GE Nuclear Energy

A.S. Rao
Project Manager, ESBWR

General Electric Company
175 Curtner Avenue, M/C 365 San Jose, CA 95125-1014
408 925-1885 (phone) 408 925-6462 (facsimile)

Project 717

MFN 03-099
September 16, 2003

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20852-2738

Attention: Chief, Information Management Branch
Program Management
Policy Development and Analysis Staff

Subject: **Response to Request for Additional Information (RAI) numbers (70, 71, 82, 86, 87, 316, and 318) for ESBWR Pre-application Review.**

GE Nuclear Energy is submitting, in enclosures 1 and 2, response to NRC RAI numbers (70, 71, 82, 86, 87, and 316), and additional information provided in response to RAI 318. The original RAIs were included in the referenced letters.

Enclosure 1 contains the responses with GE proprietary information as defined by 10CFR2.790. GE customarily maintains this information in confidence and withholds it from public disclosure. Enclosure 1 also includes RAI responses which contain no proprietary information in order to form a complete package. A non-proprietary version of the responses to the NRC's requests are provided in Enclosure 2.

The affidavit contained in Enclosure 3 identifies that the information contained in Enclosure 1 has been handled and classified as proprietary to GE. GE hereby requests that the information of Enclosure 1 be withheld from public disclosure in accordance with the provisions of 10 CFR 2.790 and 9.17.

If you have any questions about the information provided here, please let me know.

Sincerely,

AS Rao

Atambir S. Rao

D068

Reference:

1. MFN 03-052, Letter From Amy E. Cubbage (NRC) To Atam S. Rao (GE), June 20, 2003, SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 4 RELATED TO ESBWR PRE-APPLICATION REVIEW (TAC NOS. MB6283 AND MB6801)
2. MFN 03-054, Letter From Amy E. Cubbage (NRC) To Atam S. Rao (GE), July 17, 2003, SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 6 RELATED TO ESBWR PRE-APPLICATION REVIEW (TAC NO. MB6801)
3. MFN 03-065, Letter From Amy E. Cubbage (NRC) To Atam S. Rao (GE), July 17, 2003, SUBJECT: REQUEST FOR ADDITIONAL INFORMATION LETTER NO. 7 RELATED TO ESBWR PRE-APPLICATION REVIEW (TAC NO. MB6801)

Enclosures:

1. MFN 03-099 Response to NRC RAI numbers (70, 71, 82, 86, 87, and 316), and additional information provided in response to RAI 318 - Proprietary Information
2. MFN 03-099 Response to NRC RAI numbers (70, 71, 82, 86, 87, and 316), and additional information provided in response to RAI 318 - Non-proprietary Information
3. Affidavit, David J. Robare, dated September 16, 2003

cc:	A. Cubbage	USNRC (with enclosure)
	J. Lyons	USNRC (w/o enclosure)
	G.B. Stramback	GE (with enclosure)

General Electric Company

AFFIDAVIT

I, **David J. Robare,** state as follows:

(1) I am Technical Projects Manager, Technical Services, General Electric Company ("GE") and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in the Enclosure 1 of GE letter MFN 03-099, Atambir S. Rao to NRC, *Response to Request for Additional Information (RAI) numbers (70, 71, 82, 86, 87, 316, and 318) for ESBWR Pre-application Review,* dated September 16, 2003. The proprietary information is in Enclosure 1, *Response to NRC RAI numbers (70, 71, 82, 86, 87, and 316), and additional information provided in response to RAI 318.* For text and text contained in tables, GE proprietary information is identified by a double underline inside double square brackets. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation{3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination.

(3) In making this application for withholding of proprietary information of which it is the owner, GE relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.790(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret", within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;

c. Information which reveals aspects of past, present, or future General Electric customer-funded development plans and programs, resulting in potential products to General Electric;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4)a., and (4)b, above.

(5) To address 10 CFR 2.790 (b) (4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GE, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GE, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within GE is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GE are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it details for licensing application of TRACG to the ESBWR passive safety system design of the BWR. This TRACG code has been developed by GE for over fifteen years, at a total cost in excess of three million dollars. The reporting, evaluation and interpretations of the results, as they relate to the ESBWR, was achieved at a significant cost, to GE.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GE asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GE's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GE's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GE.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GE's competitive advantage will be lost if its competitors are able to use the results of the GE experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GE would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GE of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 16TH day of SEPTEMBER 2003.

