Westinghouse Electric Corporation
Energy Systems

Box 355
Pittsburgh Pennsylvania 15230-0355

AW-96-938

March 6, 1996

Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTENTION: T. R. QUAY

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

SUBJECT: WESTINGI'OUSE RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION ON THE AP600 PRHR HEAT EXCHANGER

Dear Mr. Quay:

The application for withholding is submitted by Westinghouse Electric Corporation ("Westinghouse") pursuant to the provisions of paragraph (b)(1) of Section 2.790 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 10CFR Section 2.790, Affidavit AW-96-938 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 10CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference AW-96-938 and should be addressed to the undersigned.

Very truly yours,

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

/nja

cc: Kevin Bohrer NRC 12H5

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AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

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COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Brian A. McIntyre, 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 Corporation ("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:

Brian A. McIntyre

Brian A. McIntyre, Manager
Advanced Plant Safety and Licensing

Sworn to and subscribed
before me this 7 day
of March, 1996

Rose Marie Payne

Notary Public

Notarial Seal
Rose Marie Payne, Notary Public
Monroeville Boro, Allegheny County
My Commission Expires Nov. 4, 1996
Member, Pennsylvania Association of Notaries

(1) I am Manager, Advanced Plant Safety And Licensing, in the Advanced Technology Business Area, of the Westinghouse Electric Corporation 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 the Westinghouse Energy Systems Business Unit.

(2) I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 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 the Westinghouse Energy Systems Business Unit 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 2.790 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 10CFR Section 2.790, 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) Enclosed is Letter NSD-NRC-96-4660, March 6, 1996 being transmitted by Westinghouse Electric Corporation (W) letter and Application for Withholding Proprietary Information from Public Disclosure, Brian A. McIntyre (W), to Mr. T. R. Quay, Office of NRR. The proprietary information as submitted for use by Westinghouse Electric Corporation is in response to questions concerning the AP600 plant and the associated design certification application and is expected to be applicable in other licensee submittals in response to certain NRC requirements for justification of licensing advanced nuclear power plant designs.

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

(a) Demonstrate the design and safety of the AP600 Passive Safety Systems.

(b) Establish applicable verification testing methods.

(c) Design Advanced Nuclear Power Plants that meet NRC requirements.

(d) Establish technical and licensing approaches for the AP600 that will ultimately result in a certified design.

(e) Assist customers in obtaining NRC approval for future plants.

Further this information has substantial commercial value as follows:

(a) Westinghouse plans to sell the use of similar information to its customers for purposes of meeting NRC requirements for advanced plant licenses.

(b) Westinghouse can sell support and defense of the technology to its customers in the licensing process.

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 advanced nuclear power designs 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 for developing analytical methods and receiving NRC approval for those methods.

Further the deponent sayeth not.

ENCLOSURE 1

NSD-NRC-96-4660

WESTINGHOUSE RESPONSES TO RAI 952.94 (Revision 1)

Question 952.94

Re: PRHR HX Analysis

Provide a commitment to submit a literature search and calculations quantifying critical heat flux in the passive RHR heat exchanger. Perform additional investigation of the open literature to add to the database of information on critical heat flux (CHF) limits for tube bundles and arrays. Also perform additional calculations related to fluid conditions in the PRHR heat exchanger and submit these calculations to the staff for review. These calculations should provide a quantification of the CHF margin that exists during heat exchanger operation.

Response: (Revision 1)

The following list is the literature review on the critical heat flux (CHF) for the horizontal tube and tube bundle. The asterisk denotes the literature relevant to the PRHR heat exchanger.

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7. Cornwell, K., N.W. Duffin, and R.B. Schuller, "An Experimental Study of the effects of Fluid Flow on Boiling within a Kettle Reboiler Tube Bundle", ASME Paper No. 80-HT-45.

8. Cornwell, K. and Schuller, R.B., 1982, "A Study of Boiling outside a Tube Bundle using High Speed Photography", Int. J. Heat Mass Trans., Vol 25, pp 683-690.

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10. Dykas, S. and M.K. Jenson, "Critical Heat Flux on a Tube in a Horizontal Tube Bundle", Experimental Thermal and Fluid Science, 5, pp 34-39 (1992)

11. Edwards, D.P. and M.K. Jensen, "A Two-Dimensional Numerical method of Two-Phase Heat Transfer and Fluid Flow in a Kettle Reboiler", CBT-8704693, HTL-6, Heat Transfer Laboratory, Dept. of Mechanical Engineering, Rensselaer Polytechnic Institute, August 1990.

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13.* Fujita, Y. H. Ohta, K. Hoshida, and S. Hidaka, "Heat Transfer in Nucleate Boiling just outside Horizontal Tube Bundles, Part 2 - Prediction for Tube Bundle Effect".

14.* Hasam, M.M., R. Eichhorn, and J.H. Lienhard, "Burnout during flow across a small cylinder influenced by Parallel Cylinders". Proceedings of the Seventh International Heat Transfer Conference, Munchen, Germany, 1982.

15.* Jensen, M.K., "Fundamental Issues in Shellside Boiling", Proceedings of the Engineering Foundation Conference on Pool and External Flow Boiling, Santa Barbara, California, March, 22-27, 1992.

16. Jensen, M.K., "Plenary Lecture: Advances in Shellside Boiling and Two-Phase Flow", National Heat Transfer Conference, HTD-Vol.108, Heat Transfer Equipment Fundamentals, Design, Application and Operating Problems, 1989.

17. Kern, D.Q., Process Heat Transfer, McGraw-Hill, 1980.

18.* Leong, L.S., and K. Cornwell, 1979. "Heat Transfer Coefficients in a Reboiler Tube Bundle". Chem. Engineer, No.343, April, pp.219-221.

19.* Leroux, K.M., and M.K. Jenson. "Critical Heat Flux in Horizontal Tube Bundles in Vertical Crossflow of R113". J. Heat Transfer, 110, Supplement, pp. 1271-1286.

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31.* Yao, S.C., and T.H. Hwang, "Critical Heat Flux on Horizontal Tubes in an Upward Cross Flow of Freon-113", Int. J. Heat Mass Transfer, Vol. 32, No.1, pp. 94-103, 1989.

32.* Yasunobu, F., H. Ohta, K. Hoshida, and S. Hidaka, "Heat Transfer in Nucleate Boiling Outside Horizontal Tube Bundles, Part 2 - Prediction for Tube Bundle Effect".

33.* Zuber. N., ASME. Vol. 80, p.711 (1988).

