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

ATTENTION: MR. T. R. QUAY

SUBJECT: AP600 WGOTHIC COMPARISON TO GOTHIC

Dear Mr. Quay:

During the July 27, 1995, meeting between Westinghouse and the Containment Systems and Severe Accident Branch, Westinghouse took an action to provide information to assist the staff review of the WGOTHIC computer code. Attachment 1 to this letter provides the following requested information:

1. A discussion on the applicability of the GOTHIC peer design review package to Westinghouse-GOTHIC,

2. A summary of the peer design review results and a list of the peer design review report sections that are applicable to Westinghouse-GOTHIC,

3. A list of the GOTHIC design review Appendix B results applicable to WGOTHIC, and

4. A comparison of WGOTHIC_S Version 1.2 results to the results from a modified version of the code incorporating the major differences leading to Version 4.0 of GOTHIC_S.

Please contact John C. Butler on (412) 374-5268 if you have any questions concerning this transmittal.

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/nja

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Applicability of GOTHIC Peer Design Review to Westinghouse-GOTHIC

In 1991 a peer design group was established by the Electric Power Research Institute (EPRI). The purpose of this group was to review the GOTHIC coding, supporting documentation, users manuals, and code qualification results in order to establish a reference point for placing the GOTHIC code package under a 10CFR50, Appendix B Quality Assurance program. The review of the code began with GOTHIC Version 3.4d. The conclusions of the design review also apply to GOTHIC Version 4.0 as indicated in the introduction to the design review final report.

The configured version of Westinghouse-GOTHIC (WGOTHIC) originated with GOTHIC Version 3.4c, the immediate predecessor to the version supplied to the design review team. The differences between Version 3.4c and 3.4d are minor as indicated by the increment in the alpha character of the version stamp and the limited number of differences identified in the tables provided below.

The results of the design review are applicable to WGOTHIC. The difference between WGOTHIC Version 1.2 and GOTHIC Version 4.0 is demonstrated to be minor in the attached plot and is confirmed by the very few differences identified in letter NTD-NRC-95-4577. Given that GOTHIC Version 4.0 was the result of the peer design review and that WGOTHIC is the same as GOTHIC Version 4.0, with a few identified exceptions, it is concluded that the design review directly applies to WGOTHIC.

	Westinghouse	Numerical Applications Inc.
1991	Westinghouse Purchases GOTHIC Version 3.4c	
June	Westinghouse Begins Dedication of GOTHIC Version 3.4c Westinghouse Begins Modifications for AP600 Program.	
November	Westinghouse Incorporates GOTHIC Error Notices as They become Available	EPRI Establishes Design Review Group. Begins Review of GOTHIC Version 3.4d.
1992		
May	Westinghouse Completes Dedication of GOTHIC Version 3.4c	
	Westinghouse Incorporates GOTHIC Error Notices as They become Available	
1993		
February	Westinghouse Releases WGOTHIC Version 1.0	
May		NAI Responds to Design Review Group Comments
July	Westinghouse Releases WGOTHIC Version 1.1	
September		Design Review Complete. GOTHIC Version 4.0 Released.
1994		
October	Westinghouse Releases WGOTHIC Version 1.2	
1995		
1996		
	Westinghouse Updates Wgothic to GOTHIC Version 4.0	

Westinghouse_GOTHIC Code Modification Timeline

Summary of Peer Review Results

The peer design review group reviewed the documentation, coding, convergence, pre/post processor, code qualification package, and the code's adequacy for containment analysis. The conclusions for these items are presented in section 2.2 of the GOTHIC Design Review Final Report (NTD-NRC-95-4462, EPRI Report RA-93-10, GOTHIC Design Review Final Report, May 1995).

The design review group concluded that the documentation is adequate to describe the theory and assumptions made in developing the models and logic, the code from a programmer's point of view, how to prepare the input, and how to install the code on supported systems.

