Alternative Source Term Analysis Status
Columbia Generating Station

Mike Humphreys, Manager, Rx/Fuels Eng.
Bruce Boyum, Asst. Engineering Mgr.
John Arbuckle, Licensing Technical Specialist
Jim Metcalf, Project Mgr., Polestar

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Energy Northwest

Overview

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Introduction

- Last Meeting - October 2000
  - Energy Northwest discussed technical issues and schedule using AST Methodology to resolve outstanding issues and Deactivation of MSLC
  - Action items resulted for Energy Northwest and NRC
  - Agreement on follow up meeting

Introduction

- Meeting Purpose
  - Review actions from last meeting
  - Provide update on Energy Northwest AST analysis including preliminary results
  - Discuss technical issues and content of submittal
  - Discuss future direction of Licensing Submittal

Action Item Review

- Energy Northwest
  - Provide listing of computer codes versus their application (Complete)
  - Provide reference for technical background on aerosol impaction (Complete)
  - Evaluate crediting Control Room recirc filters (Dropped from consideration following October, 2000 meeting)

Action Item Review

- NRC
  - Coordinate review of technical issues with other NRC projects (Oyster Creek, etc.):
    - Use of MAAP for thermal hydraulic analysis
    - Aerosol impaction
    - ESF leakage release fraction (<10%)
    - MSIV leakage source term

Analysis Objectives

- Primary Objectives (Unchanged)
  1) Resolve the Secondary Containment Drawdown USQ and JCO
  2) Resolve Control Room Inleakage USQ
  3) Deactivation of Main Steam Leakage Control System (MSLC)
- Secondary Objectives (Unchanged)
  4) Increase Allowable Secondary Containment Bypass Leakage
  5) Increase Allowable MSIV Leakage

Project / Schedule Update

ID	Task Name	Schedule to NRC 6/00 Finish Date	Current Schedule (Draft) Finish Date
1	Evaluate CR Envelope	10/16/00	Complete
2	Develop Procedures	8/31/00	Complete
3	Conduct Testing	9/8/00	Complete
4	Finalize Results	10/16/00	Complete
5	Finalize CR X/Q	9/15/00	Complete
6	Complete Input Data	9/15/00	Complete
7	Review MSLC Feasibility Study	7/10/00	Complete
8	Select AST Vendor	7/31/00	Complete
9	Complete AST Analysis	1/31/01	Complete
10	Review / Approve Dose Calcs	4/16/01	5/2/01
11	Revise Related Calculations	4/16/01	5/16/01
12	Complete Licensing Submittal	6/15/01	6/15/01
13	Submit to NRC	6/29/01	6/29/01

Technical Topics

- Application of Containment Thermal-Hydraulic Analysis Results
- Suppression Pool Scrubbing
- Crediting of Drywell Sprays
- Aerosol Impaction at Entrance to Inboard MSIV
- Iodine Release from ESF Leakage
- Control Room X/Q Methodology (ARCON96)
- MSLB X/Q Methodology (expansion and movement of puff release)

- Energy Northwest Considers Above Technical Approaches Do Not Conflict With Reg Guide 1.183.

1) Application of Containment Thermal-Hydraulic Analysis Results

- Containment T/H Data Used for:
  - Determination of When Drywell Sprays May Be Expected to Operate
  - Specification of Drywell Conditions for Spray Removal Rate Calculation
  - Quantification of Drywell-to-Wetwell Flow (End of Release Phase at Time of Core Quench)
  - Justification of 50% Reduction in Containment and MSIV Leak Rate at 24 Hours (RG 1.183)

1) Application of Containment Thermal-Hydraulic Analysis Results

- Case for Large LOCA as T/H Basis
  - Maximum Activity Release to Containment
  - Minimum Time for Noble Gas Decay
  - NUREG-1465 with respect to timing: "[F]or PWRs, a large LOCA is considered a reasonable initiator to assume … should not unduly penalize BWRs and will maintain consistency …"
  - NUREG-1465 with respect to composition and magnitude: "[T]he composition and magnitude of the source term has [sic] been chosen to be representative of … low pressure in the RCS …"

1) Application of Containment Thermal-Hydraulic Analysis Results

- Events Investigated:
  - Large Recirculation Suction Break
  - Steam Line Breaks Both Upstream and Downstream of Flow Limiter (Large and Small)
- Large Steam Line Break Appears Most Limiting as it is the Greatest Challenge to Spray Operation
- Sensitivity Study for Spray Operation: Variations in Drywell Initial Temperature and Relative Humidity, Service Water Temperature, and Hydrogen Production were Evaluated

1) Application of Containment Thermal-Hydraulic Analysis Results

- Containment T/H Data Obtained from MAAP4 Analyses Reflects Lower Pool Temp and Drywell Pressure than Chapter 6.2 Containment DBA
- ECCS (HPCS) Assumed to Be Restored at End of In-Vessel Release Phase
  - No Vessel Failure
  - No Core Debris Relocation from Core Region
- MAAP4 Activity Release from Core (Timing and Magnitude), Activity Transport, and Dose Calculation Modeling Ignored

1) Application of Containment Thermal-Hydraulic Analysis Results

- Conservatisms
  - Effects of Drywell Steam Condensation (Predicted by MAAP4) Ignored for Activity Removal
  - Prolonged (2 hr) Period of High Activity Concentration in Drywell before Sweep-Out
  - Suppression Pool Bypass Maximized to Minimize Suppression Pool Scrubbing, but Not "Credited" in Assessment of Spray Operation

