The Development of a 3D Consequence Analysis Software

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Contents

Introduction

- Consequence analysis is an important topic in the quantitative risk analysis (QRA) techniques. It can usually be used for predicting the severity and the range of potential hazards or for preparing the emergency response plan.
- There are lots of software (such as ALOHA, CHEMS-PLUS, CHARM, and SAFETI etc.) that can fulfil these requirements; however, most of them can only provide either top-view or side-view of a released gas cloud.
- From the emergency planning view point, it is quite important to realize the interesting concentration size of a released gas cloud and the end point of its core concentration along the possible wind influential trajectory; nevertheless, most of the software can only provide the above information one at a time.

Introduction (cont.)

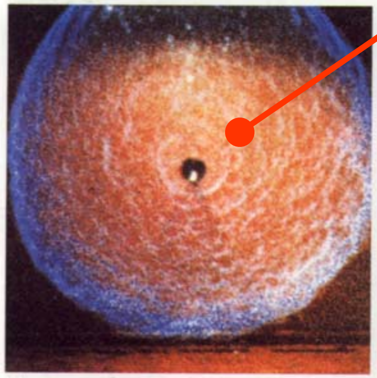
- Therefore, it is quite hard for a junior engineer to quickly grasp the whole picture of a toxic release case from the software and starts to prepare his/her emergency response-planning project
- In this research, a simple package called "Consequence Profile Reconstruction (CPR) Software, Version 2.0" is developed. With a fully opened mathematical models and source codes, the users of the CPR software can easily change the program contents according to their purpose.

(1) Physical Model

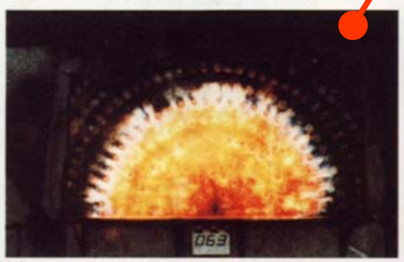
- FLACS software was employed as the physical model to calculate all kinds of fire & explosion consequences (P, J, T…)
- FLACS is a kind of CFD (computational fluid dynamics) software, it includes 3 parts:
  - CASD (computer aided scenario design)
  - flacs (flame acceleration simulator)
  - FLOWVIS (flow visualization)
- The 3D, real time simulation results can be shown in the movie files

Model Description

(a)

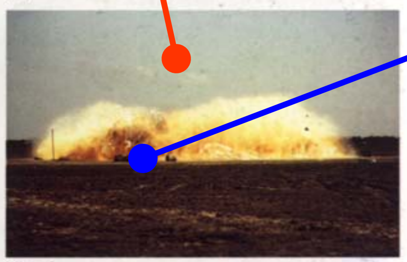


(a)



(c)

(b)



