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Integrated Engineering, Construction, and Management Solutions

Fire Analysis Preparation Implementation Approaches – Sample Problems

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Overview of Presentation

- Source Term Calculation Refresher
- Problem Description
- Strategy 1 - Very bounding
- Strategy 2 - Recognize limited combustibles
- Strategy 3 – Inclusive analysis
- Comparison of Results

Source Term Calculation – Refresher

ST	Source Term
MAR	Material at Risk
DR	Damage Ratio
ARF	Airborne Release Fraction
RF	Respirable Fraction
LPF	Leap Path

$$ST = MAR \bullet DR \bullet ARF \bullet RF \bullet LPF$$

Sample Problem – Strategy 1

- **Assumption: Combustibles will cause complete evaporation of tank contents**
  - **MAR: 2.5 kg**
  - **DR: 1.0**
- **Assumption: Vigorously burning solvent over aqueous phase burning to dryness**
  - **ARF: 1E-01**
  - **RF: 1.0**
  - **LPF: 1.0**

ST = (2.5 kg) (1.0) (1E-01) (1.0) (1.0) = 0.25 kg

Sample Problem – Strategy 1 (con't)

- **Unmitigated MOI Dose**
  - Source Term: 0.25 kg
  - Dose Conversion: 900 rem/kg

    Dose = (0.25 kg) (900 rem/kg) = 220 rem
  - This challenges 25 rem guideline

- **Mitigated Dose (credit ventilation)**
  - LPF = 0.0003 (99.97% efficient)
  - ST = (2.5 kg) (1.0) (1E-01) (1.0) (0.0003) = 7.5E-04 kg

    Dose = (7.5E-04 kg) (900 rem/kg) = 0.67 rem

Sample Problem – Strategy 1 (con't)

- Credited SSCs
  - Cell Structure – SC
  - Cell Ventilation – SC
- Credited SACs
  - Cell inventory limit – 2.5 kg
- Additional Considerations
  - Must demonstrate fire does not compromise ventilation system
  - Must demonstrate fire does not compromise structure

Sample Problem – Strategy 2

- **Assumption: Very limited amount of combustibles**
  - Combustibles: 200 # mass (3870 MJ energy)
  - MAR: 2.5 kg
- **Assumption: 10% fire energy to tank**
  - $\Delta H_{f\text{-}g}$ = 2.26 MJ/kg
  - Liquid evaporated = 54 gallons
  - DR = 54 gallons/90 gallons = 0.6
- **Assumption: Boiling aqueous solution in flowing air**
  - ARF: 2E-03
  - RF: 1.0
  - LPF: 1.0

$$ST = (2.5\ kg)\ (0.6)\ (2E\text{-}03)\ (1.0)\ (1.0) = 0.003\ kg$$

Sample Problem – Strategy 2 (con't)

- **Unmitigated MOI Dose**
  - **Source Term: 0.003 kg**
  - **Dose Conversion: 900 rem/kg**

$$\text{Dose} = (0.003\ \text{kg})\ (900\ \text{rem/kg}) = 2.7\ \text{rem}$$

- **This does not challenge 25 rem**

Sample Problem – Strategy 2 (con't)

- Credited SSCs
  - None
- Credited SACs
  - Cell inventory limit: 2.5 kg
  - Very restricted combustible limit (200 #)
- Additional Considerations
  - Concept does not assure protection of worker
  - Combustible limit importance is uncertain

Sample Problem – Strategy 3

- **Assumption: Combustible loading is limited**
  - Combustibles: 10 psf (640 # wood equiv; 5,400 MJ)
  - MAR: 2.5 kg
- **Assumptions: 10% fire energy to tank**
  - $\Delta H_{f\text{-}g}$: 2.26 MJ/kg
  - Liquid evaporated: 63 gallons
  - DR: 63 gallons/90 gallons = 0.7
  - ARF: 2E-03
  - RF: 1.0
  - LPF: 1.0

$$ST = (2.5\ kg)\ (0.7)\ (2E\text{-}03)\ (1.0)\ (1.0) = 0.0035\ kg$$

Sample Problem – Strategy 3 (con't)

