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LTR-NRC-10-69

November 10, 2010

Subject: Submittal of LTR-SGMP-09-111 P-Attachment, Rev. 1 and LTR-SGMP-09-111 NP-Attachment, Rev. 1, "Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*," (Proprietary/Non-Proprietary) for Review and Approval

Enclosed are copies of the proprietary/non-proprietary versions of LTR-SGMP-09-111 P-Attachment, Rev. 1 and LTR-SGMP-09-111 NP-Attachment, Rev. 1, "Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*" (Proprietary/Non-Proprietary).

Also enclosed is:

1. One (1) copy of the Application for Withholding Proprietary Information from Public Disclosure, AW-10-3010 (Non-Proprietary), with Proprietary Information Notice and Copyright 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 Proprietary Information 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 proprietary aspects of the application for withholding or the Westinghouse affidavit should reference AW-10-3010 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, Suite 428, 1000 Westinghouse Drive, Cranberry Township, PA 16066.

Very truly yours,

R. M. Span / FOR

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

Enclosures

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NRR

bcc: J. A. Gresham
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AW-10-3010

November 10, 2010

APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE

Subject: LTR-SGMP-09-111 P-Attachment, Rev. 1, "Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*" (Proprietary)

Reference: Letter from J. A. Gresham to Document Control Desk, LTR-NRC-10-69, dated November 10, 2010

The Application for Withholding Proprietary Information from Public Disclosure 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-10-3010 accompanies this Application for Withholding Proprietary Information from Public Disclosure, 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 the proprietary aspects of the application for withholding or the accompanying affidavit should reference AW-10-3010 and should be addressed to J. A. Gresham, Manager, Regulatory Compliance and Plant Licensing, Westinghouse Electric Company LLC, Suite 428, 1000 Westinghouse Drive, Cranberry Township, PA 16066.

Very truly yours,

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

Enclosures

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF BUTLER:

Before me, the undersigned authority, personally appeared Robert Sisk, 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:

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Strategy

Sworn to and subscribed before me
this 10th day of November 2010

Cynthia Olesky
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Cynthia Olesky, Notary Public
Manor Boro, Westmoreland County
My Commission Expires July 16, 2014
Member, Pennsylvania Association of Notaries

(1) I am Manager, Licensing and Customer Interface, in Nuclear Power Plants, 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 rule making 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 Proprietary Information from Public Disclosure 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 that 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 in LTR-SGMP-09-111 P-Attachment, Rev. 1, "Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*," (Proprietary) dated September 2010, for submittal to the Commission, being transmitted by Westinghouse letter, LTR-NRC-10-69, and Application for Withholding Proprietary Information from Public Disclosure, to the Document Control Desk. The proprietary information as submitted by Westinghouse is that associated with the technical justification of the H* Alternate Repair Criteria for hydraulically expanded steam generator tubes and may be used only for that purpose.

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

(a) License the H* Alternate Repair Criteria.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of the information to its customers for the purpose of licensing the H* Alternate Repair Criteria.

(b) Westinghouse can sell support and defense of the H* criteria.

(c) The information requested to be withheld reveals the distinguishing aspects of a methodology which was developed by Westinghouse.

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 technical justification 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).

COPYRIGHT NOTICE

Acceptable Value of the Location of the Bottom of the Expansion Transition (BET) for Implementation of H*

Revision 1

September 2010

Westinghouse Electric Company LLC
P.O. Box 158
Madison, PA 15668

Background:

The alternate repair criterion, H* (H-star), replaces the tube end weld as the pressure boundary between the primary and secondary sides of the SG with the hydraulic expansion joint between the tube and the tubesheet. The technical justification of H* demonstrates that the hydraulic expansion joint between the tube and the tubesheet provides adequate capability to satisfy the applicable structural and leakage performance criteria specified in Reference 1. The technical justification of H* determines the required length of un-degraded tubing within the tubesheet expansion region to assure that the tube cannot be pulled from the tubesheet by the limiting axial (end-cap) loads for normal operating conditions and for the limiting design basis accident with appropriate safety factors as specified in Reference 1. It is also shown that the coolant leakage through the joint is less than the leakage assumed in the FSAR for the limiting accident conditions.