The additional calculations for the AP600 PRHR are given in the response to DSER OI 21.3.3-1. In addition, calculations of the PRHR test fluid conditions will be given in the PRHR final test and analysis report.

SSAR Revision: NONE

ENCLOSURE 3

NSD-NRC-96-4660

Non-Proprietary Information

Question OI 21.3.3-1

Re. PRHR Heat Exchanger

Westinghouse must provide a detailed justification on the applicability of the straight tube passive residual heat removal heat exchanger (PRHRHX) test data to the new "C"-tube configuration.

Response:

The PRHR is used to remove heat from the primary system in the unlikely event that the main feedwater and startup feedwater systems are not available. The PRHR is also activated on an "S" signal such that it is operational for other transients such as small and large break LOCAs, SGTR, and MSLB.

The concern in the DSER Open Item is the application of the existing straight tube PRHR data to the C-tube design of the current exchanger. Test data indicates (Reference 21.3.3-1) that for a single tube, the heat transfer is higher for horizontal orientation as compared to vertical orientation for the same wall superheat as seen in Figure 1. Based on this observation the horizontal PRHR section would perform as well as or better than the vertical section. Therefore, the application of a heat transfer correlation for vertical tubes would be expected to be conservative (underestimate the heat transfer) for the horizontal section. This is valid providing that one is not near a critical heat flux limit.

The additional concern which the NRC staff has expressed is possible vapor blanketing of the horizontal portions of the heat exchanger, both the portion which is above the vertical tube portion of the heat exchanger, and the horizontal portion at the exchanger inlet. Since the primary flow comes in at the top of the exchanger and flows first through the top horizontal section then downward through the vertical section, the high heat flux regions are at the very top of the exchanger. The lower horizontal portion of the heat exchanger is at much lower temperature and heat load and will not experience critical heat flux and vapor blanketing. The regions of concern are indicated in Figure 2. The concerns are that the vapor generated in the vertical section will flow upward into the horizontal section, directly above it, and will lead to vapor blanketing of the horizontal tubes resulting in critical heat flux. A similar concern exists for the inlet section which is also horizontal excepting that there is no additional vapor generation from below this section of the exchanger, but rather the heat fluxes for this section are the highest such that larger amounts of vapor generation in the IRWST are possible. Also shown in Figure 2 is the inlet tube region which is surrounded by a support flange. This particular portion of the horizontal section is only cooled by a limited amount of natural convection from the IRWST. Therefore, it has been assumed that this portion of the heat exchanger will always be in film boiling for the transients analyzed.

The PRHR tube geometry is an important parameter in evaluating the heat exchanger performance and in determining if the different regions of the exchanger could experience critical heat flux and would become vapor blanketed. Figures 3 and 4 show the different tube pitches for the tube-to-tube distances within a given row of tubes, and the row-to-row distances for the different rows both in the vertical and horizontal direction. As the figures indicate, the tube pitch/diameter ratio is 2 for tube-to-tube spacing within a given row. The row-to-row pitch/diameter ratio is 4 for the vertical section and 2 for the horizontal section. This spacing is very open as compared to typical kettle boilers (Reference 21.3.3-2) or rod bundles where the pitch/diameter ratio is usually 1.3. The more open the tube lattice, the smaller the tube-to-tube interaction will become as vapor is generated in the IRWST due to the heat transfer from the PRHR.

The PRHR test data on the vertical tubes (Reference 21.3.3-3). indicates that the high heat fluxes occur when the primary side flow is at high flowrates characteristic of pumped flow through the heat exchanger. Figure 5 shows the peak heat fluxes from the PRHR tests as a function of the tube flowrate. As the figure indicates, the higher heat fluxes occurs with high flowrate through the tubes. and the heat flux is much smaller at the lower flowrates typical of natural circulation flows in the PRHR.

The PRHR performance has been examined for different transients to determine if the upper regions of the C-tube exchanger could experience critical heat flux. The transient calculations use the heat transfer relationships developed from the vertical PRHR experiments for free convection and boiling heat transfer on the outside of the PRHR tubes which is applied to the horizontal as well as to the vertical sections of the heat exchanger. The transients examined were:

1. The loss of normal feedwater flow to the generators

2. A one-inch small-break in the reactor cold leg.

The primary system transient response for the loss of normal feedwater was calculated using the LOFTRAN-AP code (Reference 21.3.3-4). The PRHR was modeled as described in Reference 21.3.3-4 and in the response to RAI 440.305. Figure 6 shows the LOFTRAN-AP model of the PRHR for these calculations. The first two nodes on the top horizontal section which are within the top support flange. were assumed to be in film boiling for the entire transient. The IRWST is modeled as a single node in the LOFTRAN code with a single bulk temperature. At the beginning of the transient. the IRWST is highly subcooled and has an initial temperature 120°F. The PRHR experiments and the SPES-2 (Reference 21.3.3-5) integral systems tests indicated that as the PRHR transfers heat to the IRWST, stratification occurs in the IRWST tank and an axial temperature distribution is developed. To model the axial temperature distribution in the single node LOFTRAN model, the SPES-2 data was analyzed to provide multipliers which relate the local axial IRWST fluid temperature to the bulk fluid temperature for the entire tank such that the stratification observed in the experiments was modelled in LOFTRAN.

Using the calculated stratified IRWST axial temperature profile. the time when bulk boiling begins, at the top of the vertical section of the PRHR, can be calculated. The times of interest are when the top of the IRWST tank reaches saturation as compared to when the reactor coolant pumps are tripped. Since the IRWST is initially at a very low temperature, even with accounting for the thermal stratification effects, the main reactor coolant pumps will trip long before boiling is calculated to occur in the IRWST. Once the reactor coolant pumps trip, the heat transfer from the PRHR to the IWRST decreases due to the reduced flow on the primary side of the heat exchanger. Therefore, when the PRHR heat flux is the highest, with the reactor coolant pumps operating, the IRWST tank temperatures are the lowest such that there is no bulk boiling.

When no bulk boiling occurs in the IRWST, there is no significant tube-to-tube interaction in the top horizontal section. Therefore, the critical heat flux limit for the heat exchanger can then be calculated using the critical heat flux limit for a single horizontal tube as recommended by References 21.3.3-6, 7 and 8. The critical heat flux limit for the single horizontal tube is larger than the heat flux calculated from using the heat transfer correlations developed from the vertical PRHR data such that the horizontal portion of the PRHR would not go into film boiling for this time period. Similar calculations were made for the horizontal portion of the PRHR heat exchanger which is not directly over the vertical portion of the exchanger. For the initial time period in the transient when the IRWST is highly subcooled, no bulk boiling is calculated to occur and the allowable heat flux limit can be obtained from the single horizontal tube correlations. The single tube horizontal critical heat flux correlations show ample margin to critical heat flux for this time period.

