# Slide Presentation for the BISON Topical Report Pre-Submittal Meeting

## NRC/Westinghouse

## Rockville, Maryland

## May 18, 2006

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# Agenda

- Objectives of the Meeting
- Review of BISON Topical Report Submittals
- Overview of BISON Topical Report Table of Contents
- Pressure Range for AA78 Slip Correlation
- Boron Model Description & Qualification
- ATWS Application & Qualification
- Planned Schedule
- Conclusions

# Objectives of the Meeting

- Present a summary of the justification for Slip and Void Correlation if [ ]a,c
- Present a summary of the boron model and an application example
- Present a proposed schedule for Westinghouse submittal and NRC approval
- Obtain NRC feedback

# BISON :Topical to NRC 1989

- Topical Report RPA 90-90-P-A, Rev. 0, "BISON – A One Dimensional Dynamic Analysis Code for Boling Water Reactors"

  – The original topical describing the BISON code
    – Thermal Hydraulics
    – Fuel Model
    – Kinetics
    – Basic Code validation

# BISON: Supplement to Topical to NRC 1996

- Topical Report CENPD-292-P-A, "BISON – A One Dimensional Dynamic Analysis Code for Boiling Water Reactors: Supplement 1 to Code Description and Qualification," July 1996
  - New steam line model
  - Double Drive loops for Single Loop Operation
  - New void modeling (AA78/EPRI)
  - Validation of new models

# BISON: Supplement to Topical to NRC 2006

- "Supplement to RPA 90-90-PA, BISON model and application for ATWS with Boron insertion", 2006
  - Increased Pressure range for AA78 void correlation
  - Boron reactivity model
  - Boron model validation (versus POLCA)
  - ATWS Application

# Overview of BISON Topical Report Table of Contents

- Introduction
- The Basic Model
- Justification for Slip and Void Correlation if [ ][a,c]
- The Boron Model
  - Boron Concentration Model
    - Available Boron Mass in the System
    - Boron Concentration Model
  - Neutron Kinetics Model
    - Basic Model
    - Boron Cross Section

# Overview of BISON Topical Report Table of Contents (continued)

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# Overview of BISON Topical Report Table of Contents (continued)

- ATWS Application
  - Background
  - Acceptance Criteria
  - Calculations
    - Phase One
    - Phase Two
    - Phase Three
- References

# Pressure Range for AA78 Slip Correlation

- Original AA78 correlation validated to 9.0 MPa
- Extended to 10.0 MPa in original Topical (RPA90-90)
  - Range extension by comparisons with EPRI slip
- Need for increased range for ATWS
  - Range increase to 12.0 MPa suggested
  - Extended comparisons equal to RPA 90-90
  - RMS and bias for range extension added

# Pressure Range for AA78 Slip Correlation

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# Pressure Range for AA78 Slip Correlation

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# Pressure Range for AA78 Slip Correlation

Extrapolation accuracy:

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Conclusions:

- Extrapolation of AA78 slip correlation up to 12 MPa is shown to be similar with the EPRI correlation validated up to15 MPa
- Extrapolation can be made with essentially the same RMA and bias as for the previously validated pressure range

# Boron Model

- Three different models included
  - Boron injection model - Boron Mass into the system
  - Boron concentration model - ppm in the system
  - Boron Reactivity model - $\Delta k_{eff}$ in the core

- Implementation does NOT affect
  - T/H in Topical and Supplement
  - Kinetics model from Topical if Boron is not simulated

# Boron Injection Model

- The following parameters are given as an input to the Boron injection model:

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# Boron Concentration Model

- Calculates the Boron concentration in the reactor vessel based on:
  - Boron solution insertion flow rate
  - Boron mass fraction
  - Available total Boron solution mass
  - A methodology penalty factor
  - A core simulator correction factor

# Boron Concentration Model

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# Boron Concentration Model

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# Boron Concentration Model

- The totally inserted Boron solution MB is calculated as:

$$MB = Bconc * \min(Bmass, (\int_0^t mBs * dt))$$

- To assure conservative calculations an additional factor, EB, is also applied and an effective total amount of inserted Boron, MBe, is calculated as:

$$MBe = EB * MB$$

# Boron Concentration Model

- EB accounts for two effects:

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- The total water mass Mrpv is calculated as:

$$Mrpv = i\sum_{i'1}^{ntot} v(i) * (1 - \alpha(i)) * \rho_f(i)$$

# Boron Concentration Model

- The Boron concentration ($B_{ppm}$) is calculated as:

$$Bppm = 1.E6 * EB * MBe / Mrpv$$

- Bppm is transferred to the kinetics model to calculate the reactivity impact from Boron:

$$Bppm = Bppm0 + 1.E6 * EB * MBe / Vrpv$$

# Boron Concentration Model

- The resulting equation is:

$$Bppm = Bppm\,0 + \frac{1.E6 * EBc * EB3d * MBconc * \min(Bmass, (\int_{t0}^{t} mBS * dt))}{Vrpv = i\sum_{i'1}^{ntot} v(i) * (1 - \alpha(i)) * \rho_f}$$

# Neutron Kinetics Model

- Not changed with respect to the basic equations and nuclear cross section models
  (see Topical Report RPA 90-90-P-A)

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# Boron Reactivity Model

- All cross-sections are calculated as described in the BISON topical report
- An additional set of cross-sections with Boron implemented is used for all fuel types
- From this set the Boron worth is evaluated as a differential cross-section

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# Boron Reactivity Model

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# Boron Reactivity Model

- The Boron reactivity model has the following dependencies for each cross-section:

$$\Sigma = \Sigma(\rho_c, \rho_{bp}, T_c, B_u, B_{ppm})$$

Where:

| | | |
|---|---|---|
| ρc | is the coolant density in the core/bundles | (kg/m3) |
| ρbp | is the coolant density in the bypass | (kg/m3) |
| Tc | is the coolant temperature | (K) |
| Bu | is the burnup | (Mwd/kgU) |
| Bppm | is the Boron concentration | (ppm) |

# Boron Reactivity Model Verification and Validation

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# Initial Conditions

- The state point for all studies selected to be:
  - –Thermal Power 591.4 MW
  - –Core Inlet Temperature 275 °C
  - –Recirculation Flow 3600 kg/s
  - –XenonEquilibrium
- Two different equilibriums cores :
  - –An equilibrium core with SVEA-96 Optima 2 ("Core A")
  - –An equilibrium core with another fuel type with less partial length rods ("Core B") with a smaller Boron reactivity impact caused by the fewer partial length fuel rods

# Initial Conditions

- The Boron calculations were made at three different state points:
  - –BOC (1000 EFPH)
  - –MOC (8000 EFPH)
  - –EOFP (16000 EFPH)
- The calculations were made between 0 - 1200 ppm Boron concentration for "Core A" and between 0 – 900 ppm Boron concentration for "Core B"

# Calculation Results

- The impact on keff from Boron, Δkeff, is calculated according to:

$$\Delta keff = (k_{eff}(0\ ppm) - k_{eff}) / k_{eff}(0\ ppm)$$

Where:

| | |
|---|---|
| $k_{eff}$ (0 ppm) | is $k_{eff}$ with no Boron concentration |
| $k_{eff}$ | is $k_{eff}$ with a Boron concentration of X ppm |
| $\Delta k_{eff}$ | is the differential impact on $k_{eff}$ from Boron |

# Calculation Results POLCA/BISON

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# Calculation Results POLCA/BISON

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# Boron Model Validation

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# Boron Model Validation

- The Tables and Figure in the preceding slides show that both POLCA7 and BISON predict the same trend in core reactivity variation with boron

- The impact of an increasing boron concentration on $k_{eff}$ is almost identical in BISON and POLCA7 for a given cycle-exposure
  - BISON model is considered validated

# Boron Model Validation

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# ATWS Application and Qualification

- The Westinghouse ATWS strategy for a reload is to demonstrate that the introduction of a new fuel type does not have a significant impact on the current licensing basis analysis
- The limiting transients according to the specific plant licensing basis are used as the reference case for ATWS

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# ATWS Application and Qualification

The boron model in BISON can be used to explicitly model the long-term plant response as follows:

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# Westinghouse ATWS application

