. The answer to Question Q.I.8 shows that this static quality difference decreases to zero as X_n increased toward X. Thus, the calculated vaporization rate will also decrease toward zero as X_n increases toward X.

Q.I.12

Clarify how the interphase area is included and how the effect of area is modeled in changing from nonstratified to stratified flow.

A.I.12

Both the vaporization and condensation models are empirical and do not include the interphase area explicitly as a variable. The vaporization model is based on data from depressurization experiments. The condensation model is geared mainly to provide rapid equilibration of phase temperatures. Hence, there is no need to include the effect of changing interphase area in these models.

Q.I.13

Clarify why the rate should not increase when the liquid decreases below the temperature that would make the equilibrium quality go to zero.

A.I.13

The interphase mass transfer models in RELAP5YA are written as the product of a conductance term and driving force. Conceptually, the mass transfer rate should increase as the driving force increases. In RELAP5YA, the driving force is the quality difference, $X_e - X$, but the equilibrium quality is limited to values between 0.0 and 1.0.

Hence, if the true equilibrium quality becomes less than 0.0 (subcooled liquid) or greater than 1.0 (superheated vapor), it is reset to 0.0 and 1.0, respectively. Consequently, the driving force for interphase mass transfer is also limited. However, the conductance term in the RELAP5YA models for mass transfer is always large. Thus, the limitation on the driving force has little impact on vaporization and condensation rates.

Q.I.14

Page 32 of Reference 13 states: "The main shortcoming of the air modeling in R5 is the lack of any modifications to the heat/mass transfer and drag packages when air is present. This is not believed to be a real problem for the drag packages. But the presence of noncondensables in the gaseous phase can change the heat and mass transfer rates substantially..." Clarify how the heat-transfer correlations (and in particular the ones for condensation) are modified in RELAP5YA to include the effect of noncondensable gas for flowing and nonflowing applications.

A.I.14:

Reference 13 mentioned above is listed below as Reference I.14-1. The heat transfer correlations in RELAP5YA are not modified to explicitly account for the effect of noncondensable gas. However, the local state properties will be affected by noncondensables and have some impact on the heat transfer calculation. This effect of noncondensables on heat transfer does have the correct qualitative trend. It should be noted that the effect of noncondensables on heat transfer is considered to be insignificant for PWR small break LOCAs. This has been addressed in the response to Question Q.I.3 (see Appendix A.I-3, Section 4.0).

Reference

(I.14-1) J. A. Trapp, "Descriptive Evaluation of RELAP5," EPRI-NP-2361, (April 1982).

Q.I.15

Clarify if the resistance of the noncondensable gas is included as it builds up near the condensation interface for nonflowing situations. In particular, the use of a simple multiplier may not be appropriate if the heat-transfer process becomes diffusion limited.

A.I.15

The resistance of the noncondensable gas as it builds up near the vapor-liquid interface during condensation is not explicitly modeled in RELAP5YA because it is not considered significant for PWR small break LOCAs. The justification for neglecting the added resistance to heat transfer due to a noncondensable gas layer is provided in the response to Question Q.I-3 (see Appendix A.I-3, Section 4.0).

Q.I.16

Examples and experimental bases for the heat-transfer-degradation functions that might be used should be described and justified.

A.I.16

The degradation of heat transfer due to presence of noncondensable gas is considered insignificant for PWR small break LOCA condition and is neglected in RELAP5YA. The justification is provided in the response to Question Q.I-3 (see Appendix A.I-3, Section 4.0)

Q.I.17

Clarify and justify the temperature difference that multiplies the heat-transfer coefficient when the atmosphere contains a noncondensable gas.

A.I.17

The temperature difference that multiplies the heat transfer coefficient is the difference between the wall temperature and the local saturation temperature. When noncondensable gas is present, the saturation temperature is based on the partial pressure of the vapor and will be lower than the saturation temperature corresponding to the total pressure. Thus, the temperature difference between the wall and the bulk fluid will be correspondingly affected (decreased for condensation, increased for vaporization) and is the appropriate temperature difference to be used in estimating heat transfer rates. This situation is illustrated (for condensation) in Figure I.3-1 of Appendix A.I-3 in the response to Question Q.I-3. However, as also discussed in the response to Question Q.I-3, we propose to neglect the presence of noncondensable gas in PWR small break analyses.

Q.I.18

Clarify how the condensation is modeled at the liquid interface in the pressurizer with and without a noncondensable gas present.

A.I.18

The pressurizer is modeled by RELAP5YA using the normal hydrodynamic components available in the code (SNGLVOL, BRANCH or PIPE components). In these components, RELAP5YA uses the condensation model described in Equation 2.1-21 of Reference I.18-1. The effect of noncondensables on the condensation rate as calculated by this model is discussed in the response to Question Q.I.8.

