

# **API RBI User Group**

## **January 19-20, 2004**

**API RBI Consequence Modeler Update**

**The Equity Engineering Group, Inc.**

# API RBI Consequence

- Modify philosophy surrounding the release case scenarios (hole sizes and generic failure frequencies)
- New Consequence Modeler
- Add Fluid Property Solver
- Modify Consequence Fault Trees
- Calculate Fault Tree Probabilities
- Improve Consequence Documentation in BRD
- Status of Modifications

# API RBI Consequence

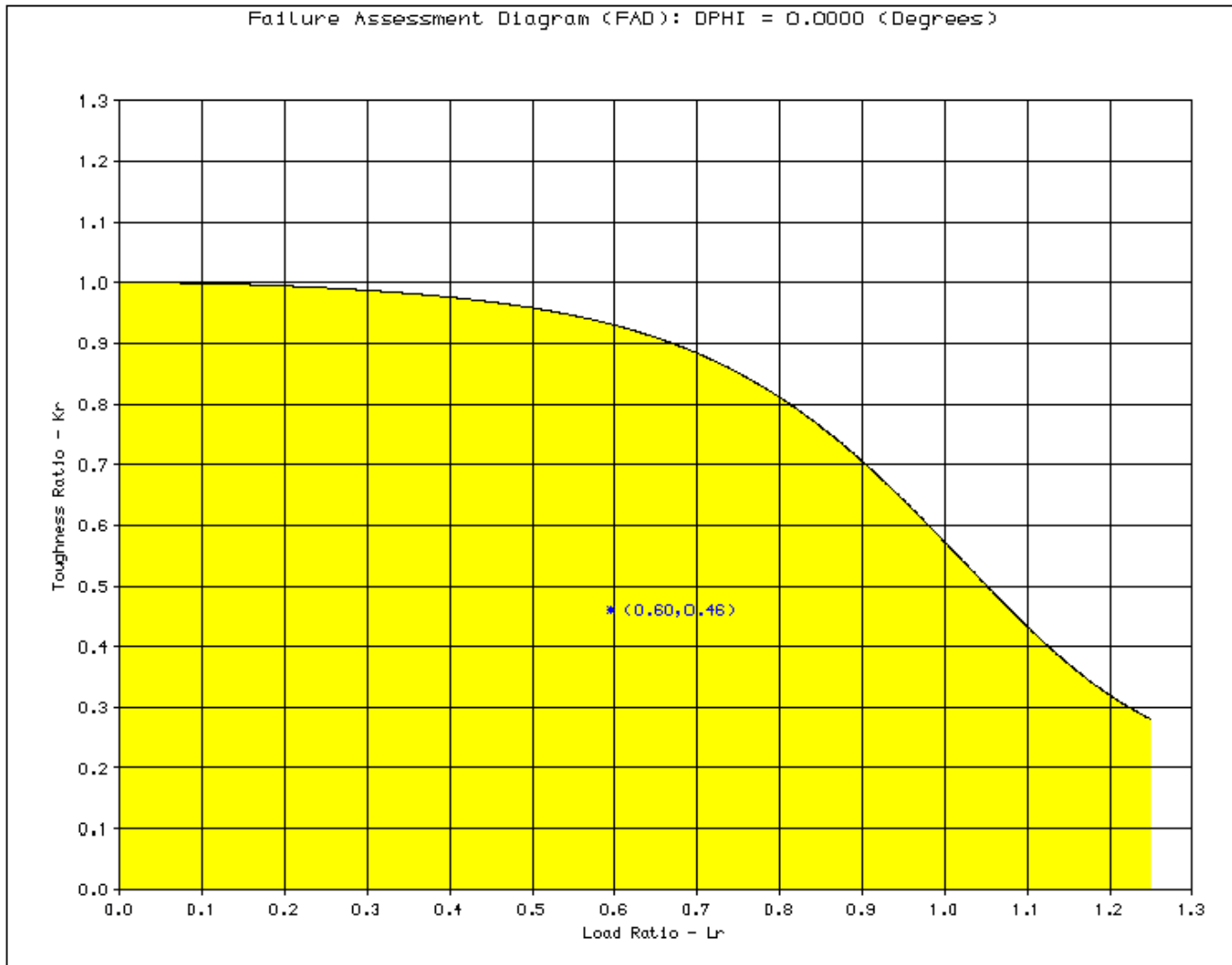
- Modify philosophy surrounding the consequence release case scenarios
  - Current software
    - Utilizes standard hole sizes with generic failure frequencies
    - Final consequence area is determined using a GFF weight based summation of the individual consequence areas for the four hole size cases
    - Weaknesses
      - Holes sizes used for release cases are generic
      - Limited data available to backup the GFFs
      - Hole sizes not related to pressure or to damage mechanism, GFF only based on equipment type
      - Probability of rupture is same within an equipment type