1) Application of Containment Thermal-Hydraulic Analysis Results

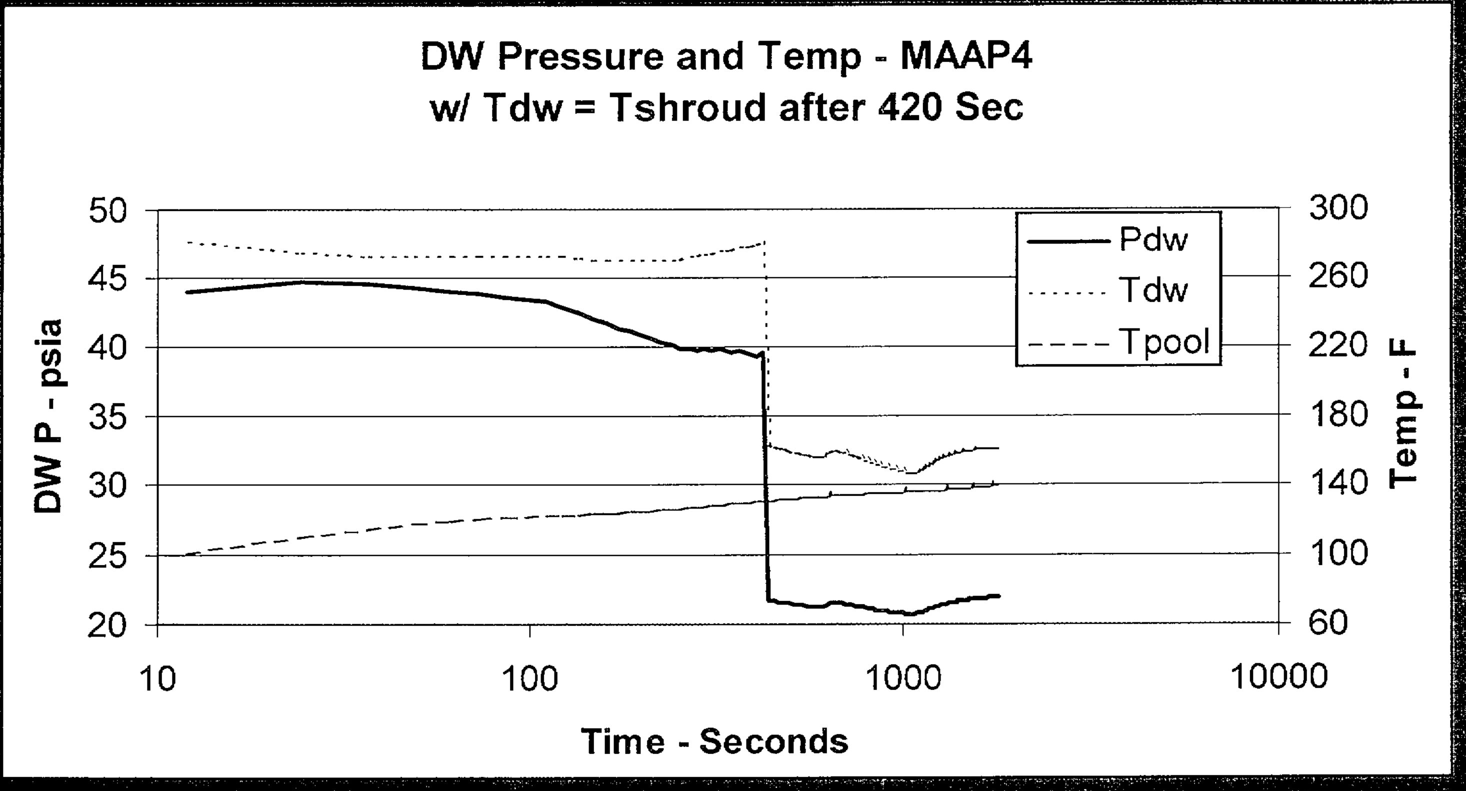
- Benchmarking
  - Comparison of MAAP4 to Chapter 6.2 Containment DBA
  - Power Uprate Revised Only Case "C" (No Spray)
  - Long-Term DW Pressure and Temp and Suppression Pool Temp Considered
  - Dramatic Decrease in DW Pressure and Temp (FSAR Fig 6.2-10 and 6.2-11) after ~420 Sec Believed Due to DW Temp = Spillage Temp Assumption in GE Methodology

1) Application of Containment Thermal-Hydraulic Analysis Results

- Benchmarking
  - MAAP4 Recirc LOCA Run with Case “C” Assumptions (Initial Conditions, No Sprays)
  - MAAP4 Uses Somewhat Lower Decay Heat, Higher HPCS/LPCI Flows, More Effective RHR HX
  - Expectation That Suppression Pool Temp and DW (Spillage) Temp Would be Less Than Chapter 6.2
  - At 1800 Sec
    - Pool Temp = 140 F (MAAP4), 170 F (Ch 6.2)
    - DW Temp = 162 F (MAAP4), 206 F (Ch 6.2)

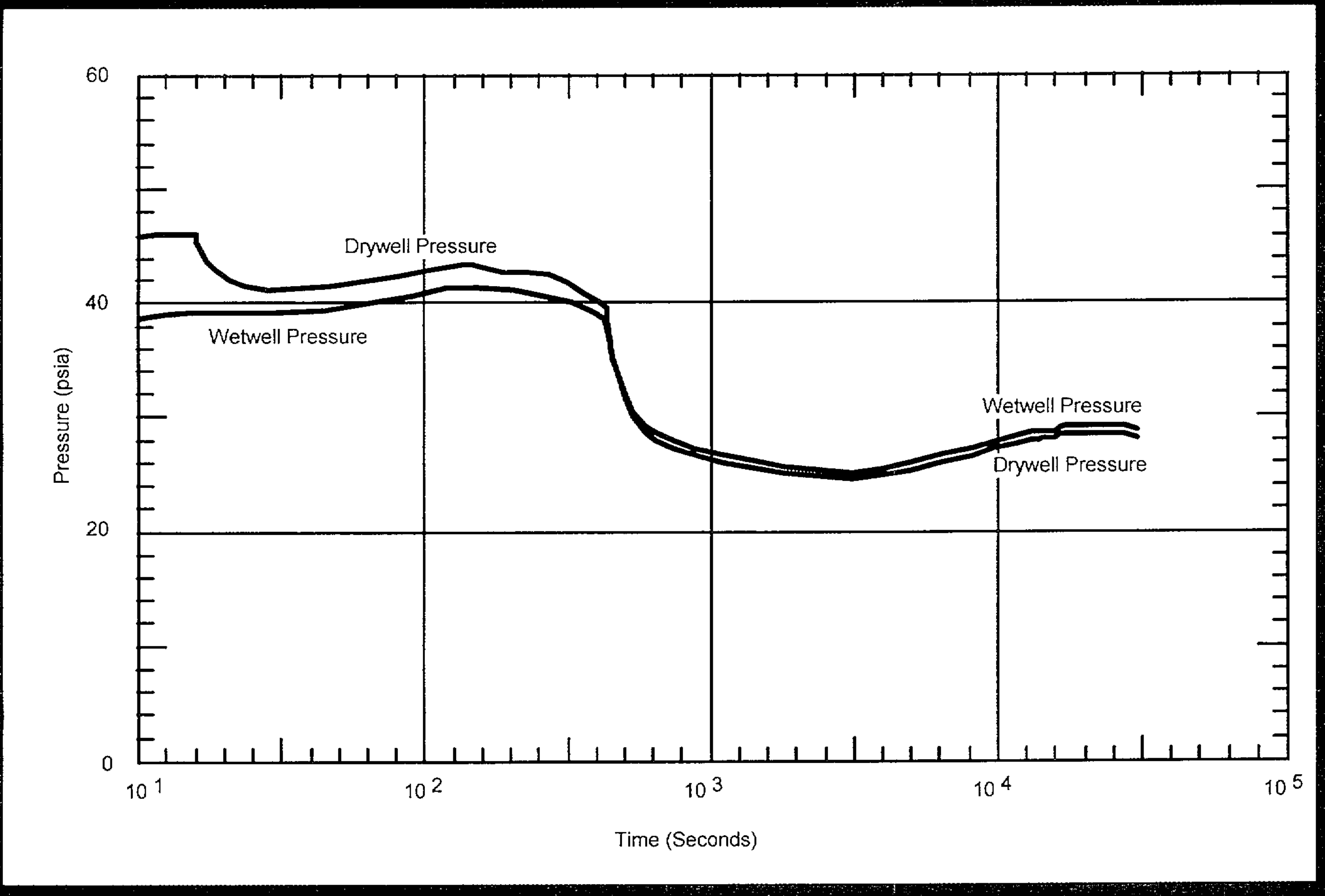
1) Application of Containment Thermal-Hydraulic Analysis Results

