SAFETY EVALUATION REPORT ON THE 1981 VERSION OF THE WESTINGHOUSE LARGE BREAK ECCS EVALUATION MODEL

1.0 INTRODUCTION

On May 15, 1981 Westinghouse requested in writing (Ref. 1) that certain changes be incorporated in their ECCS evaluation model. The primary reason for these changes was to implement revised staff requirements for cladding swelling and rupture models as described in NUREG-0630 (Ref. 2). These requirements were developed to account for new data developed subsequent to the approval of the present Westinghouse model.

Westinghouse had performed preliminary calculations which showed that by incorporating the NUREG-0630 requirements some plants would not meet the 2200°F limit of 10 CFR 50.46. Therefore in order to avoid reductions in overall peaking factor (F_q), they requested other compensating changes be incorporated in their large break evaluation model. These changes were related to the thermal-hydraulic analysis in SATAN VI (Ref. 3). They were originally developed for use in analyzing plants equipped with upper head injection (UHI) (Ref. 4), but are not unique to UHI behavior. This collection of analytical improvements has been termed "UHI Software Technology." In addition to UHI plants, certain other plants have been allowed to use UHI Software Technology (Ref. 5, 6, 7). Except for these plants, all ECCS analyses using the Westinghouse large break evaluation model have been accompanied by a supplemental estimate of the combined effect of NUREG-0630 and UHI Technology. Approval provided by this SER eliminates the need for those supplemental assessments.

Several other changes are also addressed in this SER. They are:

1) Application of the Westinghouse reflood heat transfer model to different core heights and different rod diameters (OFA and CE reloads),

2) Improved modeling of interaction between pumped safety injection and accumulator injection.

3) Miscellaneous modifications that correct logic or other relatively minor deficiencies.

4) Special requirements for analyzing reloads for Combustion Engineering (CE) Nuclear Steam Supply Systems (NSSS).

2.0 MODEL EVALUATION

2.1 CLADDING MODELS

Reference 1, as supplemented by information provided in References 8, 9, and 10, described the proposed cladding models for the "1981 Version of the Westinghouse Appendix K Evaluation Model." Among the various features of the new evaluation model are three modifications to cladding models. Those modifications consist of (1) a revised algorithm for calculating heatup rates, (2) new rupture temperature, burst strain, and flow blockage models adopted from NUREG-0630 (Ref. 2), and (3) an alteration to the prerupture strain model. These modifications are to be incorporated into the LOCTA-IV (Ref.11) and SATAN-VI (Ref.3) codes. In general these modifications update the previous Westinghouse analytical methods by (a) properly accounting for new data developed subsequent to the approval of the present Westinghouse evaluation models, and (b) formally incorporating a revised cladding failure model that is compatible with the temperature transients that would be encountered during large-break LOCAs.

2.1.1 Data Base and Modeling Limitations

The new data base (see Appendix A in Reference 2) was exclusively derived from LOCA-simulation experiments that employed internally-heated Zircaloy cladding that was tested in aqueous atmospheres. Phenomenological bases for model development (i.e., curve fitting) was qualitatively assisted by results from simpler, but less prototypical, experiments (Refs. 12 and 13) that utilized direct, self-resistance heating of the cladding. Because (a) recently released (Refs. 14 and 15) slow-ramp, high-temperature burst data indicate that part of the NUREG-0630 model is substantially non-conservative, (b) the limited number of

data in this region would result in an associated large modeling uncertainty, and (c) Westinghouse has no high-temperature burst application, Westinghouse has agreed to limit the applicability of the NUREG-0630 burst strain and flow blockage models by curtailing the functions at temperatures greater than 950°C, thus avoiding this region entirely. Within this range, the degree of swelling and rupture are not underestimated by NUREG-0630. Should a rupture temperature greater than 950°C be encountered in any plant analysis, Westinghouse would at that time have to propose an alternate method.

2.1.2 Algorithm for Temperature Ramp Rate

Plastic deformation in Zircaloy is a complex function of several variables, most notably heating rate and strain rate. For simplicity, these effects have been treated empirically as a single combined parameter expressed as temperature ramp rate.

The revised algorithm for calculating temperature ramp rates is utilized whenever cladding temperatures are determined to be within 111°C, (i.e., 200°F) of rupture. For temperatures below this 111°C band, the instantaneous ramp rate is used. The algorithm tracks and stores cladding temperature as a function of time after entry into the 111°C band. For each succeeding time step, the algorithm yields an averaged ramp rate which is equivalent to or conservatively lower than the instantaneous or initial ramp rate which was employed in the experiments referenced in NUREG-0630.

2.1.3 Rupture Temperature Model

The cladding rupture temperature model is depicted in Figure 1. Westinghouse has programmed the rupture temperature model in tabular form for 0, 14, and 28°C/s ramp rates. Westinghouse conservatively uses the 28°C/s ramp rate correlation for rates $\geq$ 28°C/s, and the 0°C/s ramp rate correlation for rates $\leq$ 0°C/s. For intermediate rates, parabolic interpolation at the appropriate ramp rate and cladding wall hoop stress is used to calculate the rupture temperature for each axial node.

By letter dated November 16, 1979 (Ref. 16), Westinghouse notified NRC of a non-conservatism identified in Westinghouse large-break ECCS evaluation models.

Specifically, Westinghouse had discovered that cladding temperature ramp rates during a large-break LOCA would be at relatively slow rates; whereas, the rupture temperature model in the large-break evaluation models was based on cladding burst tests that were conducted at relatively fast rates. Consequently, the use of the large-break evaluation models might result in the calculation of (a) delayed rupture times or (b) no rupture prediction when rupture should have occurred. Subsequent to the Westinghouse discovery, large-break LOCA analyses of plants having slow ramp rates have been performed using a combination of models from the small-break and large-break evaluation models. Use of the new Westinghouse rupture temperature model, 1981 version, approved by this SER, formally corrects this situation inasmuch as the new model is compatible with the full spectrum of potential ramp rates that might be encountered and the new model is an integral part of the 1981 evaluation model.

2.1.4 Prerupture Strain Model

The Westinghouse prerupture strain model was formulated from data reported by Hardy (Ref. 13). The model provides a time-dependent true strain as a function of true stress and other parameters. Westinghouse has determined that the use of the existing prerupture strain model with the new, more conservative, rupture temperature model results in unrealistically low pre-rupture strains. Consequently, the strain rate was increased by adjusting a coefficient in the model's equation. The calculated prerupture strains are now found to agree with KFK REBEKA and ORNL MRBT experimental data (see Appendix A in Ref. 2), but the prerupture strains will be limited to 10 percent in the ECCS Evaluation Model (as in previous EMs). The basis for this limitation is that allowing prerupture strains to exceed 10 percent results in decreased LOCA PCTs for Westinghouse plants (Ref. 9), and this is a conservative application.