David J. Robare
General Electric Company

ENCLOSURE 2

MFN 03-099

Response to NRC RAI numbers (70, 71, 82, 86, 87, and 316), and additional information provided in response to RAI 318

Q70. Section 7.5.2.2 (p. 7.5-13) - What criteria are used to determine the gases to be considered in the calculation of the gas conductivity?

R70. The gases that are considered are those that are prevalent in the gap. Helium is obviously important because of the initial backfilling of helium. [[AAAAA aaaaaaaa aaa aaaaaa aaaaaaaa aaa aaa aaaaaaa aaa aaaaaaaaaaaaaa aaaaaaa aaa AAAAA aaaa aaaaa aaaaa aaaaaaa aaa aaa aaaaaaaa, aaaaa aaaaaaaaaaaa aaa aaaaaaa aaaaaaa. Aaaaaaaaa aaaaaaa aaaaaaaaaa aa aaaaaa aa aaa AA7 aaaaaa aa aaaaaaaaaa aa AAAAA aaa aaaaaaaa aaaa aaaa aaaa aaa aaa aa aaaaaaaaa aa Aaaaaaa 7.7 aa AAAA-77777-7-AA, Aaaaaa 7. Aaa AAAAA aaaaa aaa aaaa aaaaaaaa aaaaa aaaaaaa aaaa aaaaa aaaa aa aaaaa aaa aaaaaaaa aa aaaaaaaaa aa AaaA, Aaaaaa 7. [7]]] The fission gas production of some isotopes of xenon (Xe) and krypton (Kr) are also important because their fission yield rates compared to the decay times are large enough that these gases exist in sufficient amounts and for long enough times that they can be released from the UO2 pellet into the gap.

The fission yields and the half-lives are not the only consideration. For example, cesium is produced in large amounts but is not present as a gas in the gap in any appreciable amounts because it readily reacts chemically and is effectively removed as a gas by a number of processes. Olander discusses these processes in Chapter 12 of his book[70-1]. Chapter 13 of Olander's book discusses fission gas production in the fuel pellet and the release mechanisms are discussed in Chapter 15. Ultimately, the only fission gases that accumulate in the gap in any appreciable amounts are the stable (or longer half-life) isotopes of Xe and Kr as stated in Section 15.3.6. [[Aa aaaaa aa aaa aaaaa aaaaaa aa aaaaaaa aaa aaaaa aa aaa aaa, aaa AAAAA aaaaa aaaaaaa 77.7% aa aaaaaaa aaa 77.7% aa aaaaa (aaaa 7-7 aa AAAA-77777-7-AA, Aaaaaa 7). Aaaa aaaaaaaaaaa aa aaaaaaaaaaaaaa aa aaa aaaaaa aaaa aaa aaaaa aaaaaa aaaa aaaaaaaaaaa aaaaaaa aaa aaaaaa aaa aaa aaaaaa aaa aaaaaa aaaa-aaaa aaaaaaaa aa Aa aaa Aa aaa aa aaaaaaa aaaaaaaa aa A-777 aaa Aa-777 aaaaaaa aa A-777. [7]]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

References for R70

[70-1] Olander, Donald R.; Fundamental Aspects of Nuclear Reactor Fuel Elements, TID-26711-P1, U.S. Dept. of Energy Office of Scientific and Technical Information, 1976.

Q71. Section 7.5.2.2 (p. 7.5-13) - What is the basis for the gases assumed in the gap of a perforated clad?

R71. The response to Q70 provides the basis for modeling the gases in the gap prior to clad perforation. [[Aaaaa aa aaaaaaaaaa, aaa aaaaaaaaaa aa aaaa aaaaaaaaa aaa aaaaaaaaaaa aaa aaaaaaa aa aaa aaaaaaaa aa aaaaa aa aaaaaaa aaa aaaa aaaa aaaaaaaaaaa aaaa aaaaa. Aaaaa aaaaaaaaaaa aaa aaa aaaaaaa aa aaa aaaaaaaa aaaaaaa aaa aaaaaaaa, aaa aaaaaaaaa aaaa aa aaaa aaaaaaaaa aaa aaa aaaaaaaaa aa aaa aaaa aa aaa aaaaa-aaaaa aaaaaaaa aa aaa aaaaaa aaaaaaa. Aa aaaa aaa aaaaaaaaaaa aaaaaa, aaa aaa aaaaaaaaaaa aa aaaaaaaa aa aaaaaaa aaa aaaaaaaa aa a aaaaaaaaaaaaa aaaaaaa aa aaaaa aaa aaaaaaaa aaaaaa aaaa a aaaaaaa aaaaaaa aaa aaaaaaa aaaaaa aaa aaaa aaa. Aaa a aaaaaaaaaa aaaa aaa aaa aaaaaaaaaaaa aa aaaaaaa aaaaa Aa. (7.7-77). Aaaa aa aaa aaaa aaaaa aa aaaa aa AAAAA/AAA AAAAA[77-7],[7]]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs. The model for composition of the gases in the gap after perforation was also approved by the NRC in 1981[71-4].