# API RBI Consequence

- Modify philosophy surrounding the consequence release case scenarios (Con't)
  - Proposed Revision
    - Eliminate current four hole size method, relate to damage mechanism
    - Allows pressure to govern opening area as well as release rate (i.e. higher pressure results in larger opening area)
    - Perform fracture analysis utilizing FAD Diagram to establish a rupture probability
    - Allows rupture probability to be a function of pressure, a necessity for PRV Overpressure Cases

# API RBI Consequence

- Modify philosophy surrounding the consequence release case scenarios (Con't)



# API RBI Consequence

- New Consequence Modeler
  - Address the difficulty in adding new fluids or matching an existing fluid group
  - Calculate consequence areas internally, no longer uses curve fits and area tables (black box)
  - Calculate effect of VCEs, physical explosions, BLEVEs, flash fires, jet and pool fires and fireballs
  - Imbed cloud dispersion (plume) analysis model
  - Calculate equipment and fatality areas
  - Flammable and toxic consequences

# API RBI Consequence

- New Consequence Modeler (Con't)
  - Jet Fires
  - Pool Fires
  - Flash Fires
  - Fireballs
  - Vapor Cloud Explosions
  - Non-Flammable Ruptures
    - Physical Explosions
    - BLEVEs
  - Toxic Release

# API RBI Consequence

- New Consequence Modeler (Con't)
  - Jet Fires
    - Immediate Ignition of a vapor or two-phase release
    - CCPS “Guidelines for Consequence Analysis of Chemical Release”
    - Calculates flame length and the emitted heat flux from flame
    - Calculates the distance away from the flame where the thermal radiation equals the applicable thermal radiation limit
    - Thermal Radiation Limits
      - Fatalities – 4000 Btu/hr/ft<sup>2</sup>
      - Equipment – 12,000 Btu/hr/ft<sup>2</sup>
    - Consequence Area:  $A = \pi(xs)^2$

# API RBI Consequence

- New Consequence Modeler (Con't)
  - Pool Fires
    - Immediate Ignition of a liquid release
    - “Methods for Calculation of Physical Effects” (TNO, Yellow Book, Third Edition).
    - Assumes a maximum pool diameter such that the liquid release rate is equal to the burn rates from the pool
    - Calculates flame length and the emitted heat flux from flame
    - Calculates the distance,  $x_s$ , away from the flame where the thermal radiation equals the applicable thermal radiation limit
    - Thermal Radiation Limits
      - Fatalities – 4000 Btu/hr/ft<sup>2</sup>
      - Equipment – 12,000 Btu/hr/ft<sup>2</sup>
    - Consequence Area:  $A = \pi(x_s)^2$

# API RBI Consequence

- New Consequence Modeler (Con't)
  - Flash Fires
    - Delayed Ignition of a liquid, vapor or 2-phase release
    - Considers clouds generated from pools, jets or ruptures
    - Performs a dispersion analysis of the cloud generated from continuous or instantaneous releases
    - Flash fires occur when the flame speed is slow, otherwise VCE
    - Calculates the flammable area, i.e. the ground elevation area where the cloud concentration is greater than the LFL
    - Consequence area is equal to the flammable area, no thermal radiation effects are considered (unlike a pool fire), since flash fires are low intensity, short duration flames