2.1.5 Burst Strain Model

The cladding burst strain model is depicted in Figure 2. For temperature ramp rates ≤10°C/s, the slow-ramp correlation (shown as solid curve) is used.

For temperature ramp rates ≥25°C/s, the fast-ramp correlation (shown as dashed curve) is used. Strains associated with intermediate ramp rates are determined by linear interpolation.

Flow Blockage Model

The fuel assembly flow blockage model is depicted in Figure 3. For temperature ramp rates ≤ 10°C/s, the slow-ramp correlation (shown as solid curve) is used. For temperature ramp rates ≥ 25°C/s, the fast-ramp correlation (shown as dashed curve) is used. Blockages associated with intermediate ramp rates are determined by linear interpolation.

Regulatory Conclusions

Based on the data and analyses contained in NUREG-0630, subsequent data, and our current understanding of plant loss-of-coolant transients, we have concluded that the proposed (1) algorithm for computing heatup rates will provide conservative results for all hypothetical conditions that may be encountered, (2) rupture, strain, and blockage models will predict swelling and rupture without underestimating the degree of swelling or the incidence of rupture, and (3) prerupture strain model will yield strains that are consistent with those observed in prototypical experiments, and the artificial limit on the degree of swelling will yield conservative results. We, therefore, find the models and their proposed applications to be acceptable for all PWRs with fuel supplied by Westinghouse.

2.2 UHI Software Technology

In analyzing the large break LOCA, W . inghouse has proposed to use some of the modeling techniques currently approved for use in Westinghouse plants equipped with Upper Head Injection (UHI) (Ref. 17). The following four changes were made to the SATAN VI computer program (Ref. 3):

1) pseudo-viscosity

2) equation of state

3) modified drift flux

4) elevation pressure change

These changes were reviewed and approved for UHI plants in Reference 17. None of the four changes is unique to UHI plants and would be equally suitable to non-UHI plants. We therefore find those SATAN modifications acceptable for all SATAN large break analysis.

The model approved in Reference 17 utilizes a split downcomer nodalization. This model was compared to several experimental results (Ref. 4) and found acceptable. Since the experiments were not related to UHI, these comparisons would also be applicable to non-UHI plants.

In Reference 1 Westinghouse analyzed a non-UHI plant using the UHI software technology discussed previously. Two calculations were done, one with a split downcomer nodalization and one with the traditional one-dimensional downcomer. The difference in PCT was only 11°F. Other comparisons of the split and one-dimensional downcomer models showed a similar small effect for non-UHI plants. Since the effect of the split downcomer model is small and the comparison to available data was reasonable we find the model acceptable.

Our consultants at Sandia National Laboratories are investigating the physical flow behavior which results from split downcomer modeling and associated slip flow models. In particular they are exploring the modeling as applied to the experiments mentioned above. Results of these studies will be applied to the Westinghouse model for verification.

To account more realistically for the actual Westinghouse 4-loop configuration, the intact loop cold leg was split back to the steam generator (Ref. 19). Although this was not done for UHI plants, it is actually a better representation for use with the split downcomer and is therefore acceptable.

In Reference 20, Westinghouse studies 4 methods for split downcomer modeling in 3-loop plants. Analysis using the model selected resulted in the highest PCT. Of the other three methods, two do not appear to realistically reflect loop arrangement. The remaining method resulted in the lowest PCT. The method chosen involves splitting the downcomer volume 2:1 and lumping the intact loops. Based on these sensitivity studies and loop logic, the method chosen for 3-loop plants is acceptable.

For 2-loop plants the downcomer is split equally with the intact loop attached to one node and the broken loop to the other. This of course is the only logical selection. Addition of a containment node to better handle break flow slip is also acceptable. A sensitivity study to this change actually resulted in a slight increase in peak cladding temperature (Ref. 19).

In summary, the SATAN VI coding and modeling changes described above are acceptable for analysis of all Westinghouse designed NSSS and reloads of standard CE 4/2 loop NSSS. UHI Plants have additional changes which are described in References 4 and 17.

2.3 Application of FLECHT Correlation and Skewed Power Methodology

Westinghouse intends to use the current FLECHT correlation and skewed power methodology* in LOCTA IV to calculate reflood heat transfer for all PWRS currently being supplied with their fuel. This includes 15 X 15 , 17 X 17 (standard and OFA) and CE 14 X 14 reloads.

In 1976 NRR approved (Ref. 21) the Oct. 1975 version of the Westinghouse ECCS evaluation model (Ref. 22). This included modifications to the reflood heat transfer model to accommodate 17 x 17 fuel. The request for approval (Ref. 22) and the approval (Ref. 21) was limited to 12 foot cores. This occurred even though most of the data and correlation development applied to 14 ft. cores. We have requested Westinghouse to verify that the reflood heat transfer methodology in LOCTA

*Sometimes refered to as integral of power technique.

is as represented in Reference 22 and applies to 17 x 17 fourteen foot fuel. Until such verification is received, approval of reflood heat transfer analysis methods for 14 foot cores is withheld.

In Reference 23 approval was granted to the FEB. 1978 version of the Westinghouse ECCS model (Ref. 24). This included changes to reflect new FLECHT 15 x 15 data. Part of these changes was further modification to the skewed power methodology. Several small changes were submitted (Ref. 25 and 26) to correct logic deficiencies and assure proper implementation of reflood heat transfer methodology for rod diameters slightly different from standard 15 x 15 and 17 x 17 fuel design. The changes in Reference 25 removed some inconsistancies, logic errors and redundancies. The changes have no impact but to allow LOCTA to function for non-12' cores. They are therefore acceptable.

Reference 26 documents changes required for analyzing other than the standard diameter fuel. This was considered as part of the optimized fuel assembly (OFA) review (Ref. 27). The SER on OFA (Ref. 28) gave approval to these changes for OFA fuel. Westinghouse will verify that this methodology will be used for C E reloads. Reference 18 states that the most recent skewed power methodology is applied to C E reloads because of the less than 12 foot fuel length.

The staff concludes that the reflood heat transfer methods described herein are acceptable for PWRs currently being supplied with Westinghouse manufactured Zircaloy clad fuel with the following exceptions:

1) UHI plants have added restrictions as stated in Reference 17.
2) Approval of reflood methodology for 14 foot cores is withheld pending further confirmation and verification of model acceptability.