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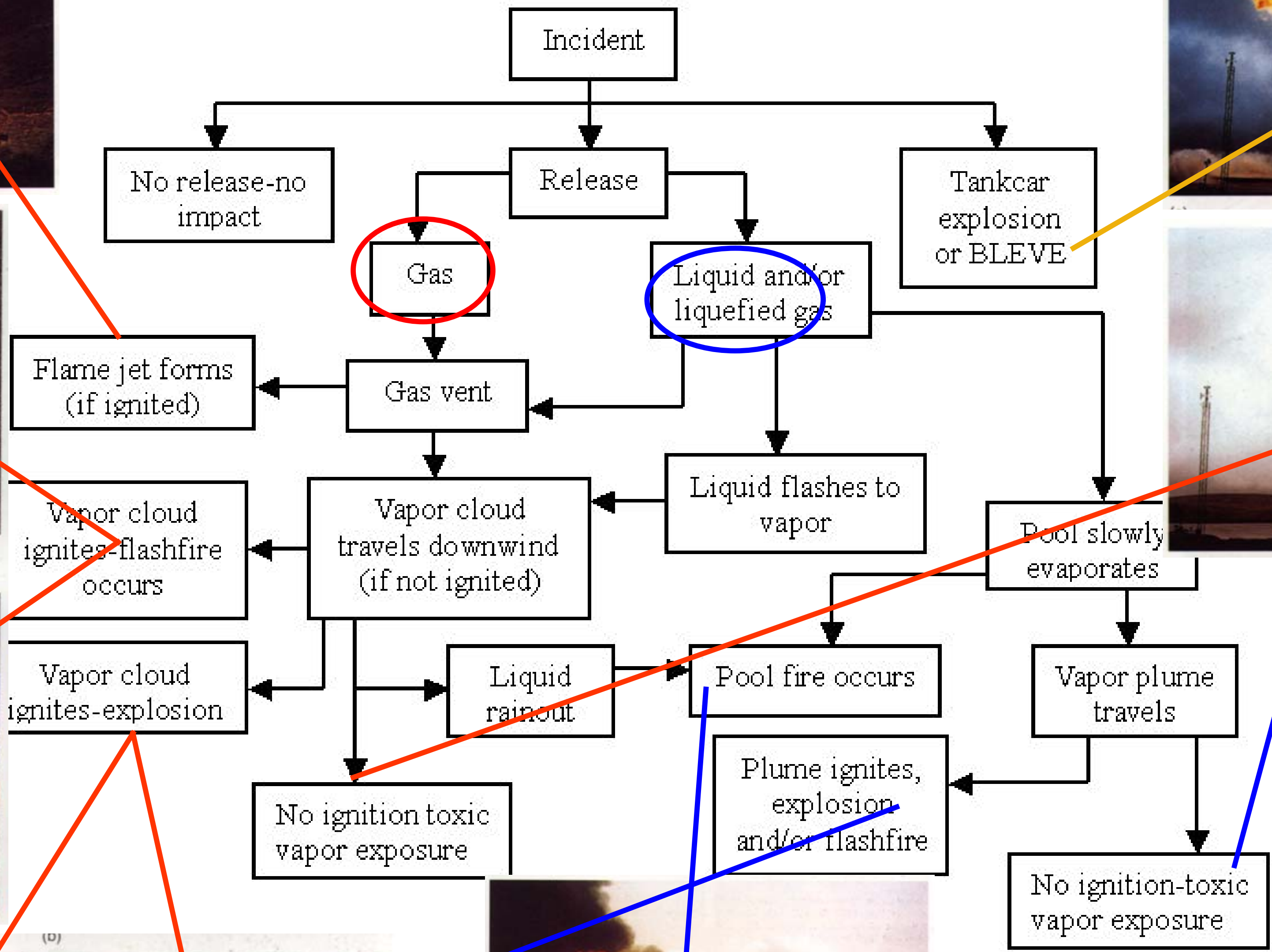
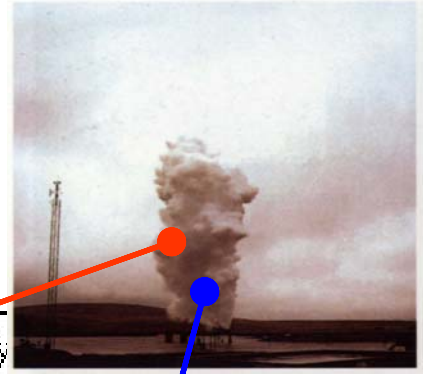