# API RBI Consequence

- New Consequence Modeler (Con't)
  - Fireballs
    - Immediate Ignition of a vapor or 2-phase release
    - CCPS “Guidelines for Consequence Analysis of Chemical Release”
    - Calculates the stored flammable mass
    - Calculates the fireball diameter, duration and its emitted heat flux
    - Calculates the distance,  $x_s$ , away from the flame where the thermal radiation equals the applicable thermal radiation limit
    - Thermal Radiation Limits
      - Fatalities – 4000 Btu/hr/ft<sup>2</sup>
      - Equipment – 12,000 Btu/hr/ft<sup>2</sup>
    - Consequence Area:  $A = \pi(x_s)^2$

# API RBI Consequence

- New Consequence Modeler (Con't)
  - Vapor Cloud Explosions (VCE)
    - Delayed Ignition of a liquid, vapor or 2-phase release
    - Considers clouds generated from pools, jets or ruptures
    - Performs a dispersion analysis of the cloud generated from continuous or instantaneous releases
    - Calculates the flammable mass throughout the cloud
    - VCE occurs when the flame speed is fast, otherwise flash fire
    - Uses the TNT Equivalency method (TNO Energy method may be better for VCEs)
    - Calculates the overpressure and impulse generated from the explosion using blast curves
    - Consequence area is based on using probit equations (N.A.Eisenberg, etal.) for fatalities due to lung rupture and impact, also use probits for equipment damage

# API RBI Consequence

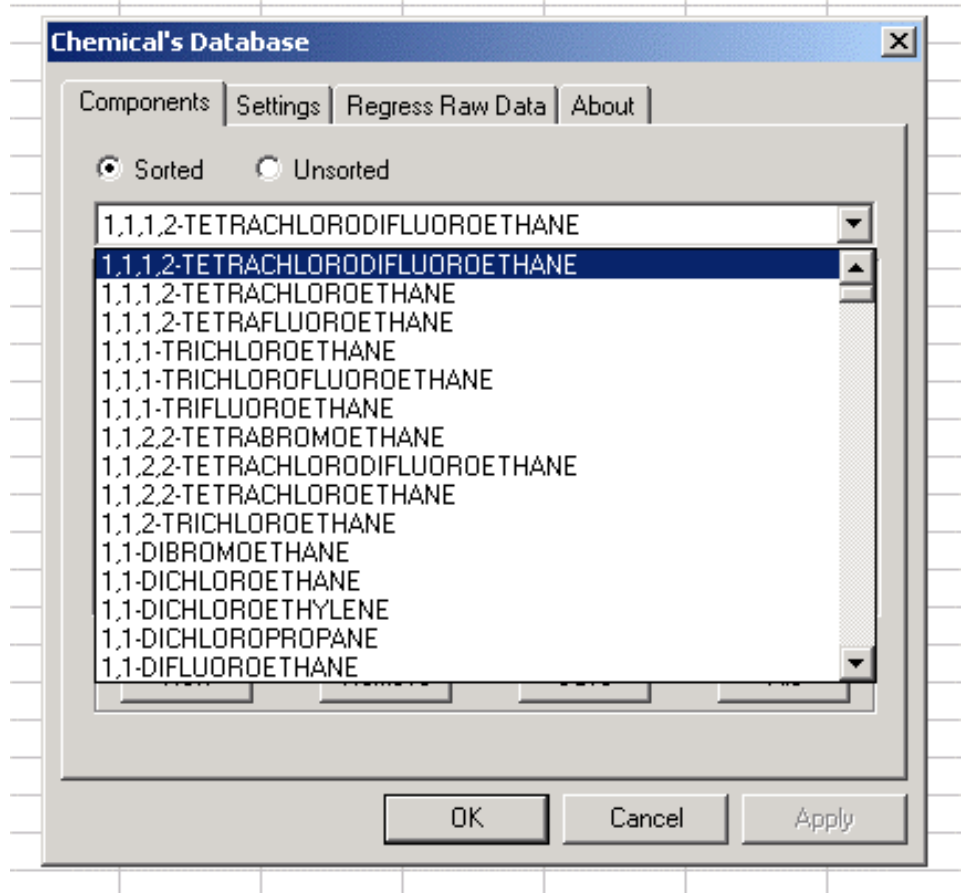
- New Consequence Modeler (Con't)
  - Non-Flammable Ruptures
    - Current RBI Methodology does not include
    - (non-ignition) Vapor or 2-phase rupture
    - Calculates the released energy for the storage conditions and subsequent blast wave (TNT equivalency)
    - Consequence area is based on calculated overpressure and using Eisenberg probit equations
    - Physical Explosion – Stored Vapor
    - BLEVE – Stored liquid, vapor or two-phase flashes
  - If fluid is flammable, non-flammable ruptures can also be followed by flammable events
    - e.g. BLEVE plus Fireball, Physical Explosion plus VCE, etc.