2.4 Accumulator/Low Head Pumped ECCS Interaction.

On December 22, 1980 Westinghouse informed the staff (Ref. 29) of changes to SATAN-VI and W-REFLOOD which affects the calculation of the injection section

pressure drop in some plants. In the affected plants, some of the pumped ECCS enters through the accumulator line between the two check valves. The current Westinghouse model assumes that the back pressure for safety injection is the reactor coolant system pressure which does not properly account for the pressure drop through the downstream check valve. This is particularly noticable during the accumulator injection period. In Reference 30, Westinghouse proposed a nodalization change for SATAN which properly accounts for injection between the check valves during blowdown. In Reference 29 they described a coding change which allowed calculation of injection section pressure during accumulator injection in W Reflood. In Reference 30, Westinghouse confirmed that proper line and valve resistance was already being accounted for when the accumulators were not injecting. Based on the foregoing information we find these changes acceptable for the affected plants.

2.5 MISCELLANEOUS CHANGES

In Reference 31, Westinghouse submitted 22 changes to SATAN and LOCTA. One of these changes was the intermediate zirc-water correction reviewed in Reference 23. This intermediate fix has been replaced by several more accurate changes to the two programs. Ten of the 21 remaining changes resulted from a thorough review of the geometry, property, and conduction solution logic which contributed to the original error. The changes are indeed improvements and have already been made. This SER constitutes approval of those changes.

Seven of the remaining changes are non-substantive and are included for diagnostic assistance or program simplification. Three changes implement more accurate fluid properties. A final change in Reference 29 corrects the burst rod time step in SATAN. Another small change in Reference 23 corrects a potential logic deficiency in LOCTA. The change was minor and necessary to avoid possible fatal errors.

All of the changes are found to be acceptable. All improve the accuracy and efficiency of the programs and none are prohibited by Appendix K.

2.6 RELOADS OF C.E. NSSS's

In Reference 18, Westinghouse submitted a description of modifications to the model approved in Reference 23. These modifications were needed to establish compliance with 10CFR50.46 and 10CFR50 Appendix K for Westinghouse reloads of C E NSSS's. The computer programs and input data were modified to account for fuel and system design differences between the CE and Westinghouse steam supply systems.

Two of the items discussed in Reference 18 (UHI Software Technology and Swelling and Rupture) were addressed in sections 2.2 and 2.1 of this SER. As noted in Section 2.2, UHI software technology including the split downcomer and containment noding are acceptable for CE plant reloads. The swelling and rupture model discussed in Section 2.1 also applies to CE reloads and supercedes the burst and blockage models described in Reference 18.

2.6.1 CHANGES TO REFLECT DESIGN DIFFERENCES

Certain other computer program input changes are required to reflect obvious differences in loop arrangement and fuel design. The SATAN nodalization was changed to conform to the CE design of four (4) cold legs and two (2) hot legs. The cold legs on the intact loop are lumped together. The broken cold leg and intact cold leg are completely separate on the other side. The control element assembly guide tubes are modeled as two volumes with appropriately large flow paths between the upper head and upper plenum. These changes conform to the obvious noding arrangement and are acceptable. In WREFLOOD (Ref. 32), the input network and piping have been modified to represent the CE loop design. This is also acceptable. In LOCTA, a change was made so that as built CE reload fuel crack and dish volumes would be calculated internally. This is also acceptable.

For the CE NSSS design injection angles of 60° and 75°, Westinghouse proposes to use the .4 psid and 1.5 psid penalties, respectively, to satisfy the Appendix K requirement. These values were approved by the staff (Ref. 33) for the CE model and are acceptable for Westinghouse analysis of CE plant reloads.

2.6.2 REFILL HEAT TRANSFER

The CE design uses a large control rod guide tube. Westinghouse proposes to modify their refill rod-to-rod radiative heat transfer model to account for the guide tube presence. The model includes a three-body system with limited enclosure and standard radiation solution procedures. Convective heat transfer is conservatively ignored on all bodies as is radiation through the gaps of the small enclosure. We, therefore, find the model acceptable for 14x14 reloads. Westinghouse has stated the further work needs to be done on 16x16 systems.

2.6.3 SENSITIVITY STUDIES

Paragraph II.3 of Appendix K requires appropriate sensitivity studies for each evaluation model. Westinghouse provided sensitivity studies to axial power shape and core shroud region nodalization. The limiting conditions of each were chosen to be referenced for plant specific analyses, e.g., the lumped shroud region noding and the chopped cosine distribution. Westinghouse analyzed steady state thermal conditions for their fuel designed for CE reloads. The results showed that early burnup yielded the highest stored energy. However, the assessment did not include a LOCA analysis. CE LOCA calculations for the plant design used in Reference 18 showed higher peak cladding temperatures (PCT) at higher burnup. We, therefore, requested Westinghouse to perform a LOCA burnup sensitivity study. Reference 34 was submitted which confirmed that the assumed low burnup indeed resulted in the highest PCT. It should be noted that this study took credit for reductions in Fq as a function of burnup. Westinghouse has stated the Fq's at high burnup were determined in a way consistent with the determination of tech spec Fq's for CE plants reloaded with their fuel.

In Reference 18, Westinghouse performed a large break study with a spectrum of discharge coefficients (C_d). The blowdown calculations investigated pumps running and pumps tripped. Generally, the pump assumptions were not significant (less than 10^{o}F). The worst case was the guillotine break with a C_d = 0.4 and pumps running.

Westinghouse also referenced numerous other sensitivity studies for model acceptance on the basis that the results would be more sensitive to model assumptions than plant differences. We agree with that assessment.

Westinghouse concludes from all these studies that to demonstrate ECCS performance of their fuel in CE NSSS applications, only the C_d = 0.4 cold leg guillotine break need be analyzed both with and without reactor coolant pumps assumed operational using a chopped cosine power shape. We agree that this should form an acceptable basis for large break plant specific submittals. However, based on differences in fuel design, plant design, and plant operation, individual plant reviewers may require additional analyses. This is consistent with the staff position in Reference 35.

3.0 CONCLUSIONS

The staff has reviewed the model for large break analyses described in the various references. We believe that the model described in this report which is based on these references is acceptable and is in compliance with Appendix K of 10CFR50. With the exceptions noted in the report, the model is applicable to all PWRs currently being supplied with Westinghouse manufactured Zircaloy clad fuel. It should also be noted that the Upper Plenum injection (UPI) "patch" is still required for two loop plants until such time as a new UPI model is approved.

This model should become effective no later than 90 days after receipt of this SER by Westinghouse. That is, all submittals demonstrating compliance with Appendix K with Westinghouse model after that time should use the model described in this report. During the 90 day period, any applicant or licensee requiring an Appendix K ECCS analysis may elect to submit a NUREG-0630 interim assessment as has been done since January 1980 or otherwise submit analyses conforming to this SER.

4.0 REFERENCES

1. Letter from T. M. Anderson (Westinghouse) to J. R. Miller (NRC), number NS-TMA-2448, May 15, 1981.

2. D. A. Powers and R. O. Meyer, "Cladding Swelling and Rupture Models for LOCA Analysis," NRC report NUREG-0630, April 1980.