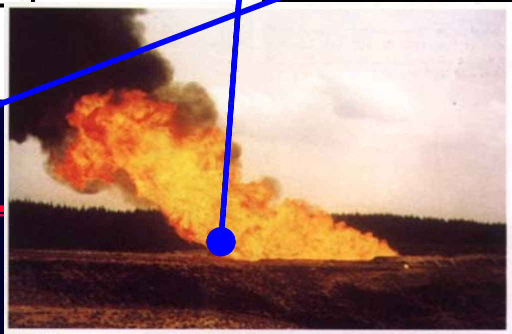
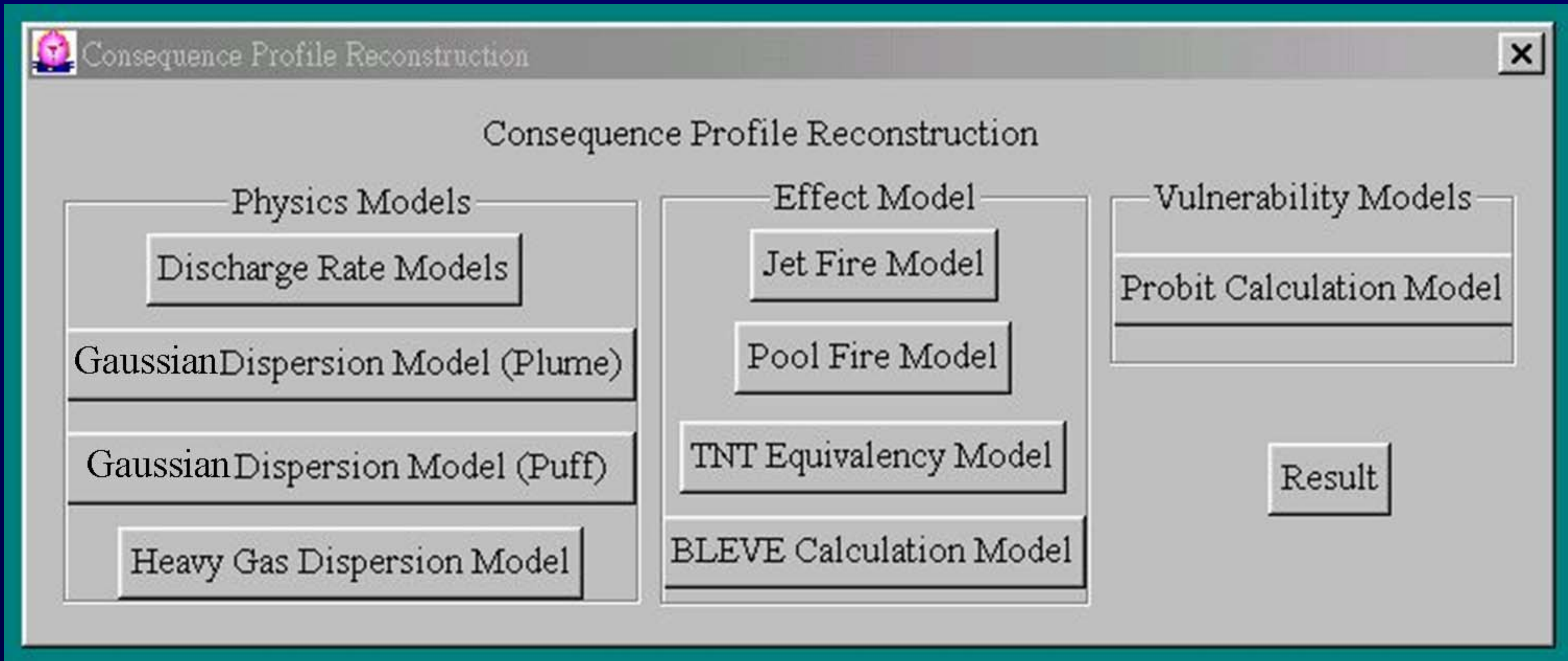


Plate 11 LNG pool fire (Mizner and Eyre, 1982) (Reproduced by permission of Shell Research Ltd)