It must be verified by regular in-service inspections in accordance with the requirements of Reference 2 that the tubing within the tubesheet expansion region is not degraded by stress corrosion cracking (SCC) over the required length defined as H*. To accomplish this, it is necessary to establish a unique, repeatable point of reference. The top of the tubesheet (TTS) is a point of reference that is readily established by current Eddy Current (EC) techniques and instruments (such as the bobbin probe). Consequently, the TTS is the point of reference chosen for H*. The recommended H* distances are specified as being measured from the TTS.

H* depends on contact between the tube and the tubesheet due to pressure loads, thermal loads and residual loads from initial installation (hydraulic expansion). (Note that the licensing basis as documented in References 3, 4, 5, and 6 excludes consideration of residual contact forces from the hydraulic expansion.) As a minimum, the technical justification assumes that line-on-line contact exists between the tube and the tubesheet over the length of the hydraulic expansion. The manufacturing process requires a tolerance of approximately [ ]^{a,c,e} inch from the TTS to assure that overexpansion above the TTS does not occur. Thus, by design, there is a short span from the TTS to the bottom of the expansion region (BET) where the assumption of line-on-line contact is not valid. The hydraulic expansion process is designed to minimize the distance from the TTS to the BET; however, the exact position of the location of the BET relative to the TTS can vary due to manufacturing tolerances as discussed below.

To address the potential variation of the location of the BET, the technical justification for H* includes a constant factor of [ ]^{a,c,e} inch for the location of the BET. This factor is added as a constant to the calculated H* distance required to meet the performance criteria because the underlying assumption of the H* calculation is that the initial condition is line-on-line tube-to-tubesheet contact.

Potential Sources of BET Position Variability

The hydraulic expansion tooling is likely the principal source of BET location variation but it also provides an effective upper limit for the potential variation of the location of the BET. Hydraulic expansions are performed using a mandrel that seats on the bottom of the tubesheet (the primary, clad side of the tubesheet), with top and bottom seals that contain the pressurizing medium, water. The distance between the seals on the mandrel is fixed by the nominal thickness of the tubesheet and cladding and the design criterion for locating the BET relative to the TTS. The design criteria for locating the BET is to minimize the crevice length and, also, to minimize the potential for overexpansions (BET located above the TTS). The nominal design position of the BET is [ ]^{a,c,e} inch below the TTS. Within these criteria, the distance between upper and lower mandrel seals is fixed for each model of SG. The lower seal is also fixed at [ ]^{a,c,e} inch above the seating surface on the mandrel. If the mandrel is not seated on the primary surface of the tubesheet, the maximum possible distance between the seating surface and the surface of the tubesheet is [ ]^{a,c,e} inch (less in practice) or the mandrel cannot be pressurized. Therefore, for all expanded tubes, the BET must be located within less than [ ]^{a,c,e} inch plus the initial design tolerance, [ ]^{a,c,e} inch, (=[ ]^{a,c,e} inch) of the TTS.

The tubesheet thickness can also vary above the minimum specified thickness and this variation is not necessarily the same across the entire surface of the tubesheet. There is also a design tolerance on the thickness of the cladding on the primary side of the tubesheet. Thus, tubesheet tolerances can create the appearance that the BET location is greater than expected from the nominal dimension. However, this variation does not reduce the contact length between the tube and the tubesheet; it is always controlled by the manufacturing tooling seated on the reference surface, the primary side of the tubesheet. For example, if a local condition exists where the combined tolerances on tubesheet thickness and cladding thickness are 0.1 inch greater than the design nominal dimension, the apparent BET position will be 0.1 inch greater than design nominal plus mandrel positioning variation without affecting the contact length between the tube and tubesheet.

The typical cumulative design tolerance for the tubesheet plus cladding minimum thickness is approximately [ ]^{a,c,e} inch. This tolerance can be larger for the Model 44F and Model 51F SGs, which specify only minimum thicknesses for the tubesheet and cladding. The actual dimensions are not known, but the cumulative tolerances for these SGs can exceed [ ]^{a,c,e} inch.