3. F. M. Bordelon, et al., "SATAN VI Program: Comprehensive Space-Time Dependent Analysis of Loss-of-Coolant," Westinghouse report WCAP-8302, June 1974.

4. M. Y. Young et. al., "Westinghouse Emergency Core Cooling System Evaluation Model Application to Plants Equipped with Upper Head Injection," WCAP-8479, Rev. 2.

5. T. P. Speis, Memo to R. W. Clark, transmitting Millstone-2 Cycle 4 Reload and Tech. Spec. Changes, October 6, 1980.

6. P. S. Check, Memo to T. M. Novak transmitting Zion Station Units 1 and 2 ECCS Analysis and Related Tech. Spec. Changes, May 11, 1981.

7. P. S. Check, Memo to T. M. Novak transmitting Turkey Point Units 3 and 4 28% Steam Generator Tube Plugging ECCS Analysis Review, June 17, 1981.

8. Letter from T. M. Anderson (Westinghouse) to J. R. Miller (NRC), number NS-TMA-2458, June 12, 1981.

9. Letter from E. P. Rahe (Westinghouse) to J. R. Miller (NRC), number NS-EPR-2467, July 15, 1981.

10. Letter from E. P. Rahe (Westinghouse) to J. R. Miller (NRC), number NS-EPR-2467, Revision 1, July 28, 1981.

11. F. M. Bordelon, et al., "LOCTA-IV Program: Loss-of-Coolant Transient Analysis," Westinghouse report WCAP-8301, June 1974.

12. Powers, op. cit., p. 90 (Reference 21).

13. D. G. Hardy, "High Temperature Expansion and Rupture Behavior of Zircaloy Tubing," Proceedings from the USAEC Topical Meeting on Water-Reactor Safety, Salt Lake City, Utah, March 26-28, 1973.

14. R. H. Chapman, "An Overview of the Multirod Burst Test Program," presentation to the NRC/RSR Program Review Briefing, Silver Spring, Maryland, January 16, 1981.

15. F. Erbacher, et al., "Burst Criterion of Zircaloy Fuel Cladding in a LOCA," paper presented to the ASTM Fifth International Conference on Zirconium in the Nuclear Industry, Boston, Massachusetts, August 4-7, 1980.

16. Letter from T. M. Anderson (Westinghouse) to V. Stello (NRC), number NS-TMA-2158, November 16, 1979.

17. G. N. Lauben, et. al., "Safety Evaluation Report on Westinghouse Electric Company ECCS Evaluation Model for Plants Equipped with Upper Head Injection," NUREG-0297, April 1978.

18. K. L. Furgusen and R. M. Kemper, "ECCS Evaluation Model for Westinghouse Fuel Reloads of Combustion Engineering NSSS," WCAP-9528, June 1979.

19. D. L. Peoples (Commonwealth Edison) letter to H. R. Denton, transmitting proposed ECCS model change for Zion, October 22, 1979.

20. T. M. Anderson (Westinghouse) letter to James R. Miller (NRC) NS-TMA-2458, June 12, 1981.

21. D. B. Vassallo, letter C. Eicheldinger (Westinghouse), transmitting SER on October 1975 Westinghouse ECCS Evaluation Model, May 13, 1976.

22. Westinghouse ECCS Evaluation Model, October 1975 Version, WCAP-8622, November 1975.

23. J. F. Stolz, letter to T. M. Anderson (Westinghouse) transmitting Safety Evaluation of Westinghouse ECCS Evaluation Model - February 1978 Version, August 29, 1978.

24. Westinghouse ECCS Evaluation Model February 1978 Version, WCAP-9220-P-A, February 1978.

25. Letter from T. M. Anderson, Westinghouse Electric Corporation, to R. Tedesco, U.S. Nuclear Regulatory Commission, NS-TMA-2014, December 13, 1978.

26. T. M. Anderson (Westinghouse) letter to D. F. Ross (NRC) NS-TMA-2379, January 30, 1981.

27. Reference Core Report 17x17 Optimized Fuel Assembly, WCAP-9500, July 1979.

28. Letter from R. Tedesco, USNRC, to T. M. Anderson, Westinghouse Electric Corp., May 22, 1981.

29. Letter from T. M. Anderson, Westinghouse Electric Corporation, to D. Ross, U.S. Nuclear Regulatory Commission, NS-TMA-2354, Decmeber 22, 1980.

30. Telecopy from R. Kemper to G. N. Lauben, August 6, 1981.

31. Letter from T. M. Anderson, Westinghouse Electric Corporation, to J. Stolz, U.S. Nuclear Regulatory Commission, NS-TMA-1981, November 1, 1978.

32. Kelly, R. D. et. al., "Calculational Model for Core Reflooding After a Loss-of-Coolant Accident (WREFLOOD Code)," WCAP-8170 (Proprietary Version), WCAP-8171 (Non-Proprietary Version), June 1974.

33. Supplement to the Status Report by the Directorate of Licensing in the Matter of Combustion Engineering, ECCS Evaluation Model Conformance to 10CFR50 Appendix K, November 13, 1974.

34. Letter from E. P. Rahe (Westinghouse) to G. N. Lauben, NS-EPR-2464, July 20, 1981.

35. Status Report by the Directorate of Licensing in the Matter of Westinghouse ECCS Evaluation Model Conformance to 10CFR50 Appendix K, October 15, 1974.

