NMC
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Kewaunee Nuclear Power Plant
Operated by Nuclear Management Company, LLC

NRC-03-077 10 CFR 50.90

July 24, 2003

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555

KEWAUNEE NUCLEAR POWER PLANT
DOCKET 50-305
LICENSE No. DPR-43
RESPONSE TO REQUEST FOR ADDITIONAL INFORMATION RELATED TO NMC REQUEST FOR THE USE OF GOTHIC 7 FOR THE KEWAUNEE NUCLEAR POWER PLANT CONTAINMENT DESIGN BASIS ACCIDENT ANALYSES

References:
1) Letter from Thomas Coutu (NMC) to Document Control Deck (NRC), "Kewaunee Nuclear Power Plant Request for Use of GOTHIC 7 in Containment Design Basis Accident Analyses", dated September 30, 2002.
2) E-mail from John Lamb (NRC) to Gerald Riste (NMC), "Request for Additional Information for use of GOTHIC 7.0 by Kewaunee TAC MB6408," dated 3/17/03

In reference 2, the Nuclear Regulatory Commission (NRC) staff requested additional information concerning the Nuclear Management Company, LLC (NMC) request to allow the use of the Gothic 7 Containment Analysis Computer Code (Gothic 7) for the Kewaunee Nuclear Power Plant accident analysis, (Reference 1). This letter is NMC's response to the NRC's request for additional information (RAI).

Attachment 1 to this letter contains the questions the NRC staff requested. Attachment 2 to this letter contains the questions the NRC staff requested with NMC's responses.

As the responses do not alter the conclusions reached in NMC's reference 1 submittal, the safety analysis, significant hazards determination, and the environmental considerations statements contained in reference 1 are still applicable and support the changes contained herein. Also, this submittal contains no new commitments.

A001

NMC requests approval of this license amendment request in accordance with the date contained in reference 1. If you have any questions concerning this submittal please contact Mr. Gerald Riste at (920) 388-8424.

I declare under penalty of perjury that the foregoing is true and correct.
Executed on July 24, 2003.

Thomas Coutu

Thomas Coutu
Site Vice-President, Kewaunee Plant

GOR

Attachments

1. NRC request for additional information.
2. NMC response to NRC request for additional information.

cc - US NRC, Region III
US NRC Senior Resident Inspector
Electric Division, PSCW

ATTACHMENT 1

NUCLEAR MANAGEMENT COMPANY, LLC
KEWAUNEE NUCLEAR PLANT
DOCKET 50-305

July 24, 2003

Letter from Thomas Coutu (NMC)

To

Document Control Desk (NRC)

NRC REQUEST FOR ADDITIONAL INFORMATION

GOTHIC 7.0

TAC MB6408

(E-mail from John Lamb (NRC) dated 3/17/03)

REQUEST FOR ADDITIONAL INFORMATION
GOTHIC 7.0
TAC MB6408

1. Attachment 1 Page 2: Where is the SPLIT option, used to model water depth on floor heat sinks, described?

2. Attachment 1 Page 3: Explain why the use of the MDL model does not "alter the existing margins to safety" when there is a demonstrated reduction in containment pressure and temperature for the main steam line break calculation.

3. NAI-1105-04 Revision 2 Page 1: Please verify that the four accident analysis cases specified in Table 1 are the current most limiting cases and remain the most limiting for KNPP.

4. NA-1105-04 Revision 2 Page 1: Section 2.0, Assumptions, states that it is assumed that the physical parameters listed in this section are correct and fully qualified. Please verify that this is true.

5. NAI-1105-04 Revision 2 Page 5: Explain (or reference the appropriate sections of the GOTHIC manuals) how bulk velocities are determined for the MLD model. Also discuss or reference the validation of these bulk velocities.

6. NAI-1105-04 Revision 2 Page 8: The statement is made that the MDLM option is applied only to vertical conductors. What is the justification for applying the MDLM to the containment dome?

7. NAI-1105-04 Rev 2/GOTHIC Technical Manual Page 9-14: The GOTHIC 7.0 Technical Manual (page 9-14) states that the GOTHIC MDLM goes farther than other approaches by including not only the effect of mist in heat and mass transfer to the wall but migration of the mist to the bulk fluid. This, as shown in Table 7 of NAI-1105-04 Rev 2, has a significant effect on the atmospheric conditions during a steam line break (i.e., on the containment pressure for both steam line break cases and on the containment temperature for Case MSLB1.1).

   (a) Please provide the physical explanation of why this migration to the bulk is justified.

   (b) Cite any experimental data, other than the experimental data used to determine the empirical constants, which confirms this migration to the bulk fluid and which quantifies the effect and justifies the amount of temperature and pressure reduction attributed to this effect by GOTHIC 7.0.

(c) Phebus test FPT0[1] is an experiment performed by the Institut de Protection et de Surete Nucleaire (ISPN) which included the measurement of thermal hydraulic conditions in a vessel with a superheated atmosphere. The NRC CONTAIN 2.0 code, using the heat mass transfer analogy, compares favorably with data from this test without a mist diffusion layer model[2]. Have comparisons been made between GOTHIC 7.0 with the results of this test? If no comparisons with this test have been made using GOTHIC 7.0, please perform a GOTHIC 7.0 calculation of FPT0. [The CONTAIN 2.0 input data are provided as an attachment to these questions for any assistance these data provide.]