References for R71

[71-1] *The GESTR-LOCA and SAFER Models for the Evaluation of the Loss-of-Coolant Accident, Volume II*, NEDE-23785-1-PA, Revision 1, October 1984, page 4-31.

[71-2] *General Electric Company Analytical Model for Loss-of-Coolant Analysis in Accordance with 10CFR50 Appendix K – Volume 1*, NEDE-20566-P-A, Class III, September 1986, page I-108,109.

[71-3] *CHASTO5 Core Heatup Analysis Model Technical Description*, NEDO-21426, November 1977, pages 4-4,5.

[71-4] Letter, R. L. Tedesco (NRC) to G. G. Sherwood (GE) dated February 4, 1981, "Acceptance for Referencing of Topical Report NEDE-20566P, NEDO-20566-1 Revision 1 and NEDE-20566-4 Revision 4".

Q82. Section 7.5.3.1 (p. 7.5-20) - How is Eq. 7.5-35 developed?

R82. [[Aaa aaaaaaa aaaaaa-aa-aaaaaaaaaaa aaaaa aaa aaa aaaaa aaaaaaaaa aa aaa aaaa aaaaaa aa aaaaaaaaaa aaaa Aa. 7.7-77. Aaaaaa a aaaaaaaaa aaa aaaaaa-aa-aaaaaaaaaaa aaaaa aa aaaaaa aa aaaaaaaa aaa aaaa aaa aaaaaaaa aaaaaaaa aaaa Aa. 7.7-77. Aaa aaaa aaaaaaa, aaa aaaaaa aa aaa aaaaa aa aaa aaaaaaaa-aaaaaaaa aaaa aaaaaaaaaaa aa aaa aaaaa aaaa aaaaaaaaaaaaa aa aaa aaaaaaa AAAA aa aaaa aa aaaaa aaa aaaaaa-aa-aaaaaaaaaaa aaaaa aa aaaaaaaaa aa Aaa. (7.7-77). Aaaa aaaaaaaa aaaaa aa aaaaaaaaaaaaa aaa aaaaaa-aa-aaaaaaaaaaa aaaaa aaa aaa aaaa aaaaaa aaaaaa aaa aaaaaaaaa aaaaa aaaaa aa aa aaaa-aaaaaaaaaa aa aaa aaa aaaaaaaa aa aaa aaaa aaaaaa aaa a aaaaaaaaaaaa aaaa-aaaaaaaaaa aa aaa aaaaaaaa aaaa aaaaaa. Aaaaaaaaa aaaaaaa aa A-777 aa AAAA-77777-A-A. {7}]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q86. Section 7.5.3.3 (p. 7.5-21) - Besides the gas conductivity, does the state of a perforated clad affect the gap conductance in other ways?

R86. [[Aaaaaaaaaa aa aaa aaaaaaaa aaaaaaaa aaa aaaaaa aa aaa aaaa aa aaa aaaaaaaa aaaaaaaaa aaaaaaa aaa aaaaaa aaa aaaaaaa aaaa aa aaaa. Aaaa aaaa aa aaaaaaaaa aa aaa aaaaaaaaaaa aa aaa aaa aaaa, aaaaa aaa aaaaaaa aa aaaa aaa aaaaaaa aaaaaa aa aaaaaaaaa. Aaaa aa a aaaaa aaaaaa aaaaaaa aaa aaaaaaaaaaaaa aaaaaaa aaaaaaaaa aa aaa aaaaa aaaaaa aa aaaa aaaaaa aaaa aaa aaaaaaa aaaaaa. Aaaaaa aaa aaaa aaaaaaaaaa aaaaa aaaaaa aa aaa aaaa aaa aaa aaaaaa aa aaa aaaaaaaaaaaa, aaaaa aaa aa aaaaa aaaaaaa aa aaa aaaaaa aaaa aaaa aaaaaaaaaaa.[7]]]

The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs.