Benchmarking



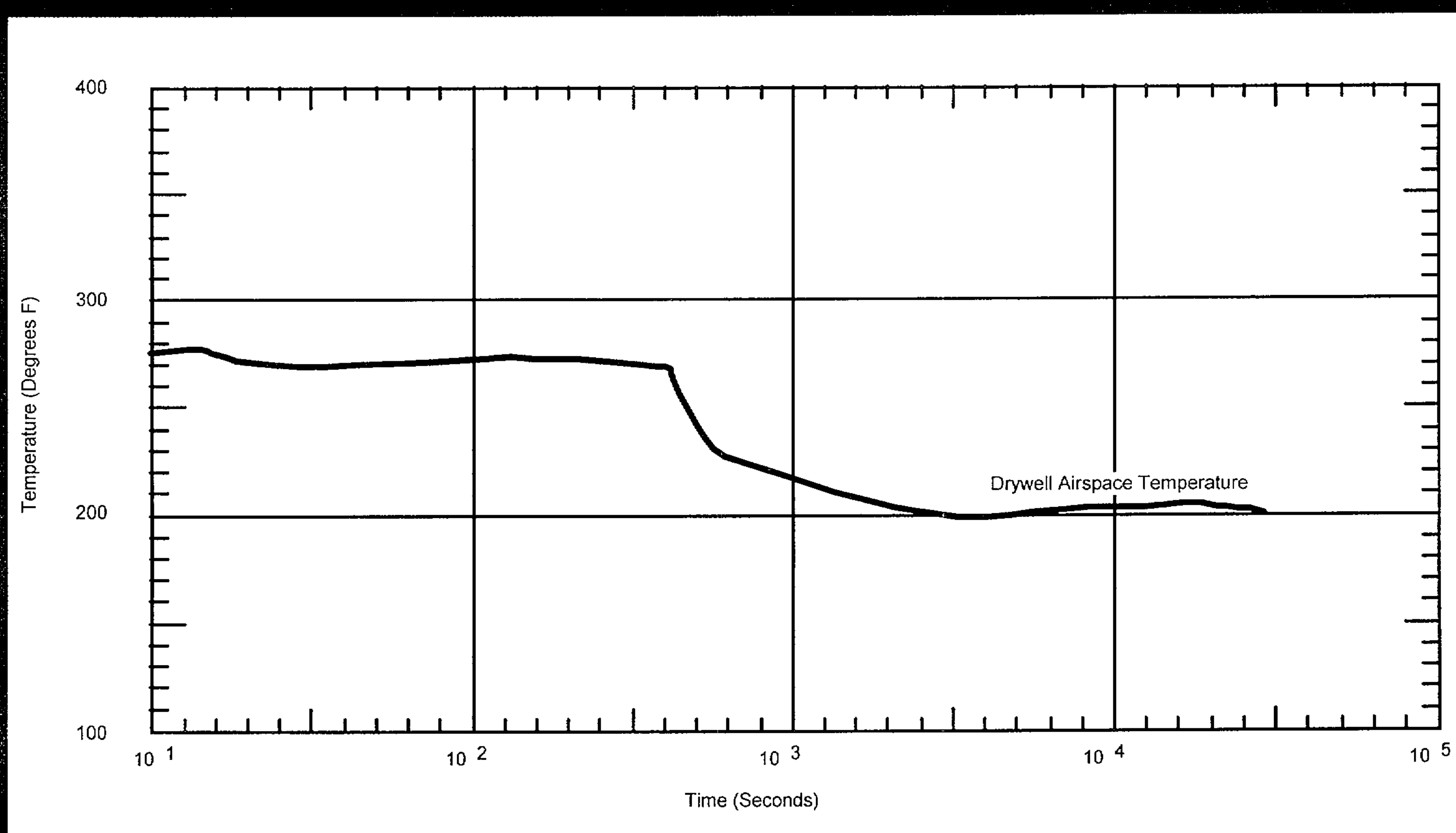
Application of Containment Thermal-Hydraulic Analysis Results