(d) If the MDLM takes credit for a portion of the mist migrating back to the superheated atmosphere, is this used instead of the 8% re-vaporization assumption used with the previously approved Kewaunee methods?

8. NAI-1105-04 Rev 2/GOTHIC Technical Manual Page 9-14:

(a) What data were used to obtain the empirical constants in the MDLM.

(b) Why is it acceptable to scale from these data to a PWR containment?

9. NAI-1105-04 Revision 2 Figures 1 and 2: A statistical factor is derived to reduce the predicted heat and mass transfer coefficients to add conservatism to the predictions of condensation heat transfer in the boundary layer for design basis calculations. Why is no such factor applied to the transfer of droplets from the boundary layer to the bulk fluid of the containment atmosphere?

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[1] "Phebus PF Programme-Final Report n the 4th Period," Phebus Report No. IP/93/195, Institut de Protection et de Surete Nucleaire, CEA, France, June 1993

[2] Jack Tills, Allen Notafrancesco, and Ken Murata, "An Assessment of CONTAIN 2.0: A Focus on Containment thermal Hydraulics (Including hydrogen Distributions) SMSAB-02 July 2002. Page 4-10. ADAMS accession number ML022170122.

Attachment
Phebus FTP0 CONTAIN 2.0 Input

```
cray
control
ncells=2 ntitl=1
nac=1 nsectn=10
ntzone=8
eoi
material
compound h2ol h2ov n2 o2 h2 conc
userdef cu
&&
times 1000.0 0.0
0.05 0.05 1.0
0.1 0.1 10.0
0.2 5.0 100.0
0.5 20.0 500.0
0.5 50.0 4000.0
0.5 100.0 8000.0
0.5 50.0  12000.0
0.5 100.0 22000.0
&&
1.0 1.0
shortedt=5
longedt=10
&& debug=3 htsurf condns evacon 0.0 0.05
thermal
userdat
cu solid molew 50.0
  rho 2 275.0 8933.
        600.0 8933.
cond 2 275.0 401.0
       600.0 401.0
 sph 2 275.0 385.0
       600.0 385.0
eoi
eoi
aerosol
diam1=1.0e-7 diam2=2.5e-4
h2ol=1.0e-8 0.693

prheat prlow-cl prengsys praer
title
FPT0 (case10) - Reference Deck
&&
                          &&
cell=1
control
nhtm=6 mxslab=5 jpool=1 jconc=5
```

```
naensy=1 nsoatm=2 nspatm=38
numtbc=1 maxtbc=10
eoi
geometry
 gasvol=10.0
 cellhist 2 0.0 0.27 0.53037 2.54469 4.44307
eoi
atmos=3
  tgas=378.086
  pgas=1.75313e5
  molefrac
   n2=0.666 o2=0.035 h2ov=0.299
eoi
condense
source=2
h2ov=38 iflag=2
t=
 0.00000E+00, 3.80000E+01, 2.79100E+03, 2.85100E+03, 8.62100E+03,
 8.73800E+03, 8.76800E+03, 9.52900E+03, 9.83500E+03, 1.00530E+04,
 1.03000E+04, 1.04220E+04, 1.05130E+04, 1.06900E+04, 1.07760E+04,
 1.13620E+04, 1.13630E+04, 1.17830E+04, 1.17840E+04,
 1.35290E+04, 1.36730E+04, 1.39600E+04, 1.40470E+04, 1.44820E+04,
 1.48880E+04, 1.50030E+04, 1.51750E+04, 1.52330E+04, 1.54940E+04,
 1.55520E+04, 1.56970E+04, 1.57270E+04, 1.59620E+04, 1.76310E+04,
 1.86560E+04, 1.96520E+04, 1.97100E+04, 2.27850E+04
mass=
 1.10000E-06, 1.94000E-03, 1.94000E-03, 5.10000E-04, 5.10000E-04,
 5.00000E-04, 5.40000E-04, 5.40000E-04, 1.21000E-03, 1.85000E-03,
 2.51000E-03, 2.79000E-03, 2.91000E-03, 3.00000E-03, 2.90000E-03,
 2.90000E-03, 1.07000E-03, 1.07000E-03, 2.90000E-03,
 2.90000E-03, 2.76000E-03, 2.49000E-03, 2.42000E-03, 2.20000E-03,
 2.00000E-03, 1.88000E-03, 1.73000E-03, 1.67000E-03, 1.53000E-03,
 1.51000E-03, 1.43000E-03, 1.51000E-03, 1.51000E-03, 1.51000E-03,
 1.51000E-03, 1.51000E-03, 4.12000E-07, 1.16000E-07
enth=
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06,
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06,
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06,
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06,
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06,
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06,
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06,
 2.74676E+06, 2.74676E+06, 2.74676E+06, 2.74676E+06
eoi

h2=6 iflag=2
t= 0.0 11362.0 11363.0 11783. 11784.  1.0e5
mass= 0.0 0.0 2.1e-4 2.1e-4 0.0 0.0
temp= 423.15 423.15 423.15 423.15 423.15 423.15