As the IRWST heats up and thermal stratification occurs, bulk boiling will occur in the IRWST fluid surrounding the PRHR tubes. When bulk boiling occurs, there can be tube-to-tube interaction in the horizontal section of the PRHR where the vapor from the lower tubes can effect the critical heat flux on the tubes above it. When this situation is calculated to occur, the single tube critical heat flux correlations, are no longer valid and a horizontal bundle critical heat flux correlation is used. The correlation selected was that by Palen and Small (Reference 21.3.3-9) which is valid for horizontal bundle critical heat flux limits.

When using the Palen and Small correlation, the conservative factor of 0.7 was not used such that the calculated critical heat flux limit is closer to a best estimate. The discussion in Reference 21.3.3-10 indicates that the Palen and Small correlation should be regarded as a lower bound for the critical heat flux in a horizontal bundle. The ratio of the single tube critical heat flux to the Palen and Small value of the critical heat flux, without the 0.7 multiplier, is 5.64. Therefore the maximum heat flux calculated from the Palen and Small correlation is significantly removed from the single tube critical heat flux limit. Similar arguments were made in Reference 21.3.3-10 on the applicability and range of uncertainty in applying the Palen and Small correlation to the PRHR when the bulk IRWST fluid was saturated. For the AP600 PRHR application, the authors indicated that the uncertainty spanned the range from heat fluxes of 60,000 Btu/hr-ft^2 to 350,000 Btu/hr-ft^2. The values used in the comparisons to the calculated PRHR heat fluxes were at the lowest limit of the uncertainty for the Palen and Small correlation and should be conservative.

Figure 7 shows the heatup of the IRWST for the loss of feedflow case during the transient. The time periods that the more detailed PRHR bundle analysis was performed is indicated on the figure. Figure 8 and 9 show the heat fluxes calculated for the different PRHR nodes at the top of the heat exchanger as a function of time during the transient. The superimposed dashed line is the critical heat flux limit from either the single tube correlation or the Palen and Small correlation. As the figures indicate, the calculated PRHR heat flux is largest when the reactor coolant pumps are operating at the beginning of the transient when the primary system temperature is the highest and the flow through the heat exchanger is maximum. At this time, the IRWST tank temperature and the local fluid temperature surrounding the PRHR tubes remains well subcooled such that the single tube critical heat flux correlation applies. The PRHR heat flux is high but well below the critical heat flux limit as calculated from the single tube correlation. Therefore, the horizontal section of the PRHR will not exceed critical heat flux and there will be no vapor blanketing of the tubes. The full heat transfer area, except for that region which is covered by the flange, can be used with the correlations developed from the vertical tube PRHR data. After the pumps have tripped, the heat flux is much lower since only natural circulation is occurring within the PRHR primary system. The calculated PRHR heat flux is below the critical heat flux as given by the Palen and Small correlation such that the existing full heat transfer area, except for the area covered by the flange, can be used with the correlations developed from the vertical PRHR data.

The PRHR heat transfer and performance was also examined for the one-inch cold leg small break. The IRWST remains subcooled for an extended period of time until ADS activation at 4336 seconds. The NOTRUMP (21.3.3-11) modeling of the PRHR is shown in Figure 10. Figure 11 shows the bulk IRWST temperature calculated from the NOTRUMP code. Also shown in the figure is the estimated temperature of the top liquid layer as estimated from the stratification model used in LOFTRAN. As the figure indicates, the IRWST remains well subcooled for the time period up to ADS activation. Therefore, there is no bulk boiling in the IRWST and there will be no tube-to tube interaction such that the single tube critical heat flux correlations can be used to determine the heat flux limit. Figures 12 and 13 show the calculated PRHR heat fluxes from the NOTRUMP calculation and indicate that these heat fluxes are below the single tube critical heat flux limit. Therefore, there will be no vapor blanketing of the PRHR such that the full heat transfer area can be used for the PRHR calculations.

In conclusion, the data from the literature indicates that the PRHR horizontal portion of the heat exchanger will not experience critical heat flux for design basis transients in which the PRHR is used to transfer heat to the IRWST. Therefore, the use of the vertical tube PRHR data is applicable for determining the PRHR heat transfer performance, for the AP600 C-tube design.

References

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21.3.3-6. Palen, J.W. Yarden, A.and J. Taborek, "Characteristics of Boiling Outside Large-Scale Horizontial Multitube Bundles". AIChE Symp. Series, No. 118. Vol. 68, pp. 50-61, (1972).

