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Figure **3.e.1-1** - Plan view of Comanche Peak upper containment **CAD** model **Figure 3.e.1-1 -Plan view of Comanche Peak upper containment CAD model** 

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Figure 3.e. **1-2** - Isometric view of area outside secondary shield wall **Figure 3.e.1-2 - Isometric view of area outside secondary shield wall** 

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Figure 3.e.1-3 - Cross-section View **1** of containment building **Figure 3.e.1-3 - Cross-section View 1 of containment building** 

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Figure 3.e.1-4 - Cross-section View 2 of containment building **Figure 3.e.1-4 - Cross-section View 2 of containment building** 



Figure 3.e.1-5 - Plan view of Comanche Peak lower containment **CAD** model **Figure 3.e.1-5 -Plan view of Comanche Peak lower containment CAD model** 

Attachment **E** Attachment E Page 28 of 49 Page 28 of 49



Figure 3.e.1-6 - Southwest isometric view of Comanche Peak lower containment **Figure 3.e.1-6 - Southwest isometric view of Comanche Peak lower containment CAD** model **CAD model** 

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Figure 3.e.1-7 - Close-up of sumps (outside secondary shield wall) **Figure 3.e.1-7 - Close-up of sumps (outside secondary shield wall)** 

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![](_page_7_Picture_1.jpeg)

**LOOPS 1 &** 4 **LOOPS** 2 **& 3 LOOPS 1 4 LOOPS** 2 & 3

Figure 3.e.1.1-1 - Isometric view of grating in RCS loop rooms **Figure 3.e.1.1-1 -Isometric view of grating in ReS loop rooms** 

![](_page_8_Figure_0.jpeg)

Figure 3.e. **1.1-2** - RCS loop room areas **Figure 3.e.1.1-2 - ReS loop room areas** 

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![](_page_9_Picture_1.jpeg)

## Figure 3.e.1.1-3 - RCS loop room grated areas **Figure 3.e.1.1-3 - ReS loop room grated areas**

Attachment E **Attachment E**  Page 33 of 49 **Page 330[49** 

![](_page_10_Figure_1.jpeg)

Figure 3.e.1.1-4 - **Figure 3.e.1.1-4**  Combined fiberglass **Combined fiberglass**  logic trees with **logic trees with**  existing transport **existing transport**  fractions **fractions** 

### Attachment E **Attachment E**  Page 34 of 49 **Page 34 of49**

![](_page_11_Figure_1.jpeg)

Figure 3.e.1.1-6 - **Figure 3.e.1.1-6**  Combined fiberglass **Combined fiberglass**  logic trees with **logic trees with**  alternate BWROG **alternate BWROG**  washdown transport **washdown transport**  fractions **fractions** 

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![](_page_12_Picture_1.jpeg)

Figure 3.e. 1.1-7 - Distribution of small and large Figure 3.e.1.1-7 -Distribution of small and large piece debris not blown to upper containment piece debris not blown to upper containment

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![](_page_13_Picture_1.jpeg)

Figure 3.e.1.1-8 - Distribution of small and large Figure 3.e.1.1-8 - Distribution of small and large piece debris not blown to upper containment piece debris not blown to upper containment

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![](_page_14_Picture_1.jpeg)

Figure 3.e. 1.1-9 - Distribution of debris washed Figure 3.e.1.1-9 - Distribution of debris washed down from upper containment down from upper containment

![](_page_15_Picture_1.jpeg)

Figure 3.e.1.2-1 Northwest isometric view lower containment **CAD** model **Figure 3.e.1.2-1 Northwest isometric view lower containment CAD model** 

![](_page_16_Figure_1.jpeg)

Figure 3.e.1.2-2 Postulated Break Locations **Figure** 3.e.1.2-2 **Postulated Break Locations** 

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![](_page_17_Figure_1.jpeg)

Figure 3.e.1.2-3 Diagram of significant features modeled Figure 3.e.1.2-3 Diagram of significant features modeled

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![](_page_18_Figure_1.jpeg)

Figure 3.e.1.2-4 Illustration of distinct floor levels **Figure 3.e.1.2-4 Illustration of distinct floor levels** 