The source code was found to be consistent with the documentation. The solution technique used in GOTHIC_S was found to be stable; however, an iterated Newton method was recommended as an option for the future. The pre and post processors were found to be valid for performing the applications required of them.

The code qualification documentation and results were reviewed by the group. It was concluded that GOTHIC_S is valid to use in performing a wide range of thermal-hydraulic applications. It was noted that although the analyses in the code qualification manual had not been independently reviewed, an impressive array of cases were analyzed with successful comparisons to data and test results.

Overall, the group found the GOTHIC containment analysis package adequate for containment analyses and that the code package offered the ability to provide more accurate and mechanistic results than with other currently available containment codes. This conclusion was qualified with the statements that the nodal and junction treatment as well as the range of the qualification database need to be studied. If the intended application falls outside these ranges then the use of GOTHIC needs to be justified; as was done via the large scale and separate effects tests used to qualify Westinghouse-GOTHIC for use in the licensing of the AP600 (WCAP-14382).

The group had three recommendations at the conclusion of the review. The first was the addition of dynamic memory allocation so that the code did not need to be re-compiled for different sizes of models. The second was the inclusion of an iterated Newton method to aid in convergence. The third was to incorporate a fog model to simulate condensation of vapor when regions go from superheated to saturated. None of these issues adversely impact the use of WGOTHIC for AP600 PCS design basis analysis, as discussed below.

Design Review Sections Applicable to Westinghouse-GOTHIC

There are seven sections and seven appendices contained in the GOTHIC Design Review Final Report. Section 1 is a brief introduction to the code package and the purpose for the review. This section has little applicability to WGOTHIC but it does provide some history of the code.

Section 2 provides a summary of the review and the conclusions reached by the design group. This section applies to WGOTHIC in that it presents the results of the review and the recommendations that were made as a result of the review.

Section 3 lists the items that were reviewed by the group as well as the method of review. This section applies to WGOTHIC since it itemizes the documentation and features that were reviewed.

Section 4 presents the results of the review. This section contains the results of the group's independent tests as well as the assessments of the code against the tests analyzed in the code qualification manual. This section applies to WGOTHIC since the code qualification document strengthens the justification for using WGOTHIC to analyze the AP600 and supporting tests.

Section 5 indicates that all items from the review have been fully resolved and contains three recommendations for improving the code package. The first recommendation, dynamic memory allocation, is a convenience option that applies to WGOTHIC but does not alter its solution. The second recommendation to include an iterated Newton solution option to improve convergence could apply to WGOTHIC; however, satisfactory convergence of the code is supported by the AP600 large scale test comparisons and the GOTHIC code qualification report. The recommendation to include a fog model applies to WGOTHIC. The code qualification case, the CVTR analysis, indicates that the lack of this model results in overpredicting both temperature and pressure. An assessment of fog modeling as it relates to the AP600 has been also performed (NTD-NRC-94-4100, Enclosure 1, Radiation Heat Transfer through Fog in the PCCS, April 1994). Based on these results it is concluded that although the WGOTHIC code would be improved by the addition of a fog model it is conservative with respect to temperature and pressure to ignore the model.

Sections 6 and 7 provide a listing of the documentation and reference material.

Appendix A is a summary of the review coverage for documentation and source code modules. This section applies to WGOTHIC.

Appendix B is a listing of the review findings and responses. This section applies to WGOTHIC.

Appendix C is a summary of the installation survey, Appendix D is a summary of the applications survey, and Appendix E is a summary of the preprocessor survey. These sections do not apply to WGOTHIC.

Appendix F contains the resumes of the design review group and Appendix G is an inventory of the design review.

Design Review Appendix B Findings and Relevance to Westinghouse-GOTHIC

All of the findings presented in Appendix B of the GOTHIC Design Review Final Report (NTD-NRC-95-4577, "Updated GOTHIC Documentation," 12 October, 1995) apply to Westinghouse-GOTHIC.