WESTINGHOUSE RUPTURE TEMPERATURE MODEL

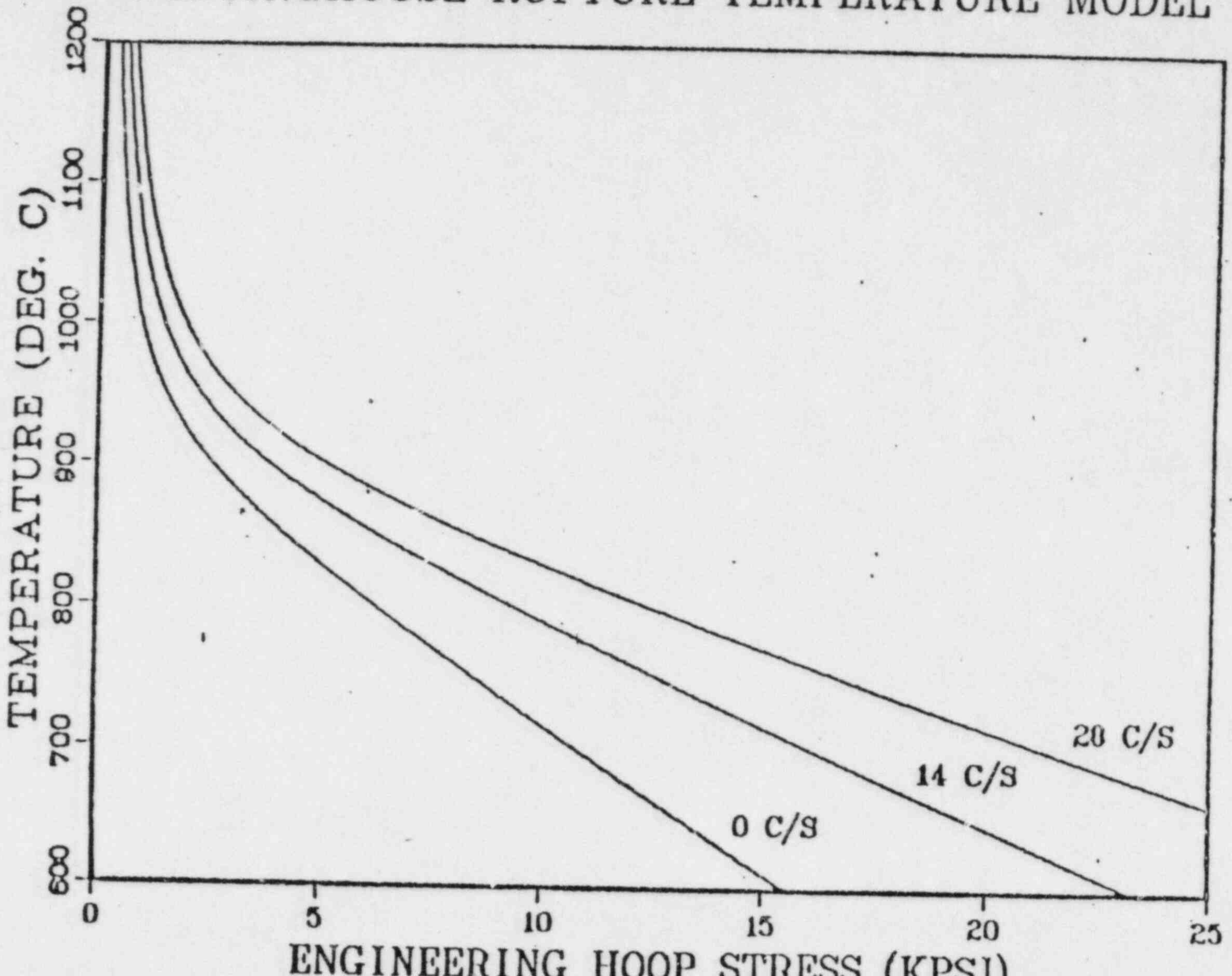

FIGURE 1

WESTINGHOUSE BURST STRAIN MODEL

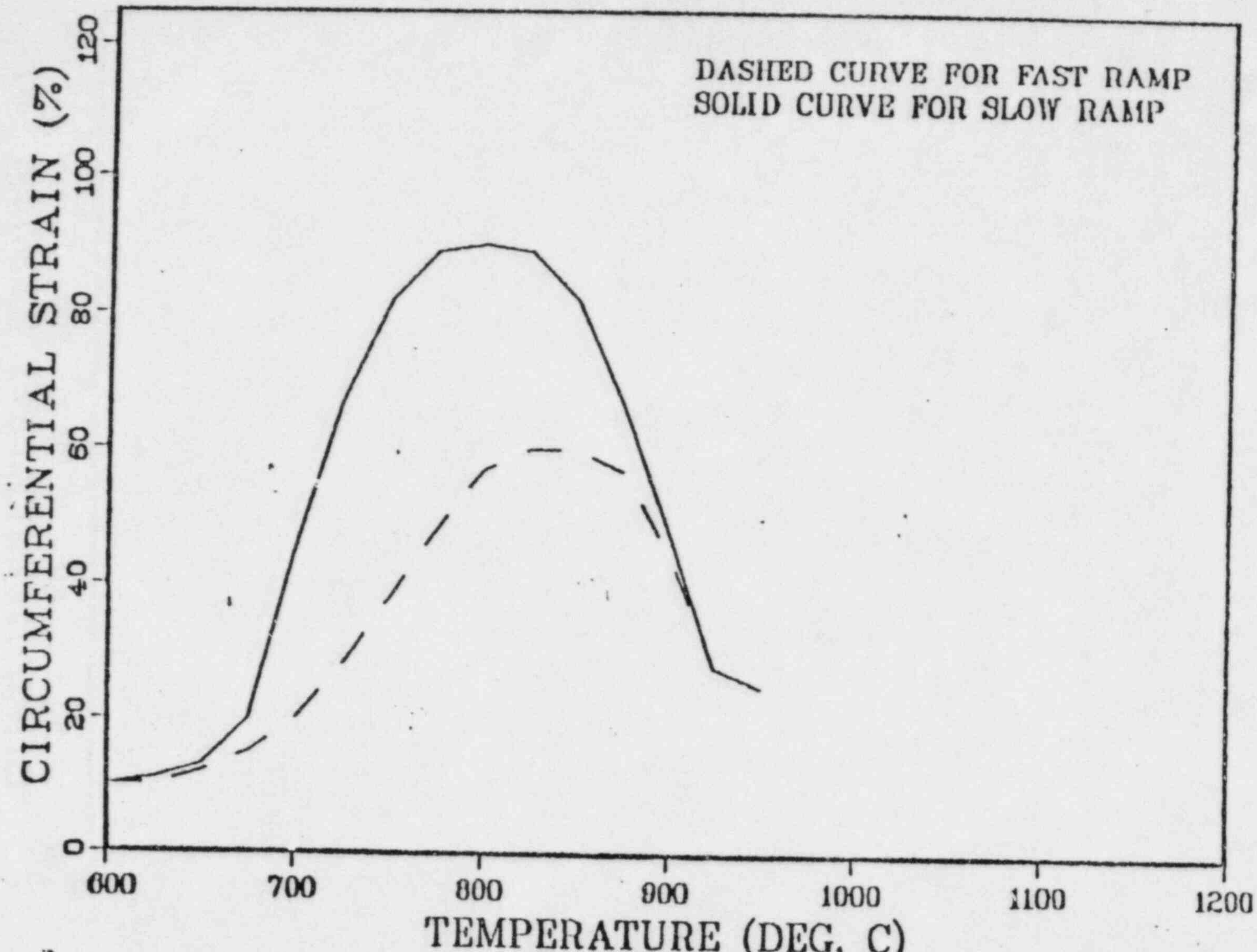

FIGURE 2

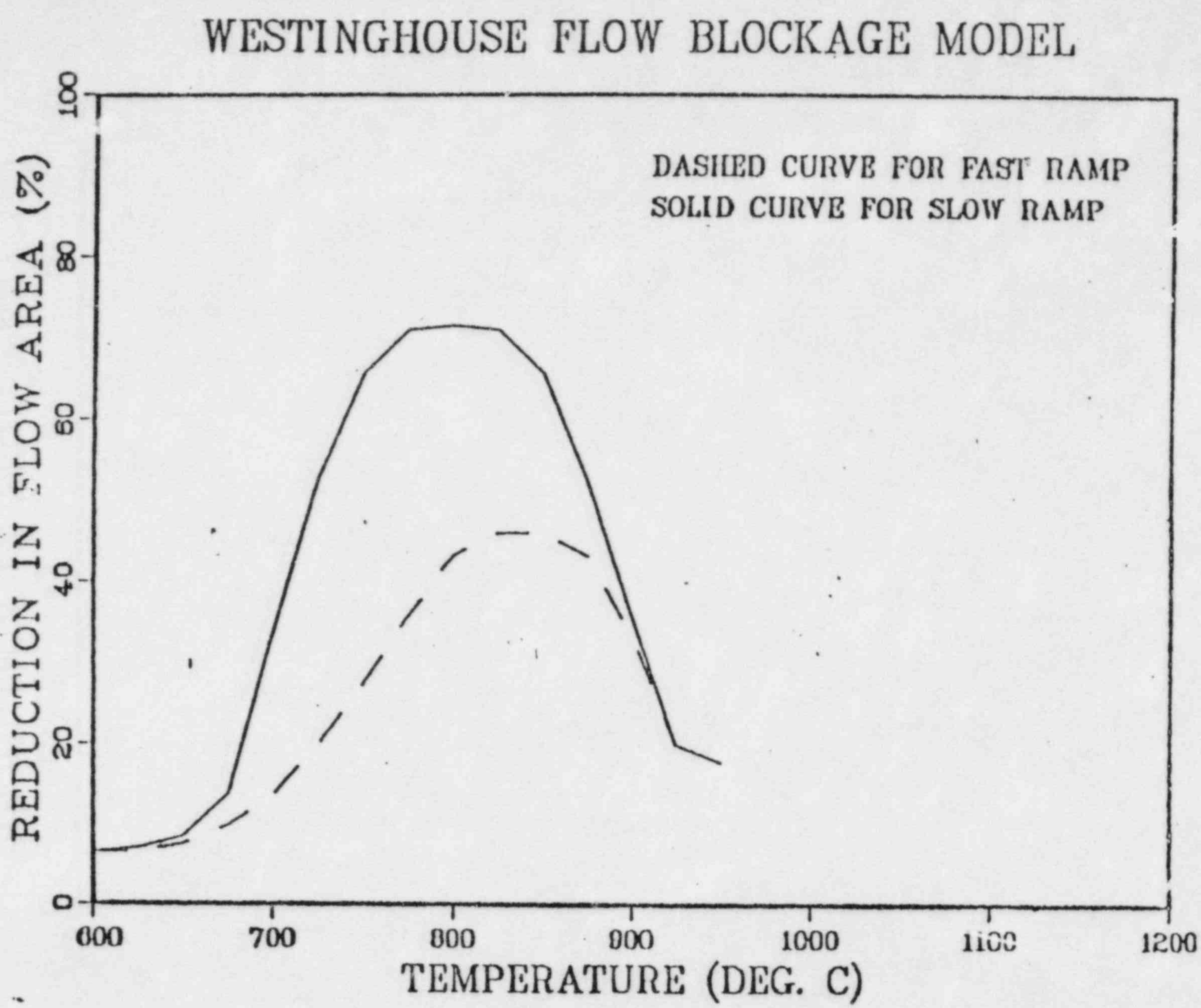
WESTINGHOUSE FLOW BLOCKAGE MODEL
DASHED CURVE FOR FAST RAMP
SOLID CURVE FOR SLOW RAMP
REDUCTION IN FLOW AREA (%)
0
20
40
60
80
100
600
700
800
900
1000
1200
TEMPERATURE (DEG. C)

FIGURE 3

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Paragraph II.3 of Appendix K requires appropriate sensitivity studies for each evaluation model. Westinghouse provided sensitivity studies to axial power shape and core shroud region nodalization. The limiting conditions of each were chosen to be referenced for plant specific analyses, e.g., the lumped shroud region noding and the chopped cosine distribution. Westinghouse analyzed steady state thermal conditions for their fuel designed for CE reloads. The results showed that early burnup yielded the highest stored energy. However, the assessment did not include a LOCA analysis. CE LOCA calculations for the plant design used in Reference 18 showed higher peak cladding temperatures (PCT) at higher burnup. We, therefore, requested Westinghouse to perform a LOCA burnup sensitivity study. Reference 34 was submitted which confirmed that the assumed low burnup indeed resulted in the highest PCT. It should be noted that this study took credit for reductions in Fq as a function of burnup. Westinghouse has stated the Fq's at high burnup were determined in a way consistent with the determination of tech spec Fq's for CE plants reloaded with their fuel.

In Reference 18, Westinghouse performed a large break study with a spectrum of discharge coefficients (C_d). The blowdown calculations investigated pumps running and pumps tripped. Generally, the pump assumptions were not significant (less than 10^oF). The worst case was the guillotine break with a C_d = 0.4 and pumps running.