The current EC techniques have good capabilities for identifying the edge of a significant structure such as the top of the tubesheet; however identification of the TTS and the BET can sometimes be confused by other manufacturing artifacts. The precision of the measurement can be affected by deposits on the top of the tubesheet and manufacturing artifacts such as bulges and overexpansions near the top of the tubesheet. Close manual examination of the data can usually discriminate between the tubesheet and deposits or manufacturing anomalies, however, there are occasions when the identified location of the TTS can be confused by the sludge signal or local anomalies, leading to an apparently greater distance between the TTS and the BET.

The limiting expected BET variation is estimated as follows:

Design BET Location	[ ]^{a,c,e} inch
Maximum Mandrel mis-positioning	[ ]^{a,c,e} inch
Structure tolerances	[ ]^{a,c,e} inch
EC accuracy (estimate based on field of view of the bobbin probe)	-0.20 inch
Total	**[ ]^{a,c,e} inch**

<u>The above assessment is not a comprehensive assessment. It is to be interpreted as an estimate of the maximum possible position of the BET below the TTS because the maximum tolerances are included. Occurrence of a value of this magnitude or greater would be expected to be extremely rare.</u>

Results of BET Position Studies

Table 1 summarizes the results of the BET position studies completed as of the date of this assessment. Except for studies performed independently by several utilities, Table 1 is based on References 7 through 18. The results show that the 95th percentile values of the BET positions are generally less than 0.3 inch from the top of the tubesheet with few exceptions. The largest 95th percentile value of BET position among the H* candidate plants is 0.32 inch. The 95th percentile positions were developed for each SG including both the hot leg and the cold leg transitions.

Table 1 also shows the mean and maximum BET positions and the number of BET positions greater than 1 inch below the TTS. Only three plants have identified BET positions more than 1 inch below the TTS. Among all plants, there are 9 BET positions more than 1 inch below the TTS. As discussed above, it is not considered physically possible, based on the manufacturing methods, to achieve BET positions more than 1 inch below the TTS; rather, it is believed that artifacts in the eddy current signals confused the true position of the BET in these few instances. Most such artifacts can be resolved by close examination of the EC signals, however, occasionally, it was found that it was not possible to resolve an apparent large offset and, therefore, these are included in the database.

Table 1

Summary of BET Measurements

Plant	Model	SG	No.> 1.0 in.	Max (in.)	Mean (in.)	95%ile (in.)
Vogtle 1	F	1	0	0.66	0.082	0.167
		2	0	0.42	0.085	0.22
		3	0	0.69	0.146	0.25
		4	0	0.51	0.104	0.242
Vogtle 2		1	0	0.72	0.059	0.16
		2	0	0.47	0.14	0.228
		3	0	0.68	0.084	0.14
		4	0	0.8	0.08	0.158
Seabrook		A	0	0.62	0.129	0.245
		B	0	0.68	0.137	0.240
		C	0	0.39	0.146	0.263
		D	0	0.39	0.170	0.255
Wolf Creek		A	0	0.47	0.131	0.20
		B	0	0.66	0.170	0.25
		C	0	0.49	0.172	0.24
		D	0	0.44	0.139	0.22
Salem 1		A	0	0.44	0.149	0.27
		B	0	0.53	0.152	0.242
		C	0	0.34	0.132	0.213
		D	0	0.35	0.15	0.232

(table continued on next page)