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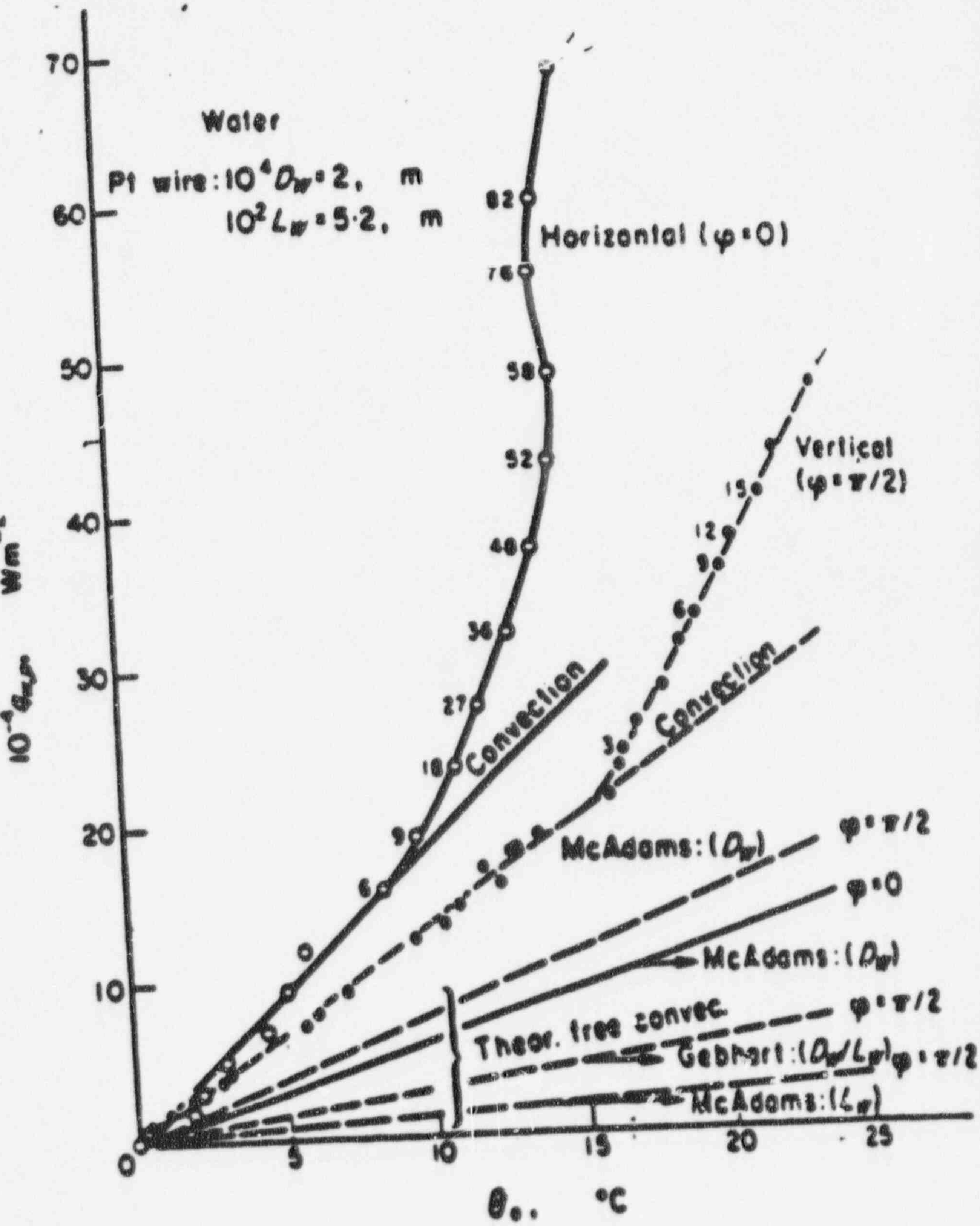
21.3.3-10. Sloan, S.M., McEllgot, D.M. and L.A. Stickler, "Evaluation of the Westinghouse PRHR Test Facility and Test Matrix for RELAP5/MOD3 Code Assessment", INEL-95/0373, Rev.2, (1993).

21.3.3-11. Kemper, R.M. "Applicability of the NOTRUMP Computer Code to AP600 SSAR Small-Break LOCA Analysis", WCAP-14206,(1994).

SSAR Revision: NONE

Figure 1

CONVECTION AND BOILING HEAT TRANSFER FROM WIRES AT DIFFERENT ANGLES (REFERENCE 1)



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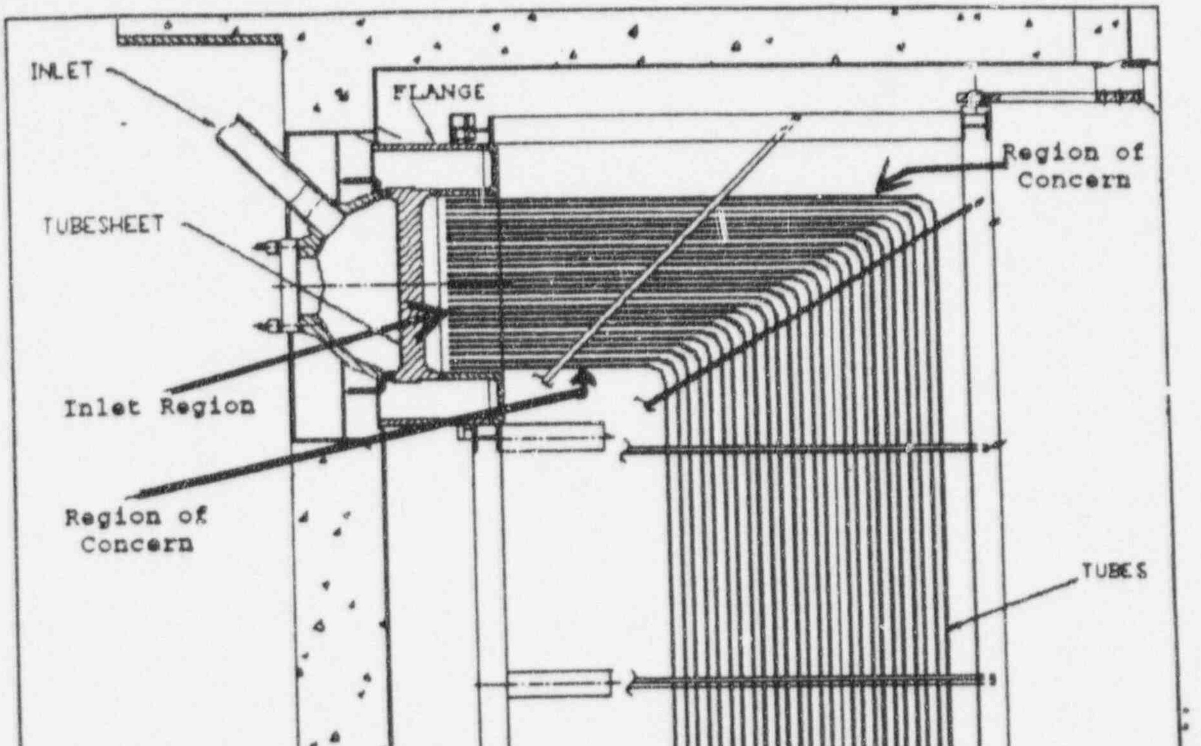
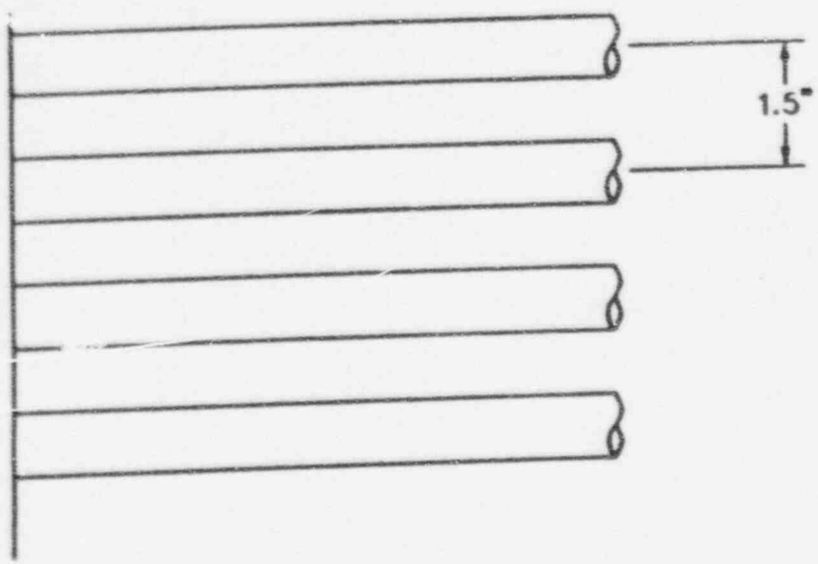