Westinghouse also referenced numerous other sensitivity studies for model acceptance on the basis that the results would be more sensitive to model assumptions than plant differences. We agree with that assessment.

Westinghouse concludes from all these studies that to demonstrate ECCS performance of their fuel in CE NSSS applications, only the C_d = 0.4 cold leg guillotine break need be analyzed both with and without reactor coolant pumps assumed operational using a chopped cosine power shape. We agree that this should form an acceptable basis for large break plant specific submittals. However, based on differences in fuel design, plant design, and plant operation, individual plant reviewers may require additional analyses. This is consistent with the staff position in Reference 35.

3.0 CONCLUSIONS

The staff has reviewed the model for large break analyses described in the various references. We believe that the model described in this report which is based on these references is acceptable and is in compliance with Appendix K of 10CFR50. With the exceptions noted in the report, the model is applicable to all PWRs currently being supplied with Westinghouse manufactured Zircaloy clad fuel. It should also be noted that the Upper Plenum injection (UPI) "patch" is still required for two loop plants until such time as a new UPI model is approved.

This model should become effective no later than 90 days after receipt of this SER by Westinghouse. That is, all submittals demonstrating compliance with Appendix K with Westinghouse model after that time should use the model described in this report. During the 90 day period, any applicant or licensee requiring an Appendix K ECCS analysis may elect to submit a NUREG-0630 interim assessment as has been done since January 1980 or otherwise submit analyses conforming to this SER.