Plant	Model	SG	No.> 1.0 in.	Max (in.)	Mean (in.)	95%ile (in.)
Millstone 3	F	A	7	1.74	0.181	0.315
		B	0	0.74	0.212	0.313
		C	0	0.91	0.190	0.323
		D	0	0.66	0.190	0.312
Byron 2	D5	A	0	0.37	0.095	0.19
		B	0	0.29	0.072	0.16
		C	0	0.34	0.083	0.17
		D	0	0.5	0.195	0.28
Braidwood 2		A	0	0.75	0.08	0.175
		B	0	0.37	0.098	0.172
		C	0	0.58	0.165	0.28
		D	0	0.79	0.169	0.25
Catawba 2		A	0	0.62	0.065	0.17
		B	0	0.45	0.097	0.207
		C	0	0.39	0.055	0.118
		D	0	0.65	0.079	0.227
Comanche Peak 2		A	0	0.55	0.172	0.26
		B	0	0.72	0.162	0.25
		C	0	0.65	0.145	0.24
		D	0	0.72	0.189	0.30
Turkey Point 3	44F	A	0	0.41	0.133	0.257
		B	0	0.48	0.165	0.282
		C	0	0.63	0.173	0.275
Turkey Point 4		A	0	0.46	0.154	0.23
		B	1	1.07(1)	0.156	0.26
		C	0	0.39	0.146	0.24
Robinson 2		A	1	1.08	0.177	0.295
		B	1	1.12	0.177	0.295
		C	0	0.66	0.185	0.275
Point Beach 1		1	To be determined			
		2				
Surry 1	51F	A	To be determined			
		B				
		C				
Surry 2		A		0.78	na	na
		B		0.91	na	na
		C		0.82	na	na

Notes:
(1) This tube was removed from service; 9 tubes with BET>1 inch below TTS remain in service as of 8/30/2010.

Assessment of the Impact of the Location of the BET on H*

The recommended values of H* at 0.95 probability and 50% confidence (95/50) for the affected models of SGs are provided in References 3, 4, 5, and 6. Reference 19 provided a sensitivity study for the value of H* if more restrictive probabilistic criteria were applied, i.e., 0.95 probability at 95% confidence (95/95) on a whole bundle and whole plant basis.

The recommended H* values from References 3 through 6 are summarized on Table 2 along with the more conservative values calculated at 95/95. These values are based on the Square Root Sum of Squares (SRSS) method discussed in the technical justification reports. Each of the plants that have filed license amendment requests (LAR) have requested a conservative value of H* as shown on Table 2. Except for the Model D5, the requested H* depths were determined in References 3, 4, 5, and 6 based on a 5-sigma combination of uncertainties using the SRSS method to provide added margin above the already conservative recommended values of H*. The LARs submitted by the Model D5 plants to date utilized a 95/95 value determined from an SRSS approach (Reference 4).

Reference 19 provided information regarding the conservatism included in the recommended values of H* for the different models of SGs including an assessment of the impact on H* of including a minimum value of residual contact pressure (RCP). The Safety Evaluation Reports (SER) (Reference 20, typical) are based, in part, on recognition that the recommended H* values include significant margin relative to the 95/95 value of H* based on refined Monte Carlo (MC) Analysis of the complement of tubes in the entire limiting plant for each of the models of SGs.

Reference 21 provided the 95/50 whole bundle Monte Carlo results for each of the models of SGs including the applicable corrections for NOP thermal distribution and crevice pressure. These results are reproduced on Table 3.

To calculate the change in the H* value when the probability criteria are changed from 95/50 whole bundle to 95/95 whole plant, the original Monte Carlo analysis was repeated for the following cases:

- 95/50 Whole Bundle
- 95/95 Whole Bundle
- 95/50 Whole Plant
- 95/95 Whole Plant

The first case repeats the original MC analysis but provides slightly different results. Because Monte Carlo analysis is based on random sampling, repeat sampling of the same data generally results in small numerical differences and the largest differences will occur in the extreme values. This explains the differences between Tables 3 and 4. Tables 5, 6 and 7 provide the results for the latter three cases. All cases were performed using the same data and the same sampling technique.

Table 8 summarizes the minimum available margin between the best prediction of H* and the requested H* depths from the LARs. The margin is characterized as minimum because it does not take into account the conservatism inherent to the best prediction of H*. For example, the analysis of record for H* assumes that the residual contact pressure (RCP) from the hydraulic expansion process is zero. Based on the test data (Reference 21) and the analysis (References 3, 4, 5, and 6), positive RCP exists. If the minimum test result for RCP (approximately equal to the calculated minimum RCP) is included (Reference 19), the best predictions for H* are reduced. Table 9 provides a margin assessment for H* when the minimum RCP is included.