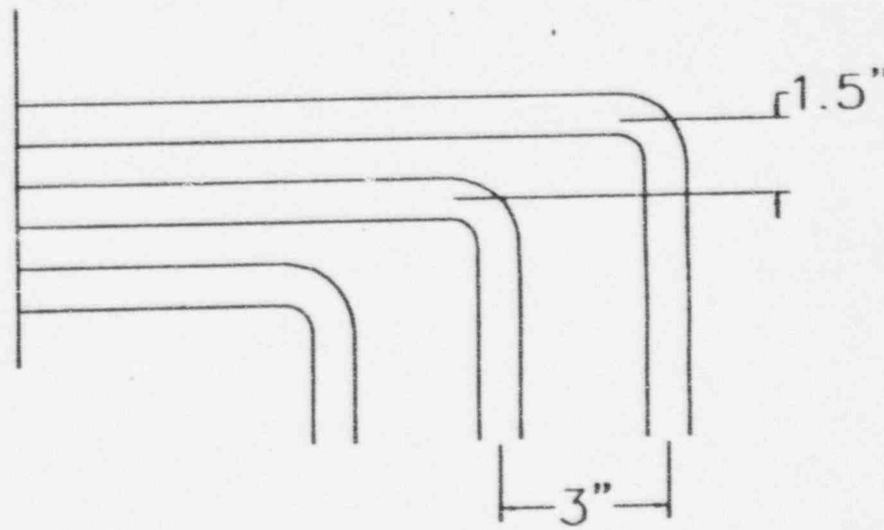
Figure 2 PRHR Heat Exchanger

PASSIVE RHR HEAT EXCHANGER

PRHR HX Tube Spacing in Horizontal Bundle



Plan View



Section View

Figure 3
PRHR Tube Spacing

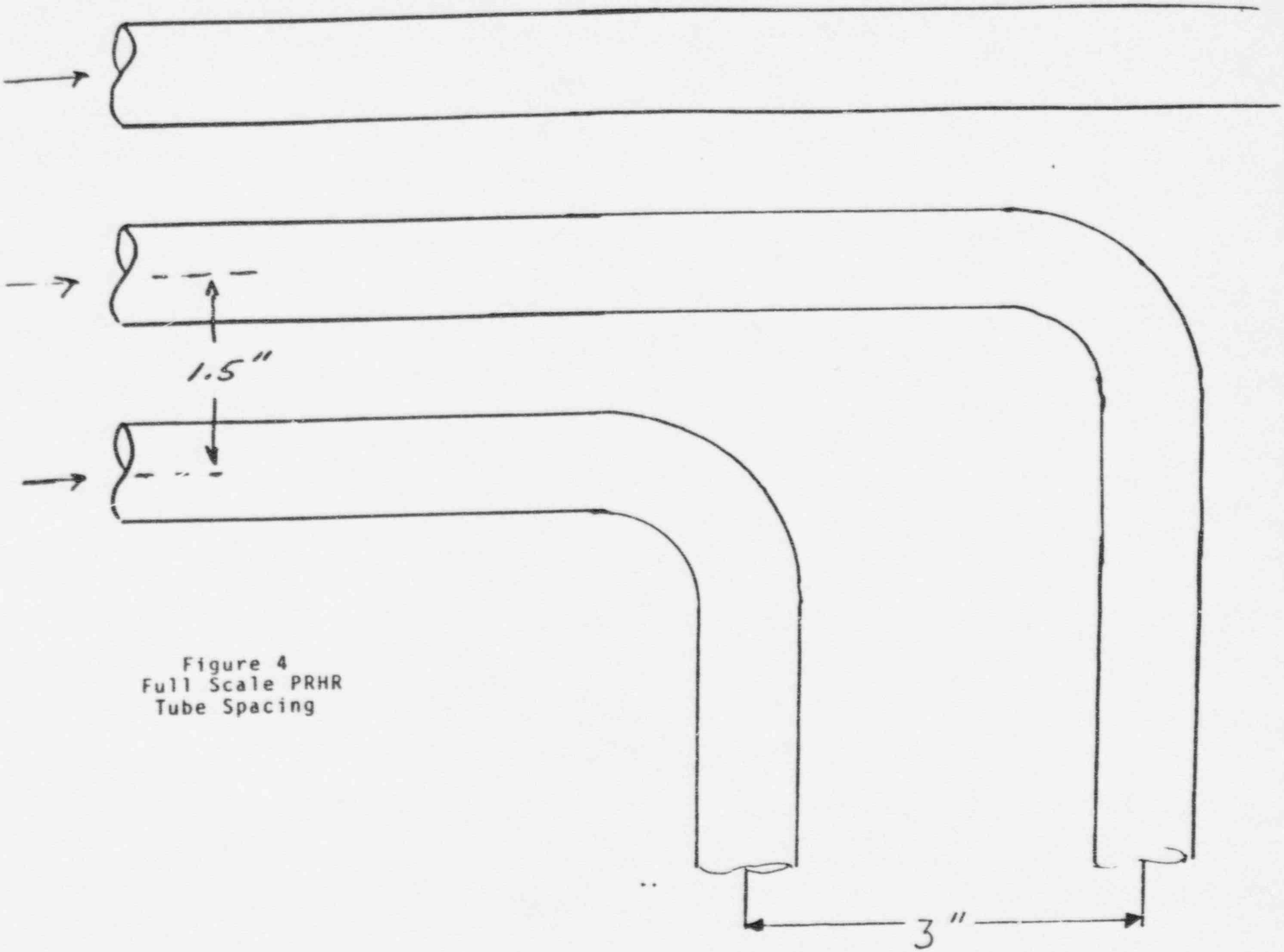


Figure 4
Full Scale PRHR
Tube Spacing

Figure 5
PRHR Peak Heat
Flux Data

ab

PRHR Tests - Series 5

Flow [gpm]

