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Our ref: LTR-NRC-09-25
May 12, 2009

Subject: Fifth Set of Responses to the Second Round of NRC's Request for Additional Information by the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16747-P, "POLCA-T: System Analysis Code with Three-Dimensional Core Model" (TAC No. MD5258) (Proprietary/Non-Proprietary)

Enclosed are copies of the Proprietary and Non-Proprietary versions of the fifth set of responses to the second round of NRC's request for additional information by the Office of Nuclear Reactor Regulation for topical report WCAP-16747-P, "POLCA-T: System Analysis Code with Three-Dimensional Core Model."

Also enclosed is:

1. One (1) copy of the Application for Withholding, AW-09-2575 (Non-proprietary) with Proprietary Information Notice.
2. One (1) copy of Affidavit (Non-proprietary).

This submittal contains proprietary information of Westinghouse Electric Company, LLC. In conformance with the requirements of 10 CFR Section 2.390, as amended, of the Commission's regulations, we are enclosing with this submittal an Application for Withholding from Public Disclosure and an affidavit. The affidavit sets forth the basis on which the information identified as proprietary may be withheld from public disclosure by the Commission.

Correspondence with respect to the affidavit or Application for Withholding should reference AW-09-2575 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P.O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Enclosures
cc: P. Yarsky, NRR
G. Bacuta, NRR

T007
NRR

Westinghouse

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Our ref: AW-09-2575
May 12, 2009

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-NRC-09-25 P-Enclosure, "Fifth Set of Responses to the Second Round of NRC's Request for Additional Information by the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16747-P, 'POLCA-T: System Analysis Code with Three-Dimensional Core Model' (TAC No. MD5258)" (Proprietary)

Reference: Letter from J. A. Gresham to Document Control Desk, LTR-NRC-09-25, dated May 12, 2009

The application for withholding is submitted by Westinghouse Electric Company LLC (Westinghouse) pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains commercial strategic information proprietary to Westinghouse and customarily held in confidence.

The proprietary material for which withholding is being requested is identified in the proprietary version of the subject report. In conformance with 10 CFR Section 2.390, Affidavit AW-09-2575 accompanies this application for withholding, setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information which is proprietary to Westinghouse be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-09-2575 and should be addressed to J. A. Gresham, Manager of Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, P. O. Box 355, Pittsburgh, Pennsylvania 15230-0355.

Very truly yours,

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Cc: P. Yarsky, NRR
G. Bacuta, NRR

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared J. A. Gresham, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Westinghouse Electric Company LLC (Westinghouse) and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

J. A. Gresham

J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing

Sworn to and subscribed
before me this 12th day
of May, 2009.

Sharon L. Markle
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Sharon L. Markle, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Jan. 29, 2011
Member, Pennsylvania Association of Notaries

LTR-NRC-09-25
May 12, 2009

bcc: J. A. Gresham, 1L
W. Rinkacs, 1L, 1A (Nivelles, Belgium)
C. Brinkman, 1L, 1A (Westinghouse Electric Co., 12300 Twinbrook Parkway, Suite 330, Rockville, MD 20852)
RCPL Administrative Aide, (letter and affidavit only)
B. Beebe, 1L
T. Rodack, 1L
A. Leidich, 1L, 1A
A. Mingo, 1L, 1A
Y. Dag, 1L, 1A
File

Reference: See attached EP-304-2

(1) I am Manager, Regulatory Compliance and Plant Licensing, in Nuclear Services, Westinghouse Electric Company LLC (Westinghouse) and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of Westinghouse.

(2) I am making this Affidavit in conformance with the provisions of 10 CFR Section 2.390 of the Commission's regulations and in conjunction with the Westinghouse "Application for Withholding" accompanying this Affidavit.

(3) I have personal knowledge of the criteria and procedures utilized by Westinghouse in designating information as a trade secret, privileged or as confidential commercial or financial information.

(4) Pursuant to the provisions of paragraph (b)(4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

(i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Westinghouse.

(ii) The information is of a type customarily held in confidence by Westinghouse and not customarily disclosed to the public. Westinghouse has a rational basis for determining the types of information customarily held in confidence by it and, in that connection, utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Westinghouse policy and provides the rational basis required.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential competitive advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Westinghouse's competitors without license from Westinghouse constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use 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 a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Westinghouse, its customers or suppliers.

