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AREVA

## ***Agenda***

- ***Introduction - Mike Schoppman***
- ***Containment Analysis – Paul Bergeron***
- ***Mass & Energy Inputs – Keith Higar***
- ***Summary & Conclusions – Mike Schoppman***

# Containment Analysis Using GOTHIC

## > Meeting Objectives

### ◆ Short-term Applications

#### • Steam Generator Replacement Projects

- Fort Calhoun – mid 2005
- St. Lucie – June 2006
- Crystal River 3 – December 2007
- Three Mile Island – January 2008

#### • Power Uprate Projects

- Davis Besse MUR - end 2005
- Davis Besse EPR – 2006
- 2 Potential EPRs – 2007-2008

### ◆ Long-term Applications

### ◆ Provide Technical overview of BAW-10252(P)

### ◆ Schedule for NRC Review

***Analysis of Containment  
Response using GOTHIC  
BAW-10252 (P)***

*Framatome-ANP*

***Paul A. Bergeron***  
*Supervisor Analysis Services*

**White Flint, Md. September 23, 2004**

# Containment Analysis Using GOTHIC

## > Report Outline

- ◆ **GOTHIC code description**
- ◆ **Reference to code validation**
- ◆ **GOTHIC Model Description**
  - **Discussion of various code options**
- ◆ **Analysis Approach**
  - **Treatment of inputs for LOCA and MSLB/FWLB**
- ◆ **Sample Calculations**
  - **LOCA (hot leg and cold leg pump suction breaks)**
  - **MSLB**
- ◆ **Appendices**
  - **Comparison to applicable standards**
  - **Sample calculation inputs**

# ***Containment Analysis Using GOTHIC***

- > Presentation Outline**
  - ◆ ***Overall Approach***
  - ◆ ***Methodology Application***
  - ◆ ***GOTHIC description***
  - ◆ ***General GOTHIC Model***
  - ◆ ***GOTHIC Model Elements***
  - ◆ ***GOTHIC Inputs***
  - ◆ ***Sample Calculations***
  - ◆ ***Mass & Energy Release***
  - ◆ ***Summary***

# Containment Analysis Using GOTHIC

## > Overall Approach

- ◆ *BAW-10252(P) describes GOTHIC model and inputs*
- ◆ *Method is flexible to accept input M&Es from various sources*
  - *RELAP/licensing basis/other acceptable methods*
- ◆ *Follow industry standards & practices*
  - *NUREG-0800*
  - *ANSI/ANS-56.4 guidelines*
  - *Staff SERs on similar applications*
  - *GOTHIC Users Group*
- ◆ *Qualified against comprehensive set of standard problems and several test facilities*
- ◆ *Follow Plant Licensing Basis*
- ◆ *Sample calculations demonstrate method*

# ***Containment Analysis Using GOTHIC***

## ***> Methodology Application***

- ◆ Calculate Peak Pressure and Temperature responses***
- ◆ Rupture of High Energy Lines in Containment (LOCA, MSLB, & FWLB)***
- ◆ Applicable to Large Dry Containments for PWRs***
- ◆ Applicable to Once Through or Recirculating SGs***
- ◆ Conservative inputs selected***
- ◆ Calculate containment sump temperature and building temperature and pressure response***



# Containment Analysis Using GOTHIC

## > GOTHIC

- ◆ **General purpose thermal-hydraulic tool for analysis of containment and confinement buildings**
- ◆ **Developed by EPRI for use in Nuclear industry**
- ◆ **Solves conservation equations for multi-component and multi-phase flow (steam/gas mixture, continuous liquid, liquid drops)**
- ◆ **Phase balance equations coupled by interface models for mass , energy, and momentum**
- ◆ **Includes set of models for operating equipment**
- ◆ **Benchmarked against several integral and separate effects testing**
- ◆ **Applied throughout industry for containment and building pressure & temperature analysis**

# *Containment Analysis Using GOTHIC*

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# Containment Analysis Using GOTHIC