a,b

Figure 6 LOFTRAN Noding of PRHR Heat Exchanger

Figure 7

LOFTRAN: Loss Of Normal Feedwater

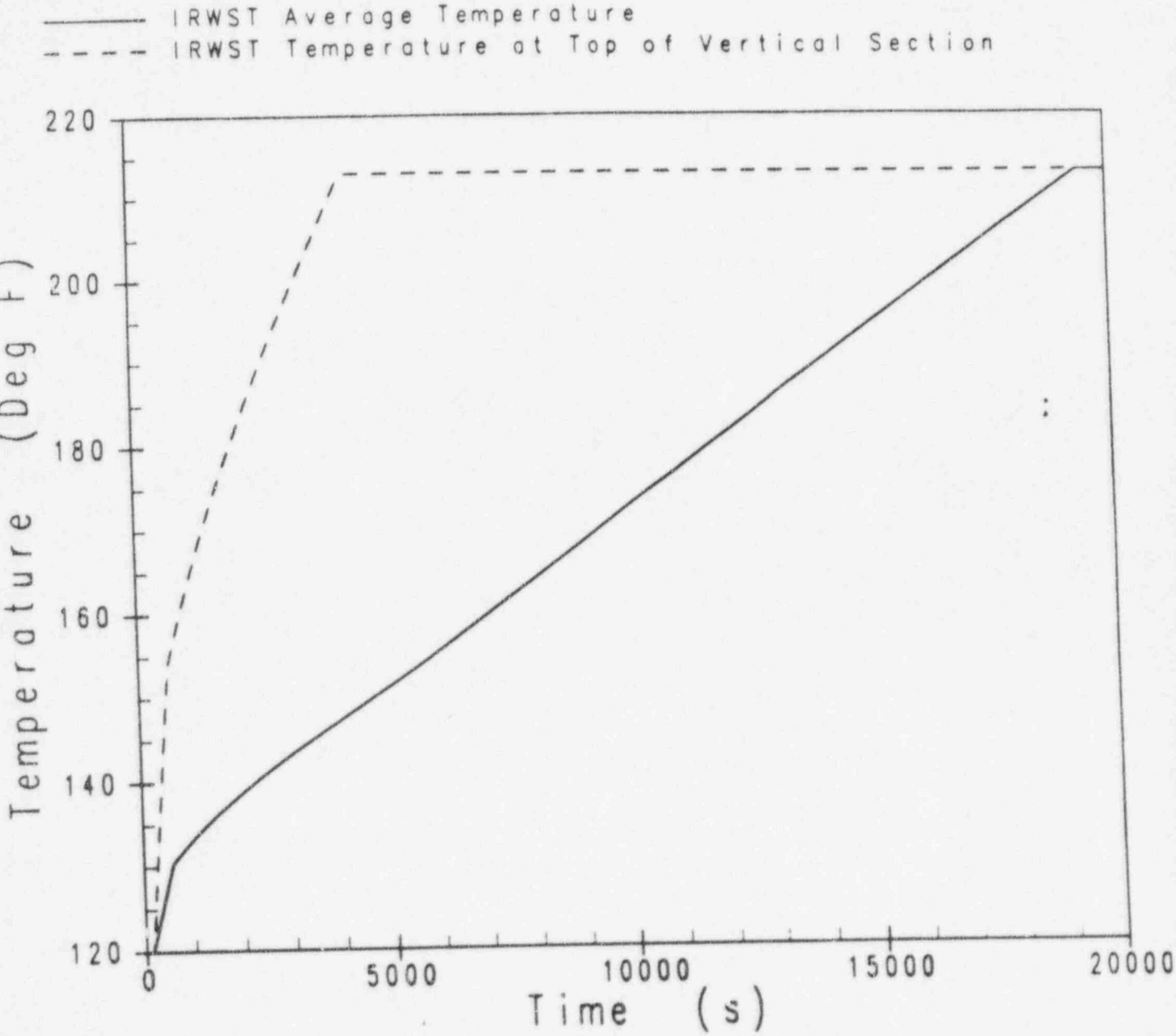