(e) It reveals aspects of past, present, or future Westinghouse or customer funded development plans and programs of potential commercial value to Westinghouse.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Westinghouse system which include the following:

(a) The use of such information by Westinghouse gives Westinghouse a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Westinghouse competitive position.

(b) It is information which is marketable in many ways. The extent to which such information is available to competitors diminishes the Westinghouse ability to sell products and services involving the use of the information.

(c) Use by our competitor would put Westinghouse at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Westinghouse of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Westinghouse in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Westinghouse capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence and, under the provisions of 10 CFR Section 2.390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same original manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in this submittal is that which is appropriately marked LTR-NRC-09-25 P-Enclosure, "Fifth Set of Responses to the Second Round of NRC's Request for Additional Information by the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16747-P, 'POLCA-T: System Analysis Code with Three-Dimensional Core Model' (TAC No. MD5258)" (Proprietary), for submittal to the Commission, being transmitted by Westinghouse letter (LTR-NRC-09-25) and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse Electric Company is that associated responses to NRC requests for additional information.

This information is part of that which will enable Westinghouse to:

(a) Obtain generic NRC licensed approval for use of the advanced dynamic system analysis code POLCA-T in performing BWR licensing analysis.
(b) Specific applications using the POLCA-T computer code will include Control Rod Drop Accident (CRDA) analysis and BWR stability analysis.

Further this information has substantial commercial value as follows:

(a) Future applications of the POLCA-T computer code will include BWR Transient Analysis and Anticipated Transient Without Scram (ATWS) analysis.
(b) Assist customers to obtain license changes.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Westinghouse because it would enhance the ability of competitors to provide similar fuel design and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without purchasing the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Westinghouse effort and the expenditure of a considerable sum of money.

In order for competitors of Westinghouse to duplicate this information, similar technical programs would have to be performed and a significant manpower effort, having the requisite talent and experience, would have to be expended.

Further the deponent sayeth not.

PROPRIETARY INFORMATION NOTICE

Transmitted herewith are proprietary and/or non-proprietary versions of documents furnished to the NRC in connection with requests for generic and/or plant-specific review and approval.

In order to conform to the requirements of 10 CFR 2.390 of the Commission's regulations concerning the protection of proprietary information so submitted to the NRC, the information which is proprietary in the proprietary versions is contained within brackets, and where the proprietary information has been deleted in the non-proprietary versions, only the brackets remain (the information that was contained within the brackets in the proprietary versions having been deleted). The justification for claiming the information so designated as proprietary is indicated in both versions by means of lower case letters (a) through (f) located as a superscript immediately following the brackets enclosing each item of information being identified as proprietary or in the margin opposite such information. These lower case letters refer to the types of information Westinghouse customarily holds in confidence identified in Sections (4)(ii)(a) through (4)(ii)(f) of the affidavit accompanying this transmittal pursuant to 10 CFR 2.390(b)(1).

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Fifth Set of Responses to the Second Round of NRC's Request for Additional Information by the Office of Nuclear Reactor Regulation for Topical Report (TR) WCAP-16747-P, "POLCA-T: System Analysis Code with Three-Dimensional Core Model" (TAC No. MD5258) (Non-Proprietary)

Westinghouse Electric Company
P.O. Box 355
Pittsburgh, Pennsylvania 15230-0355

NRC RAI 2-12

It is possible in POLCA7 to model fuel with varying axial geometry (e.g. part length fuel rods). POLCA7 includes an axial homogenization feature to treat sub-nodal geometry changes in terms of the nodal cross sections. However, it is not clear how thermal hydraulic data are treated for sub-nodal geometry changes. In the zone interface between fully rodded and partially rodded regions the heated perimeter, the wetted perimeter, heat transfer surface area, and hydraulic diameter change. It is possible for these geometry changes to occur within a node, as opposed to a node interface. This is likely to occur for core models where several fuel types are included, such as mixed core applications. Please describe how the hydraulic data are utilized and/or modified when geometry changes occur axially within a node in POLCA-T. The response should address:

(5) user guidance for axial nodalization for mixed cores

(6) any axial nodalization requirements in POLCA7

(7) treatment of the geometric hydraulic data in POLCA-T

(8) calculation of sudden pressure losses at a sub-nodal elevation such as expansion above part length fuel rod plena.