- > **GOTHIC Model Elements**
  - ◆ **Containment Volume (single lumped volume)**
  - ◆ **Heaters**
    - **RCS Metal exposed to steam & water**
    - **SG stored energy**
    - **Decay heat**
    - **Containment Air Coolers**
  - ◆ **ECCS pre and post RAS**
  - ◆ **Spray pre and post RAS**
  - ◆ **Conductors (Heat Sinks)**
  - ◆ **Reactor Coolant System Volume**
  - ◆ **Spill**
  - ◆ **RHR Heat Exchanger**

# ***Containment Analysis Using GOTHIC***

## **> GOTHIC Inputs**

- ◆ ***Selected Options***
- ◆ ***Initial Conditions***
- ◆ ***Containment Heat Structures***
- ◆ ***Containment Heat Removal Systems***
- ◆ ***Mass & Energy Release***
  - ***Plant specific licensing basis***
  - ***Short-Term Release (RELAP)***
  - ***Long-Term Release (GOTHIC)***

# Containment Analysis Using GOTHIC

## > GOTHIC Options

- ◆ **Blowdown droplet size (100 microns)**
- ◆ **Phase separation per ANSI/ANS-56.4 (flashing to the saturation temperature at containment steam partial pressure)**
- ◆ **Revaporization (8% revaporization fraction for Steam breaks)**
- ◆ **Spray Droplet size (spray nozzle specification)**
- ◆ **Wall condensation**
  - **LOCA : Tagami / Uchida; or MDLM (with NRC restrictions, if available in future GOTHIC versions)**
  - **MSLB: Uchida; or MDLM (with NRC restrictions)**

# Containment Analysis Using GOTHIC

## > **Initial Conditions**

- ◆ **Containment pressure, temperature, & humidity**
- ◆ **Consistent with licensing basis or derived through sensitivity analysis**
  - **Maximum initial pressure for peak pressure analysis**
  - **Low humidity for peak pressure analysis**
  - **Low initial temperature for limiting blowdown peak**
  - **High initial temperature for limiting reflood peak**

# ***Containment Analysis Using GOTHIC***

## **> Containment Heat Sinks**

- ◆ ***Conductors are used to model major structural heat sinks***
- ◆ ***Heat transfer limited to condensation or natural convection***
- ◆ ***No credit is taken for forced convection or radiation***
- ◆ ***When credited, heat transfer from liquid pool based on liquid natural convection***

# ***Containment Analysis Using GOTHIC***

## **> Containment Heat Removal**

- ◆ ***Containment air coolers (fan coolers)***
- ◆ ***Containment spray system***
- ◆ ***RHR heat exchanger loops***
- ◆ ***Recirculation from containment sump***
- ◆ ***Secondary coolant heat exchanger loops for component cooling or service water may also be included***



# Containment Analysis Using GOTHIC

## > Mass & Energy (GOTHIC)

### ◆ Long-Term Mass & Energy (M&E) Release

- *Short-Term generated by RELAP or Plant specific licensing basis*
- *Transition time selected when conditions become quasi-static*
- *GOTHIC / RELAP mass & energy continuous at transition*
- *GOTHIC model includes*
  - *Decay heat*
  - *Stored energy terms for RCS (including SG)*
  - *Conservatively accounts for energy release to containment*
  - *Heat removal systems*
- *Long-term GOTHIC model calculates M&E release*
  - *Predicts steam production in core and heat transfer from remaining heat sources*