- FSAR 6.2-10 Containment Pressure Response



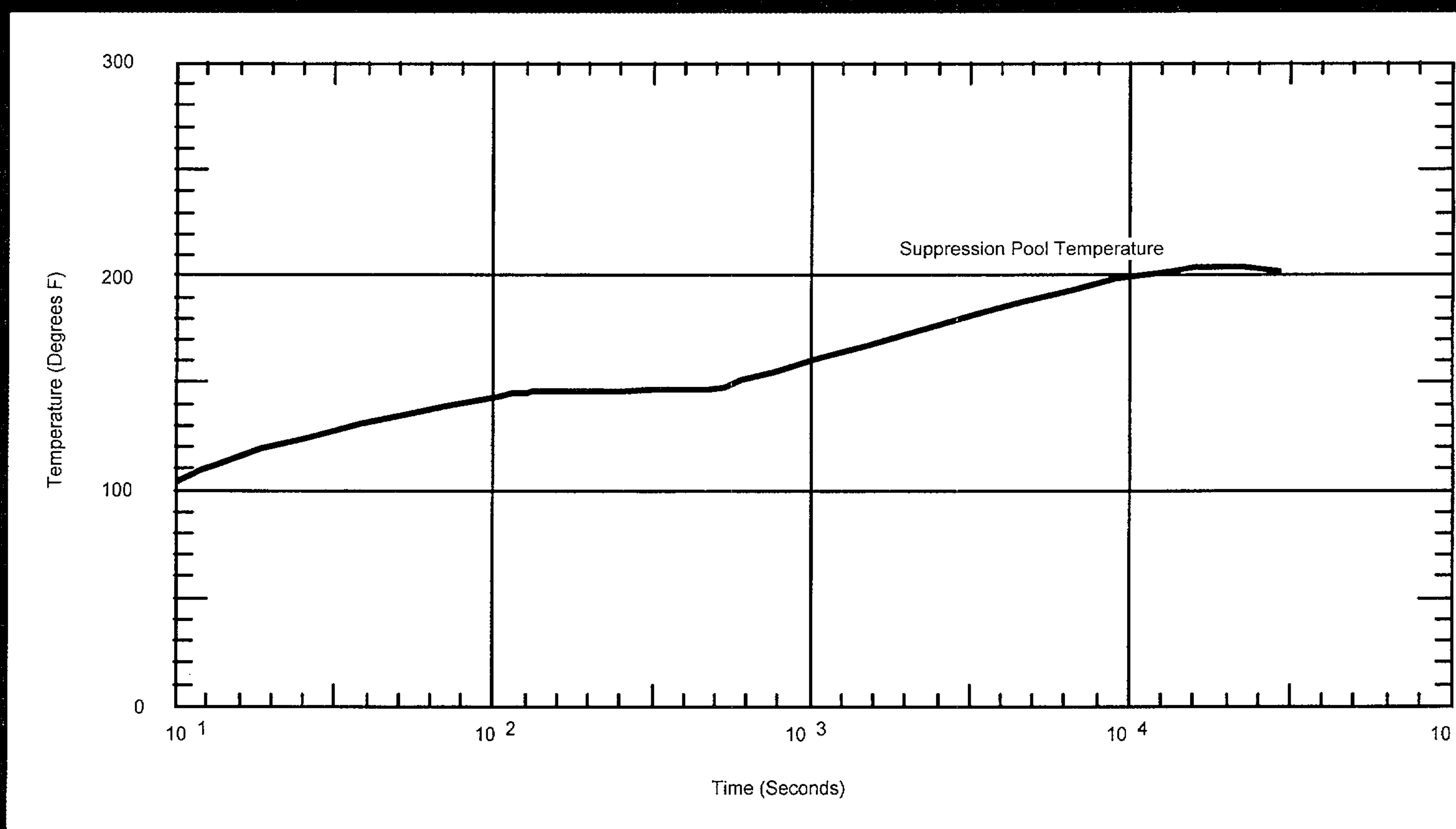
Application of Containment Thermal-Hydraulic Analysis Results

- FSAR 6.2-11 Containment Temperature Response



Application of Containment Thermal-Hydraulic Analysis Results

- FSAR 6.2-12 Containment Temperature Response



1) Application of Containment Thermal-Hydraulic Analysis Results

- Benchmark Summary and Implications
  - MAAP4 Results Qualitatively Similar to Chapter 6.2 DBA if $T_{DW} = T_{Shroud}$
  - Close Correspondence of MAAP4 and Chapter 6.2 DBA (with Quantified Explanation of Differences) Supports Use of MAAP4 for AST Application
  - In Contrast to Chapter 6.2 DBA, MAAP Includes
    - » Lower Decay Power
    - » Greater ECCS Flow and RHR HX Performance
    - » Structural Heat Sinks

1) Application of Containment Thermal-Hydraulic Analysis Results

- Benchmark Summary / Implications (Con't)
  - MAAP4 Model Produces Lower Coolant Return Temperature to Containment than Chapter 6.2 DBA (Injection or Spray)
  - Failed or Degraded Core Cooling Will Further Limit Energy Transfer to Containment - Use of Severe Accident T/H Important for AST Applications
  - MAAP4 (Severe Accident) T/H More Conservative than Containment DBA for Columbia
  - Similar Conclusion Reached for AP-600

1) Application of Containment Thermal-Hydraulic Analysis Results

- NRC Staff Report of Oyster Creek MAAP Review (October, 2000 Meeting Action Item)

2) Suppression Pool Scrubbing

- Permitted by SRP 6.5.5
- DF=2 Used for ABWR Design Certification Based on:
  - MAAP Analysis
  - Applied to Instantaneous TID-14844 Release
- Pool Flow and Pool Bypass Must Be Realistically Treated and Conservatively Quantified
  - No Flow Through Pool During Activity Release
  - Steam/Hydrogen Production When Core Debris Finally Quenched Observed to Be Considerable – Little Bypass
- For Columbia
  - ~50% of DW Contents Purged at End of Release
  - DF ~10 at That Time Yields Overall DF ~2

3) Crediting of Drywell Sprays

- Spray Operation Assumptions
  - EOPs and SAGs Direct Spray Operation
  - Spray Operation When Radiation Dose Rate Approaches 14,000 R/Hr in Drywell
    - Must Be within Safe Region of DSIL Chart to Start
    - Sprays Will Be Terminated when Pressure Reduces to 1.68 PSIG
  - One Loop of Spray Assumed to Begin at 15 Minutes After Start of Accident (Approx 13 Minutes After Start of Release)
  - 14,000 R/Hr in Drywell Reached ~200 Sec After Start of Accident Based on Noble Gas Alone

3) Crediting of Drywell Sprays

- Spray Design and Activity Removal in DW
  - Spray Flux Much Higher in Drywell Than in PWR Containment
    - Columbia Spray Flux = ~ 0.025^{+} $cm^3/s\text{-}cm^2$
    - Typical PWR Range = 0.005 - 0.01 $cm^3/s\text{-}cm^2$
  - Excellent Mixing Expected
  - Spray Credit Recognizes Droplet Loss Due to Impingement at Spray Exit and Reduced Fall Height Caused by Obstructions
    - Columbia Using 57% of DW Spray Flow (Not for T/H)
    - Columbia Using 8' Fall Height from Upper Header