```

```
eoi

struc

name=vessel
type=wall shape=slab nslab=4 chrlen=3.9
tunif=383.15
slarea=25.16
&& bcinner
&& natcor1 0.0 0.014 0.33 0.33
&& filmflow
&&  slope=90. width=0.152
&& eoi
bcouter tsurf=383.15 eoi
compound= cu cu cu cu && cu cu cu cu cu cu cu
x= 0.0 0.001 0.002 0.004 0.008
eoi

name=wet
type=wall shape=slab nslab=4 chrlen=1.5
&& tunif=347.15
tunif=352.15
slarea=2.324
bcinner
&& natcor1 0.0 0.014 0.33 0.33
 filmflow
  slope=90. width=0.145
 eoi
eoi
bcouter
var-parm
 flag=2 name=twcond
  var-x=time
&&  x=10 0.0 2791.0 2851. 9529. 10690. 13529.
  x=10 0.0 2941.0 3001. 9529. 10690. 13529.
&&      15494. 19652. 19710. 22785.
       15494. 19802. 19860. 22785.
  var-y=tsurf
  y=10 353.15 353.15 350.15 350.15 354.15 354.15
       353.15 353.15 349.15 349.15
 eoi
eoi
compound= cu cu cu cu && cu cu cu cu cu cu cu
x= 0.0 0.001 0.002 0.004 0.008
eoi

name=dry
type=wall shape=slab nslab=4 chrlen=1.0
tunif=393.15
```

```
slarea=1.062
&& bcinner
&& natcor1 0.0 0.014 0.33 0.33
&& filmflow
&&  slope=90. width=0.152
&& eoi
&& var-parm
&&  flag=2 name=force
&&  var-x=time
&&  x=3 0.0 1.0e5 2.0e5
&&  var-y=velocity
&&  y=3 1.0 1.0 0.0
&& eoi
&& eoi
bcouter tsurf=393.15 eoi
compound= cu cu cu cu && cu cu cu cu cu cu cu
x= 0.0 0.001 0.002 0.004 0.008
eoi

name=collar
type=wall shape=slab nslab=4 chrlen=0.16
tunif=366.15
slarea=0.303
&& bcinner
&& natcor1 0.0 0.014 0.33 0.33
&& filmflow
&&  slope=90. width=0.152
&& eoi
&& var-parm
&&  flag=2 name=force
&&  var-x=time
&&  x=3 0.0 1.0e5 2.0e5
&&  var-y=velocity
&&  y=3 1.0 1.0 0.0
&& eoi
&& eoi
bcouter tsurf=366.15 eoi
compound= cu cu cu cu && cu cu cu cu cu cu cu
x= 0.0 0.001 0.002 0.004 0.008
eoi

name=swall
type=wall shape=slab nslab=4 chrlen=0.37
tunif=363.15
slarea=0.84
slhite= 0.37037       slelev=0.185185
&& bcinner
&& natcor1 0.0 0.014 0.33 0.33
&& filmflow
```

```
&&  slope=90. width=0.152
&& eoi
&& var-parm
&&  flag=2 name=force
&&  var-x=time
&&  x=3 0.0 1.0e5 2.0e5
&&  var-y=velocity
&&  y=3 1.0 1.0 0.0
&& eoi
&& eoi
bcouter tsurf=363.15 eoi
compound= cu cu cu cu && cu cu cu cu cu cu cu
x= 0.0 0.001 0.002 0.004 0.008
eoi

name=sflr
type=floor shape=slab nslab=4 chrlen=0.5
tunif=363.15
slarea=0.27
slhite=0.008        slelev=-0.004
&& bcinner
&& natcor1 0.0 0.014 0.33 0.33
&& filmflow
&&  slope=90. width=0.152
&& eoi
&& var-parm
&&  flag=2 name=force
&&  var-x=time
&&  x=3 0.0 1.0e5 2.0e5
&&  var-y=velocity
&&  y=3 1.0 1.0 0.0
&& eoi
&& eoi
bcouter tsurf=363.15 eoi
compound= cu cu cu cu && cu cu cu cu cu cu cu
x= 0.0 0.001 0.002 0.004 0.008
eoi

engineer sump 1 1 2 1.0
overflow 1 2 0.371
eoi

low-cell
 geometry 0.0001
 bc 295.0 1.0e5
  concrete
   compos=1 conc=2.0e5
   temp=363.15
  eoi
```

```
  pool
    compos=1 h2ol=100.0
    temp=363.15
    physics
      boil
    eoi
  eoi
eoi

rad-heat gaswal 1.236
emsvt
0.85 0.85 0.85 0.85 0.85 0.85 0.85
eoi

cell=2
control
jpool=1 jconc=5
eoi
geometry
 gasvol=1.0e6
 cellhist 1 -1.0 100.0 9.9999e4
 eoi
atmos=3
  tgas=293.15
  pgas=0.966e5
  molefrac
   n2=0.9367 o2=0.0493 h2ov=0.014
eoi
condense
low-cell
 geometry 0.00001
 bc 295.0 1.0e5
  concrete
   compos=1 conc=2.0e5
   temp=295.0
  eoi
  pool
    compos=1 h2ol=0.0
    temp=293.15
    physics
      boil
    eoi
  eoi
eoi


 eof
```

ATTACHMENT 2

NUCLEAR MANAGEMENT COMPANY, LLC
KEWAUNEE NUCLEAR PLANT
DOCKET 50-305

July 24, 2003

Letter from Thomas Coutu (NMC)

To

Document Control Desk (NRC)

NMC's RESPONSE TO the NRC Staff's

REQUEST FOR ADDITIONAL INFORMATION Concerning

GOTHIC 7.0

TAC MB6408

RESPONSE TO
REQUEST FOR ADDITIONAL INFORMATION
GOTHIC 7.0
TAC MB6408

1. Attachment 1 Page 2: Where is the SPLIT option, used to model water depth on floor heat sinks, described?

Response to 1: The SPLIT option is discussed on pages 11-19 and 11-20 of the GOTHIC 7.0 User Manual and page 9-2 of the GOTHIC 7.0 Technical Manual.