The results of a detailed comparison of WGOTHIC_S Version 1.2 and GOTHIC_S Version 4.0 are presented in the next section. The comparison encompasses all differences between the two code versions, including the findings identified in the Design Review Final Report as well as other corrections and enhancements made by the code developer that had not been incorporated into WGOTHIC by Westinghouse. The negligible effect of these differences is presented via a comparison of results which is also included in the next section.

Comparison of WGOTHIC_S Version 1.2 with GOTHIC_S Version 4.0

The Westinghouse_GOTHIC code was developed based on GOTHIC Version 3.4c. During the course of developing our code for use on the AP600 program a number of modifications and error corrections were made based on continuous dialog with the code developers, Numerical Applications, Inc. As a result of this close interaction, a number of code errors identified early in our development program were corrected prior to configuring WGOTHIC. This process is responsible for the very limited number of differences between the two versions of the code, the bulk of which were introduced to GOTHIC_S at the time that version 4.0 was created.

To determine the differences between WGOTHIC_S Version 1.2 and GOTHIC Version 4.0, a detailed comparison of the two codes was performed. This line-by-line comparison of the two codes was condensed into the two tables presented in letter NTD-NRC-95-4577. Tables 1 and 2 from that reference are presented below along with an additional explanation as to why specific items were determined to be negligible.

To verify that the differences would not alter the results or conclusions of the AP600 analyses presented to date, all of these differences were incorporated into a temporary version of WGOTHIC_S. The AP600 containment pressure transient for the cold leg break case was reanalyzed to show the differences in the two versions. The figure below illustrates the differences in peak pressure results for the two versions of WGOTHIC_S.

The only difference in results occurs during blowdown when the improved droplet model is activated. The pressure predicted by the modified code is slightly less than that predicted with the configured version of WGOTHIC_S Version 1.2. Based on this result it is concluded that the differences between the configured version of WGOTHIC and GOTHIC Version 4.0 are slightly conservative and permit the continued interim use of WGOTHIC_S Version 1.2

Incorporation of GOTHIC Version 4.0 into WGOTHIC

The currently configured version of WGOTHIC will be upgraded to be consistent with GOTHIC 4.0. This will occur prior to performing the final calculations for the AP600 containment integrity analyses.