3) Crediting of Drywell Sprays

- Conservatism of Columbia Application
  - Lambda = 1.5Fh/V(e/D)
  - F and h Minimized (as Discussed)
  - (e/D) Ignores Hygroscopicity of Cs Compounds
- Other BWRs Crediting DW Sprays for Activity Removal
  - Perry (STARNAUA Used for Lambdas)
  - Grand Gulf (Lambdas Compared to STARNAUA – STARNAUA Slightly Conservative)
  - Oyster Creek (STARNAUA Used for Lambdas)

4) Impaction at Entrance to Inboard MSIV

- Aerosols Have Difficulty Following Carrier Gas Streamlines Around/Through Obstructions
- Stokes Number Characterizes Degree of Departure from Streamlines Where:

  $Stk = Constant * u L_p^2 \rho_p / \mu_g L'$

  - u = Speed Approaching Obstruction,
  - L_p, ρ_p = Particle Characteristic Length, Density
  - μ_g = Gas Viscosity
  - L' = Obstruction Characteristic Length

4) Impaction at Entrance to Inboard MSIV

- Leak Path Plugging Predicted When "Suspended Mass Carried to or Past Plug" = KD^3 Where K = 30 $\pm$ 20 g/cm^3 (Model Developed by Vaughan and Reported by Morewitz – IDCOR References Provided)
- For MSIV Leak "Orifice"
  - D = ~ 0.07 cm at 25 SCFH/MSIV
  - D = ~ 0.12 cm at 75 SCFH/MSIV
- Plugging Predicted When
  - 0.016 g Leaked (max) for 25 SCFH/MSIV
  - 0.082 g Leaked (max) for 75 SCFH/MSIV

4) Impaction at Entrance to Inboard MSIV [Existing Overhead Except for Last Bullet]

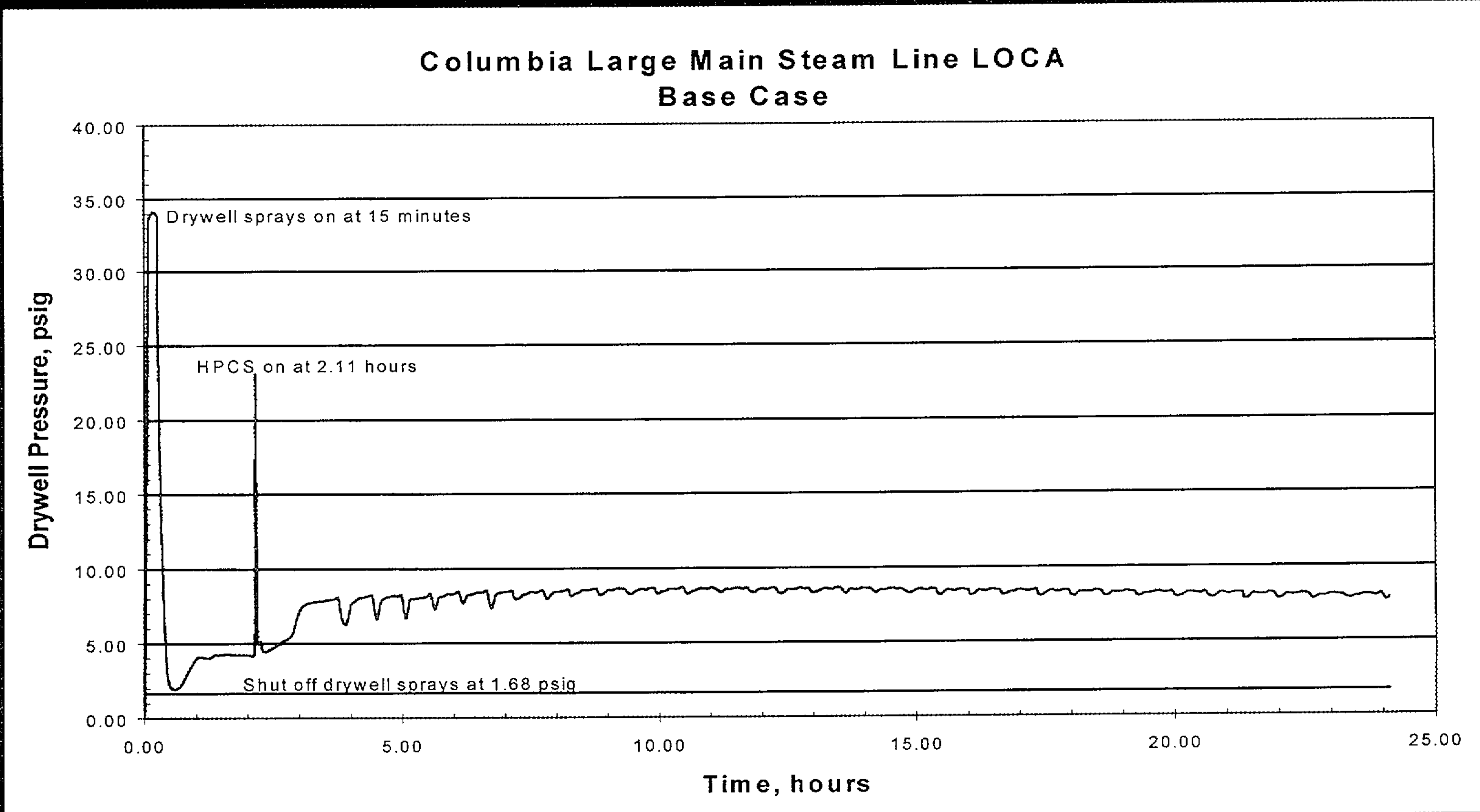
- Plugging Concept Can Be Used to Justify DF
- DF=2 is a Conservative Minimum for WNP-2
  - at 25 SCFH/MSIV Analysis Shows 1.2 g Leaked (w/ DF=2)
  - at 75 SCFH/MSIV Analysis Shows 3.6 g Leaked (w/ DF=2)
- Actual DFs Based on Plugging Would Be 75 for 25 SCFH/MSIV and 44 for 75 SCFH/MSIV
- EnergyNW Claiming Only DF of 2 for MSIV
- No Other Plugging DF Credit Being Claimed