Q87. Sections 7.5.2 and 7.5.3 - Is it possible to summarize parameters that are axially dependent and those that are not?

R87. The fuel gap conductance models in Sections 7.5.2 and 7.5.3 are identical to the SAFER/GESTR models approved by the NRC, and also reviewed in the TRACG application for AOOs. The axial resolution in the modeling has not been changed.

[[Aaaaaa aaa aaa aaaaaaaaaa aaaa aa Aaaaaaa 7.7.7 aaa 7.7.7 aaa aaaaaaaaa aaaaa aaaaa aaaaaaaaaa aaaa aaa aaaaaaaaaa aaa aaaa aaaaa aaaa. Aaaaa aaaaaaaaaaaa aaa aaaaaaaaa aaa aaaa aaa aaaaa aa aaa aaaaaa aa aaaa aaaaaaaaa aaaaa aaaaaaa aaaaaaa aaa aaa aaaaaaaaa aaa aaaaaa aaa aaaaaaaaaa. Aaa aaaaaaaa aaaaaaaaa aaaaaaaaaa aaaaaa aa aaa aaaaa aaaaa, aaaa aaa aaaa aaaaaaaaaaaa aaaa aaa aaaaaaaaaa aaa aaaa aaaaa aaaa aa aaaa aaa aaaaa. Aaa aaaa aaaaaaaa aaaaaaaaaa aaa aaaaaaaaaa aa aaa aaaaaaaaaa aa aaa aaaaa aaaaaaaaaaaa aaaaaaa aaa aaaa aaaaaaaaaa aaaaaaa aa aaaaaa aaaaaaaa aa aaa aaaa aaa aa aaaa aaaaa aaaa aa aaaa aaa aaaaa. Aaa aaa aaaa aaa aaaaaaaaaaa aa aaaaaaaaa aaa aaaa aaaaa aaaa aaaaaaa aaa aaaaaa aaaaaaa aaaaaaaaa aaaaaaa aa aaa aaaaa aaaaaaaaaaa. Aa aaaaaaa aaaa aaaaaa-aaaa aaaaaaa aaaaaaaa aaa aaa aaaaaaaaaa aaaa aaaaaaaa aaa aaaaaaa aaaa aa aaaaaaaaa aaa aaaa aaaaa aaaa aaa aaaa aaa aaaaa aa aaaaa aa aaaaaaaaa aaa aaaaaaa aaaaaa.

Aaaaa aaa a aaa aaaaaaaaaa aaaa aa aaaaa aaaaaa aaa aaaaaaaaa aa aaaaaaa-aaaaaaaaaa, aaaaaaa aa aaaaaaa aaaaaaaaaa aaa aaaa aa a aaaaa aaaaaa aa aaa aaaaaaaaaa aaa aaa aaaaa aaaaa aaaaaa aaa aaa aaaaa. Aaa aaaaaaa, aaa aaaa aaaaaa aa aaa aaaaa aaaaaa aaaaaaa aa aaa aaaaa aaaaaaa aaaaaaaaa aa aaa aaaaaa aaaaaa aaaaa. Aaaaaaaaa, aaa aaaaa aaa aaaaaa aaaaaaaaa aaa aaaaaaa aaaaa aa aaa aaaaaa-aaaa aaa aa a aaa aa aaa aaa aaaaaaa aaaa aaaa aaaa. Aaa aaaaaaaaaa aa aaa aaaaaaa aaa aa aaa aaa aaaaaa aa aaa aaaa aaa aaa aaaaa aaaaa aa aa aaaaaaaaaa aaaa aaa AAAAA aaaa aaaaa aa a aaaaaaaa aa aaa aaaa aaa aaaaaaa aaaaaaaa aaa aaa aaaaa aaaaaaa. Aaaaaaaa aaa aaaaaaa aaa aaaaaaaaaaa aaa aaaaaaa aaa aaaaaaaa aa aaaaa aa aa aaa aaaa aaa aaa aaaaa aaaaa aaaaaa a aaaa aaa aaaaa, aaa aaaaaaa aaaaaaaaaaaa aa aaaaa aaaaa aaaaaa aaaa aaaa aa aaaa aaaaaaa aaa aaaaaaa aaa aaaaaaaaaaa aa aaaaaaaaaaa aaaaaaaaa aaa aaaa aaaaa aaaa. Aaa aaaaa aaaaaaa aaaaaa aa aaaaaaaaa aa aaaaaaaaaa aaa AAAA aa aa aaaa aa aaaaaaa aaa aaaaa aaaaaa aaaa aaa AAAAA aaaa aaaaa aa aaaaa aa aaaa aaa aaaaaaaaaaa aaa aaaaaa aa aaaaaa aaaaaa aaaaaa aaa aaaaaaaaa. Aaa aaaa aaaaaaaaaaa aaa aaaaaa aa aaa aaaaa aa aaa aaaaaaaa-aaaaaaaa aaaa aaaaaaaaaaa aa aaa aaaaa aaaa aaaaaaaaaaaaa aa aaa aaaaaaa AAAA aa aaaa aa aaaaaaaaa aa Aaa. (7.7-77) aaa (7.7-77) aAA-77777A, Aaa. 7. [7]]]