Figure 8

LOFTRAN: Loss Of Normal Feedwater

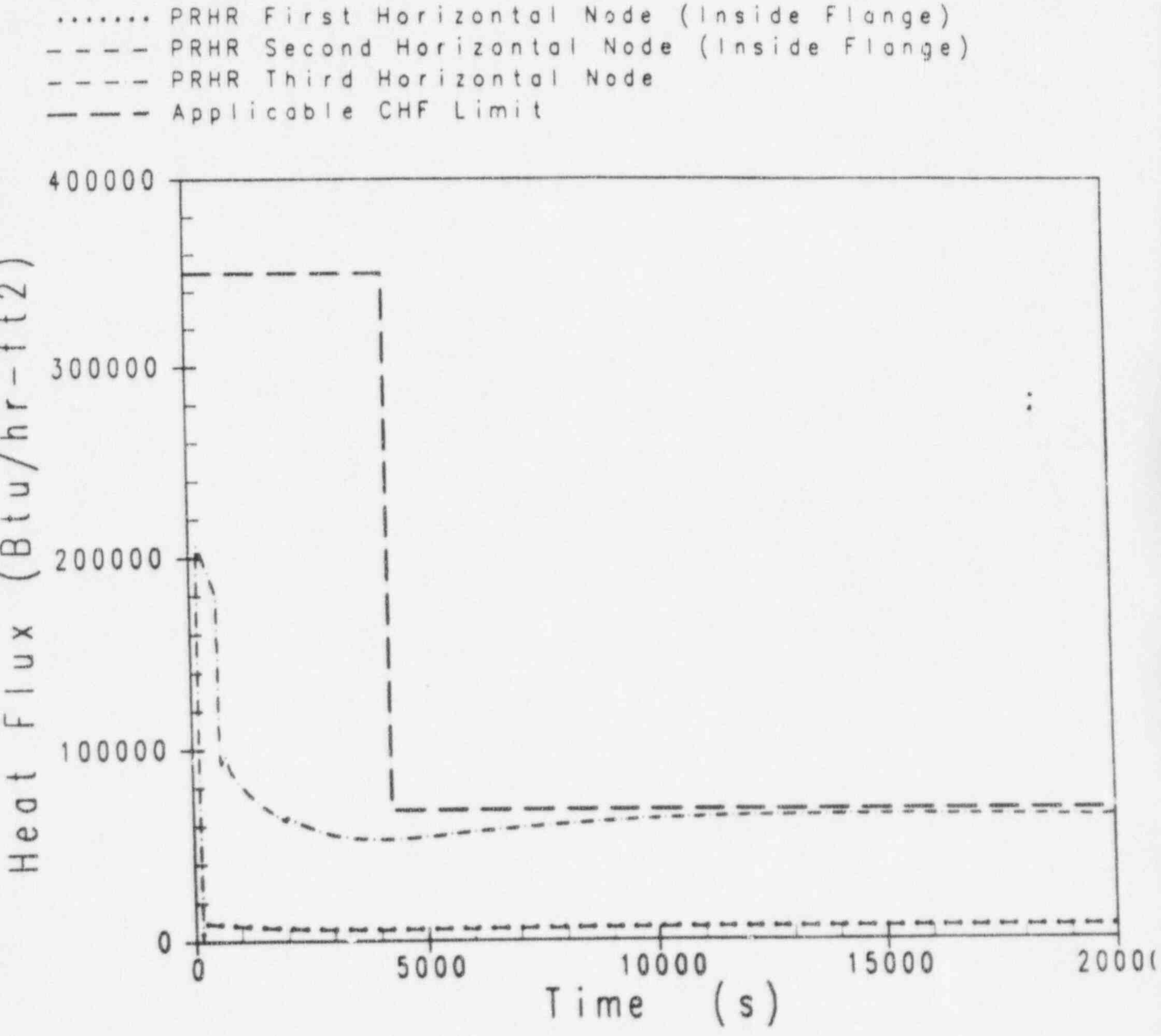
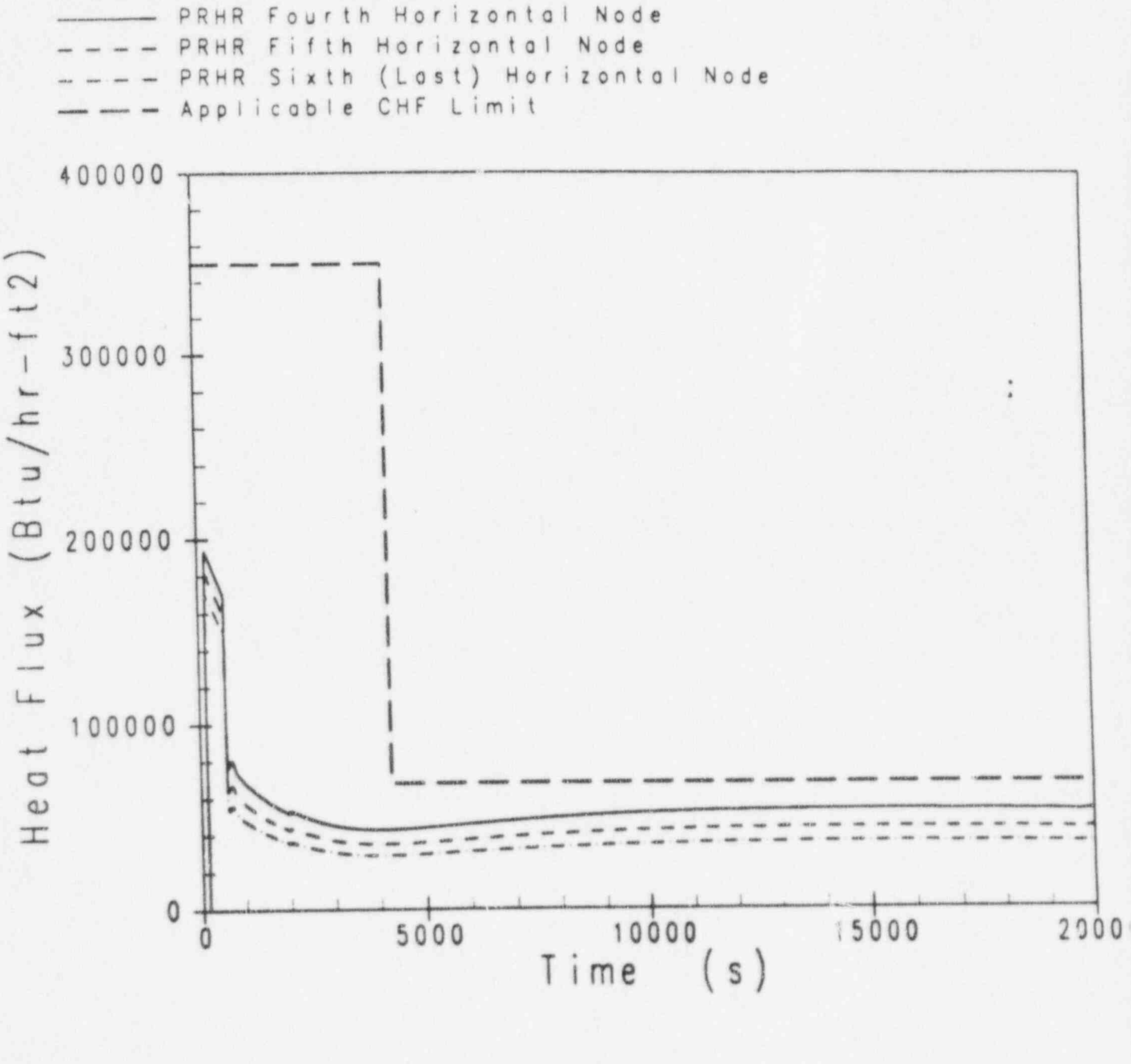