4.0 REFERENCES

1. Letter from T. M. Anderson (Westinghouse) to J. R. Miller (NRC), number NS-TMA-2448, May 15, 1981.

2. D. A. Powers and R. O. Meyer, "Cladding Swelling and Rupture Models for LOCA Analysis," NRC report NUREG-0630, April 1980.

3. F. M. Bordelon, et al., "SATAN VI Program: Comprehensive Space-Time Dependent Analysis of Loss-of-Coolant," Westinghouse report WCAP-8302, June 1974.

4. M. Y. Young et. al., "Westinghouse Emergency Core Cooling System Evaluation Model Application to Plants Equipped with Upper Head Injection," WCAP-8479, Rev. 2.

5. T. P. Speis, Memo to R. W. Clark, transmitting Millstone-2 Cycle 4 Reload and Tech. Spec. Changes, October 6, 1980.

6. P. S. Check, Memo to T. M. Novak transmitting Zion Station Units 1 and 2 ECCS Analysis and Related Tech. Spec. Changes, May 11, 1981.

7. P. S. Check, Memo to T. M. Novak transmitting Turkey Point Units 3 and 4 28% Steam Generator Tube Plugging ECCS Analysis Review, June 17, 1981.

8. Letter from T. M. Anderson (Westinghouse) to J. R. Miller (NRC), number NS-TMA-2458, June 12, 1981.

9. Letter from E. P. Rahe (Westinghouse) to J. R. Miller (NRC), number NS-EPR-2467, July 15, 1981.

10. Letter from E. P. Rahe (Westinghouse) to J. R. Miller (NRC), number NS-EPR-2467, Revision 1, July 28, 1981.

11. F. M. Bordelon, et al., "LOCTA-IV Program: Loss-of-Coolant Transient Analysis," Westinghouse report WCAP-8301, June 1974.

12. Powers, op. cit., p. 90 (Reference 21).

13. D. G. Hardy, "High Temperature Expansion and Rupture Behavior of Zircaloy Tubing," Proceedings from the USAEC Topical Meeting on Water-Reactor Safety, Salt Lake City, Utah, March 26-28, 1973.

14. R. H. Chapman, "An Overview of the Multirod Burst Test Program," presentation to the NRC/RSR Program Review Briefing, Silver Spring, Maryland, January 16, 1981.

15. F. Erbacher, et al., "Burst Criterion of Zircaloy Fuel Cladding in a LOCA," paper presented to the ASTM Fifth International Conference on Zirconium in the Nuclear Industry, Boston, Massachusetts, August 4-7, 1980.

16. Letter from T. M. Anderson (Westinghouse) to V. Stello (NRC), number NS-TMA-2158, November 16, 1979.

17. G. N. Lauben, et. al., "Safety Evaluation Report on Westinghouse Electric Company ECCS Evaluation Model for Plants Equipped with Upper Head Injection," NUREG-0297, April 1978.

18. K. L. Furgusen and R. M. Kemper, "ECCS Evaluation Model for Westinghouse Fuel Reloads of Combustion Engineering NSSS," WCAP-9528, June 1979.

19. D. L. Peoples (Commonwealth Edison) letter to H. R. Denton, transmitting proposed ECCS model change for Zion, October 22, 1979.

20. T. M. Anderson (Westinghouse) letter to James R. Miller (NRC) NS-TMA-2458, June 12, 1981.

21. D. B. Vassallo, letter C. Eicheldinger (Westinghouse), transmitting SER on October 1975 Westinghouse ECCS Evaluation Model, May 13, 1976.

22. Westinghouse ECCS Evaluation Model, October 1975 Version, WCAP-8622, November 1975.

23. J. F. Stolz, letter to T. M. Anderson (Westinghouse) transmitting Safety Evaluation of Westinghouse ECCS Evaluation Model - February 1978 Version, August 29, 1978.

24. Westinghouse ECCS Evaluation Model February 1978 Version, WCAP-9220-P-A, February 1978.

25. Letter from T. M. Anderson, Westinghouse Electric Corporation, to R. Tedesco, U.S. Nuclear Regulatory Commission, NS-TMA-2014, December 13, 1978.

26. T. M. Anderson (Westinghouse) letter to D. F. Ross (NRC) NS-TMA-2379, January 30, 1981.

27. Reference Core Report 17x17 Optimized Fuel Assembly, WCAP-9500, July 1979.

28. Letter from R. Tedesco, USNRC, to T. M. Anderson, Westinghouse Electric Corp., May 22, 1981.

29. Letter from T. M. Anderson, Westinghouse Electric Corporation, to D. Ross, U.S. Nuclear Regulatory Commission, NS-TMA-2354, Decmeber 22, 1980.

30. Telecopy from R. Kemper to G. N. Lauben, August 6, 1981.

31. Letter from T. M. Anderson, Westinghouse Electric Corporation, to J. Stolz, U.S. Nuclear Regulatory Commission, NS-TMA-1981, November 1, 1978.

32. Kelly, R. D. et. al., "Calculational Model for Core Reflooding After a Loss-of-Coolant Accident (WREFLOOD Code)," WCAP-8170 (Proprietary Version), WCAP-8171 (Non-Proprietary Version), June 1974.

33. Supplement to the Status Report by the Directorate of Licensing in the Matter of Combustion Engineering, ECCS Evaluation Model Conformance to 10CFR50 Appendix K, November 13, 1974.

34. Letter from E. P. Rahe (Westinghouse) to G. N. Lauben, NS-EPR-2464, July 20, 1981.

35. Status Report by the Directorate of Licensing in the Matter of Westinghouse ECCS Evaluation Model Conformance to 10CFR50 Appendix K, October 15, 1974.