![](_page_19_Picture_0.jpeg)

Figure 3.e.1.2-5 Streamlines showing water origination Figure 3.e.1.2-5 Streamlines showing water origination areas for each sump (Loop 4 LBLOCA, two trains) areas for each sump (Loop 4 LBLOCA, two trains)

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![](_page_20_Figure_1.jpeg)

Figure 3.e.1.2-6 Vectors showing pool flow direction (Loop 4 LBLOCA Single Train Sump A) **Figure** 3.e.1.2-6 **Vectors showing pool flow direction (Loop 4 LBLOCA Single Train Sump A)** 

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![](_page_21_Picture_1.jpeg)

Figure 3.e.1.2-7 Loop 4 LBLOCA Single Train Sump B **Figure** 3.e.1.2-7 **Loop 4 LBLOCA Single Train Sump B** 

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![](_page_22_Picture_1.jpeg)

Figure 3.e.1.2-8 Loop 4 LBLOCA Single Train Sump A **Figure 3.e.1.2-8 Loop 4 LBLOCA Single Train Sump A** 

![](_page_23_Figure_1.jpeg)

Figure **3.f-1** Cutting Planes for Test Flume Modeling **Figure 3.f-1 Cutting Planes for Test Flume Modeling** 

![](_page_24_Figure_1.jpeg)

Figure **3.f-2** Cutting Planes for Test Flume Modeling **Figure 3.f-2 Cutting Planes for Test Flume Modeling** 

![](_page_25_Picture_1.jpeg)

Figure **3.f-3** Prepared Large **LDFG** (Nukon) - Dry **Figure 3.f-3 Prepared Large LDFG (Nukon) -Dry** 

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![](_page_26_Picture_1.jpeg)

Figure **3.f-4** Prepared Large **LDFG** (Nukon) - Wet **Figure 3.f-4 Prepared Large LDFG (Nukon) - Wet** 

### Attachment F Page 1 of 24

# NRC Public Meeting **NRC Public Meeting**

### 7/9/2009 **7/9/2009**

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## **Recap**

## **"** Turbulence and flow are related • Turbulence and flow are related

- Literature treats suspension in terms of shear velocity Literature treats suspension in terms of shear velocity
- Literature **would** indicate that at most pieces smaller than **1"x1"** Literature-would indicate that at most pieces smaller than 1 "x1" could transport. **All** others cannot. could transport. All others cannot.
- Experimental values for TKE required for suspension are much Experimental values for TKE required for suspension are much higher-than analytical values. higher-than analytical values. <sup>J</sup>
- **TKE comparison between flume and containment** 
	- Containment point sources of turbulence lead to higher Containment point sources of turbulence lead to higher levels of TKE in containment vs. flume
	- **-** Containment TKE levels were reported on the flume Containment TKE levelS were reported on the flume approach, not the prototypical approach path. approach, not the prototypical approach path.
	- **-** Turbulent kinetic energy levels are low relative to what can Turbulent kinetic energy levels are low relative to what can reasonably expected to affect transport. reasonably expected to affect transport.
		- **0** Random velocity fluctuations are small relative to mean. Random velocity fluctuations are small relative to mean.

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### Attachment F Page **3** of 24

![](_page_29_Figure_1.jpeg)

Solving flow problems since 1894

## **Prototypical single strainer approach**

**1** Look at four approaches to central strainers **• Look at four approaches to central strainers** 

![](_page_30_Figure_3.jpeg)

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## Turbulence Approach TKE **Turbulence Approach TKE**

Typical approach turbulence velocity is slightly lower **• Typical approach turbulence velocity is slightly lower** 

![](_page_31_Figure_3.jpeg)

1-ft increments back from Strainer Module **/** Test Strainer 1-ft increments back from Strainer Module / Test Strainer

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## Typical Approach Velocity **Typical Approach Velocity**

• Flume approach is VERY conservative relative to **• Flume approach is VERY conservative relative to**  containment **containment** 

![](_page_32_Figure_3.jpeg)