# API RBI Consequence

- New Consequence Modeler (Con't)
  - Toxic Release
    - Release of a toxic liquid, vapor or 2-phase fluid
    - Considers toxic clouds generated from pools, jets or ruptures
    - Performs a dispersion analysis of the cloud generated from continuous or instantaneous releases
    - Calculates concentration as a function of location and time
    - Toxic limits checked include: EPA toxic endpoints, IDLH, AEGL-3, ERPG, LC-50, probits
    - Calculates the toxic area, i.e. the ground elevation area where the cloud concentration is greater than the toxic limit

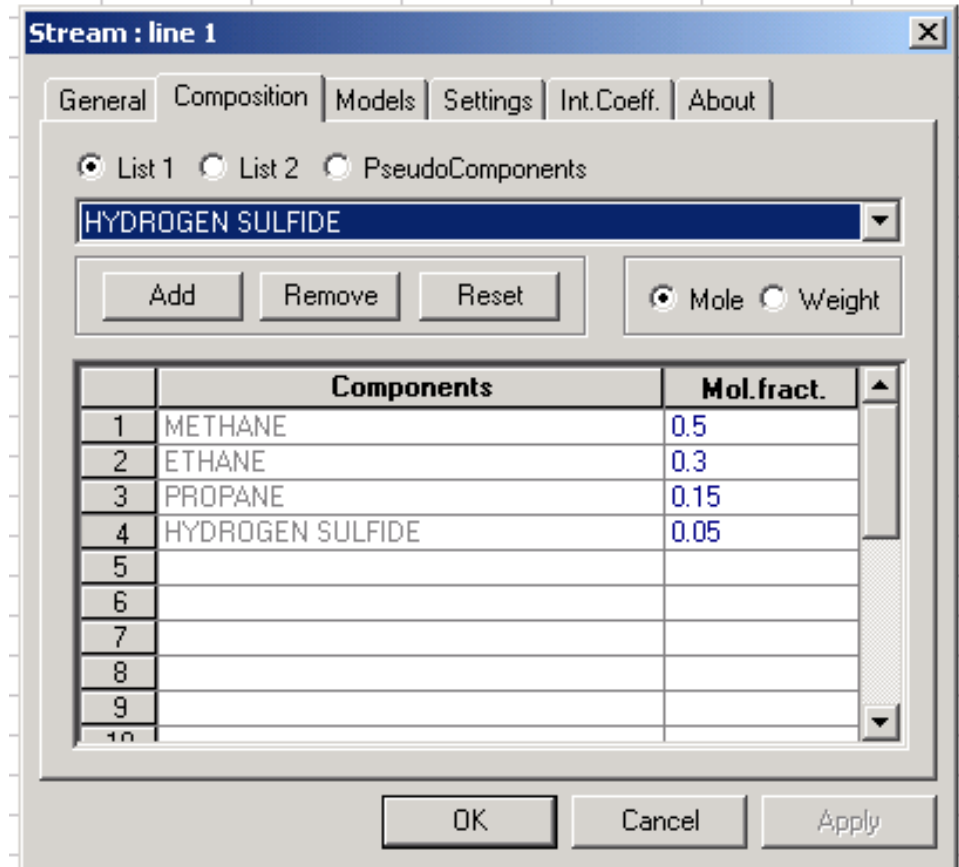
# API RBI Consequence

- Add Fluid  
Property Solver
  - Pick List of 200 Plus Pure Component Fluids
  - Include  $\approx$  70 EPA Toxic Fluids
  - Add LFL, UFL, AIT, EPA Toxic Endpoint, IDLH, AEGL-3 as applicable for each fluid