2. Attachment 1 Page 3: Explain why the use of the MDL model does not "alter the existing margins to safety" when there is a demonstrated reduction in containment pressure and temperature for the main steam line break calculation.

Response to 2: The use of the MDLM model does not alter the existing margins to safety even though there is a demonstrated reduction in containment pressure and temperature results for the main steam line break (MSLB) calculation. The outline below shows the hierarchy of limits from normal steady state operation to actual barrier (fission product barrier) integrity limits.

1) Actual Barrier Integrity Limits

2) Defined Barrier Integrity Limits

3) Event Acceptance Limits

4) Event Analysis Results

    a) Model Uncertainties
    b) Model Conservatisms
    c) Design Input Conservatisms

5) Operating Envelope Limits

    a) Planned operating maneuvering allowance and steady state operating allowance

6) Steady State Operation

Safety Margin is defined as the margin between event acceptance limits (3) and the actual barrier integrity limits (1). Analysis Margin is the margin between event analysis results (4) and event acceptance limits (3). The use of the MDLM correlation for calculating the heat and mass transfer from containment atmosphere to containment structural heat sinks reduces the containment evaluation model uncertainties and in the case of the MSLB accident reduces the event analysis results for containment pressure and temperature. The improved heat and mass transfer modeling has given the MSLB event analysis increased analysis margin to the event acceptance limits. However, since the event acceptance limits have not been changed the Safety Margin has not been affected. Therefore, the use of the MDLM correlation does not alter the existing margins to safety.

3. NAI-1105-04 Revision 2 Page 1: Please verify that the four accident analysis cases specified in Table 1 are the current most limiting cases and remain the most limiting for KNPP.

Response to 3: The four accident analysis cases specified in Table 1 were the limiting containment integrity analysis (CIA) cases for the current (prior to Stretch Power Uprate) safety analyses. The purpose of the GOTHIC MDLM submittal is to obtain approval for application of the GOTHIC MDLM method to KNPP design basis CIA. To justify the use of the GOTHIC MDLM method, a sub-spectrum of cases representing various design basis accidents, power levels, break sizes, single active failures, etc. was considered. This provides assurance that the method is applicable to the complete spectrum of KNPP design basis CIA analyses, namely LOCA and MSLB containment analyses.

Presented below are the limiting CIA cases and associated GOTHIC CIA results from the Stretch Power Uprate safety analyses. From the cases below it can be concluded that the cases specified in Table 1 of NAI-1105-04 Revision 2 page 1 continue to represent a valid basis for the application of the GOTHIC MDLM method to KNPP design basis CIA, specifically the cases for CIA containment pressure and temperature response at Stretch Power Uprate conditions.

LOCA Containment Response Results

Case	**Peak Press. (psig)**	**Peak Temp.(°F)**
DEPSMINSI	42.7 @58.1 sec	261.2 @14 sec
DEPSMAXSI 1 Fan Cooler Fails	42.3 @58.1 sec	261.3 @38 sec
DEPSMAXSI 1 Spray Pump Fails	42.3 @58.1 sec	261.3 @38 sec
DEHL	44.4 @19.9 sec	264.7 @19.8 sec

MSLB Containment Response Results

Case	**Peak Press (psig)**	**Peak Temp (°F)**
1.4 sqft break at 0% power 1 Train of Containment Safeguards Fails	45.91	267.3

4. NA-1105-04 Revision 2 Page 1: Section 2.0, Assumptions, states that it is assumed that the physical parameters listed in this section are correct and fully qualified. Please verify that this is true.

Response to 4: In Section 2.0, Numerical Applications Inc.(NAI) is communicating the fact that NAI has not been contracted to independently verify the basis for the design input contained in the Kewaunee DBA models transmitted to NAI for use in the analysis. For example, NAI has not been contracted to perform containment walk-downs to verify the surface area of passive heat sinks inside containment.

The physical parameters listed in Section 2.0 (i.e., "the physical parameters in the existing Kewaunee DBA models") are correct and have been fully qualified for the purpose of the MDLM study. The Kewaunee DBA models transmitted to NAI were the current design basis accident analysis models available at the time. The DBA models were created by Westinghouse based on verified design input obtained from NMC. Analyses that directly support the Kewaunee plant and that utilize the GOTHIC MDLM model (e.g., Stretch Power Uprate CIA analyses) are performed with the appropriate current Kewaunee DBA models.

5. NAI-1105-04 Revision 2 Page 5: Explain (or reference the appropriate sections of the GOTHIC manuals) how bulk velocities are determined for the MLD model. Also discuss or reference the validation of these bulk velocities.