Westinghouse Response to RAI 2-12 (1)

The modeling of the core in POLCA-T, including its axial discretization (nodalization), follows that of POLCA7 in terms of number of thermal segments, hydraulic loss coefficients, heat transfer areas, etc. for each bundle type. The transfer of this data to POLCA-T is done automatically. Hence, the user does not need to take additional actions when importing the core model into POLCA-T, regardless of whether or not it concerns a homogenous or mixed core. The impact of this is discussed below.

Westinghouse Response to RAI 2-12 (2)

The treatment of the hydraulic data in POLCA7 is described in chapter 4.5, BWR THERMAL-HYDRAULIC MODEL, of CENPD-390-P-A. This includes how to take into account axial variations in assembly design. The POLCA7 thermal hydraulic (T/H) model allows for a non-uniform axial mesh, although it is required to be consistent over the entire core. In practice only equidistant nodal meshes are used.

Westinghouse Response to RAI 2-12 (3)

As stated for answer 1 above, the geometrical data is transferred to POLCA-T when POLCA7 has read the input files from POLCA-T (POLCA7 is called from POLCA-T).

[

]a, c.

a,c

Westinghouse Response to RAI 2-12 (4):

The calculation of sudden pressure losses due to area change when a part length rod has an overshoot to a volume cell (node) is [

]^{a,c}.

NRC RAI 11-14

The staff requires additional information regarding the gas gap heat conduction model in POLCA-T.

(5) Please describe the relationship between the Sutherland weighting factors and the weighting factors used in the STAV 7.2 code described in WCAP-15836-P-A.

(6) Please explain why heat capacities at constant pressure are used in POLCA-T whereas heat capacities at constant volume are reported in CENPD-285-P-A.

(7) Equation 14-10 and 14-11 appear to be analogous to Equations 2.3-8 and 2.3-9 of CENPD-285-P-A, respectively. However, these equations are different. Please explain the discrepancy.

(8) Please explain why the empirical constant C is given as 114.5 in WCAP-16747-P while the same constant is given as 114.94 in CENPD-285-P-A.

Westinghouse Response to RAI 11-14 (1)

The properties of gases described in chapter 20.3 of the WCAP 16747-P are used for thermal-hydraulic simulation when a mix of non-condensable gases occurs in the system simulation as non-condensable gases. Therefore the sentence "It concerns mainly fission gases ... " has been unintentionally put in wrong place. The sentence will be changed to "It concerns only gases that are treated as a non-condensable species in the gas phase during thermal-hydraulic simulations." Therefore, a revision of chapter 20.3 is needed. An additional chapter, 20.4 "PROPERTIES OF GASES IN THE GAS GAP", will be also included in the WCAP 16747-P.

The revised chapter 20.3 and the additional chapter 20.4 are suggested as follows.

20.3 PROPERTIES OF NON-CONDENSABLE GASES

Evaluation of some properties of gases is necessary in POLCA-T. It concerns only gases that are treated as non-condensable species in the gas phase during thermal-hydraulic simulations.

Thermal conductivity of pure gases is approximated with the formula:

$$k = a \cdot T^{b} \tag{20-3}$$

where coefficients ***a*** and ***b*** are shown in Table 20-1.

The effective thermal conductivity of a single pure gas in a gas mixture is calculated, based on the thermal conductivity of pure gases making up the mixture, according to the following equation:

$$K_i = \frac{k_i \, x_i}{\sum_{j=1}^{n} A_{ij} \cdot x_j} \tag{20-4}$$

where:

- k_i = thermal conductivity of pure gas i, W m^{-1} K^{-1},
- x_i = mole fraction of gas i in the mixture,
- A_{ij} = Sutherland weighting factor for the gas species i, in the gas mixture, and
- n = number of gas constituents in the mixture.