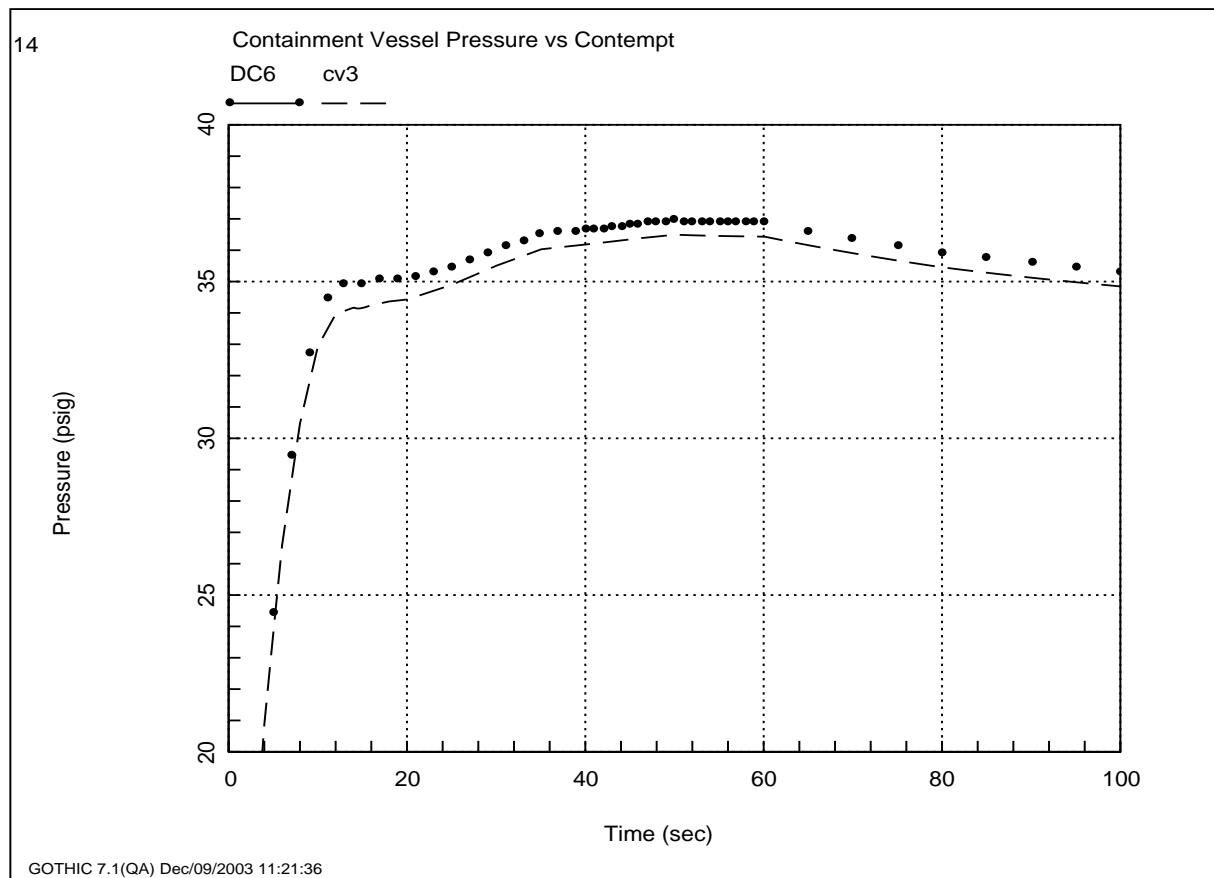
# ***Containment Analysis Using GOTHIC***

## **> *Sample Analysis***

- ◆ ***Hot leg Break***
- ◆ ***Cold leg break RCP suction***
- ◆ ***MSLB***
- ◆ ***GOTHIC response compared to CONTEMPT for short-term transient***
- ◆ ***GOTHIC response agrees well with CONTEMPT***