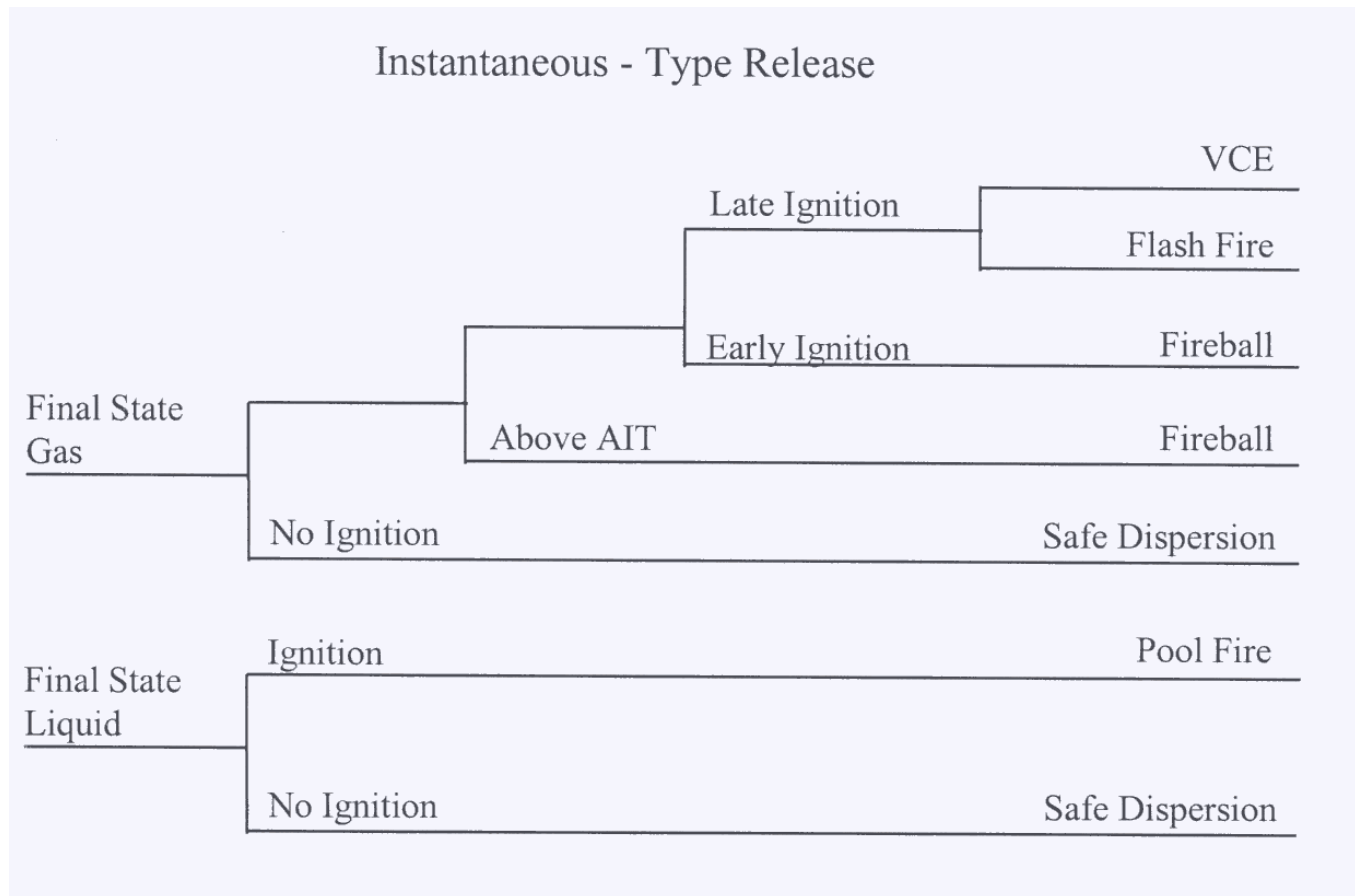
# API RBI Consequence

- Add Fluid Property Solver
  - Allows User Defined Mixtures to be Created
  - Greatly simplifies the process of adding new fluids
  - Enables two-phase events
  - Maintain the current representative fluid groups, e.g. C1-C2, C3-C4, C25+