The Sutherland weighting factor can be obtained from the following equation:

$$A_{ij} = \frac{1}{4} \cdot \left\{ 1 + \left[\frac{\mu_i}{\mu_j} \cdot \left(\frac{M_j}{M_i} \right)^{3/4} \cdot \frac{T + S_i}{T + S_j} \right]^{1/2} \right\}^{2} \cdot \frac{T + \sqrt{S_i \cdot S_j}}{T + S_i} \tag{20-5}$$

where:

- μ = viscosity of pure gas,
- M = molecular weight,
- T = temperature in degree Kelvin, and
- S = Sutherland constants for gas species.

Molecular weights and Sutherland constants for some common gases are shown in Table 20-2. Viscosity of pure gases is approximated with $\mu = a \cdot T^{b}$ where coefficients a and b are given in Table 20-3.

Table 20-4 Thermal Conductivity of Gases: $k = a \cdot T^{b}$		
Gas	**a**	**b**
Nitrogen	$5.314 \cdot 10^{-4}$	0.6898
Hydrogen	$1.6355 \cdot 10^{-3}$	0.8213
Oxygen	$1.853 \cdot 10^{-4}$	0.8729
CO	$1.403 \cdot 10^{-4}$	0.9090
CO_2	$9.460 \cdot 10^{-6}$	1.3120

Table 20-5 Molecular Weights and Sutherland Constants for Gases		
Gas	**Molecular Weight**	**Sutherland Constant**
Nitrogen	28.060	110.6
Hydrogen	2.016	93.4
Oxygen	32.000	127.0
CO	28.010	118.0
CO_2	44.010	274.0

Table 20-6 Viscosity of Pure Gases: $\mu = a \cdot T^{b}$		
Gas	**a**	**b**
Nitrogen	$0.46667 \cdot 10^{-6}$	0.64550
Hydrogen	$0.16851 \cdot 10^{-6}$	0.69647
Oxygen	$0.51638 \cdot 10^{-6}$	0.65601
CO	$0.44641 \cdot 10^{-6}$	0.65304
CO_2	$0.23544 \cdot 10^{-6}$	1.74008

20.4 PROPERTIES OF GASES IN THE GAS GAP

The properties of gases in the gas gap are evaluated in POLCA-T in accordance with Reference 20.2.

Thermal conductivity of pure gases is approximated with the formula:

$$k^* = aT^b \tag{20.6}$$

where coefficients a and b are shown in Table 20-4.

k_i^* is the effective thermal gas conductivity of species i in the mixture. k_i^* can be calculated using the method which provides an averaging technique for calculating thermal conductivity of monoatomic and polyatomic gas mixtures, namely:

$$k_i^* = \frac{k_i}{1 + \sum_{j=1}^{n} \psi_{ij}(x_j / x_i)} \tag{20.7}$$

where k_i is the thermal conductivity of constituent gas, x the mole fraction, and ψ_{ij} the weighting factor which is a function of molecular weights, temperature and viscosities. The weighting factor ψ_{ij} appearing in eq. (20.7) is calculated by

$$\psi_{ij} = \phi_{ij}\left[1 + 2.41\frac{(M_i - M_j)(M_i - 0.142M_j)}{(M_i + M_j)^2}\right] \tag{20.8}$$

where

$$\phi_{ij} = \frac{\left[1 + \left(\frac{k_i}{k_j}\right)^{1/2}\left(\frac{M_i}{M_j}\right)^{1/4}\right]^2}{2^{3/2}\left(1 + \frac{M_i}{M_j}\right)^{1/2}} \tag{20.9}$$

and

n = number of components in mixture
M = molecular weight of the chemical species i
K_i = thermal conductivity of the chemical species i
x_i = mole fraction of the chemical species, i

The coefficients ***a*** and ***b*** in thermal conductivity of pure gases in Eq. (20.6) are shown in Table 20-4. The molecular weights for these gases are shown in Table 20-5. The coefficients ***a*** and ***b*** in viscosity of pure gases approximated with $\mu = a \cdot T^{b}$ are given in Table 20-6.