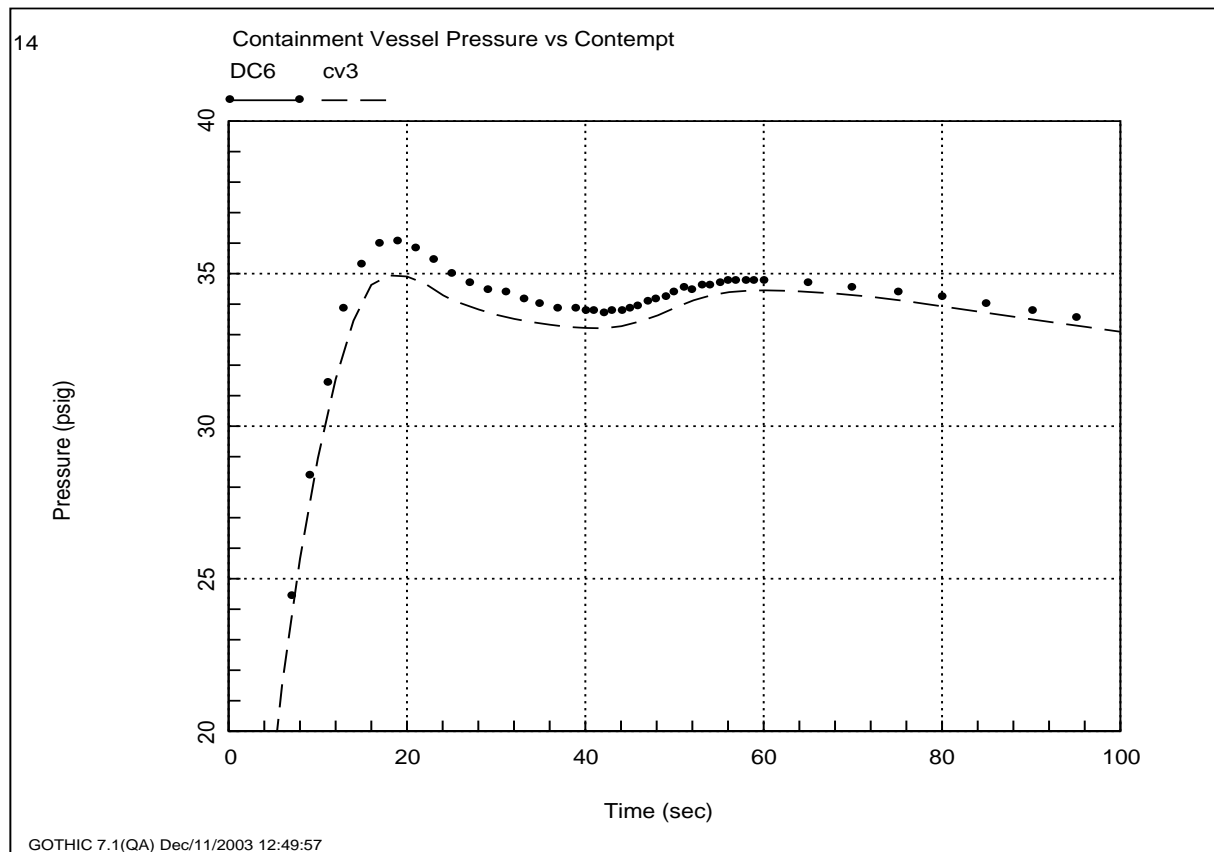
# Containment Analysis Using GOTHIC

## > Hot leg Break



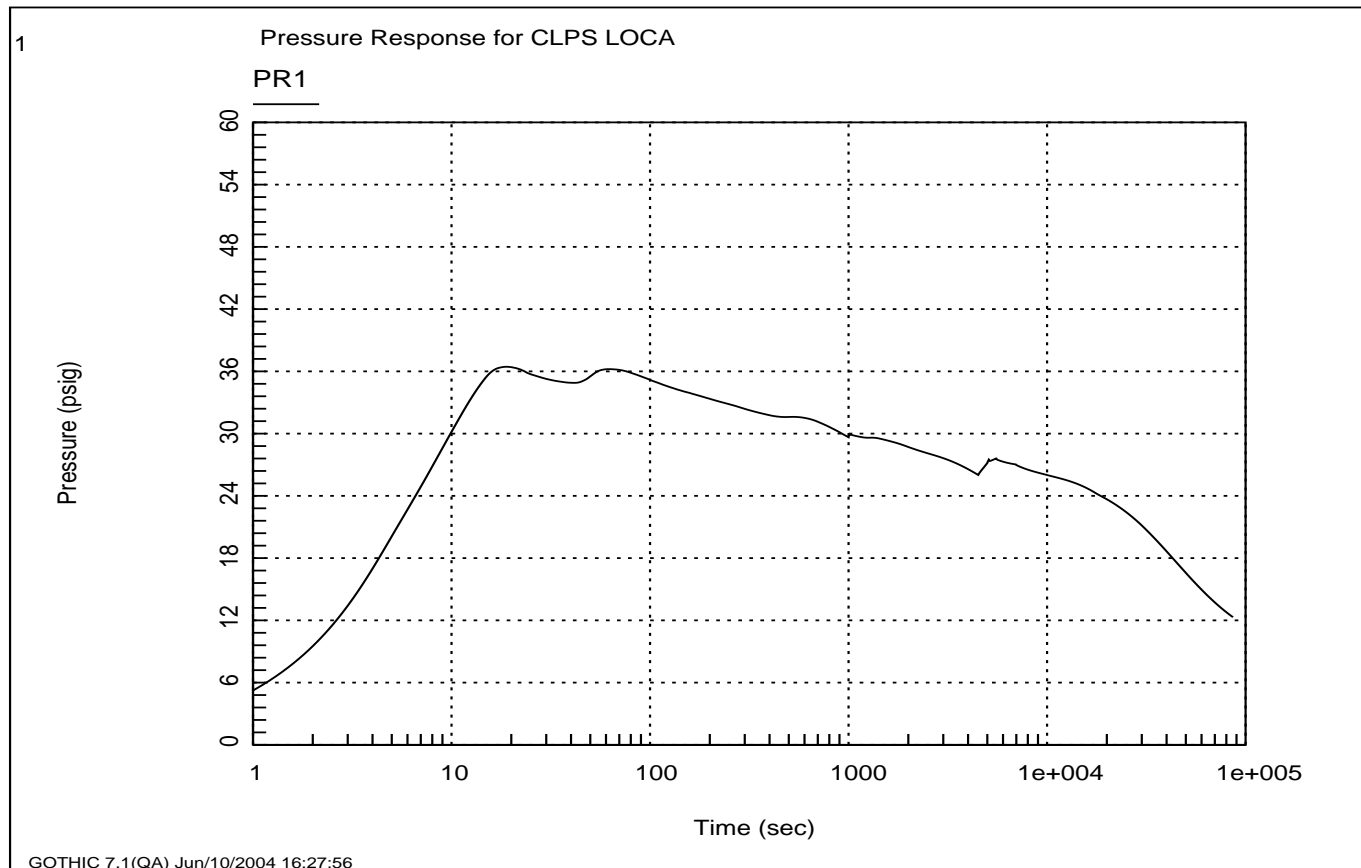
# Containment Analysis Using GOTHIC

## > Cold leg RCP suction Break



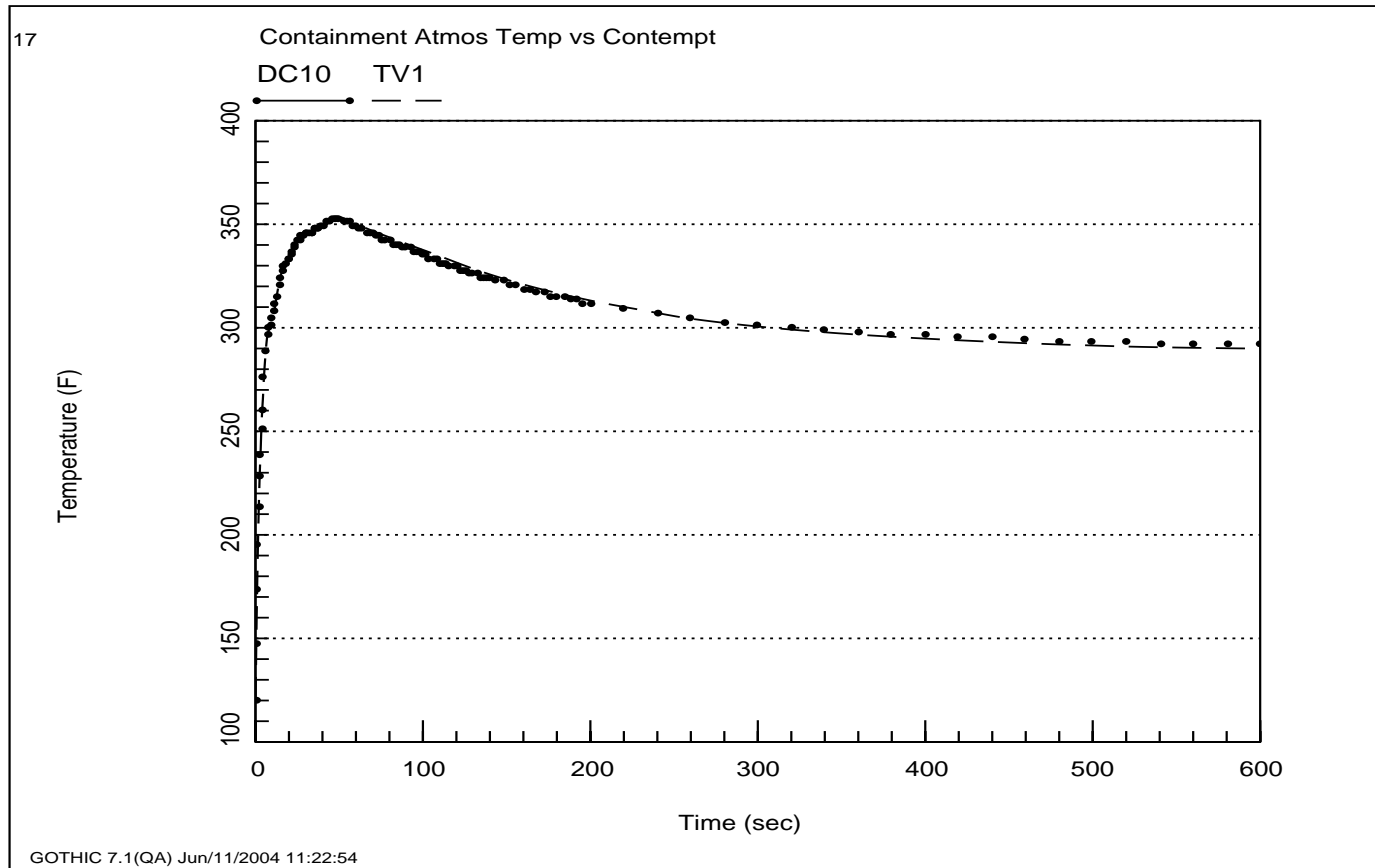
# Containment Analysis Using GOTHIC

> **Cold leg Break RCP suction Break (long-term)**



# Containment Analysis Using GOTHIC

## > MSLB



# ***Mass and Energy Release Rates GOTHIC Boundary Condition***

*Framatome-ANP*

***Keith E. Higar***  
*Principal Engineer-Analysis Services*

**White Flint, Md. September 23, 2004**

# ***Containment Analysis Using GOTHIC***

- > *Mass and Energy Release Rates Source***
  - ◆ *Licensee's Analysis of Record***
  - ◆ *Updated Final Safety Analysis Report (UFSAR)***