Reference

(I.18-1) R. T. Fernandez, et al., "RELAP5YA - A Computer Program for LWR System Thermal-Hydraulic Analysis, Volume I," YAEC Report YAEC-1300P, October 1982.

Q.I.19

Clarify how the condensation process is modeled for pressurizer sprays with and without a noncondensable gas present.

A.I.19

The pressurizer spray is modeled in RELAP5YA as a liquid-filled junction injecting into volumes comprising the upper regions of the pressurizer. The effect of noncondensables on the condensation rate will be as given by the model described in Equation 2.1-21 of Reference I.19-1 and as further discussed in the response to Question Q.I-8. During most of the small break analyses the reactor coolant pumps are expected to be tripped. The pressurizer sprays will not be operable when the reactor coolant pumps are off and the condensation process associated with the sprays will not be effective.

Reference

(I.19-1) R. T. Fernandez, et al., "RELAP5YA - A Computer Program for LWR System Thermal-Hydraulic Analysis, Volume I," YAEC Report YAEC-1300P, October 1982.

Q.I.20

Clarify how the condensation process is modeled between the levels of a stratified flow with and without a noncondensable gas present.

A.I.20

RELAP5YA does not explicitly account for the geometry of the flow pattern in calculating condensation rates. The condensation model is described in Equation 2.1-21 of Reference I.20-1. The effect of noncondensables on the condensation rate is discussed in the response to Question Q.I.8.

Reference

(I.20-1) R. T. Fernandez, et al., "RELAP5YA - A Computer Program for LWR System Thermal-Hydraulic Analysis, Volume I," YAEC-1300P, October 1982.

V. SYSTEMS VERIFICATION AND OTHER EXPERIMENTAL VERIFICATION

Q.V.8

Figure 5.3-5 of Reference 12 shows that the break flow was overpredicted from 200 to 800 seconds, and yet Figure 5.3-9 of Reference 12 shows the change in calculated total mass to be less than the data from the same period. Also, Figure 5.3-3 of Reference 12 shows the calculated pressure agreed almost exactly with the data during this time period so the HPIS flow would also be expected to agree very closely with the data. Clarify why then if the break flow was overpredicted during this period, the change of the total mass was less than the data.

A.V.8

There appears to be an inconsistency in the reported data. Table V.8-1 presents system mass values at 200 and 800 seconds for both the LOFt L3-6 data and the RELAP5YA calculation. In addition, the average flow rates in and out of the system are also listed. Using these values, a mass balance calculation was made to check the system mass numbers presented in Figure 5.3-9. Comparison of the two system mass numbers shows that the RELAP5YA calculation agrees with the system mass obtained from a mass balance while the L3-6 data does not. The difference between the two system masses for the L3-6 data is about 1,300 lbm. Taking the worst combination of the measurement uncertainties only accounts for about 350 lbm (Uncertainties: Inventory ± 110 lbm, break flow ± 15%, HPSI flow ± 0.044 lbm/sec, RCP injection ± 0.035 lbm/sec). Therefore, there is an unexplained inconsistency in the reported test data.

TABLE V.8-1

	System Mass at 200 Sec	Break Flow	HPIS Flow	Reactor Coolant Pump Injection	System Mass at 800 Sec from Mass Balance	System Mass at 800 Sec
L3-6 Data	9,770 lbm	7.8 lbm/sec Total 4,680 lbm	.92 lbm/sec Total 552 lbm	.216 lbm/sec Total 130 lbm	5,772 lbm	4,465 lbm
RELAP5YA	8,623 lbm	8.8 lbm/sec Total 5,284 lbm	.92 lbm/sec Total 552 lbm	.216 lbm/sec Total 130 lbm	4,021 lbm	4,032 lbm

VI. FLOW REGIMES

Q.VI.8

The rates of phase separation in flowing fluid will determine if steam and noncondensable gas will separate from the liquid at the top of the candy canes for B&W plants or the top of the U-bends in CE and W plants. Clarify how the phase separation is modeled as the two-phase fluid flows around the high-point bends.

A.VI.8

No special treatment is given to the phase separation at the top of the steam generator U-bends. The standard RELAP5YA interphase drag models described in Section 3.1 of Reference VI.8-1 are used.

Reference

(VI.8-1) R. T. Fernandez, et al., "RELAP5YA - A Computer Program for Light Water Reactor Thermal-Hydraulic Analysis, Volume I: Code Description," YAEC-1300P, October 1982. (Proprietary)

Q.VI.40

Clarify and justify the verification provided by systems and experimental comparisons for interruption and restart of natural circulation.

A.VI.40

Please see the response to Questions Q.III.1 through Q.III.4 as provided in our July 1, 1985 submittal.