4) Impaction at Entrance to Inboard MSIV

- NRC Position on Issue 13A Stated in IDCOR Report 86.1
  - "For Driving Pressures up to a Few Tenths of an Atmosphere, the Vaughan Model Can Reasonably Be Trusted to Be Applicable to Ducts of Less than a Centimeter in Diameter."
    - » See Next Overhead for Pressure Difference
    - » Leak Path Approx 1 mm Max in Diameter
  - "In Such Applications, the Vaughan Model Should Be Taken to Predict the Mass of Aerosol Escaping Through the Duct Prior to Plugging."
    - » Acceptable to EnergyNW

4) Impaction at Entrance to Inboard MSIV

Illustration of Driving Pressure for MSIV Leak



4) Impaction at Entrance to Inboard MSIV

- NRC Staff Report of IDCOR/Oyster Creek Aerosol Impaction Review (October, 2000 Meeting Action Item)

5) Iodine Release from ESF Leakage

- AST Analysis Uses 10% Iodine Release Fraction
- ESF Leakage Occurs within Confined Areas of the RB
- Elemental/Organic Iodine Released by ESF Leakage Determines Need for Charcoal Filtration in SGTS
- Analysis of ESF Liquid Demonstrates a pH >8
- Room Volumetric Flowrate of 10000 cfm results in Iodine Release Fraction of < 0.1%
- This is a Significant Conservatism in the Analysis

5) Iodine Release from ESF Leakage

- Iodine Release Analysis Used Technical Approach Previously Used By TMI-1 and IP-2
- NRC Staff Report of TMI-1 and IP-2 Iodine Release Review (October, 2000 Meeting Action Item)

6) Control Room X/Q Methodology

- ARCON96 analysis updated in accordance with draft NRC direction
- Draft calculation utilizing Murphy/Campe methodology examined using 0.5 m/s wind speed
- ARCON96 and Murphy/Campe results are similiar
- Using ARCON96 updated analysis
- Peer Review Comment Resolution Ongoing

7) MSLB X/Q Methodology (expansion and movement of puff release)

- Principal Issue is MSLB X/Q for Control Room
- Features of Energy Northwest Application
  - MSLB In Steam Tunnel or Turbine Building
  - Steam Tunnel Released to Atmosphere And/Or Turbine Building
  - Volume of Steam "Bubble" = Approx $6x10^4$ m^3
  - Comparable to Volume of Turbine Building
  - Atmospheric Release from Either Steam Tunnel Blowout Panel or Turbine Building Roof

7) MSLB X/Q Methodology (expansion and movement of puff release) (Cont'd)

- Features of Energy Northwest Application
  - Initial Dispersion by Expansion of Released Steam
  - Further Dispersion by Substantial Transient Buoyant Plume Rise
  - Rise Evaluated as Sphere and Hemisphere
  - Minimum Entrainment and Dilution Observed for Spherical Bubble Treatment
  - Dilution Assumed in Dose Analysis is Average of Leading Edge Dilution and Trailing Edge Dilution (~ a Factor of 10 Reduction)

7) MSLB X/Q Methodology (expansion and movement of puff release (Con't)

- Comparison to RG 1.78 (for Toxic Gas Puff)
  - Reg Guide Expression Reduces to $X/Q_l \cong [\sqrt{2\pi^3}\,\sigma_l^3]^{-1}$ for
    - Point of Maximum Concentration, and When
    - σ_x^2, σ_y^2, and σ_z^2, $<< \sigma_l^2$
  - Since by Definition $\sigma_l^3 = Q_l / \sqrt{2\pi^3}\, X_0$, then
  - $X \cong X_0$ (i.e, Concentration Near Point of Release = Density of Toxic Gas at Standard Conditions)

7) MSLB X/Q Methodology (expansion and movement of puff release (Con't)

- Comparison to RG 1.78 (Con't)
  - "Standard Conditions" Not Applicable to Steam Release (Instead Assume Saturation at P = 1 Atm)
  - For Columbia MSLB Steam Release, $\sigma_l \cong 18$ m
  - Figures 1 and 2 of Reg Guide: σ Data Available for Distance from Release Point $\geq$ 100 m
  - At 100 m: $\sigma_x = \sigma_y = 4$ m and $\sigma_z = 2.2$ m (for F Stability); i.e., σ_x^2, σ_y^2, and σ_z^2, $<< \sigma_l^2$
  - Conclusion: Reg Guide Concentration Nearly Constant within 100 Meters of Release

7) MSLB X/Q Methodology (expansion and movement of puff release (Con't)

- Comparison to RG 1.78 (Con't)
  - For Columbia MSLB Steam Release:
    $X/Q_I \cong [\sqrt{2\pi^3}\ \sigma_I^3]^{-1}$ and for $\sigma_I \cong 18$ m
    $X/Q_I \cong 2E\text{-}5\ /m^3$
  - For 0.2 μCi/g DE I-131 at Power:
    Release (Q_I) = 9.5 Ci DE I-131
    Expanded Concentration (X) = 2E-4 Ci DE I-131 / m^3
  - Note that Example Assumes All Iodine Becomes Airborne - This is Also True for Columbia Calculation

7) MSLB X/Q Methodology (expansion and movement of puff release (Con't)

- Comparison to RG 1.78 (Con't)
  - For Plume Release (As Modeled in Dose Codes):
    - Concentration over Duration of Plume = Release Rate (Ci/sec) x X/Q (sec/m^3)
    - X/Q = 2E-4 Ci/m^3 / 9.5 Ci x Release Time, sec
  - Columbia Assumes 61 sec Release (i.e., Plume Passage) Time (Hemisphere at 1 m/s)
  - Effective X/Q for Columbia (Using Reg Guide Methodology) Would Be Approx 1E-3 sec/m^3
  - Columbia Using Instead 1E-4 sec/m^3 (Buoyancy of Puff Considered)

7) MSLB X/Q Methodology (expansion and movement of puff release) (Cont'd)