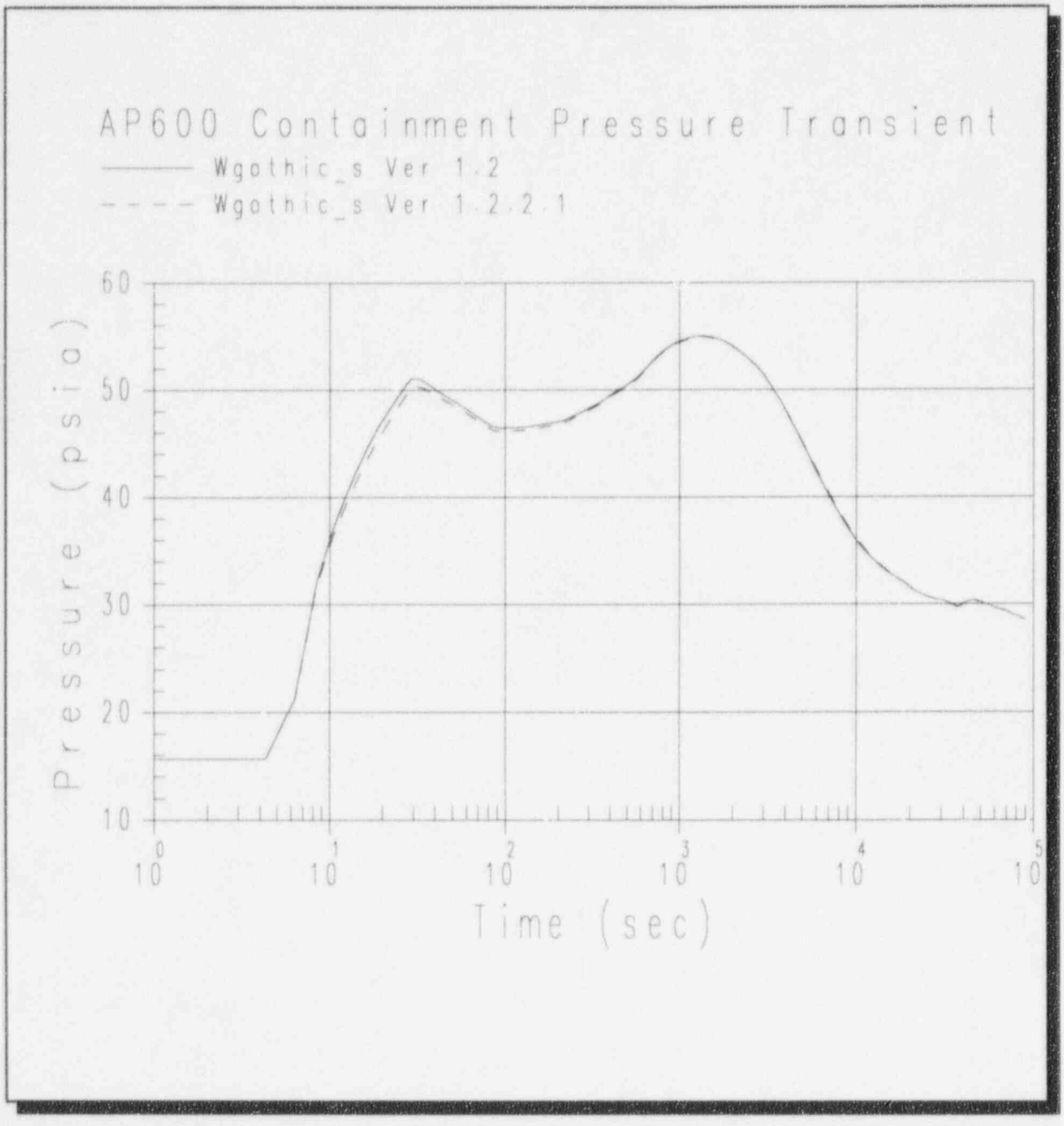
AP600 Containment Pressure Transient
Wgothic_s Ver 1.2
Wgothic_s Ver 1.2.2.1
Pressure (psia)
60
50
40
30
20
10
10^0
10^1
10^2
10^3
10^4
10^5
Time (sec)

Table 1: Identified Differences Between GOTHIC_S Version 4.0 and WGOTHIC_S Version 1.2 Determined to be Negligible

ROUTINE	DESCRIPTION	GOTHIC Version 4.0	WGOTHIC Version 1.2	REASON
blkdat.f	Coefficient used to calculate saturated liquid enthalpy	0.005245502294	0.005245502284	Small numerical difference in a single factor of the equation used to calculate the saturated liquid enthalpy.
boiling.f	Film thickness calculation for use in calculating the single phase liquid heat transfer coefficient	[0.5*dh*(1.-(1-liq_frac)$^{0.5}$)]/wet_frac	[0.25*dh*liq_frac]/wet_frac	This regime is not predicted to occur during the transients calculated for the containment analyses supporting the AP600.
boiling.f	Version 4.0 deleted the logic setting the minimum single liquid and vapor heat transfer coefficient to 3.66*k/dh	hspl=(0.023*rel$^{.8}$*prl$^{.4}$)*xkliq/de hspv=(.023*reg$^{.8}$*prmix$^{.4}$)*cmix/de	hspl=max(3.66,.023*rel$^{.8}$*prl$^{.4}$)*xkliq/de hspv=max(3.66, .023*reg$^{.8}$*prmix$^{.4}$)*cmix/de	These regimes are not predicted to occur during the transients calculated for the containment analyses supporting the AP600.
condin.f	Corrected conversion factor from Watts/m2 to Btu/hr*ft2 when specifying a fixed surface heat flux	0.08805	0.317	The analyses supporting the AP600 containment analyses have been performed exclusively in English units.
intfr.f	Corrected the calculation of the average small bubble radius	rbub=min(rbub,0.5*dhyd,0.02)	rbub=min(rbub,1.0*dhyd,0.04)	A bubbly flow regime is not predicted to occur in the AP600 containment analyses.
intfr.f	Deleted a small bubble heat transfer coefficient calculation option	hshlv=(2.0+0.74*reb$^{0.5}$*prl$^{0.333}$)*ykf*dbubi	hshlv=max[(2.0+0.74*reb$^{0.5}$*prl$^{0.333}$)*ykf*dbubi, rlp*(hlt-hf)*ykf*dbubi/(rvp*(hf-hg))]	A bubbly flow regime is not predicted to occur in the AP600 containment analyses.
intfr.f	Corrected the minimum droplet interfacial drag coefficient	cdd=4.0	cdd=0.45	These changes are a result of improvements in the droplet regimes considered in the code.