The minimum margins available between the requested H* depths and the best method calculated values of H* permit definition of an acceptable location of the BET greater than the [ ]^{a,c,e} inch already included in the predicted values of H*. Among the H* candidate plants, very few instances exist where the measured BET location exceeds 1.0 inch (see Table 1). Typically, the plants with such BET locations have committed to either removing the tubes with BET locations greater than 1.0 inch from service or excluding them from the H* population. BET locations of 1.0 inch are readily accommodated by the available minimum margins, which exceed [ ]^{a,c,e} inches for the Models F, D5 and 44F SGs and [ ]^{a,c,e} inches for the Model 51F SG (see Table 8). It is noted that a measured BET location of 1.0 inch is only [ ]^{a,c,e} inch greater than the BET location of [ ]^{a,c,e} inch already included in the predicted H* values.

The margins between requested and calculated values of H* on Tables 8 and 9 apply at the critical radius of the tubesheet, i.e., the radius at which the value of H* is the greatest for a given model SG. Figure 1 shows the normalized radial profile of H* for the affected models of SGs. The normalization basis is the maximum value of H* across the radius of the tubesheet in the critical region of the tubesheet as discussed in References 3, 4, 5 and 6, the H* WCAPs. By definition, the normalized values of H* at all radii other than the critical radius and outside the critical region are less than unity; therefore, additional margin exists between the requested and predicted values of H* at all but the critical radius.

The probabilistic value of H* is calculated for the whole bundle and whole plant based on a sector approach. That is, rather than assuming that all tubes are located at the critical tubesheet radius, the calculation takes into account that the tubes not located at the critical radius have significantly lower probabilities of exceeding the minimum required length of un-degraded tube. However, for each radial sector of the tubesheet, the maximum H* value for that sector was assumed in the bundle and plant probability calculations. Therefore, despite the fact that a sector-based approach was utilized in the probability calculation, it is reasonable to utilize the normalized H* profiles to identify the additional margin for tubes not located at the limiting tubesheet radius.

To calculate total margin available for a tube not located at the limiting radius, the available margin from Tables 8 and 9 is calculated using the following equation:

$$M_{rtotal} = M_{rlimiting} + H^*_{limiting} \times (1-N_r)$$

where,

M_{rtotal} is the total margin in inches at radius r
$M_{rlimiting}$ is the margin at the limiting radius from Tables 8 or 9
$H^*_{limiting}$ is the limiting value of H* as requested in the LARs for a given model of SG
N_r is the normalization factor from Figure 1 for a given SG model

For example, assume a tube located at a radius of approximately 33.5 inches in a Model F SG has a BET measurement that exceeds [ ]^{a,c,e} inches. It is desired to calculate the available margin for this tube assuming the licensed inspection depth is as requested in the LAR, 13.1

inches. From Table 8, the available margin for the limiting position in the bundle is [ ]^{a,c,e} inches. The normalized H* value for the tube at approximately 33.5 inches radius is [ ]^{a,c,e} from Figure 1-a. Therefore, the available margin for that tube is:

M_{rtotal} =[ ]^{a,c,e} + (1 – [ ]^{a,c,e}) * 13.1 = [ ]^{a,c,e} inches

Therefore, for this hypothetical tube, a BET location of 4.07 inches could be accommodated because the predicted value of H* already includes a BET adjustment of [ ]^{a,c,e} inch.

The calculations to determine the tubesheet radius of a tube whose row and column number are known are straightforward using the Pythagorean Theorem if the Row 1 radius and the tube pitch and number of columns in the bundle are known. Table 10 provides this information for the affected models of SG.

Table 2
Recommended and Requested Values of H*

Model SG	Recommended H* at (95/50) – SRSS	Higher Probability H*at (95/95)-SRSS ^{a,c,e}	Requested H* Value in LAR (6)
F			13.10
D5			16.95
44F			17.28
51F			16.67

Notes:
(1) Reference 3
(2) Reference 4
(3) Reference 5
(4) Reference 6
(5) Reference 19
(6) Plant specific LARs for respective models.