Table 20-4 Thermal Conductivity of Gases: $k=aT^{b}$

Gas	a	b
Helium	3.366×10^{-3}	0.668
Argon	3.421×10^{-4}	0.701
Xenon	4.0288×10^{-5}	0.872
Krypton	4.726×10^{-5}	0.923
Hydrogen	1.6355×10^{-3}	0.8213

Table 20-5 Molecular Weights for Gases

Gas	Molecular Weight
Helium	4.003
Argon	39.994
Xenon	131.300
Krypton	83.700
Hydrogen	2.016

a,c

The accommodation coefficients for fuel and cladding surfaces (α) are shown in Table 20-7

[ ] a,c

20.5 REFERENCES

20.1 L. Haar, J. S. Gallagher, G. S. Kell, "NBS/NRC Steam Tables." Hempshire Publishing Corporation, 1984.

20.2 "Fuel Rod Design Methods for Boiling Water Reactors," CENPD-285-P-A (proprietary), CENPD-285-NP-A (non-proprietary), July 1996.

As seen in the chapter above POLCA-T uses an identical set up of weighting factors etc, as in STAV 7.2, CENPD-285 for gases in the gas gap. All the information stated in chapter 20.4 has been implemented in POLCA-T from the first release.

This update of chapters 20.3, 20.5 as well as the additional chapter 20.4 will be included in the revision of the Topical Report WCAP-16747-P.

Westinghouse Response to RAI 11-14 (2)

This is an editorial error. To be consistent with the Topical Report WCAP-15836-P-A, the specific heat in equations (14-9) and (14-10) should be the specific heat at constant volume. However, the specific heat is canceled out in (14-13). This editorial error does not affect the temperature jump distance calculation.

Westinghouse Response to RAI 11-14 (3)

There are editorial errors in equations (14-10) and (14-11). In (14-10), the specific heat should be C_v. Equation (14-11) should read:

$$\lambda_i = C\sqrt{T/M_i}\left(\frac{\mu_{i,eff}}{P}\right)$$

Westinghouse Response to RAI 11-14 (4)

The empirical constant C is 114.94 in the POLCA-T code as stated in CENPD-285-P-A. It is a typing error in the Topical Report WCAP-16747-P and it will be corrected.

NRC RAI 11-15 (1)

Fuel Thermal Conductivity Model

The POLCA-T fuel thermal conductivity model does not appear to treat the fuel thermal conductivity degradation effect consistent with the model approved by the staff in STAV7.2. Please refer to WCAP-15836-P-A, particularly the response to RAI 2. Please revise the POLCA-T fuel thermal conductivity model to be consistent with the STAV7.2 model.

Westinghouse Response to RAI 11-15 (1)

In POLCA-T there are different models of fuel thermal conductivity depending on which version of STAV is selected: the currently NRC licensed version of STAV, any other similar thermal mechanical model approved in other countries or older previous versions of STAV . The model in WCAP-16747-P, equations 14-32--14-38, is the present default conductivity model for fuel pellets and equations 14-42,14-43 is the present default relocation model. The equation set presented in WCAP-15836-P-A is from STAV 7.2 and will be used in POLCA-T when performing licensing calculations in the US. If this model is changed POLCA-T will be also updated with the new approved fuel rod models, The NRC approval of any new thermal-mechanical model is independent of POLCA-T itself and is licensed separately as previously seen in WCAP-15836-P-A.

To be consistent with the WCAP-15836-P-A the fuel thermal conductivity model and pellet relocation model therein are included as a subchapter to 14.2.1 Pellet Conductivity. The following text will be included:

14.2.1 Pellet Conductivity

Default model

Text as it is now with typographical correction of 14.37.

Typographical error in equation 14-37.

$$K_3 l^{K_4 T} \;--->\; K_3 e^{K_4 T}$$

STAV 7.2

The fuel thermal-conductivity models in STAV 7.2 have been improved compared to the default thermal-conductivity by the introduction of [ ]a,c.