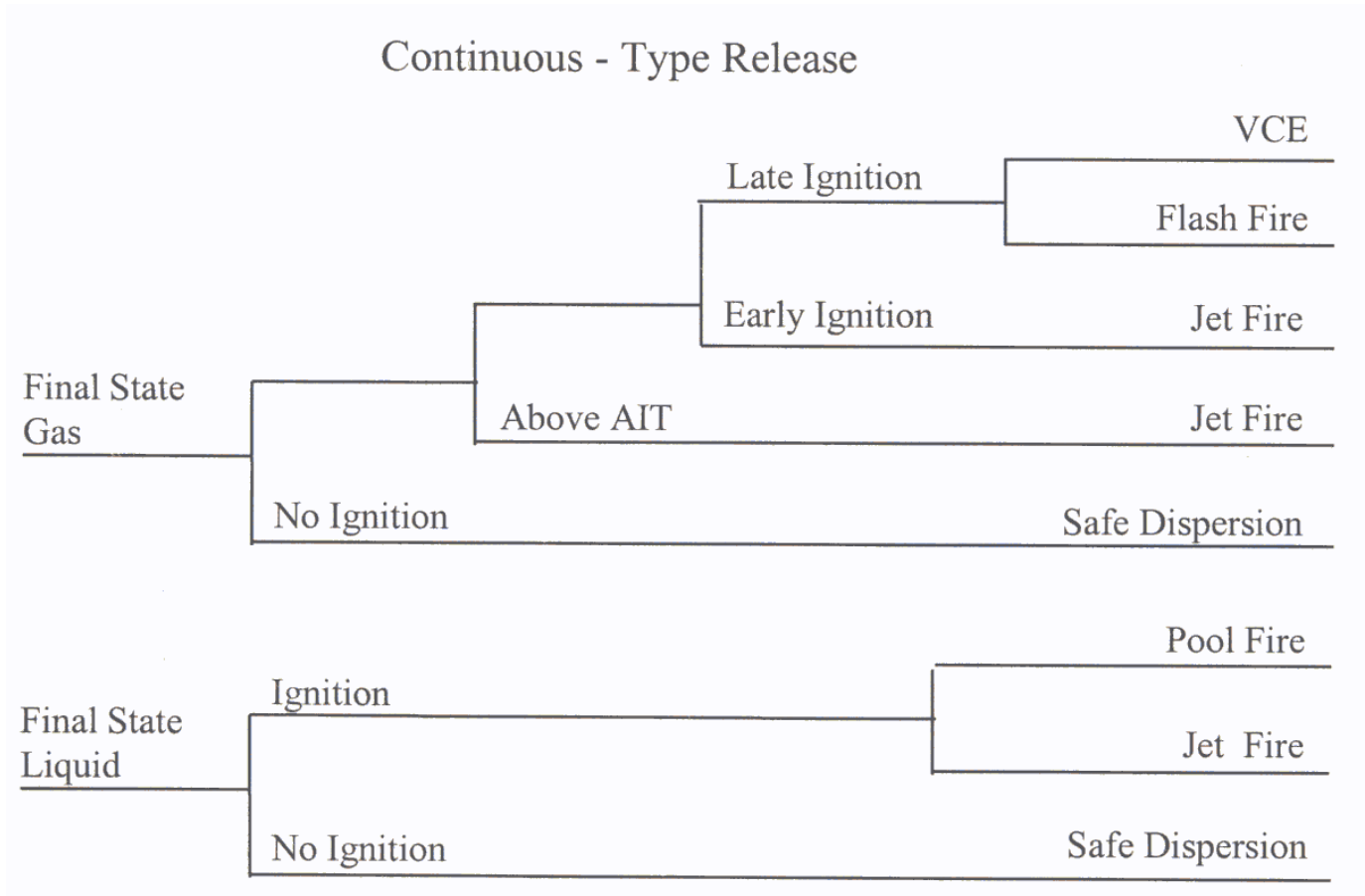
# API RBI Consequence

- Modify Consequence Fault Trees
  - Include Two-Phase Releases
  - Add BLEVE Event and Physical Explosion Event (non-flammable rupture)