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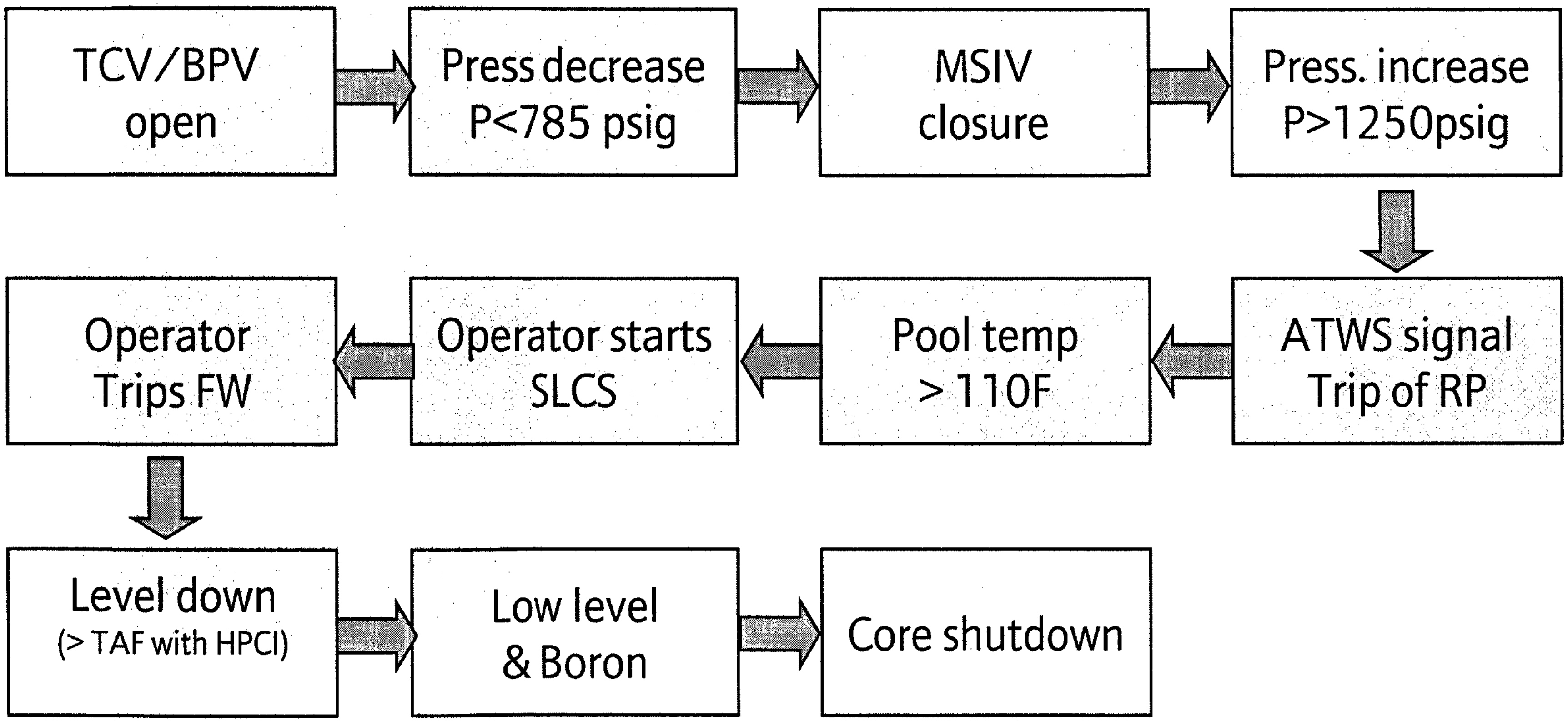
# PRFO Transient Sequence of Events



# Example of ATWS Scenario

- Pressure regulator failure – increasing demand
  - Fast depressurization
  - MSIV closure on low RPV pressure
  - Fast pressurization
  - ATWS signal on high pressure
  - Manual feedwater trip
  - Manual water level control at about 0 above top of active fuel
  - Recirculation stops due to lack of downcomer pressure head
  - Internal Core/Core bypass circulation maintains core cooling
  - Start of Boron injection in the lower plenum

# Example of ATWS Scenario – Pressure

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# Example of ATWS Scenario – Steam Flow

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# Example of ATWS Scenario – Core Flow

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# Example of ATWS Scenario – Water Level

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# Example of ATWS Scenario – Boron Insertion

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# Example of ATWS Scenario – APRM

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# Example of ATWS Scenario – APRM

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# Energy Released to the Containment

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# Suppression Pool Temperature

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# Planned Schedule

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# Conclusions

A second Supplement to the BISON code Topical Report RPA-90-90-P-A will be submitted to:

- Extend the validity range of the AA78 slip correlation to 12 MPa
- Implement the boron concentration model

The main application of these modifications is the ATWS analysis

# Conclusions

- Extrapolation of the AA78 slip correlation is validated by comparison to the EPRI correlation which is valid up to 15 MPa
- The AA78 current validation range is up to 10 MPa and the ATWS peak RPV pressure acceptance criterion for typical BWR/3 reactors is slightly above (10.3 MPa)
- The extension of the AA78 slip correlation was submitted to the NRC as a part of the LAR for the introduction of SVEA-96 Optima2 at Quad Cities and Dresden

# Conclusions

- The boron model is validated by comparison against the 3D core simulator POLCA7
- The purpose of the boron model in BISON is to conservatively calculate the mass and energy released to the containment during an ATWS event
  - The GOTHIC code will be used to calculated the containment loads
  - The GOTHIC code containment models will be submitted separately