- **Unmitigated MOI Dose**
  - Source Term: 0.0035 kg
  - Dose Conversion: 900 rem/kg

  Dose = (0.0035 kg) (900 rem/kg) = 3.1 rem

- **This does not challenge 25 rem**

Sample Problem – Strategy 3 (con't)

- **Assumption: Cell structure is reinforced concrete rated for >2 hours**
  - **Fire loading (10 psf) would not be expected to cause cell structure to fail (qualitative assessment)**

Sample Problem – Strategy 3 (con't)

- Filter plugging
  - Soot fraction: 0.2 kg/kg consumed
  - Mass consumed: 600 #, 272 kg

$$\text{Soot demand} = (0.2)\ (272\ \text{kg}) = 54\ \text{kg}$$

  - Typical load to cause plugging: 0.5 kg/filter
  - Number of filters: 9

$$\text{Soot capacity} = (9\ \text{kg})\ (0.5\ \text{kg/filter}) = 4.5\ \text{kg}$$

  - Capacity < Demand
  - Filter pluggage expected

Sample Problem – Strategy 3 (con't)

- Credited SSCs
  - Cell structure maintains stability during fire
- Credited SACs
  - Cell inventory limit – 2.5 kg
  - Combustible loading limit (10 psf)
- Additional Considerations
  - Concept does not assure protection of worker
  - Ventilation system may not need to be SC

Sample Problem – Other Considerations

- **Assumption: Very limited amount of combustibles**
  - Combustibles: 10 psf (640 # wood equiv; 5,400 MJ)
  - MAR: 1.25 kg (45 gallons)
- **Assumptions: 10% fire energy to tank**
  - $\Delta H_{f\text{-}g}$ = 2.26 MJ/kg
  - Theoretical liquid evaporated = 54 gallons
  - DR = 1.0 (54 gallons/45 gallons)
- **Assumption: Fire burns to dryness**
  - ARF: 1E-01
  - RF: 1.0
  - LPF: 1.0

$$ST = (1.25\ kg)\ (1.0)\ (1E\text{-}01)\ (1.0)\ (1.0) = 0.12\ kg$$

Sample Problem – Other Considerations (con't)

- **Unmitigated MOI Dose**
  - Source Term: 0.12 kg
  - Dose Conversion: 900 rem/kg

  Dose = (0.12 kg) (900 rem/kg) = 110 rem

- **This challenges 25 rem**

Sample Problem – Filter Capacity

- Filter plugging
  - Soot fraction: 0.2 kg/kg consumed
  - Mass consumed: 50 #, 22.7 kg

$$\text{Soot demand} = (0.2)\ (22.7\ \text{kg}) = 4.5\ \text{kg}$$

  - Typical load to cause plugging: 0.5 kg/filter
  - Number of filters: 9

$$\text{Soot capacity} = (9\ \text{kg})\ (0.5\ \text{kg/filter}) = 4.5\ \text{kg}$$

  - Capacity ~ Demand
  - Rely on transfer to alternate train to limit plugging potential

Sample Problem – Strategy 3 (con't)

- Credited SSCs
  - Ventilation system – SC
  - Building structure - SC
- Credited SACs
  - Cell inventory limit – 2.5 kg
  - Combustible loading limits
    - 50 pounds (Prevents filter pluggage)
    - 10 psf (Protects structure)
- Additional Considerations
  - Ventilation system will protect workers
  - Treat fire with ventilation pluggage as beyond design basis accident

Comparison of Sample Results

	Strategy 1 Full evaporation	Strategy 2 Limited combustibles	Strategy 3 Inclusive
Public unmitigated dose	220 rem	2.7 rem	3.1 & 110 rem
Ventilation system	Not evaluated	SS – uncertain SC - no	SS – active SC - passive
Building structure	Not evaluated	SC	SC
Radiological inventory	2.5 kg (SAC)	2.5 kg (SAC)	2.5 kg (SAC)
Combustible loading	Unlimited	200 # plastic (SAC) 10 psf (AC)	50 # wood equiv. (SAC) 10 psf (AC)
Comment	Analysis incomplete	Won't work for low inventory	Filter pluggage BDBA