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## **Conclusions**

- \* Flume turbulence is lower Flume turbulence is lower
- $\mathscr{P}$  Importance is very questionable
	- Magnitudes of random velocity fluctuations are low relative to mean Magnitudes of random velocity fluctuations are low relative to mean
- The key to transport is BULK VELOCITY - Importance is <u>very questionable</u><br>- Magnitudes of random velocity fluctuations are low<br>- The key to transport is BULK VELOCITY<br>- Flume velocity is DOUBLE relative to typical c
	- Flume velocity is DOUBLE relative to typical containment Flume velocity is **DOUBLE** relative to typical containment approach velocity for single train sump A operation.

![](_page_33_Picture_7.jpeg)

#### Attachment F Page **8** of 24

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## General Overview **General Overview**

- \* Discussion of conservative representation of containment Discussion of conservative representation of containment approach velocities in test flume approach velocities in test flume
- \* Discussion of relevant physics of turbulence Discussion of relevant physics of turbulence
	- Role of turbulence in debris suspension Role of turbulence in debris suspension
		- **9** NEI 04/07 NEI04/07
		- **9** Open Literature Open Literature
- Overview of CFD predicted containment turbulence Overview of CFD predicted containment turbulence

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- \* Overview of CFD predicted flume turbulence Overview of CFD predicted flume turbulence
- \* Discussion Discussion

![](_page_34_Picture_10.jpeg)

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# RAI 10 & 11

- Are flume flow turbulence conditions  **Are flume flow turbulence conditions**  prototypical of conditions in **prototypical of conditions in containment ?**
- **Are point sources of turbulence near** <br>**Are point sources of turbulence near** modeled areas of containment **modeled areas of containment**  accounted for in the flume **? accounted for in the flume?**  i  $\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$

![](_page_35_Picture_4.jpeg)

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> **Solving flow problems since 1894** - Solving flow problems since 1894 - - -, - - - -

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 $\sum_{i=1}^n \sum_{j=1}^n \frac{1}{j!}$ 

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## Containment Average Approach Velocity **Containment Average Approach Velocity**  Representation in Test Flume . **Representation in Test Flume**

- At each 1 ft increment back from each strainer array along  **At each 1 ft increment back from each strainer array along**  the water approach path to the strainers, calculate the **the water approach path to the strainers, calculate the**  weighted average of the velocity along a vertical plane: **weighted average of the velocity along a vertical plane:** 
	- **-** The weighted average at each increment is weighted by twice **The weighted average at each increment is weighted by twice**  the fastest velocity at the increment under consideration. **the fastest velocity at the increment under consideration.**
	- **-** Low velocities in wake regions behind obstacles were ignored **Low velocities in wake regions behind obstacles were ignored**
	- **-** Only velocity vectors pointing towards the strainer array were **Only velocity vectors pointing towards the strainer array were**  considered **considered**
	- **-** Low velocities in the near wall regions were ignored **Low velocities in the near wall regions were ignored**

![](_page_36_Picture_7.jpeg)

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# Physics of Turbulence **Physics of Turbulence**  Turbulent vs. Laminar Flow **Turbulent vs. Laminar Flow**

- Turbulent (Re > 2000) vs. Laminar Flow (Re < 2000)  **Turbulent (Re > 2000) VS. Laminar Flow (Re < 2000)** 
	- $-$  Re = UR<sub>h</sub>/ $v$  > 2000 for open channel flow [1]
		- \* U = Characteristic Velocity U = Characteristic Velocity
		- $\cdot$  R<sub>h</sub> = Characteristic Length Scale = Hydraulic Radius
		- $v =$  Kinematic Viscosity

## -. Calculation for Containment and Flume **Calculation for Containment and Flume**

![](_page_37_Picture_201.jpeg)

Conclusion: Flow in Flume is Turbulent - **Conclusion: Flow in Flume is Turbulent** 

![](_page_37_Picture_10.jpeg)

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Solving-flow problems since 1894 **Exercise 1894** And the state of the state of

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[1] "Flow through open channels", Raju, K.G.R., McGraw-Hill,