Response to 5: For lumped analysis, such as used in the discussed model, the bulk velocity is approximated as described in Section 14.8.1 of the GOTHIC 7.0 Technical Manual. The estimated velocity is the average of the volume inlet and outlet velocities scaled to the characteristic cross section area of the volume. A multiplier is applied to account for secondary flows induced by high velocity jets. For the lumped volume Kewaunee containment model, the equation used to estimate the velocity reduces to

$$U_C = \frac{LuA}{2V} Min(2, \frac{V}{LA})$$

where L and A are the length and area specified for the break junction and V is the containment volume. Since $LA << V$, this reduces to

$$U_C = \frac{LuA}{V} = \frac{L\dot{M}}{V\rho}$$

where $\dot{M}$ is the break flow rate and ρ is the density of the expanded jet. Using the containment diameter for the characteristic length, L, and the peak flow rate from the maximum temperature MSLB case, this gives a peak bulk velocity of approximately 6.8 ft/s which is only a factor of two to three larger than what is expected from natural convection. There is no experimental data available for the bulk average velocity in a large volume during a blowdown that could be used for direct comparison with the GOTHIC prediction. Therefore, we must rely on indirect validation for the estimated bulk velocity. In the lumped parameter calculations, the bulk velocity primarily impacts the forced convective heat and mass transfer and consequently it indirectly impacts compartment pressures and temperatures. GOTHIC has been compared against pressure and temperature measurement for a large number of experiments as documented in the GOTHIC Qualification report. Overall, these tests show that GOTHIC compares well with the temperature and pressure measurements and it is inferred that the bulk average velocity is reasonably accurate.

In the GOTHIC input for the Kewaunee LOCA and MSLB cases, the length parameter for the source junction was set to 1 ft. Consequently, the calculated bulk velocity was always less than 0.1 ft/sec eliminating any consideration of forced convection in the heat and mass transfer.

6. NAI-1105-04 Revision 2 Page 8: The statement is made that the MDLM option is applied only to vertical conductors. What is the justification for applying the MDLM to the containment dome?

Response to 6: Experimental results for condensation on flat plates [1] indicate only slight variation in the effective heat transfer coefficient for plates at various angle ranging from down facing horizontal to vertical. The heat transfer rates were largest, by a small amount, for a horizontal surface. Similar behavior was observed for condensation on the dome and walls of a test vessel for the AP600 containment [2]. On horizontal surfaces the heat and mass transfer is apparently enhanced by the formation and fall of drops as opposed to the film roughing on vertical surfaces. Since the experimental evidence indicates that the heat and mass transfer rate for downward facing horizontal surfaces is at least as large as it is for vertical surfaces, the MDLM option can be conservatively applied to all vertical and downward facing surfaces.

7. NAI-1105-04 Rev 2/GOTHIC Technical Manual Page 9-14: The GOTHIC 7.0 Technical Manual (page 9-14) states that the GOTHIC MDLM goes farther than other approaches by including not only the effect of mist in heat and mass transfer to the wall but migration of the mist to the bulk fluid. This, as shown in Table 7 of NAI-1105-04 Rev 2, has a significant effect on the atmospheric conditions during a steam line break (i.e., on the containment pressure for both steam line break cases and on the containment temperature for Case MSLB1.1).

   (a) Please provide the physical explanation of why this migration to the bulk is justified.

   (b) Cite any experimental data, other than the experimental data used to determine the empirical constants, which confirms this migration to the bulk fluid and which quantifies the effect and justifies the amount of temperature and pressure reduction attributed to this effect by GOTHIC 7.0.

   (c) Phebus test FPT0[3] is an experiment performed by the Institut de Protection et de Surete Nucleaire (ISPN) which included the measurement of thermal hydraulic conditions in a vessel with a superheated atmosphere. The NRC CONTAIN 2.0 code, using the heat mass transfer analogy, compares favorably with data from this test without a mist diffusion layer model[4]. Have comparisons been made between GOTHIC 7.0 with the results of this test? If no comparisons with this test have been made using GOTHIC 7.0, please perform a GOTHIC 7.0 calculation of FPT0. [The CONTAIN 2.0 input data are provided as an attachment to these questions for any assistance these data provide.]

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3 "Phebus PF Programme-Final Report n the 4th Period," Phebus Report No. IP/93/195, Institut de Protection et de Surete Nucleaire, CEA, France, June 1993

4 Jack Tills, Allen Notafrancesco, and Ken Murata, "An Assessment of CONTAIN 2.0: A Focus on Containment thermal Hydraulics (Including hydrogen Distributions) SMSAB-02 July 2002. Page 4-10. ADAMS accession number ML022170122.

(d) If the MDLM takes credit for a portion of the mist migrating back to the superheated atmosphere, is this used instead of the 8% re-vaporization assumption used with the previously approved Kewaunee methods?

Comment on 7: *The reduction in pressure and temperature shown in Table 7 of NAI-1105-04 Rev 2 is due to the use of the MDLM option for some surfaces versus the Uchida option in the "Improved" model.* The condensation rate predicted by the MDLM is based on a heat and mass transfer analogy. The reduction in temperature and pressure for this application is primarily due to the incorporated heat and mass transfer coefficients. The formation and migration of mist in the boundary layer has a minimal impact for this application. Mist is formed in the boundary layer only if conditions warrant it (i.e., super saturated conditions in the boundary layer using the analytic temperature and steam concentration profiles). To address this issue, the two MSLB cases were rerun with the mist generation and migration deactivated. Results are shown in the table below.

Table 1 Kewaunee MSLB Results with and without Mist Generation

	Peak Pressure		Peak Temperature	
Model	**MDLM**	**MDLM w/o Mist**	**MDLM**	**MDLM w/o Mist**
MSLB1.4	58.73	58.75	264.2	264.2
MSLB1.1	54.80	54.83	258.0	258.1

The contribution of the mist in the application is very small. This is because the containment atmosphere is very nearly saturated for these cases.