The thermal conductivity of UO_2 fuel is temperature and burnup dependent with the following form:

$$k = P\left[\frac{K_1}{K_2 + K_3 u + K_5(1 - K_6 u)\min(T,1650)} K_7 e^{(K_8 T)}\right] \qquad (14\text{-}32b)$$

for $0 \le T \le T_m(u' w_g)(^\circ C)$

where

k	=	thermal conductivity in (W/m °C)
P	=	porosity correction factor (see below)
T	=	temperature (°C)
$b(u)$	=	fuel burnup dependent term (see below)
$T_m(u)$	=	burnup-dependent melting temperature (°C)
u	=	local burnup, MWd/kgUO_2
u'	=	local burnup, MWd/kgU

[ ]a,c

Gadolinium Fuel Thermal Conductivity

$$k = P\left[\frac{K_1}{K_2 + K_3 u + K_4 w_g + K_5(1 - K_6 u)\min(T,1650)} K_7 e^{(K_8 T)}\right] \qquad (14\text{-}37b)$$

for $0 \le T \le T_m(u' w_g)(^\circ C)$ and $0 \le w_g \le 0.1$

[ ] a,c

T_m according to equation 14-33, P according to equation 14-34.

As a consequence of using the STAV 7.2 option the pellet relocation model is modified, Equation 14-42 and 14-43 in WCAP-16747-P and the last sentence in chapter 14.1.3 must be completed with the following text [ ]a,c .The numbers are empirical constants.

14.2.2.3 Pellet Relocation Model

Default

Text as in WCAP -16747-P

STAV7.2

The following pellet relocation model is used for the option STAV7.2:

[ ] a,c

and

[ ] a,c

Other quantities in the equations above are according to the definitions described for the default relocation model.

NRC RAI 11-15 (2)
Gas Gap Pressure

Please describe how the plena are incorporated in the calculation of the gas gap pressure. It is not clear from Section 14.1.4.1 how this calculation is performed. Please compare the POLCAT methodology to the previously approved STAV6.2 method described in Section 2.3.2 of CENPD-285-P-A. Please comment on any non-conservatism that is introduced by assumptions regarding the gas temperature.

Westinghouse Response to RAI 11-15 (2)

In the calculation of the gas gap pressure the plena volume, temperature and its molar content of gas are taken into account. The temperature in the plena is assumed to be the same as the gas gap temperature in the uppermost fuel rod cell. This calculation is performed for each average fuel rod and possible hot rod in each time step.

Equation 14-30 then becomes:

$$p_{rod} = \frac{n_{tot} R}{\frac{V_{plena}}{T_{plena}} + \sum_{k=1}^{K} \frac{V_k}{T_k}}$$

where

n_{tot}	total number of moles
R	gas constant
V_k	volume of gas gap at each elevation k
T_k	temperature of gas gap at each elevation k
V_{plena}	volume of plenum
T_{plena}	temperature of plenum

<u>POLCA-T methodology versus CENPD-285-P-A , Section 2.3.2</u>

In the present version of POLCA-T axial strain of the cladding due to thermal expansion, axial force balance between the pressure forces and the spring force, which can cause axial strain during depressurization are [ ]^{a,c}. This affects the plenum volume and also the stress in the cladding.

The assumption that the plenum has the same temperature as the uppermost gas gap temperature is a deviation from CENPD-285-P-A and is conservative. See STAV7.2 in WCAP-15836-P-A.

The temperature of the dishing volume contribution is assumed to be at the average gas gap temperature.

NRC RAI 11-15 (3)
Translation of Previously Approved Models

The staff has noted minor differences between the fuel model described in POLCA-T and historically approved models that may be the result of typographical errors (see parts (1) and (2) of this RAI, RAI 11-2, RAI 11-13S1, and RAI 11-14).

Please provide a comprehensive listing of the models in Section 14 of the POLCA-T LTR and compare these models to the previously approved analogous models in either STAV or CHACHA. Please provide appropriate references. If these models are different due to typographical inconsistencies, please correct these inconsistencies.

If the models are different because a new model is introduced for review and approval please clearly note these to assist the staff in its ongoing review. Please provide appropriate qualification of any new models to assist the staff in its assessment of the POLCA-T capabilities and range of application.

If a model from an earlier approved version of STAV or CHACHA is retained in POLCA-T relative to a superseding model in the most recently approved versions of STAV or CHACHA, please justify why the historical model is appropriate.