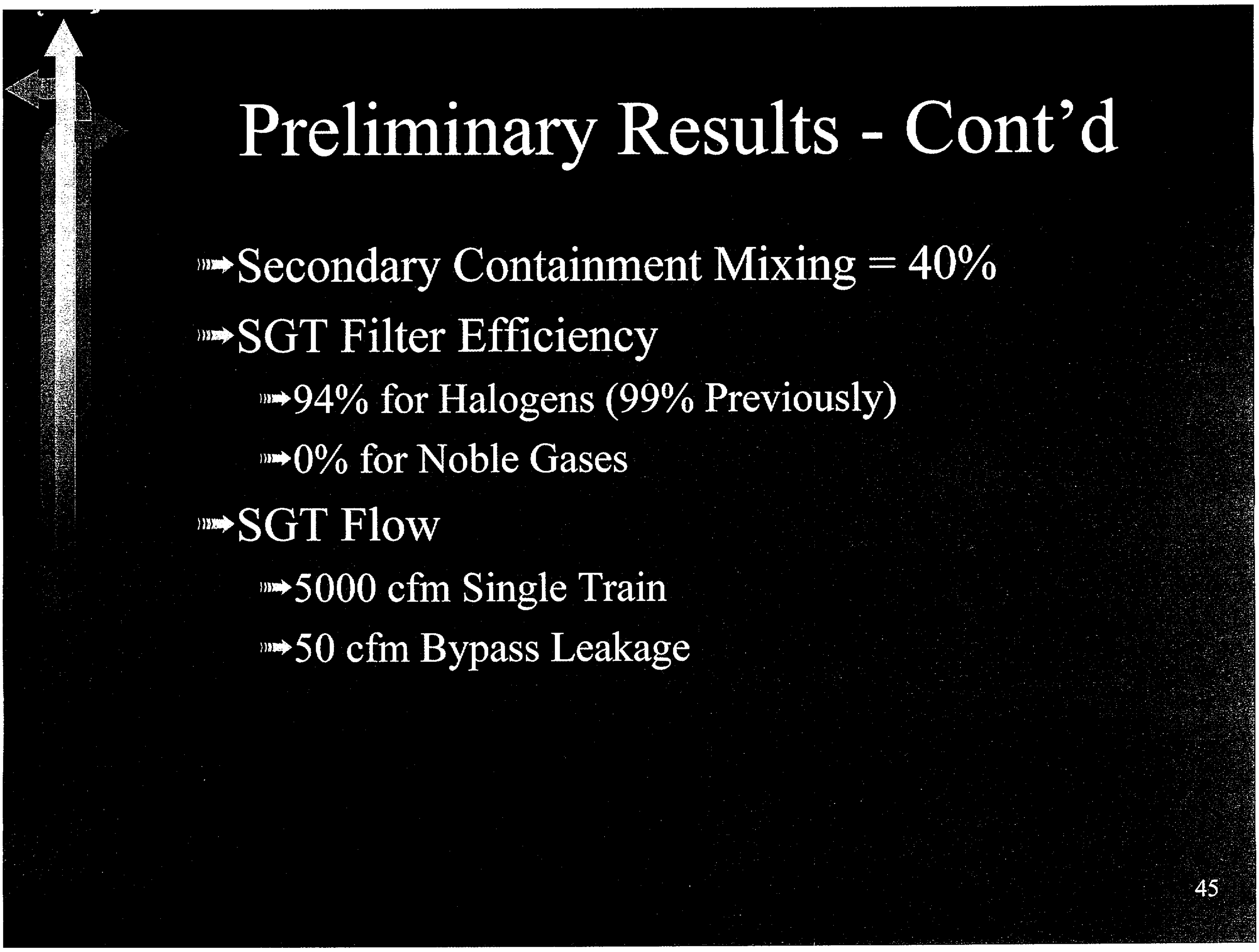
- Energy Release Rate for BWR MSLB Very Large - Typically of the Order of 10E10 Joule
- Two Independent Confirmations Made of Simple Model
  - CALPUFF Code Used to Calculate the Relative Concentration of Plume at Receptor Location (i.e., the CR Local Intake). CALPUFF Predicted Dilution Factors of 10^5 Minimum
  - UC Berkeley Consultant Also Asked to Review Problem – Numerically-Integrated Puff Model Yielded Results Within Approximately a Factor of 4 of CALPUFF
- Factor of 10 Dilution Appears Very Conservative

Preliminary Results

- Control Room Doses Limiting All Cases
- LOCA Doses Bound Non-LOCA Accidents
- Non-LOCA Accidents Analyzed
  - CRDA
  - FHA
  - MSLB Outside Containment

Preliminary Result - Cont'd

- LOCA Analysis Major Assumptions
  - Containment Leakage = 0.5%/day (vs 0.32%/day)
  - Secondary Containment Bypass Leakage = .04%/day (14.5 scfh vs 0.74 scfh currently)
  - Secondary Containment Drawdown Time = 20 minutes (6.2 minutes calculated)
  - During Drawdown Time:
    - No SGT Filtration Credited
    - Sec Ctmt Leakage Rate = 1 vol/day
    - Containment Leakage Directly to Environment


Preliminary Results - Cont'd
Secondary Containment Mixing = 40%
SGT Filter Efficiency
94% for Halogens (99% Previously)
0% for Noble Gases
SGT Flow
5000 cfm Single Train
50 cfm Bypass Leakage
45

Preliminary Results Cont'd

- Control Room Filter Efficiency
  - 94% for Elemental and Organic Iodine (95% Previously)
  - 94% for Particulate Iodine (99% Previously)
- ESF Leakage Into Secondary Containment
  - 1 gpm (2 gpm used in Calculation)
  - 10 % Iodine Release Fraction (< 0.1% Calculated)

Preliminary Results Cont'd

- Control Room Inleakage
  - Measured Leakage = 82 +/- 36 scfm and 76 +/- 24 scfm (Train A and B)
  - Analyzed Leakage
    - 300 cfm/150 cfm (before/after 30 minutes)
    - 300 cfm/200 cfm
    - 350 cfm/200 cfm
    - 300 cfm for entire accident

Preliminary Results Cont'd

- Dose Analysis Results
  - Variables in analysis:
    - Control Room Inleakage
    - ESF Leakage Treatment
      - Release Fraction
      - Credit SGT Charcoal
    - MSIV Leakage