Table 3
95/50 Whole Bundle Results (1)

SG Model	Raw H* (MC Surface Sampling)	Correction for NOP Thermal Distribution			Final H* (MC Surface Sampling; Limited Number of Tubesheets; NOP Thermal Offset)		
	95/50 Whole Bundle	Original	Revised			P_{crev} Correction	Final H*
F							
D5							
44F							
51F							
(1) Reference 19							

a,c,e

Table 4
95/50 Whole Bundle Results (Re-Analysis)

SG Model	Raw H* (MC Surface Sampling)	Correction for NOP Thermal Distribution			Final H* (MC Surface Sampling; Limited Number of Tubesheets; NOP Thermal Offset)		
	95/50 Whole Bundle	Original	Revised			Pcrev Correction	Final H*
F							
D5							
44F							
51F							

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Table 5
95/95 Whole Bundle Results (Re-Analysis)

SG Model	Raw H* (MC Surface Sampling)	Correction for NOP Thermal Distribution			Final H* (MC Surface Sampling; Limited Number of Tubesheets; NOP Thermal Offset)		
	95/95 Whole Bundle	Original	Revised			Pcrev Correction	Final H*
F							
D5							
44F							
51F							

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Table 6
95/50 Whole Plant Results (Re-Analysis)

SG Model	Raw H* (MC Surface Sampling)	Correction for NOP Thermal Distribution			Final H* (MC Surface Sampling; Limited Number of Tubesheets; NOP Thermal Offset)		
	95/50 Whole Plant	Original	Revised			Pcrev Correction	Final H*
F							
D5							
44F							
51F							

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Table 7
95/95 Whole Plant Results (Re-Analysis)

SG Model	Raw H* (MC Surface Sampling)	Correction for NOP Thermal Distribution			Final H* (MC Surface Sampling; Limited Number of Tubesheets; NOP Thermal Offset)		
	95/95 Whole Plant	Original	Revised			Pcrev Correction	Final H*
F							
D5							
44F							
51F							

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Table 8
Minimum Margin between Requested H* and 95/95 Whole Plant H*

SG Model	Requested H* Value in LAR (inch)	Final 95/95 Whole Plant H*From MC*(inch)	Minimum Margin (inch)
F	13.10		
D5	16.95		
44F	17.28		
51F	16.67		

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Table 9
Margin between Requested H* and 95/95 Whole Plant H* When Minimum Residual Contact Pressure (1) Is Included

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SG Model	Requested H* Value in LAR (inch)	95/95 Whole Plant H*From MC* Including RCP (inch)	Correction for NOP Thermal Distribution (net)	95/95 Whole Plant H*From MC* Including RCP(inch)	Crevice Pressure Adjustment (inch) (2)	Final 95/95 Whole Plant H*From MC* Including RCP (inch)	Margin (inch)
F	13.10						
D5	16.95						
44F	17.28						
51F	16.67						

Notes: (1) Based on pullout testing
(2) Figure 8-1 of References 3, 4, 5 and 6

Table 10
SG Design Information

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SG Model	Pitch (inch)	Row 1 Radius (inch)	No. of Columns
F			
D5			
44F			
51F			

Effect of BET Location on the H* Pullout Resistance Calculations

The structural calculation of the H* value depends on the deformation of the tubesheet due to thermal and differential pressure loading. These loads result in a contact pressure profile through the thickness of the tubesheet. If it is assumed that the tube and the tubesheet are not initially in contact for some distance, say 1.0 inch, from the top of the tubesheet, one might ask if the predicted length of tube in contact with the tubesheet required to provide essentially the same margin against tube pull-out would be the same as that assuming tube to tube contact exists over the full thickness of the tubesheet. A specific numerical solution requires complete re-analysis for H* based on the postulated assumption. However, based on the experience of the H* analysis model developments and multiple sensitivity studies, a sound engineering judgment is possible to address the postulated case.

H* is defined by an integration of the contact pressure profile from the top of the tubesheet downward to determine the axial position at which the integrated resisting forces are equal to the applied pullout forces. Therefore, the rate of change (slope) of the contact pressure profile from the top of the tubesheet is a reasonable indicator of the effect on H* of a postulated TTS non-contact initial condition. If the slope of the contact pressure profile through the tubesheet from top to bottom is positive, the predicted required length of contact (i.e., H*) would decrease if the position of the BET in a tube were greater than [ ]a,c,e inch below the TTS because the integrated resisting force would be greater deeper within the tubesheet. Therefore, the available margin argument above applies.