WESTINGHOUSE RUPTURE TEMPERATURE MODEL

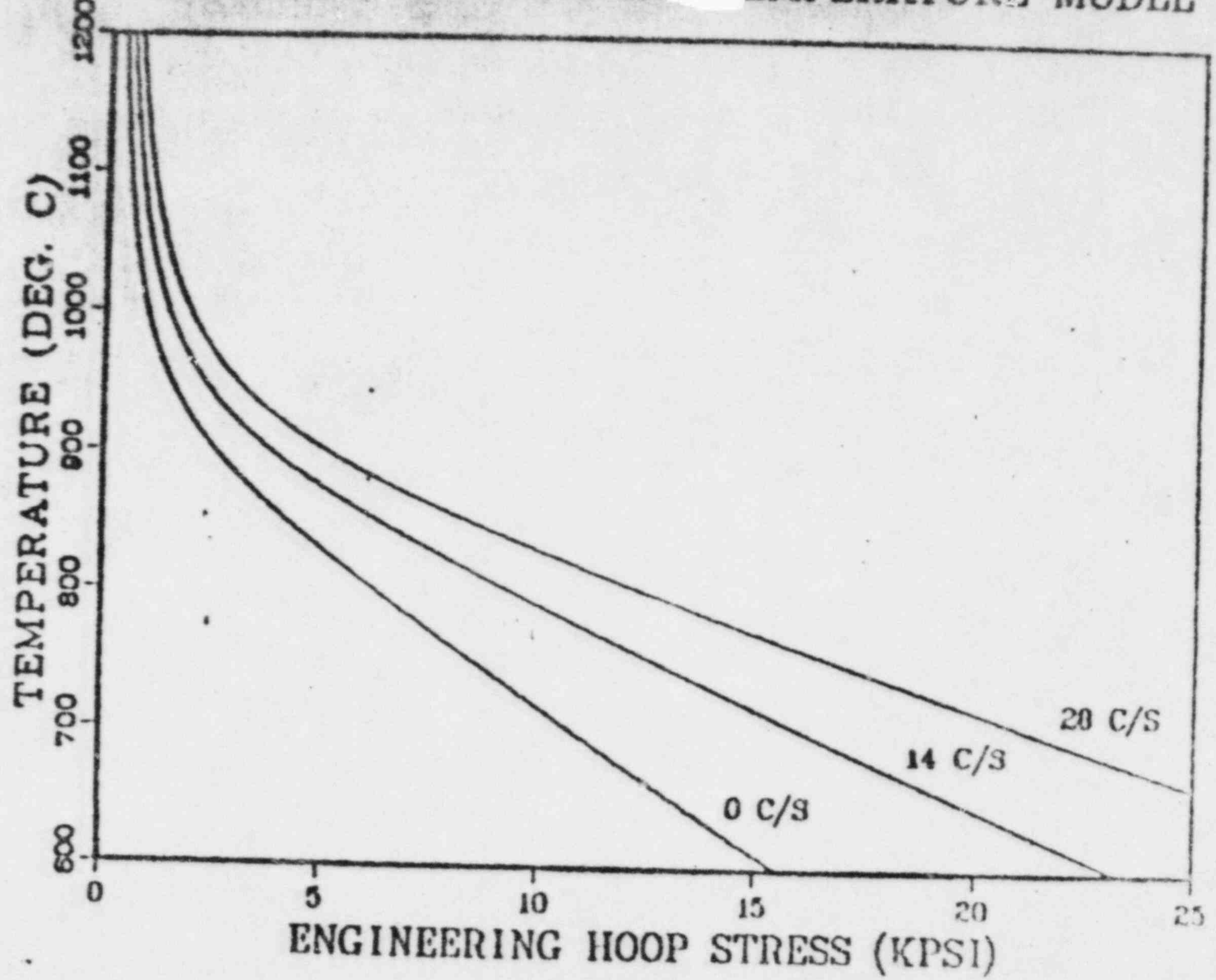

FIGURE 1

WESTINGHOUSE BURST STRAIN MODEL

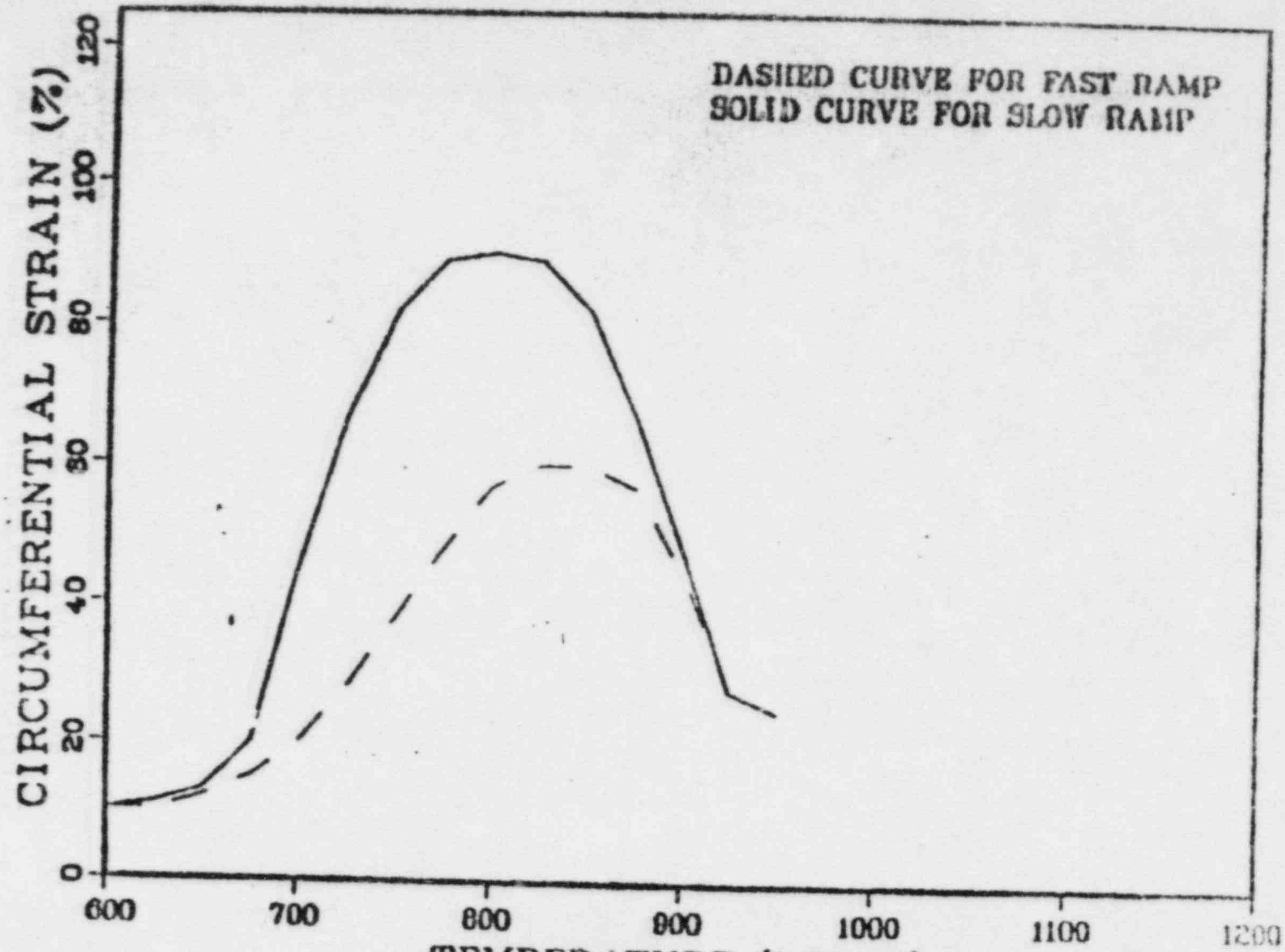

FIGURE 2