Response to 7(a): When the mist is generated in the boundary layer, it must be removed by some mechanism to avoid continual build up in the boundary layer. Relative motion of fluid species within the boundary layer is due primarily to turbulent and molecular diffusion. Mist diffusion is from regions of high mist concentration to regions of low mist concentration. When the bulk atmosphere is superheated, the mist concentration in the bulk atmosphere is zero. Migration of mist given a superheated bulk atmosphere will therefore be from the boundary layer, a high mist concentration region, to the bulk atmosphere, a low mist concentration region. Assuming that mist contacting the wall sticks, the mist concentration at the wall is also zero promoting migration toward the wall as well. However, since the turbulence intensity decreases as the wall is approached, the diffusion is expected to be predominately toward the bulk atmosphere.

Response to 7(b): While the formation of a fog or mist near a condensing surface has been observed, there are no known direct measurements of the formation rate or of its impact on the heat transfer rate to the surface. Mori and Hijikata [9] observed fog formation near a cooled cylinder in atmospheric conditions. Mist formation was observed in an experimental investigation of a reflux condenser [11] as describe in [10]. Several investigators have attempted to account for the fog formation in the heat and mass transfer process [12]. Fox [10] reviewed previous investigations that incorporate mist formation and presents his own modeling approach. Validation of the mist effect is accomplished by comparisons with overall heat and mass transfer rates with experimental data such as has been done for GOTHIC. Peterson [13] accounted for the presence of mist by multiplying the sensible heat transfer coefficient by a factor of 7. Besides the data set used to adjust the unknown parameters in the MDLM, GOTHIC has been compared with experimental data from the MISTRA and TOSQAN test facilities and now also from the Phebus tests (see below).

The MISTRA tests [15] measured condensation rates and atmosphere conditions for a 200°C steam injection into a 100 m^3 vessel initially filled with air. The GOTHIC results are in good agreement with the measured temperature and humidity but over predicted the pressure rise by about 7%. The TOSQAN test is part of ISP-47 [14]. It consists of steam and air at 124-138C injection into a 7 m^3 vessel with condensation on a temperature controlled surface. The vessel mean superheat ranged from 4 to 13C. GOTHIC matched the measured vessel pressure for the two different injection rates and was in good agreement with the vessel average temperature. The Phebus results are shown below. These tests were not used in the development of MDLM but the agreement with data is very good and provides further validation of the MDLM, including the mist generation and migration.

Response to 7(c): The Phebus test FPT0 had not been used to qualify the GOTHIC MDLM option. Using the CONTAIN 2.0 input provided with the RAI, a GOTHIC model was constructed for Phebus test FPT0. The model was similar to the CONTAIN model, using a single lumped volume for the containment and a small sump volume to collect the condensate. Results for the pressure, temperature, humidity and condensation rate are shown in Figures 1 through 4. In these figures, the symbols represent the measured Phebus data as digitized from the figures presented in [16] and the lines represent the GOTHIC results. The original test report was not available so we do not know the accuracy of the test measurements or the accuracy of the test description. There is generally good agreement for all parameters, probably within the uncertainty in the experiment. Most of the difference between the measured and predicted pressure can be eliminated by a change in the cold wall temperature of 0.5C or a change in the initial humidity of 1%. Results are also presented (Figures 5-8) for the same test case with the conservative factor used for the Kewaunee analysis (0.717) applied to the MDLM heat and mass transfer coefficients. The pressure is significantly over predicted at all conditions. There is a smaller relative impact on the vapor temperature but the predicted temperature generally exceeds the measured value. There is only small changes to the condensation rate. For this test, when the conditions are steady, the condensation rate must match the steam injection rate to obtain the steady conditions. Therefore, the condensation rate at the steady conditions is the same with or without the multiplier. However, to achieve the same condensation rate with the conservative multiplier, the steam concentration must be higher as evidenced in the graph for the humidity. This is also reflected in the higher pressure and temperature when the conservative multiplier is applied.