During the NRC staff audit of H* on June 14 and 15, 2010, (Reference 22), the NRC requested verification that the above argument is true for all tubesheet radii for which the predicted H* value was within 1 inch of the maximum H* position. Based on the requested H* values shown on Table 2, the normalized values of H* that are 1 inch less than the requested value of H* are shown on Table 11 in the "Ratio" column. The values of the ratio define the minimum and maximum radii for each model of SGs in Figure 1 by the intersection of the radial H* profile with the normalized (ratio) value of H* (see Figure 1-a for example).

Figures 2, 3, 4 and 5 show the contact pressure profiles at several tubesheet radii, for the Model F, D5, 44F and 51F SGs. The radii chosen for each model of SG were the critical radius and the two adjacent radial points from among the six radii that define the radial profile of H* as shown on Figure 1. The selected radii reasonably represent the tubesheet radii within which the H* value is 1 inch or less than the requested H* value.

Table 11
Tubesheet Radii at which the H* Value is within 1 inch of the Requested H* Value

SG Model	Requested H* (in.)	(H*-1):H* Ratio(1)	(H*-1) Radius (in.)		Radius Evaluated (in.)	
			Min	Max	Min	Max
F	13.1					
D5	16.95					
44F	17.28					
51F	16.67					

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Notes: (1) The ratio is defined as the requested (maximum)value of H* minus 1 divided by the requested value of H*.

The contact pressure profiles at the radii considered for all of the models of SGs exhibit the characteristic increase in contact pressure with increasing depth into the tubesheet. The contact pressure profiles for all radii considered in each of these models of SG are similar in slope; thus it is reasonable to expect that the profiles at the specific maximum and minimum radii at which the H* value is 1 inch or less than the maximum value will also exhibit the same characteristic trend. Therefore, a position of the BET more than [ ] a,c,e inch below the TTS will not result in an increase in the predicted value of H*.

For some of the larger TS radii, where the H* margin is the greatest, the slope of the contact pressure curve may become negative over the thickness of the tubesheet from the top of the tubesheet to the bottom. For such locations, a small increase in the required tube to tubesheet contact length could be expected if it were assumed that the BET is located at more than [ ]a,c,e inch below the top of the tubesheet. An analysis was performed to determine the effect of an increase in the BET position from [ ] a,c,e inch to [ ] a,c,e inch below the TTS for a case where the contact pressure gradient through the thickness of the tubesheet is negative, top to bottom.

Figure 6 shows the contact pressure profiles for the Model F SG including several at larger radii (>40 inches). At larger tubesheet radii, the slope of the contact pressure axial profile flattens and becomes negative from top to bottom. The tubesheet radius at which this occurs is far removed from the critical radius for H* where the margins to the requested H* values are large. The steepest negative slope occurs at the largest tubesheet radius. An analysis was performed to evaluate the available margin to the requested H* value for the Model F (see Table 8) based on the contact pressure profile at a radius of 59.28 inches from Figure 6. Numerical integration was performed to determine the area under the curve between [ ]^{a,c,e} and 1.0 inch below the TTS. Similarly, numerical integration was performed to determine the length below 13.1 inches (the requested H* value) required to yield the same area under the curve. A loss of contact length of [ ]^{a,c,e} inch at the TTS requires an increase in contact length of [ ]^{a,c,e} inches below the requested H* distance. Therefore, the available margin must be able to accommodate an additional increase in length of [ ]^{a,c,e} to validate the margin argument.

The normalized H* value at a radius of 59.28 inches in the Model F SG is approximately [ ]^{a,c,e}. Based on the discussion above, the total margin available at this radius is:

$$M_{rtotal} = M_{rlimiting} + H^*_{limiting} \times (1-N_r)$$

$M_{rlimiting}$ = [ ]^{a,c,e} in. from Table 8
$H^*_{limiting}$ = 13.1 in. from Table 8
N = [ ]^{a,c,e}

M_{rtotal} = [ ]^{a,c,e} inches

Figure 7 shows the axial contact pressure profile for the Model D5 SG at a tubesheet radius of 42.97 inches as a representative case. From a similar analysis as discussed above, a loss of contact length of [ ]^{a,c,e} inch at the TTS requires an increase in contact length of [ ]^{a,c,e} inch below the requested H* distance (16.95 inches), an increase in the H* length of [ ]^{a,c,e} inch. The total margin available at a radius of 42.97 inches is [ ]^{a,c,e} inches.