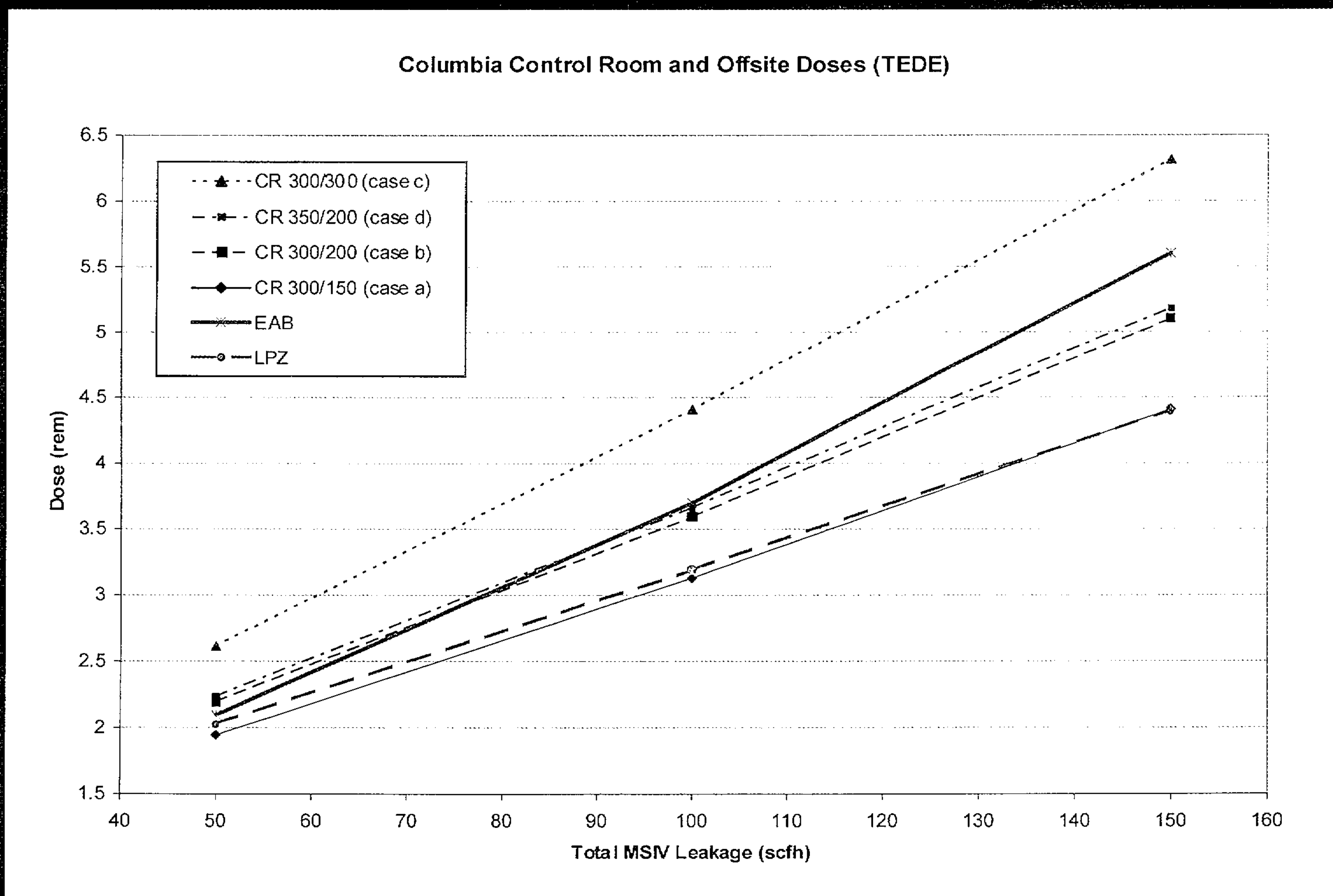
Preliminary Results Cont'd

- Offsite and CR TEDE From ESF Leakage Iodine Release (10% Release Fraction)

CR Inleakage(1)	CR(2)	EAB(2)	LPZ(2)
300/150	.874	.02	.26
300/200	1.068	.02	.26
300/300	1.434	.02	.26
350/200	1.088	.02	.26

(1) Leakage in CFM. Initial Leakage/Leakage After 30 min.
(2) Dose in REM TEDE.

Preliminary Results (cont'd)



Preliminary Results Cont'd

- Example LOCA Dose Results:
  - Case 1
    - MSLC Deleted
    - Control Room Inleakage = 300cfm/150cfm,
    - Total MSIV Leakage = 100 scfh
    - ESF Iodine Release = 10%
    - SGTS Charcoal Credit = Yes
      - Dose (TEDE):
        - CR = 4.57 R (0.87 R ESF, 0.5 R Shine)
        - EAB = 3.72 R (.02 R ESF)
        - LPZ = 3.46 R (0.26 R ESF)

Preliminary Results Cont'd

- Case 2
  - MSLC Deleted
  - Control Room Inleakage = 300cfm/150cfm,
  - Total MSIV Leakage = 100 scfh
  - ESF Iodine Release = 0.1%
  - SGTS Charcoal Credit = No
    - Dose (TEDE):
      - CR = 4.02 R (0.12 R ESF, 0.5 R Shine)
      - EAB = 3.73 R (0.003 R ESF)
      - LPZ = 3.31 R (0.03 R ESF)

Preliminary Results Cont'd

- Other Accident Analyses (Using Control Room Inleakage = 300cfm/150cfm):
  - Fuel Handling Accident:
    - CR Dose = 0.58 R TEDE
    - EAB = 0.64 R
    - LPZ = 0.21 R
    - Results Not Sensitive to SGT Charcoal Filtration

Preliminary Results Cont'd

- Control Rod Drop Accident:
  - CR Dose = 0.388 R TEDE
  - EAB = 0.021 R
  - LPZ = 0.024 R
- Main Steam Line Break Accident:
  - CR Dose = 0.014 R TEDE
  - EAB = < 1% of Limit
  - LPZ = < 1% of Limit

Preliminary Results (cont'd)

- Tech Spec Changes Anticipated
  - Section 3.6.1.3 - Primary Containment Isolation Valves
    - Increase Secondary Containment Bypass Leakage from 0.74 scfh to 0.04%/day (14.5 scfh) and revise the allowable MSIV leakage
  - Section 3.6.1.8 - Main Steam Isolation Valve Leakage Control (MSLC) System
    - Delete the MSLC System

Preliminary Results (cont'd)

- Section 3.6.4.1 - Secondary Containment
  - Change the Surveillance Requirement to Verify Every 24 Hours that the Pressure Within Secondary Containment is < 0 inch (vs 0.25 inch) of Vacuum Water Gauge
  - Increase Secondary Containment Drawdown Time from 120 seconds to 20 minutes
- Section 5.5.7 - Ventilation Filter Testing Program
  - Increase Standby Gas Treatment System Flow Rate from 4457 cfm to 5000 cfm

Preliminary Results (cont'd)

- AST Peer Review
  - Duke Engineering (X/Q Review)
  - Grand Gulf
  - Perry (Tentative)

Summary

- On Schedule for Submittal June 2001
- Capture Concerns, Questions, or Actions from this Discussion
- Propose Next Meeting with the Submittal