  - ◆ *Hand Calculations***
  - ◆ *AREVA – RELAP5/MOD2-B&W (BAW-10252-P)***



# ***Containment Analysis Using GOTHIC***

## **> AREVA – RELAP5/MOD2-B&W (BAW-10252-P)**

- ◆ ***NRC Approved Code (BAW-10164PA)***
- ◆ ***NRC Approved LOCA Methods***
  - ***Once-Through Steam Generators (BAW-10192-PA)***
  - ***Recirculating Steam Generators (BAW-10168-PA)***
- ◆ ***NRC Approved non-LOCA Methods***
  - ***Once-Through Steam Generators (BAW-10193-PA)***
  - ***Recirculating Steam Generators (BAW-10169-PA)***
- ◆ ***NUREG-0800 (SRP Section 6.2.1.3 & 4)***
- ◆ ***ANSI/ANS-56.4***

# ***Containment Analysis Using GOTHIC***

- > Comparison to Standards (Appendix A)**
  - ◆ Guidance of Standards met**
  - ◆ Clarification on the intent of the Guidance**
    - Fuel clad swelling should not be considered**
    - Justification for Refill Period**
    - For CL Breaks, steam leaving the SG should be assumed to be superheated to the temperature of the secondary side fluid**
    - No entrainment assumed in MSLB – level swell explicitly modeled**

# ***Containment Analysis Using GOTHIC***

## **> Summary**

- ◆ ***GOTHIC extensively used in industry***
- ◆ ***FANP overall approach consistent with Industry practice***
- ◆ ***Method flexible, applies to wide range of plant designs with large dry containments***
- ◆ ***Inputs and options conservatively selected***
- ◆ ***Flexibility in use of M&Es***
- ◆ ***Sample calculations for range of breaks demonstrates method***