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BLEVE- Boiling Liquid Expanding Vapor Explosion: Simulation and Risk Analysis

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Abstract

A model was developed for estimating the thermodynamic and the dynamic state of the boiling liquid during a boiling liquid expanding vapor explosion (BLEVE) event. The model predicts, simultaneously, the bubble growth processes in the liquid at the superheat-limit state, the front velocity of the expanding two-phase mixture, and the shock wave pressure formed by the fluid expansion through the air.

The model predictions of the shock wave strengths, in terms of TNT equivalence, were compared against those obtained by simple energy models. The study reveals what are the important mechanisms that dominate two-phase blowdown and BLEVE accidents. The research presents an overview of the mechanism, the causes, the consequences, and the preventive strategies associated with BLEVEs. They are therefore important computational tools for environmental safety assessments.

The Motivation

Risk assessments modeling of accidents involving pressurized vessels containing hazardous materials

Relevant Industries:

- Nuclear and Power Generation (LOCA)
- Petroleum, Chemical (Pressurized Gases)

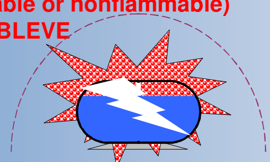
What is a BLEVE?

(Boiling Liquid Expanding Vapor Explosion)

Explosive Release of Pressure Liquefied Gas (PLG) caused by a very rapid evaporation.

Any liquefied vapor (flammable or nonflammable) can cause a BLEVE

Shock Wave

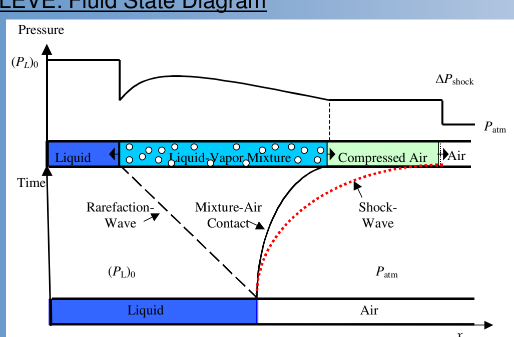


Mexico City, 1984

The Model

The model predicts, simultaneously, the bubble growth processes in the liquid at the superheat-limit state, the front velocity of the expanding two-phase mixture, and the shock wave pressure formed by the fluid expansion through the air.

BLEVE: Fluid State Diagram



Conservation Equations

Two-Phase Mixture — **Air**

Continuity equations

$$\frac{\partial}{\partial t}[\varepsilon_k\rho_k]+\frac{\partial}{\partial x}[\varepsilon_k\rho_k u]=\dot{m}''_{ik}-\varepsilon_k\rho_k u\frac{1}{A}\frac{dA}{dx}$$

$$\frac{\partial}{\partial t}[\rho_{air}]+\frac{\partial}{\partial x}[\rho_{air}u]=-\frac{1}{A}\frac{dA}{dx}$$

Momentum equations

$$\rho_m\frac{\partial u}{\partial t}+\rho_m u\frac{\partial u}{\partial x}+\frac{\partial P}{\partial x}=-(f_{wL}+f_{wG})-\rho_m g\frac{dZ}{dx}$$

$$\rho_{air}\frac{\partial u}{\partial t}+\rho_{air}u\frac{\partial u}{\partial x}+\frac{\partial P}{\partial x}=0$$

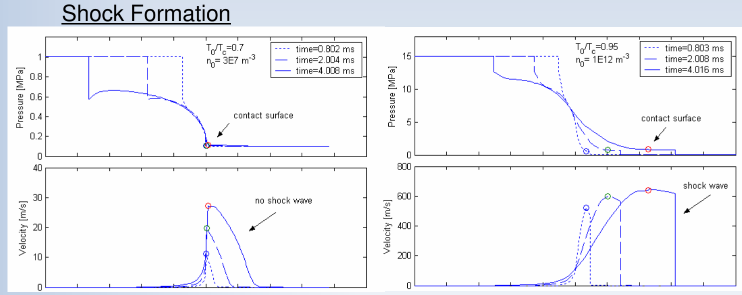
Energy/ Entropy equations

$$\varepsilon_k\rho_k\frac{\partial h_k}{\partial t}+\varepsilon_k\rho_k u\frac{\partial h_k}{\partial x}+\varepsilon_k\frac{\partial P}{\partial t}-\varepsilon_k u\frac{\partial P}{\partial x}=-(\dot{q}''_{ik}+\dot{q}''_{wk}+f_{wk}u)$$

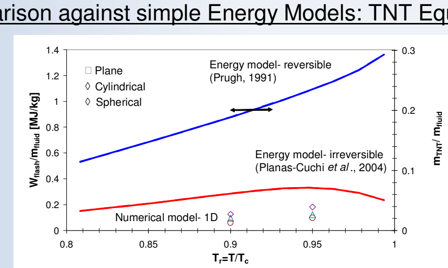
$$\frac{\partial s_{air}}{\partial t}+u\frac{\partial s_{air}}{\partial x}=0$$

Results

Shock Formation



Comparison against simple Energy Models: TNT Equivalence



Conclusions

- The shock formation is associated with high initial temperatures.
- BLEVE formation at T0/TC~0.89-0.90
  - Superheat-limit state during the initial depressurization
  - higher vapor pressures
- The simple energy models calculations over-estimated the shock wave strength.