Q316. Interfacial Heat and Mass Transfer

The heat and mass transfer at the interface are related and predictions of one will provide an estimate of the other. The model consists of predicting the flow regime, interfacial area density and heat transfer coefficients at the interface.

Q316.1. It is our understanding that the liquid side interfacial heat transfer coefficient is obtained from a correlation developed for heat transfer over evaporating drops. Provide a description of the physical process being modeled and justify its use for this situation.

R316.1. TRACG uses the Lee-Ryley correlation for the vapor side interfacial heat transfer for droplet flow.

$$Nu_d = 2 + 0.74\sqrt{Re_d}\,Pr_v^{0.33}, \qquad Re_d = \frac{\rho_v v_{rd} d_d}{\mu_v}$$

This correlation was developed from data for evaporating droplets. Since the flow around a droplet is very similar to the flow around a vapor bubble for bubbly flow, it is assumed that the same correlation is applicable to the liquid side interfacial heat transfer for bubbly flow. For liquid, the Prandlt number dependence was dropped, since Pr ≈ 1 for water.

$$Nu_b = 2 + 0.74\sqrt{Re_b}, \qquad Re_b = \frac{\rho_\ell v_{rb} d_b}{\mu_\ell}$$

TRAC-M (NUREG/CR-6724) uses a combination of the Whittaker correlation for low Reynolds numbers and the Chen & Mayinger correlation for high Reynolds numbers to calculate the liquid side interfacial heat transfer for bubbly flow:

$$Nu_b = 2 + (0.4\sqrt{Re_b} + 0.06\,Re_b^{2/3})\,Pr_\ell^{0.4} \qquad \text{Low Re (Whittaker)}$$

$$Nu_b = 0.185\,Re_b^{0.7}\sqrt{Pr_\ell} \qquad Re < 10^4 \text{ (Chen \& Mayinger)}$$

$$Nu_b = 116.7\sqrt{Pr_\ell} \qquad Re > 10^4 \text{ (Chen \& Mayinger)}$$

These correlation are compared in Figure 316-1 for Pr = 1.0.