Westinghouse Response to RAI 11-15 (3)

A list of equations in POLCA-T and its counterpart in STAV, CENPD-285-P-A, WCAP-15836-P-A or CHACHA are compiled in Table 3.1 below.

a,c

a,c

a,c

a,c

Table 3.1 Cross Reference list of equations used in Chapter 14 of WCAP-16747-P

From the above compilation of equations and their counterparts in other approved LTRs we can see that all equations have a reference or if not they are of basic nature or part of a derivation.

Equations 14-80 – 14-108, used for power generation due to metal-water reaction and cladding rupture, are the same as in LTR RPB-90-93-P-A and CENPD-293-P-A (CHACHA-3D). In the answer to RAI 11-13S1 we have shown that the models in POLCA-T give the same results as stated in CENPD-293-P-A to the measured data provided in NUREG-0630.

Most of the equations for gas gap heat transfer and the pellet model in WCAP-15836-P-A refer to CENPD-285-P-A as shown in table 1 above.

Some of the equations are pure correlations based on STAV simulation with its models for fission gas release (equations 14-47—14-59), and for swelling, densification and creep deformation (equations 14-40, 14-41 and 14-70).

Deviations from WCAP-15836-P-A include the equation for the pellet conductivity, equation 14-32/14-37, and the correlation for pellet relocation, equations 14-42 and 14-43. See also the answer to part 4 of this RAI.

As stated in the answer to sub question (1) above the user can opt to use the equations for conductivity and relocation from WCAP-15836-P-A. In order to be consistent with WCAP-15836-P-A a revision of chapters 14.2.1 and 14.2.2.3 will be made in the approved version.

Changes due to typographical errors

Equations 14-18 to 14-23 are obsolete, not used and will be removed in the approved version of the report.

NRC RAI 11-15 (4)
Historical Limitations and Conditions

In its review of STAV7.2, the staff lists five conditions in its approving SE. Please refer to WCAP-15836-P-A. Confirm the applicability of these conditions to the current LTR. If it has been determined that a particular condition is not equally applicable to POLCA-T, please provide a detailed rationale justifying the position.

Westinghouse Response to RAI 11-15 (4)

The five conditions listed in WCAP-15836-P-A as a result of the NRC review of the Westinghouse thermal mechanical modeling of BWR fuel performance are acceptable for dynamic analyses with one exception.

As stated in the SER conditions, STAV 7.2 is considered to be a correlation and no parameter which has been used to fit data is allowed to be changed without further justification. One of these correlation constants is a parameter denoted Γ, (gamma), in chapter 2.3.1 of WCAP-15836-P-A. Γ is a parameter accounting for the relocation contribution to the gas gap geometrical change during burnup and heating. The factor Γ is defined as an azimuthally "misfitting" fraction in a statistical manner between relocated (cracked) pellet fragments and clad. This parameter has been used to account for heat transfer contributions due to partial pellet cladding contact resulting from fuel segment relocation $\Re$. This can lead to partial pellet-clad contact before full gap closure.

In all STAV versions [ ]^{a,c}, except for in STAV7.2 where [ ]^{a,c} during the model calibration of thermal gap heat transfer to best fit the measured fuel temperatures. As can be seen in figure 4.1 below, the (partial) contact fraction of relocated cracked pellet fragments and clad shall always be smaller than [ ]^{a,c}.

Assume there are N relocated pellet segments that fit the relocated cycle having radius, R_{relo}. Each of the segments contacts the relocated cycle with peripheral length S_i. Then the azimuthal "misfitting" will be:

$$2\pi R_{relo} - \sum_{i=1}^{N} S_i \, . \qquad (4.1)$$

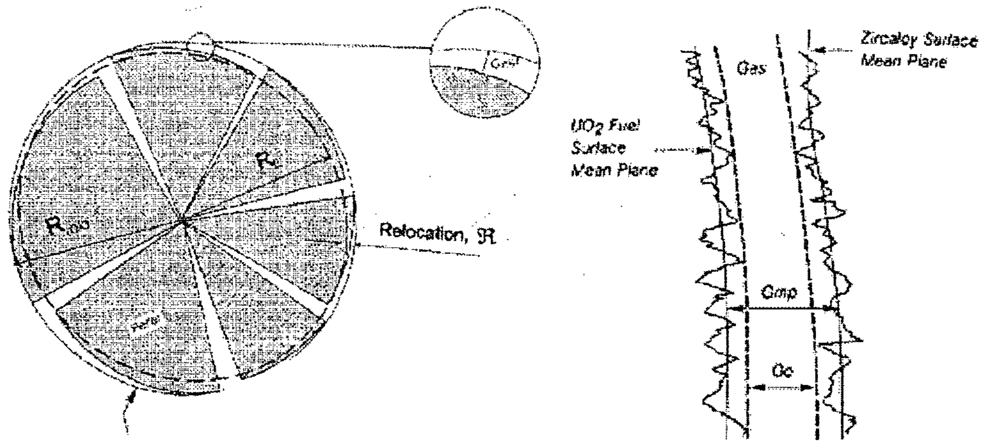

Figure 4.1 Cracked pellet segments and relocation deformation

From a theoretical point of view relocation, or cracking of the pellet, can not be fully applied to the gas gap heat transfer calculation in the thermal gas gap. Thermal gas gap is the gas gap that is used in calculating the pellet average surface temperature. This means that [ ]a,c.

As mentioned before [ ]a,c has historically had a value close to [ ]a,c. It should be mentioned that a value close to [ ]a,c was included in the originally submitted version of STAV 7.2, but the value was changed to [ ]a,c as a result of the reviewing process to add conservatism to the steady-state calculations. At the time of the STAV 7.2 approval no further investigation was performed by Westinghouse on how this additional conservatism would affect the dynamic calculations.

In tables 4.2 and 4.3,and figures 4.2 and 4.3, results of stability calculations for Decay Ratio (DR) and oscillation frequency (Fr) are shown with the pellet heat conductivity and pellet relocation using [ ]a,c (as described in WCAP-15836-P-A). The calculations were also performed with the POLCA-T STAV model (including the pellet heat conductivity and pellet relocation model as described for POLCA-T) using [ ]a,c. This is the theoretically acceptable contact fraction used in all previous versions of STAV, including STAV 6.2 as described in CENPD-285-P-A.

a,b,c

[ ]a,b,c

Table 4.2 POLCA-T calculated decay ratios

[ ]a,b,c

Table 4.3 POLCA-T calculated oscillation frequencies

[ ]a,b,c

Figure 4.2 POLCA-T calculated decay ratios

[ ]a,b,c

Figure 4.3 POLCA-T calculated oscillation frequencies

As can be observed, the measured decay ratios and oscillation frequencies are in agreement to measured data using [ ]^{a,c}. Using [ ]^{a,c}, the stability parameters (decay ratio and oscillation frequency) are over-predicted. The slightly different pellet heat conductivity models as well as the differences in the relocation models of POLCA-T and STAV 7.2 are not of significant importance.

So, the theoretical discussion is very well supported by stability measurements. It is hence justified that [ ]^{a,c} for fast dynamic applications like stability and fast transient CPR calculations where the gas gap dynamic behavior is of importance.

Using [ ]^{a,c} gives a more physical transient CPR response since, as can be seen in the stability results above, the fuel time constant is too small using [ ]^{a,c}. The underestimation of the fuel time constant would give a faster surface heat flux increase during e.g. pressurization events in the CPR limiting bundle(s) and thus a larger overly conservative transient CPR decrease for those transients.

Westinghouse will therefore use [ ]^{a,c} for all dynamic applications, e. g. Appendix C and D. The [ ]^{a,c} would have little or no impact on the ATWS (App. D) application due to the slow nature of the complete reactor shutdown process during those accidents.

[ ]^{a,c} in steady-state applications since the output parameters of importance for steady-state applications in STAV is correlated using a [ ]^{a,c}.

Westinghouse Response to Open Items from NRC Audit

Open items 6 & 7 from the NRC audit regarding the correction of numerical results for the fuel enthalpy calculation for control rod drop accident analysis and the stability analysis will be address during the creation of the Westinghouse approved topical report after receipt of the safety evaluation.

A follow-up letter will be provided to the NRC to resolve open item 9 from the audit regarding the evaluation of downstream effects on RAMONA and BISON resulting from changes in [ ]^{a,c}.