VII. CORE STEAM COOLING

Q.VII.9

Clarify the range in conditions for the core level assessment tests compared with the expected range in SBLOCA calculations.

A.VII.9

Reference VII.9-1 presents an extensive assessment of RELAP5YA compared to many separate effects and integral test results which address relevant thermal-hydraulic phenomena including core level. The most relevant tests for core level assessment are the boil-off tests. The boil-off tests used for assessment were:

1. The quasi steady-state boil-off Test 3.09.10I conducted at Oak Ridge National Laboratory in the Thermal-Hydraulic Test Facility (THTF). The objective of the boil-off test series was to study the heat transfer and mixture level swell under SBLOCA conditions in Pressurized Water Reactors (PWRs).

   The conditions for Test 3.09.10I are shown below:

System pressure	650 psi
Mass flux	$2.19.10^4$ lbm
Linear power/rod	0.68 kW/lb

2. The system boil-off experiment, Test 6441/6, conducted at General Electric, San Jose in the Two-Loop Test Assembly (TLTA) facility.

   The boil-off tests attempted to simulate system conditions which might occur during a small break LOCA in a BWR, if none of the Emergency Core Cooling Systems, including the ADS were available.

   In these tests, the recirculation loops were blocked off and the liquid inventory was slowly boiled off at a constant pressure and constant bundle power. The power level was representative of decay

heat in a BWR. The main objective of these tests was to evaluate heat transfer in a partially covered bundle at decay power levels and low flows.

The phenomena and the range of conditions encountered in this test will also be encountered during SBLOCAs in PWRs before the accumulator actuation if the flow from the high power safety injection pumps bypasses the core.

The initial conditions for Test 6441/6 are:

System pressure	395 $\pm$ 10 psia
Bundle power	250 $\pm$ 2 kW
Initial two-phase level	Bundle top

One of the integral tests used in the assessment of RELAP5YA simulates a small break LOCAs with core uncovery Test L3-6/L8-1 was a small break test performed in the Loss of Fluid Test (LOFT) facility at the Idaho National Laboratory. Test L3-6, which was a SBLOCA with the pumps running, was extended into a more severe transient (L8-1) which produced core uncovery and heatup.

For the performance of Experiment L3-6/L8-1, the LOFT facility was configured to simulate a small break equivalent to a 4-inch diameter rupture in the cold leg of a large (approximately 1,000 MWe) commercial Pressurized Water Reactor. In Experiment L3-6, the primary coolant pumps were not tripped until the hot leg depressurized to 311.83 psia. The High Pressure Injection System (HPSI) flow was then terminated and the break left open. Experiment L8-1 started when the primary coolant pumps were tripped. When the maximum fuel cladding temperature reached 600.53^{o}F, core reflood was initiated.

Experiment L3-6/L8-1 was initiated from primary coolant system conditions of:

Hot leg temperature	579.1 ± 3.24°F
Cold leg temperature	544.5 ± 3.24°F
Hot leg pressure	2,156.7 ± 20.3 psia
Intact loop flow rate	1,065.48 ± 5.72 lb/sec
Power level	50 ± 1 MW
Maximum linear heat generation rate	16.06 ± 1.12 kW/ft

Since this is a transient test, the conditions in the test facility varied with time. A detailed account of the integral test conditions are presented in Reference VII.9-1.

<u>Reference</u>

(VII.9-1) Fernandez, R. T., R. K. Sundaram, J. Ghaus, A. Husain, J. N. Loomis, L. Schor, R. C. Harvey and R. Habert, "RELAP5YA - A Computer Program for Light-Water Reactor System Thermal-Hydraulic Analysis, Volume III: Code Assessment," Yankee Atomic Electric Company Report YAEC-1300P, Volume III (October 1982). (Proprietary)

X. ADDITIONAL QUESTIONS THAT ARE CONCERNED WITH SEVERAL AREAS

Q.X.7

Since the release of the version of RELAP5 used as the bases for your small break evaluation model, numerous corrections and updates to RELAP5 have been made to correct errors and improve the numerics of the RELAP5 computer program. Provide a description of the quality assurance program used by you to incorporate required changes in your EM model (e.g., corrections of coding errors). Include in this description the program to validate your EM model when changes are made.

A.X.7

Yankee Atomic Electric Company utilizes a Quality Assurance Manual to provide guidelines to the engineers to assure that design changes and additions are consistent with safety and licensing requirements. In particular, instructions WE-103 and WE-108 are the two guidelines relevant to the issue of the quality assurance of computer codes and engineering analyses.

WE-103 provides guidelines for the performance, review, approval and control of engineering calculations and analyses.

WE=108 provides guidelines for development, acquisition, modification, verification, testing and approval of computer codes that will be used for WE-103 calculations.

Copies of WE-103 and WE-108 are attached.