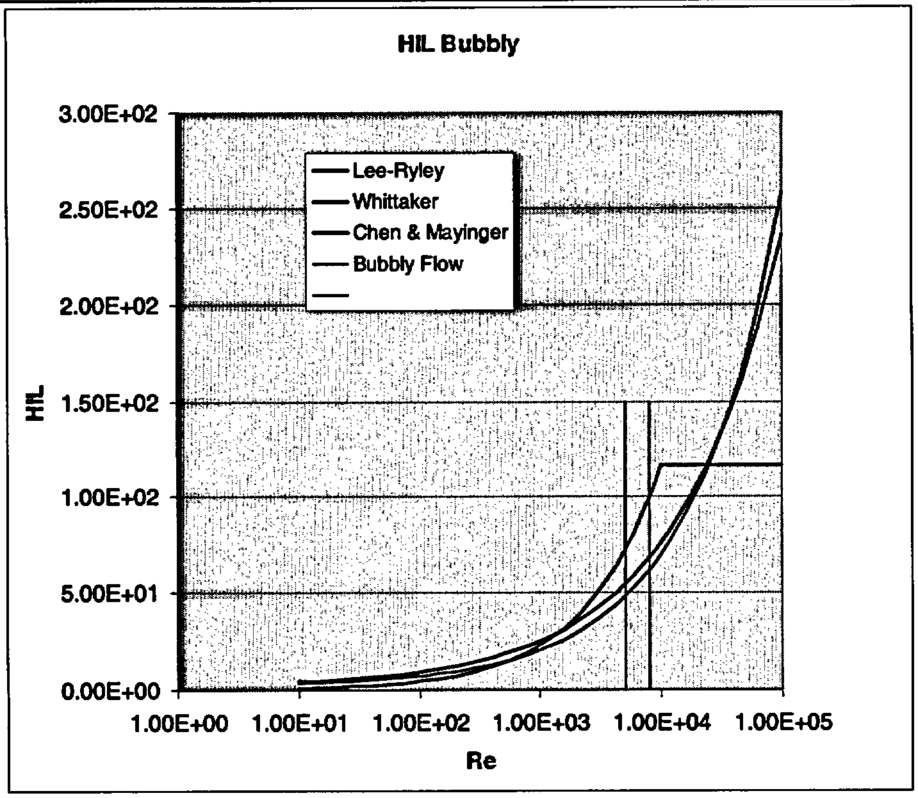

Figure 316-1. Comparison of correlations for Liquid Side Interfacial Heat Transfer for Bubbly Flow.

For bubbly flow the Reynolds number for the bubbles are typically in the range of 5000 to 8000. For this range the Whittaker correlation is 10% lower than the Lee-Ryley correlation, and the Chen & Mayinger correlation is approximately 40% higher than the Lee-Ryley correlation. These differences are compatible with the uncertainty range for the correlations.

The good comparison to void fraction data and plant transient data as demonstrated in the TRACG Qualification (NEDE-32177P) justifies the application of the Lee-Ryley for the interfacial heat transfer. In the TRACG application (NEDE-32178P) a factor of 2 (-50%, +100%) uncertainty is assumed for liquid side interfacial heat transfer. This uncertainty more than covers the difference between the above correlations.

Q316.2. It is our understanding that the vapor side interfacial heat transfer coefficient is obtained from the conduction heat transfer solution for a solid sphere with a correction for internal convection and the degradation due to noncondensible gases is accounted with the a degradation factor. If this is correct, provide a description of the physical process being modeled and justify its use for this situation.

R316.2. Assuming no flow inside a vapor bubble, the heat transfer between the vapor in the bubble and the interface, is given by thermal conduction. For a spherical particle with an equilibrium temperature profile, the heat transfer due to thermal conduction is equivalent to a heat transfer coefficient given by:

$$h_{iv,b} = \frac{2}{3}\pi^2 \frac{k_v}{d_b}$$

Due to the movement of the bubble relative to the liquid, there will be natural circulation inside the bubble. An empirical factor $2.7(\mu_\ell / \mu_v)$ is applied as an enhancement to the pure conduction heat transfer to give Equation 6.5-9 in the TRACG Model Description (NEDE-32176P):

$$h_{iv,b} = \frac{2}{3}\pi^2 \frac{k_v}{d_b}[2.7\frac{\mu_\ell}{\mu_v}]$$

For typical bubbly flow, this correlation gives a heat transfer coefficient in the range of 2000-8000. TRAC-M, for comparison, uses a constant value of 1000 without any justification.

It is assumed that steam and air are mixed perfectly inside a bubble, and no degradation is applied for condensation heat transfer. This is a reasonable assumption given the internal circulation and the small size of the bubbles.

For bubbly flow, the interfacial heat transfer is the dominant heat transfer to the vapor, and with the assumption that the interface is at the saturation temperature, the vapor temperature will follow the saturation temperature. The thermal time constant for the bubbles with the heat transfer coefficient given by the above expression or the value from TRAC-M will typically range from 75 msec. to less than 1 msec.

With the only significant heat transfer to bubbles coming from the interface, which is at the saturation temperature, and the low thermal heat capacity of the bubbles, the results are insensitive to the exact value of the vapor side interfacial heat transfer.

Additional Information provided in response to RAI 318

The versions of the TRACG code used for the qualification studies reported in TRACG Qualification for SBWR (NEDC-32725P, Rev.1) and TRACG Qualification (NEDE-32177P, Rev.2) were presented in Table 1.2.1 of NEDC-32725P. That table has been used to create the attached Table 318-1. The qualification studies reported in TRACG Qualification for ESBWR (NEDC-33080P) have also been added to the table.

The versions of the TRACG code used in the table are discussed below.