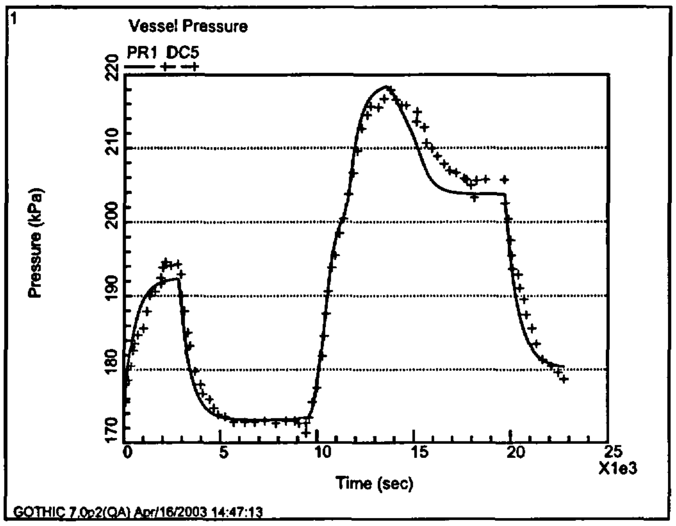

Figure 1 Phebus FPT0 Pressure – Best Estimate

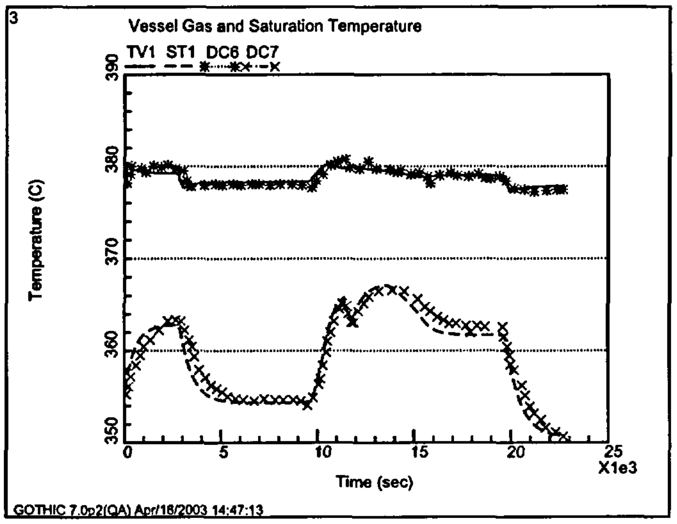

Figure 2 Phebus FPT0 Temperature – Best Estimate

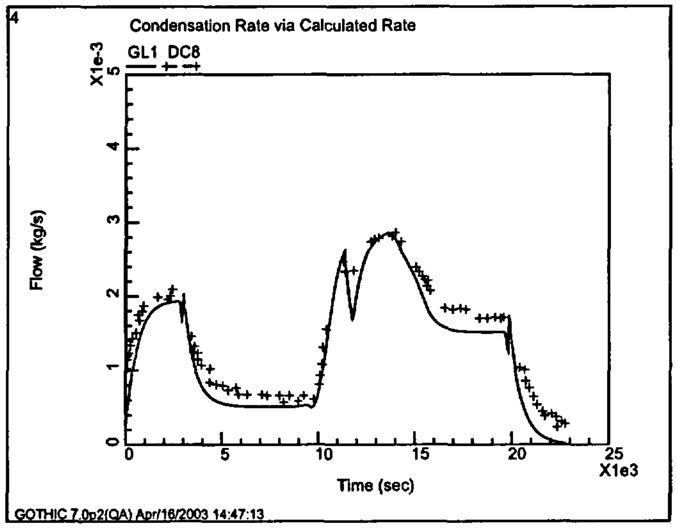

Figure 3 Phebus FPT0 Condensation Rate – Best Estimate

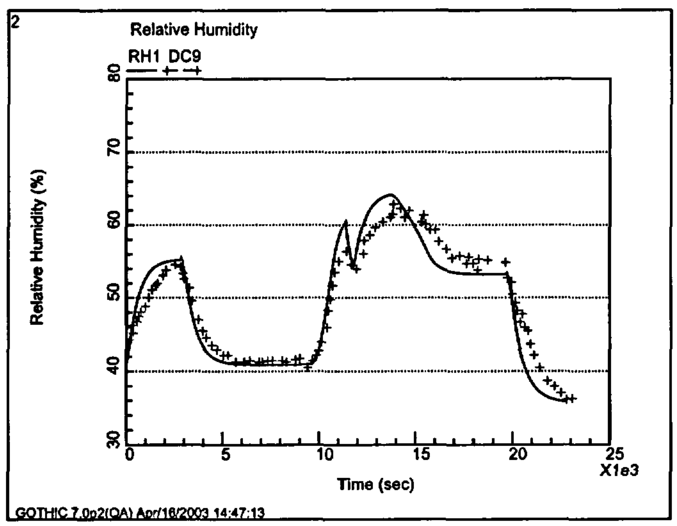

Figure 4 Phebus FPT0 Humidity – Best Estimate

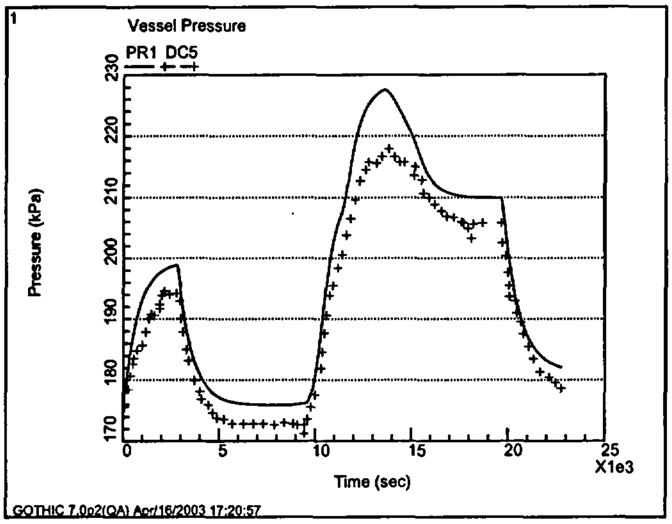

Figure 5 Phebus FPT0 Pressure with Conservative Factor on MDLM

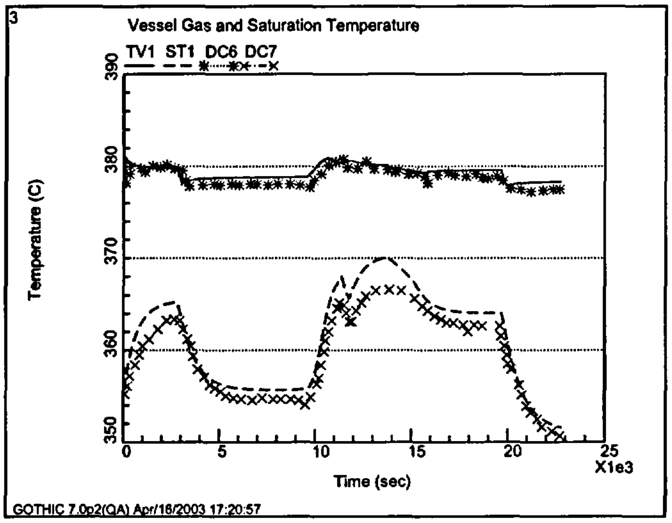

Figure 6 Phebus FPT0 Temperature with Conservative Factor on MDLM

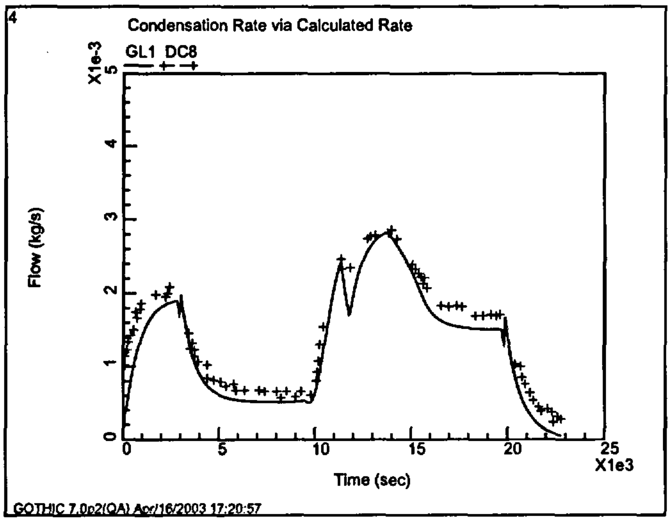

Figure 7 Phebus FPT0 Condensation Rate with Conservative Factor on MDLM

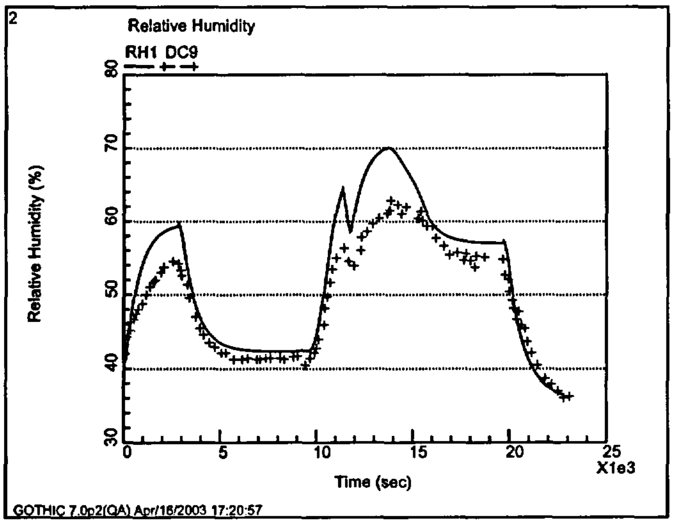

Figure 8 Phebus FPT0 Humidity with Conservative Factor on MDLM

Response to 7(d): For the Kewaunee application, the revaporization fraction was not specified. The default GOTHIC models for interphase heat and mass transfer are used. These models employ a heat and mass transfer analogy to get the phase change and the sensible heat transfer as described in the GOTHIC Technical Manual. The default interphase heat and mass transfer models typically give results close to those obtained using a specified revaporization rate of 8%. As shown in Table 2, the peak pressures and temperatures calculated when the 8% revaporization option is used with MDLM are very close to those obtained using MDLM with the default interface heat and mass transfer (IHMT) model for the two MSLB cases.

Table 2 Kewaunee MSLB Results with Default and 8% Revaporization Options

	Peak Pressure		**Peak Temperature**	
Model	**MDLM w/ Default IHMT**	**MDLM w/ 8% Revap**	**MDLM w/ Default IHMT**	**MDLM w/ 8% Revap**