Figure 9

LOFTRAN: Loss Of Normal Feedwater



a,b

Figure 10 NOTRUMP Noding of PRHR Heat Exchanger

Figure 11

NOTRUMP: One Inch Small Break

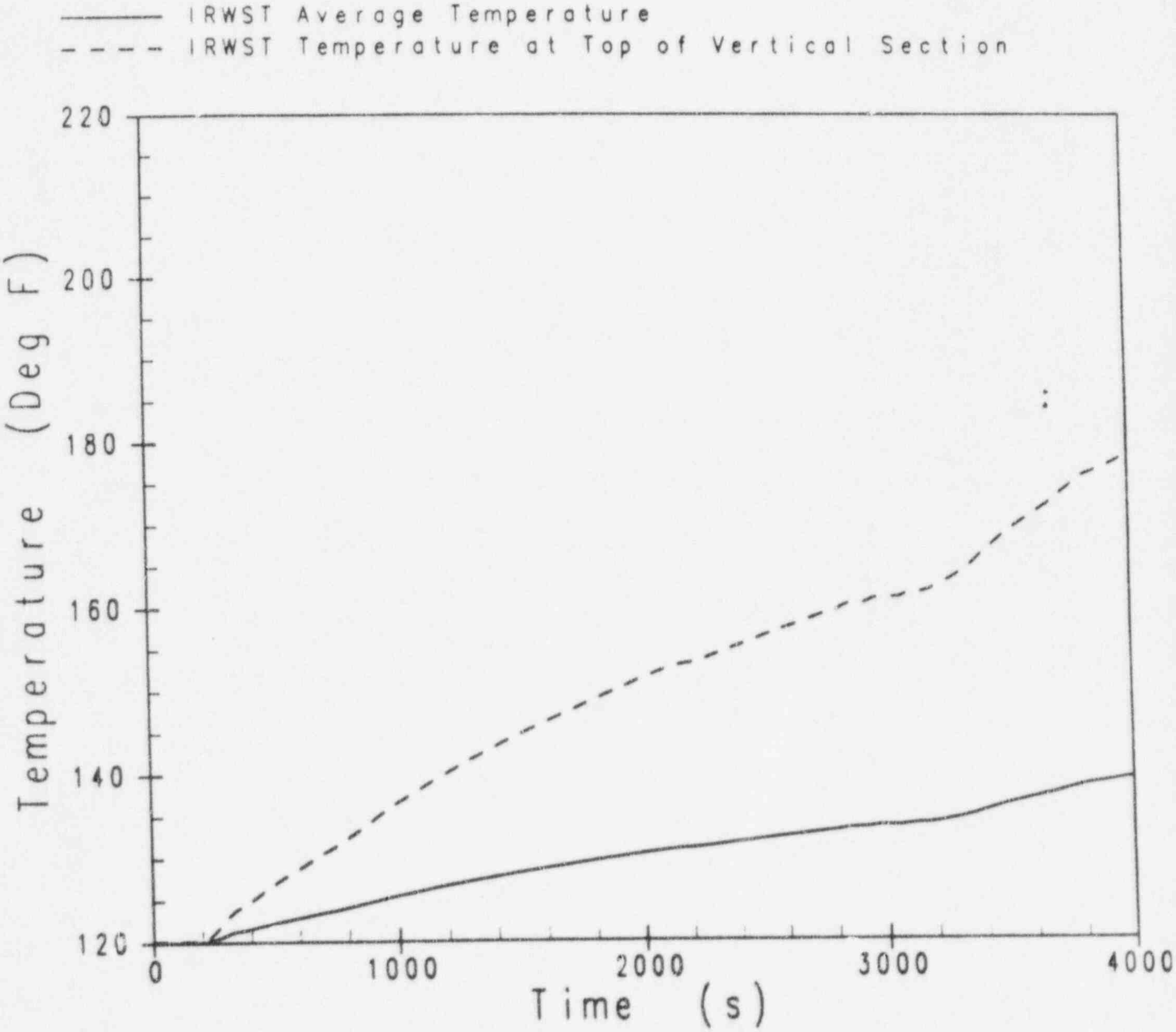


Figure 12

NOTRUMP: One Inch Small Break

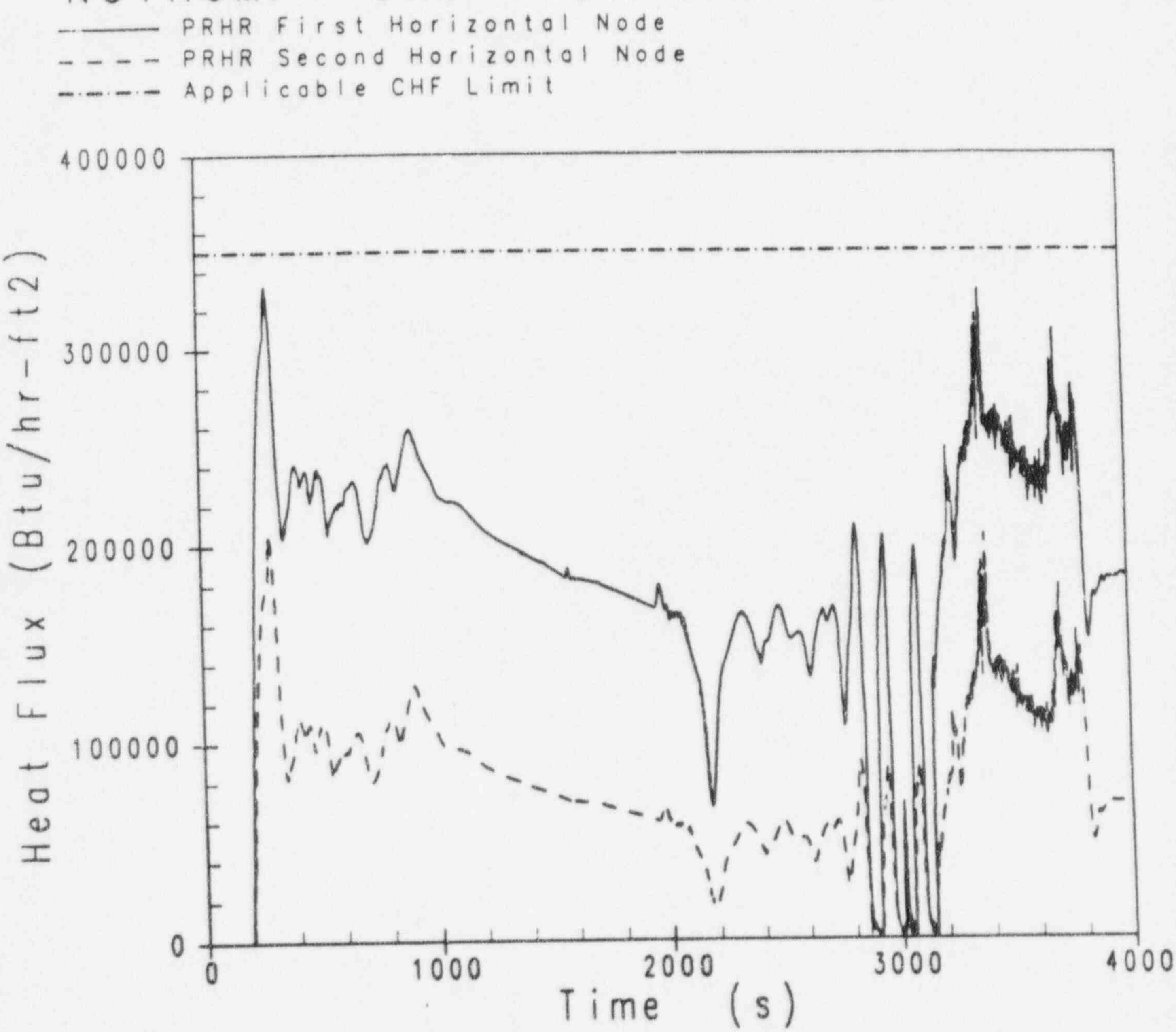


Figure 13

NOTRUMP: One Inch Small Break