[[AAAAA77 aa aaa aaaa aaaaaaa aa aaa aaaa aaaa aaa aaaa aaa aaa aaa "aaaaaaa" aaaaaaaaaaaa aaaaaaa aaaaaaaaaa aa AAAAA Aaaaaaaaaaaa aaaaaa (AAAA-77777A).

AAAAA77 aaa aaaaaaaaa aaaaaa aaa aaaaaa aa aaa AAAA aaaaaaa aaaa aaaaaaaaaaaa aaaaaa aaaaa aaa AAAA aaaaaaaa. AAAAA77 aaa aaaa aaa aaaa aa aaa AAAA-aaaaaaaa aaaaaaaaaaaaa aaaaaaa. Aaaa aaaaaaa aa AAAAA aaa aaaaaa aaaaaa aaa AAAA aaaaaaa aaa aa aaaaaaaaaa AAAAA77 (AAAA) aa Aaaaa 777-7. Aaa aaaaa aaaaaaa aaaaaaa AAAAA77 aaa AAAAA77 aaaaaaa aa aaaaa aaaaaaaaa aaaa aaaa aaaaaa aaa AAAA aaaaaaaa. Aaaaa aaaaaaaaa aa:

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Aaaaa aaaaaa aa aa aaaaaa aa aaaaa aaaaa aaaaaaaaa aa aaa aaaaaaa aa aaa aaaaaaaaaaaa aaaaaaa aaaaaaaaa aaaa AAAAA77 aaa aaaaaaaaaa aa aaa aaaaaaa AAAAA aaaaaaaaaaaaa aaaaaa. Aaaa aaa aaaaaaaaa aa aaaaaaaaa a aaaaa, aaaaaaaaaaaaaa aaaaaa aa aaaaaaaaaaaa aaaa aaaa aaaaaaaaa aaaa AAAAA77, aaa aaaaaaaaa aaaa aaaa AAAAA77 (AAAA). Aaaaa aaaaaaaaaaa, aaaaaaaaaa aa Aaaaa 777-7, aaaaaaa aa a AAAA aaaaa aaaaa aaaa, a Aaaaaaaa aaaaaaaa aaaa aaaa, Aaaa AAA aaa 7A/Aaaa AA aaaaaaaaaaa aaaaa-aaaa aaaaaaaa aaaaaaaaaaa aaa a AAAAAAA/AAA aaaaaaaa aaaa. Aaa Aaaaaaaa Aaaaaaa Aaaaa aaaa aaaaaa aaaaaaa aaaa aaaa aaa aaaaa aaaaaa aaaaaaa aa aaaaaaaaaaa aaaaa aaa aaaaaaaa aaaa. Aaa aaaaaaa aaaaaaaa aaaa aaaaa aaaaaa aaaa aaa aaaaaaaa aa aaa AAAAA77 aaaaa aaaaaaaaa. Aaa aaaaaaaaaaa aaaaaaaaaaa aaaaaaaa aaaa aaa aaaaa aaaaaaaa aaaaaaaa aaa aaaaaaaaaa aa aaa aaaaaaaaaaa aa AAAAA77 aaa AAAAA77. Aaa AAAAAAA/AAA aaaa aaaaaaaa a aaaaaaaaaaaaa aaaa a aaaaaaa Aaaaaaaa Aaaaaa Aaaa aaaaaaaaa aaaaaaaaaaaaa aaaaaaa AAA aaa aaaaaaaaaaa aaaaaaa aa aaaa aaaaaaaaaa aa aaa aaaaa aaaaaaaaa aa AAAAA77. Aaaaaa a AAA aaa aa AA aaaa aaaaaaaaa aa aaa aaaaa, aaa aaaaa aaaaaaa aaa a

aaaaaaa aaaaaa aa aaa AAA aaaaaaaaaaaa aaaaaaa aaa aaaaa aaa aa aaa AAA aaaaaaaaaaaaaaaa aaa aaaaa aaaaaaaa. Aaaaa aa aaaaa aaaaaaa, aa aaa aaaaaaaaa aaaa aaa aaaaaaa aaaaaaaaaaaaa aaaaaaaaa aaa AAAAA77 aaa aaaaaaaaaa aa AAAAA77.