MSLB1.4	58.73	58.75	264.2	264.2
MSLB1.1	54.80	54.83	258.0	258.1

8. <u>NAI-1105-04 Rev 2/GOTHIC Technical Manual Page 9-14</u>:

(a) What data were used to obtain the empirical constants in the MDLM.

(b) Why is it acceptable to scale from these data to a PWR containment?

Response to 8(a): The data used to set the empirical constants in the MDLM are listed below:
1. Uchida tests with air and nitrogen [3].
2. University of Wisconsin in vessel atmospheric tests [4].
3. University of Wisconsin in vessel pressurized tests [4].
4. University of Wisconsin flat plate tests [6].
5. MIT tests on the outer surface of a vertical cylinder [5].
6. Nusselt theory for pure steam [7].
7. CVTR steam blowdown tests [8].

These tests are all described in Section 5 of the GOTHIC 7.0 Qualification Report.

Response to 8(b): As indicated in NAI-1105-04 Rev 2, the parameter range of the test set used to adjust and validate the MDLM covers the parameter range expected for the DBA in Kewaunee.

9. <u>NAI-1105-04 Revision 2 Figures 1 and 2</u>: A statistical factor is derived to reduce the predicted heat and mass transfer coefficients to add conservatism to the predictions of condensation heat transfer in the boundary layer for design basis calculations. Why is no such factor applied to the transfer of droplets from the boundary layer to the bulk fluid of the containment atmosphere?

Response to 9: The mist generation and transfer to the bulk, when it occurs, is directly related to the condensation rate. Therefore, when the conservative factor was applied to the heat and mass transfer coefficients, the same reduction factor is effectively applied to the generation of mist.

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