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# Physics of Turbulence **Physics of Turbulence**  "Magnitude" of Turbulence **"Magnitude" of Turbulence**

- Turbulence Level is a function of Shear Velocity [2] **Turbulence Level is a function of Shear Velocity [2]**  •
	- **-** By Definition [2]: **U\*** S8 By Definition [2]:  $u^* = \sqrt{\frac{u^*}{n}} \cdot \frac{1 - \text{bare}}{1 - \text{bare}}$

**f** - Darcy-Weisbach friction factor u\*- shear velocity  $* = \sqrt{\frac{f \cdot U^2}{8}}$  f – Darcy-Weisbach friction factor<br>u\*- shear velocity

- Magnitude of Turbulent Velocity Fluctuation: Magnitude of Turbulent Velocity Fluctuation:
	- $u' = u^* (2.3 \exp(-y/h))$  for  $y/h < 0.1$  [3]
	- **•**  $u' = u^* (1.27 \exp(-y/h))$  for  $y/h = 0.1$  [3] Where: Where:
		- u' = Turbulent Fluctuating Velocity u' = Turbulent Fluctuating Velocity
		- u\* = Shear velocity u\* = Shear velocity
		- y = Vertical Length Scale <sup>y</sup>= Vertical Length Scale
		- h = Depth of Flow

- **\*** Note: **Note:**  •
	- $f_{\text{containment}} f_{\text{flume}}$
	- Ycontainment = Yflurme and hcontainment = hflume Y containment = Yflume **and** hcontainment = hflume
- ° Expected flow turbulence levels in the flume due to flowing  **Expected flow turbulence levels in the flume due to flowing**  water are of the same order as containment **water are of the same order as containment**

**A L E [3** Neu **<sup>I</sup>**an Azra R. 'Truec Chrceitc **an** Ineacto bewe Patce . - [2] The Hydraulics of Open Channel Flow. Chanson, H., Arnold, 1999. A L DEN - - - [3] ~ezu, I and Azuma, R , 'Turbulence Charactenstics and Interaction betw~en Particles and Fluid in Particle-Laden Open Channel Flows", Journal of Hydraulic Engineering, -Solvingllow·problems since 1894 . - - c \_ \_ . ~ \_\_ .?ctober~OQ4. . \_ \_ .' .'

![](_page_39_Picture_1.jpeg)

# Role of Turbulence in Suspension Role of Turbulence in Suspension

- **9** Turbulence studies have shown that the fluid shear velocity is Turbulence studies have shown that the fluid shear velocity is directly related to turbulence level **[3]** directly related to turbulence level [3]
- **\*** Onset of debris suspension is expected to occur when the Onset of debris suspension is expected to occur when the magnitude of the turbulent velocity fluctuation is greater **by** magnitude of the turbulent velocity fluctuation is greater by some margin than the settling velocity of the debris as defined some margin than the settling velocity of the debris as defined **by** the following expression: by the following expression:

![](_page_39_Figure_5.jpeg)

- **-** Open literature brackets the range of critical values: 0.2 to 2.0 [2] Open literature brackets the range of critical values: 0.2 to 2.0 [2]
- Minimum Shear velocity, u<sup>\*</sup><sub>(Flume and Containment)</sub> = 0.031 ft/s
- Range of settling velocity susceptible to suspension: Range of settling velocity susceptible to suspension:
	- Material with settling velocity  $< 0.15$  ft/sec (c.v. = 0.2)
	- Material with settling velocity  $< 0.06$  ft/sec (c.v. = 2)

![](_page_39_Picture_11.jpeg)

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## Role of Turbulence in Suspension **Role of Turbulence in Suspension**

 $\checkmark$ 

- **\*** Table 4-2, **NEI** 04/07 **Table 4-2, NEI 04/07**  •
	- Only loose fibers easily suspended **Only loose fibers easily suspended**  by turbulence (w<sub>o</sub><0.15 ft/s)
	- Only 1/4" x ¼" clump turbulence **Only** %" x %" **clump turbulence**  requirements verified experimentally **requirements verified experimentally**  (Analytical TKE levels questionable **(Analytical TKE levels questionable**  as indicated in SER) **as indicated in SER)**
	- Experimental value tends much **Experimental value tends much**  higher than analytical value **higher than analytical value**