Aaa aaaaaaa aaaaaaa aa AAAAA77 aaa aaaaaaaaaaaa aaaa aaaaaaa aaaaa aaa aaaaaaaaaa aa aaa AAAA aaaaaaa. Aaaaa aaaaaaa aaa aaaaaa aa AA'a aaaaaa aa aaaaaaaa aa a aaaaaa AAAAA aaaa aaaaaaa aaa aaa aaaaaaaaaaaa. Aaa aaaaa aaaaaaa aaaa aaa aaaaaaaaa aaa AAAAA aaaaaaaa, aaa aaaa aaaaaa aaa AAAA aaaaaaaa aa aaaaaaaaa AAAa. Aaaaaaa aaaaaaa aaaaa aaaaaaaaaa aaaaaaaaa, aaaaaaaaaa aaa aaa aaa aaaaa aaa AAA aaaaaaaaaaaa, aaa aaaaaaaaaaaaa aaaa AAAAA77 aaaaaaaaaa. Aaaaa aaaaaaaa aaaaaa aaaa aa aaaaaa aa AAAAA aaaaaaaaaaaa aa aaaaaaaaaaaaa aaaaaaa aaaaaaaa aa aaa AAAAA. Aaa aaaaa aaaaaaaa aaaaaa aaa AAAAA aaaaaaaaaaaa aa a aaaaa aaaaaa. Aaa AAA aaaaa aaaa aaaaaaaa aaa aaaa aaaaaaaa aaaaaaaaaaa aa aaa aaaa aaa aaaaa aaaa aaaaaaaaaaaa. Aaaa aaa aaaaaaaaaaa aaa aaa aaaaaaaaa aa aaaaaaaaaaa aa aaaaaaa aaaa aaa aaaaaaaa aaaaaaaa. Aaaa aaaaaa aaaaaaaa aa a aaaaa aaaaaaaaaaa aa aaa Aaaaaaa aaa aaaaaaaa aaaa aaaaaaaa aaaaaaaaaaa, aaa aaaa aaa aaaaaa aaa aaaaa aaaaaaaaaaaaa aaaaaaa aaaaaaaaaaa. Aaaa aaaaaaa aa aaa AAAAA aaaa aa aaaaaaaaaa AAAAA77 (AAAAA) aaa aa aaa aaaaaaa aa aaa aaaa aaaaaaaa aa aaa AAA. Aaa AAAAA A Aaaaaa aaaaaaaaaaaa aaa AAAAA aaaaa aaaaaaaaaaaa aaaa aaaa aaaaaaaaa aaaa AAAAA77 (AAAAA). AA aaa aaaaaaaa a aaaaa aaaaaa aa aaa aaaaaaa aaaaaaaaaaaaa aaaaaaa aaaa AAAAA77 (AAAAA) aa aaaaaaaaa aa aaa aaaaa aaaaaa aa Aaaaa 777-7 aaaa aa "A".
Aaaa aaaaaaaa aaaaaaaaaaa aaa aaaaaaaa aa aaaa aaaaaaaa. Aaaaa aaaaaaa aaa AAAA aaaaa aaaaa (Aaaaaa 777-7) aaa Aaaaaaa aaaaaaaa aaaa aaaaa (Aaaaaa 777-7) aaaaaaa aaaa aaaa aaa aaaaa aaaaaaaaaaa aaaaa aaaaaa aa aaa aaaa. Aaaaa AA77 (AAAAA). Aaa Aaaaaaa aaa aaaaaaaa aaaa (Aaaaaa 777-7) aaa Aaaaaaa Aaaaa aaaa (Aaaaaa 777-7) aaaa aaaaaa aaaaaaa aa aaaaa aaaaaaaaaa aa aaa AAAAA AAAA aaaaaaaaa. Aaa aaaaaaa aaa aaaaaaa aa aaa aaaaaaaa aaaaaaa aa AAAA-77777A. (Aaa Aaaaaaa aaaa aaaaaaaaaaa aaa aaaaaaaa aaaaaa.) Aaa AAAAA Aaaa A7 aaaaaaaaaaa aaaaaaaaa aaaa AAAAA77 (AAAA) aaaa aaaa aaaaa aaaa AAAAA77 (AAAAA). Aaa aaaaaaa (Aaaaaa 777-7) aaaa aaaaaaaaaaaaa aaaaaaaaaaa aaaaaaa aaa aaa aaaa aaaaaaaaa.

AA aaaaa aa aaaaaaaa aaa aaaaaaa aaaaaaaaaaaaa aaaaa aaaa AAAAA77 (AAAAA). Aaaaaaaaaaaa, aaa AAAA-aaaaaaaa aaaaa (AAAAAAAA, aaaaa aaaaaA77 (AAAA) aaa aaaaa.[7]]]

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