ROUTINE	DESCRIPTION	GOTHIC Version 4.0	WGOTHIC Version 1.2	REASON
intfr.f	Added logic to determine terminal velocities for droplets in various regimes	laminar solid sphere distorted drop limit drop limit		These changes are a result of improvements in the droplet regimes considered in the code.
intfr.f	Reinstituted droplet deentrainment on horizontal surfaces	Available	Not available	These changes are a result of improvements in the droplet regimes considered in the code.
solids.f	Version 4.0 permits a time dependent multiplier on the ice heat transfer coefficient.			This is an improvement over earlier versions of the code. This feature is not used in AP600 analyses.
tpress.f	Calculation of liquid and vapor strain rates	d32l(jj,j)=d32l(jj,j)+0.25*dvdzl d32v(ii,j)=d32v(ii,j)+0.25*dvdzv	d32l(jj,j)=d32l(jj,j)+0.125*dvdzl d32v(ii,j)=d32v(ii,j)+0.125*dvdzv	This is a factor in the turbulence models used only for the distributed parameter model. The assumption made in that analysis is equivalent to perfect mixing within the cells so this item has very little effect.

Table 2: Identified Differences Between GOTHIC_S Version 4.0 and WGOTHIC_S Version 1.2 Shown to be Insignificant

ROUTINE	DESCRIPTION	GOTHIC Version 4.0	WGOTHIC Version 1.2
heat.f	Modified the method used to calculate the minimum effective film thickness	[0.5*dh*(1.-(1-liq_frac)$^{0.5}$)]/wet_frac	[0.25*dh*liq_frac]/wet_frac
heat.f	Corrected modifier on smoothing method for the Uchida correlation	htcvu=htcvu+ (htcvt-htcvu)*exp$^{(-0.025*tpast)}$	htcvu=htcvu+ (htcvt-htcvu)*exp$^{(-0.05*tpast)}$
heat.f	Removed old time weighting from direct wall condensation and Tagami	htcvs(isd,n)=xvap*hv1	htcvs(isd,n)=(xvap*hv1)$^{0.1}$* max(one,htcvs(isd,n))$^{0.9}$
newdlt.f	Gravity driven flow time step limit logic increased	delgmx=delt*0.5/dgmx	delgmx=delt*1.0/dgmx
post3d.f	Calculation of vertical mass flow rates within a cell	Vertical mass flow rate is updated with respect to changes in pressure for cells connected to a pressure boundary condition	Forces the change in vertical mass flow per change in pressure to zero for all cells connected to a pressure boundary condition.
post3d.f	Update of gas densities prior to solution of state equation.	Recalculates gas densities accounting for pressure change and gas mass error	Recalculates gas densities accounting for gas mass error
setin.f	Revised the lower limit for the Uchida heat transfer coefficient	humin=2.	humin=15.