![](_page_40_Picture_308.jpeg)

![](_page_40_Picture_7.jpeg)

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![](_page_41_Figure_1.jpeg)

Solving flow problems since 1894

![](_page_42_Figure_1.jpeg)

Solving flow problems since 1894

![](_page_43_Figure_1.jpeg)

Solving flow problems since 1894

![](_page_44_Figure_1.jpeg)

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## Test Flume Turbulent Kinetic Energy **Test Flume Turbulent Kinetic Energy CFD** Geometry **CFD Geometry**

![](_page_45_Figure_2.jpeg)

![](_page_45_Picture_3.jpeg)

![](_page_46_Figure_0.jpeg)

### Attachment F Page 21 of 24

## Turbulent Kinetic Energy Profiles **Turbulent Kinetic Energy Profiles**

Area averaged quantities for planes **• Area averaged quantities for planes**  back from sump I strainer **back from sump / strainer** 

![](_page_47_Figure_3.jpeg)

### 1-ft increments back from Strainer Module / Test Strainer 1-ft increments back from Strainer Module I Test Strainer

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# Summary of Comparison **Summary of Comparison**

- \* Flume turbulence levels on par with Approach #2 to strainers  **Flume turbulence levels on par with Approach #2 to strainers**  in containment for both one and two train operation. **in containment for both one and two train operation.**
- For one train operation, turbulence level in the flume is on the  **For one train operation, turbulence level in the flume is on the**  order of that in the plant over most of Approach #1. **order of that in the plant over most of Approach #1.**
- \* The flume turbulence level near the test strainer is similar to ------1  **The flume turbulence level near the test strainer is similar to** r---- . the higher turbulence in the field at the upstream end of the : **the higher turbulence in the field at the upstream end of the**  array. **array.** 
	- **"** For areas where flume turbulence is lower than containment: •. **For areas where flume turbulence is lower than containment:** 
		- Greatest part of turbulent kinetic energy is below **Greatest part of** turbulent kinetic **energy is below**  estimated required level for suspension of 1" smalls **estimated required level for suspension of 1" smalls**  based on settling velocities **based on settling velocities**
		- Fines are suspended by both flume and containment <sup>&</sup>lt;**Fines are suspended by both flume and containment**  turbulence levels turbulence levels
		- Debris > 4" is not able to be suspended by either **Debris> 4" is not able to be suspended by either**  containment or flume turbulence levels **containment or flume turbulence levels**

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#### Attachment F Page **23** of 24

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# Summary of Comparison (cont'd) **Summary of Comparison (cont'd)**

- $-$  Settling velocity is proportional to the inverse of viscosity
	- Between flume (120F) and containment (~200F) viscosity is half
- Effective turbulence level in the flume is double due to **Effective turbulence level in the flume is double due to**  lower settling velocity in flume **lower settling velocity in flume**

![](_page_49_Figure_5.jpeg)

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![](_page_49_Picture_6.jpeg)

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## **RAI Response Summary** , .. !V

- Flume flow conditions are turbulent and are  **Flume flow conditions are turbulent and are**  representative of flow generated turbulence. <sup>~</sup>**representative of flow generated turbulence.**
- Turbulence levels observed are in general not sufficient ~<'  **Turbulence levels observed are in general not sufficient**  to keep smalls above 1" suspended in containment or **to keep smalls** above 1 **" suspended in containment or**  flume. r-'-- -.. ,.------1 **fl u me.**
- **I, September 19 Fear strainer turbulence levels are higher in the flume I also improve compared to containment calculated values.**
- **Point sources of turbulence from jetting located further** *r***/** $\sqrt{2}$  **away from the strainers are not modeled in the flume. Example 20 However, blocking of debris by the flow structures existing in this area is also not considered.** 
	- Point sources of turbulence are generally located outside  **Point sources of turbulence are generally located outside**  the mean radius of travel modeled in the flume. **the mean radius of travel modeled in the flume.**

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