It is concluded that, although at larger tubesheet radii the slope of the contact pressure axial profile may become negative so that the contact pressure decreases with increasing depth into the tubesheet, the net effect resulting from this to increase the H* distance is very small. At the same larger radii, the H* radial profile falls off rapidly (see Figure 1); therefore, the available margin to the requested value of H* increases rapidly, so that the small increase in the predicted value of H* is easily accommodated at these radii.

The increase in the margin at the largest tubesheet radius for each of the models of SG is summarized on Table 12: The minimum increase in margin to the requested H* value is 6.68 inches for the Model F SGs. It is not credible that an increase in the BET location of [ ]^{a,c,e} inch would result in an increase of the predicted value of H* by more than 6 inches in any of the models of SG. In summary, it is concluded that no negative impact on the requested value of H* would occur even if it were assumed that the location of the BET is [ ]^{a,c,e} inch below the TTS.

Table 12
Additional Margin Available at the Largest Tubesheet Radius

Model	H* Requested (inch)	Max Radius H* Factor (see Figure 1)	Minimum Margin at Limiting Radius	Max Radius Additional Margin (inch)	Max Radius Total Margin (inch)
F	13.10				
D5	16.95				
44F	17.28				
51F	16.67				

a,c,e

Summary and Conclusions:

1. The currently inspection depths as requested in the respective LARs and licensed by the NRC provide significant margin over the H* values recommended in the technical justifications for all Models of SG.
2. The recommended value of H* for all models of SG are shown to be significantly conservative in comparison to the values calculated using the Monte Carlo analysis technique.
3. The recommended values of H* and those calculated using the Monte Carlo technique include an adjustment of [ ]a,c,e inch for the potential position of the BET.
4. The maximum value of BET position, assuming maximum process and component tolerances, is estimated to be approximately [ ]a,c,e inch below the TTS.
5. Only nine tubes in the population of candidate H* plants (two plants are not known as of the date of this report) exhibit a BET location greater than 1.0 inch below the TTS.
6. The largest 95^{th} percentile value of BET location among the population of H* candidate plants is 0.32 inch.
7. The available margins between the requested (licensed) inspection depth and the 95/95 whole plant values, neglecting any contribution from residual contact pressure, calculated using the MC technique are equal to, or greater than, [ ]a,c,e inches for all models of SG at the limiting position in the bundle.
8. The margins between the inspection depth and the calculated H* values increase as the position in the bundle varies from the limiting position.
9. The margins between the inspection depth and the calculated H* values increase if residual contact pressure is included. All tests to date have shown that hydraulic expansion results in positive residual contact pressure.
10. A variation of the BET position of a minimum of 1.0 inches, compared to the [ ]a,c,e inch allowance already included in the calculated values of H*, is readily accommodated by the available margins between the planned inspection depth and the calculated H* values. This conclusion is true for all radii in all models of SGs at which the predicted value of H* is within 1 inch of the maximum H* value.
11. At larger radii where a reversal of slope of the axial contact pressure profile may occur, the net increase in required H* length is negligible compared to the increase in margin at these locations.

12. A BET location of 1.0 inch below the TTS is acceptable for the implementation of H* without any adjustment in inspection depth.

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Figure 1
Normalized H* for Various Tubesheet Radii

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Figure 2
Model F Contact Pressure Axial Profile at Various TS Radii

a,c,e

Figure 3
Model D5 Contact Pressure Axial Profile at Various TS Radii

a,c,e

Figure 4
Model 44F Contact Pressure Axial Profile at Various TS Radii

a,c,e

Figure 5
Model 51F Contact Pressure Axial Profile at Various TS Radii

a,c,e

Figure 6
Model F Contact Pressure Axial Profiles at Multiple TS Radii

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Figure 7
Model D5 Contact Pressure Axial Profile at Larger TS Radius (42.97 in.)