# API RBI Consequence

- Modify Consequence Fault Trees (Con't)
  - Add Potential for VCE or Flash Fire from Evaporating Liquid Pool Release



# API RBI Consequence

- Calculate Fault Tree Probabilities
  - Currently, Probability Table is per Representative Fluid Groups
  - Probabilities not a function of amount of released material

**Final State Gas - Processed Below AIT**

Fluid	Probabilities of Outcomes					
	Ignition	VCE	Fireball	Flash Fire	Jet Fire	Pool Fire
C1-C2	0.2	0.04		0.06	0.1	
C3-C4	0.1	0.03		0.02	0.05	
C5	0.1	0.03		0.02	0.05	
C6-C8	0.1	0.03		0.02	0.05	
C9-C12	0.05	0.01		0.02	0.02	
C13-C16						
C17-C25						
C25 +						
H <sub>2</sub>	0.9	0.4		0.4	0.1	
H <sub>2</sub> S	0.9	0.4		0.4	0.2	

# API RBI Consequence

- Calculate Fault Tree Probabilities (Con't)
  - Probability of Ignition (POI) and Probability of Delayed/Immed. Ignition (POEGI) currently a Toggle based only on AIT

**Final State Gas - Processed Above AIT**

Fluid	Probabilities of Outcomes					
	Ignition	VCE	Fireball	Flash Fire	Jet Fire	Pool Fire
C1-C2	0.7				0.7	
C3-C4	0.7				0.7	
C5	0.7				0.7	
C6-C8	0.7				0.7	
C9-C12	0.7				0.7	
C13-C16						
C17-C25						
C25 +						
H <sub>2</sub>	0.9				0.9	
H <sub>2</sub> S	0.9				0.9	

# API RBI Consequence

- Calculate Fault Tree Probabilities (Con't)
  - Where Possible, Eliminate Hard-Coding of Ignition Probabilities
    - Function of Released Flammable mass (LFL and UFL)
    - Continue to Use AIT as an upper bound
  - Per Cox, Lees and Ang, 1990
    - POI is related to flow (log/log) of flammable mass
    - 1% POI at .5 kg/s and 30% POI at 100 kg/s for gasses
    - 1% POI at .5 kg/s and 7% POI at 100 kg/s for liquids
  - Per Cox, Lees and Ang, 1990
    - POEGI is related to flow (log/log) of flammable mass
    - 3% POEGI at .5 kg/s and 25% POEGI at 100 kg/s for gasses
    - 2.5% POEGI at .5 kg/s and 20% POEGI at 100 kg/s for liquids
  - Probability of VCE versus Flash Fire (Delayed Ignition)
    - Function of Cloud Properties – Flame Speed

# API RBI Consequence

- Improve Consequence Documentation in BRD
  - Fully document methodologies used for Consequence outcomes/events (i.e. VCE, Flash fire, Pool Fire, Jet fire, Toxic Release, BLEVE etc.
  - Plume analysis performed by advanced fluid modeling software, if not using API RBI software, guidance for using other plume analysis software will be provided

# API RBI Consequence

- Status of Modifications
  - Development of release case scenario (i.e. characteristic crack length) philosophy has commenced
  - Consequence Calculator Completed
    - In-Testing/Debug
    - Demo end of February to mid-March
    - Use Representative Fluid Groups to perform limited results checking
    - Incorporate in Revision 6.0 by June 2004
  - Fluid Property Solver Completed
    - E<sup>2</sup>G or API licensed Distributor through NIST (Supertrapp)
    - Imbedded NIST Code in Consequence Calculator
    - Toxic and Flammable Data (LFL,UFL, $\Delta H_C$ ,EPA Toxic Endpoints, IDLH, etc.) for most materials have been added

# API RBI Consequence

- Status of Modifications (Con't.)
  - Development of fault tree probability equations in progress, eliminate hard-coding of fault tree probabilities and dependency on representative fluid group
  - BRD Revision
    - Documentation of consequence methodology has commenced
    - Target for a BRD draft, end of March
    - Ballot in April
    - Released with BRD in June, 2004