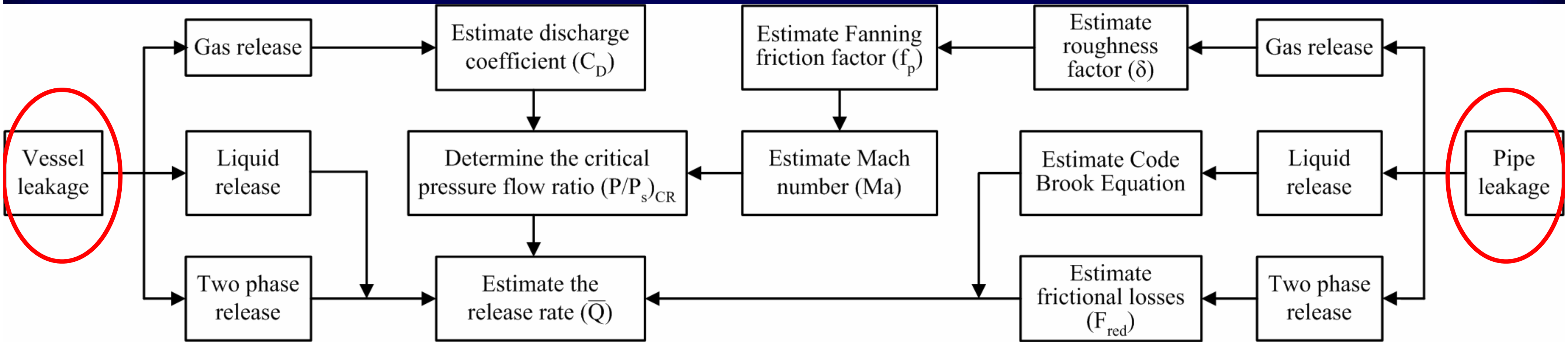
Model Description



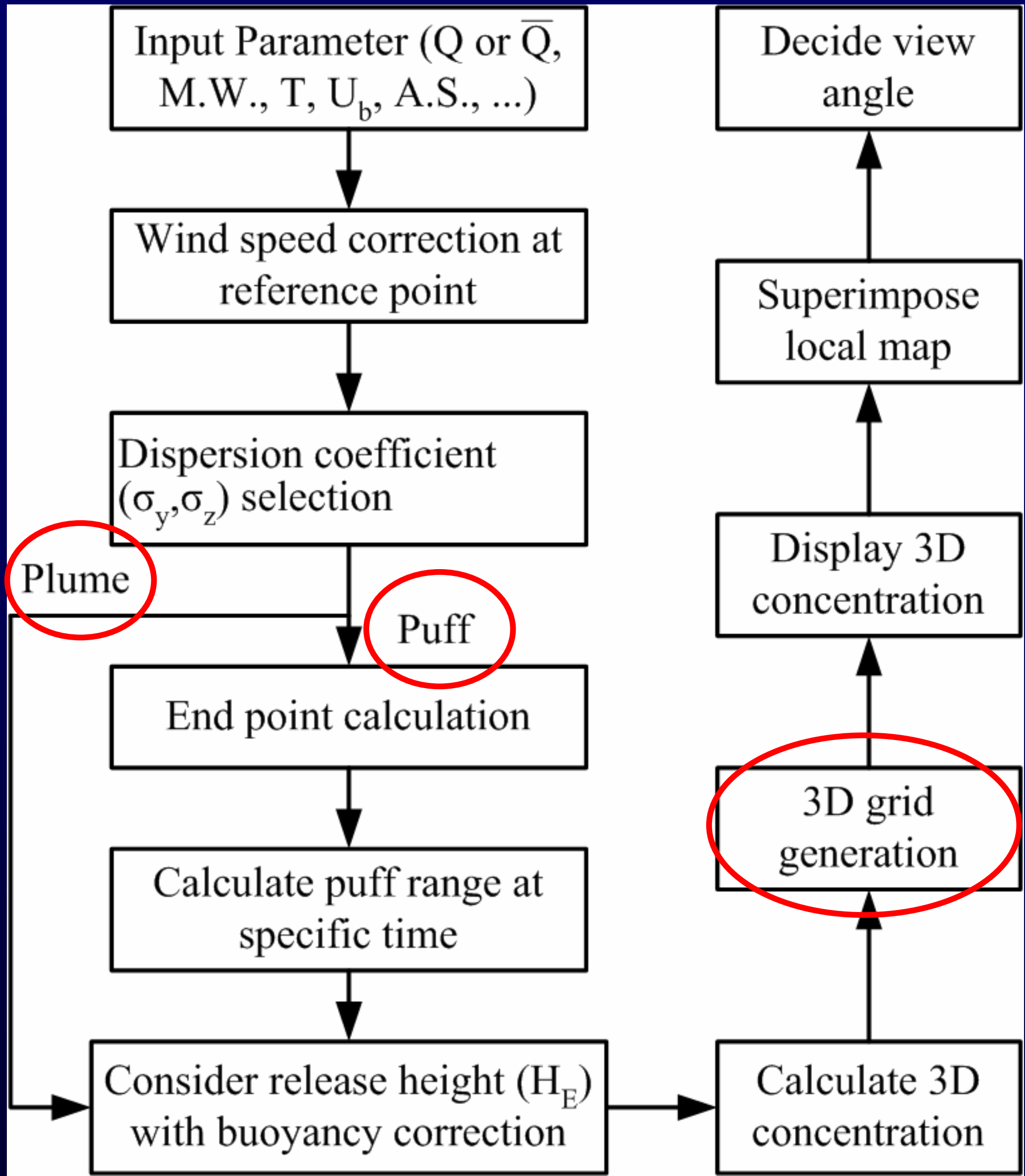
Flowchart of Gas, Liquid, and Two-Phase Release Calculation

The source model is used to describe the different release patterns which includes:

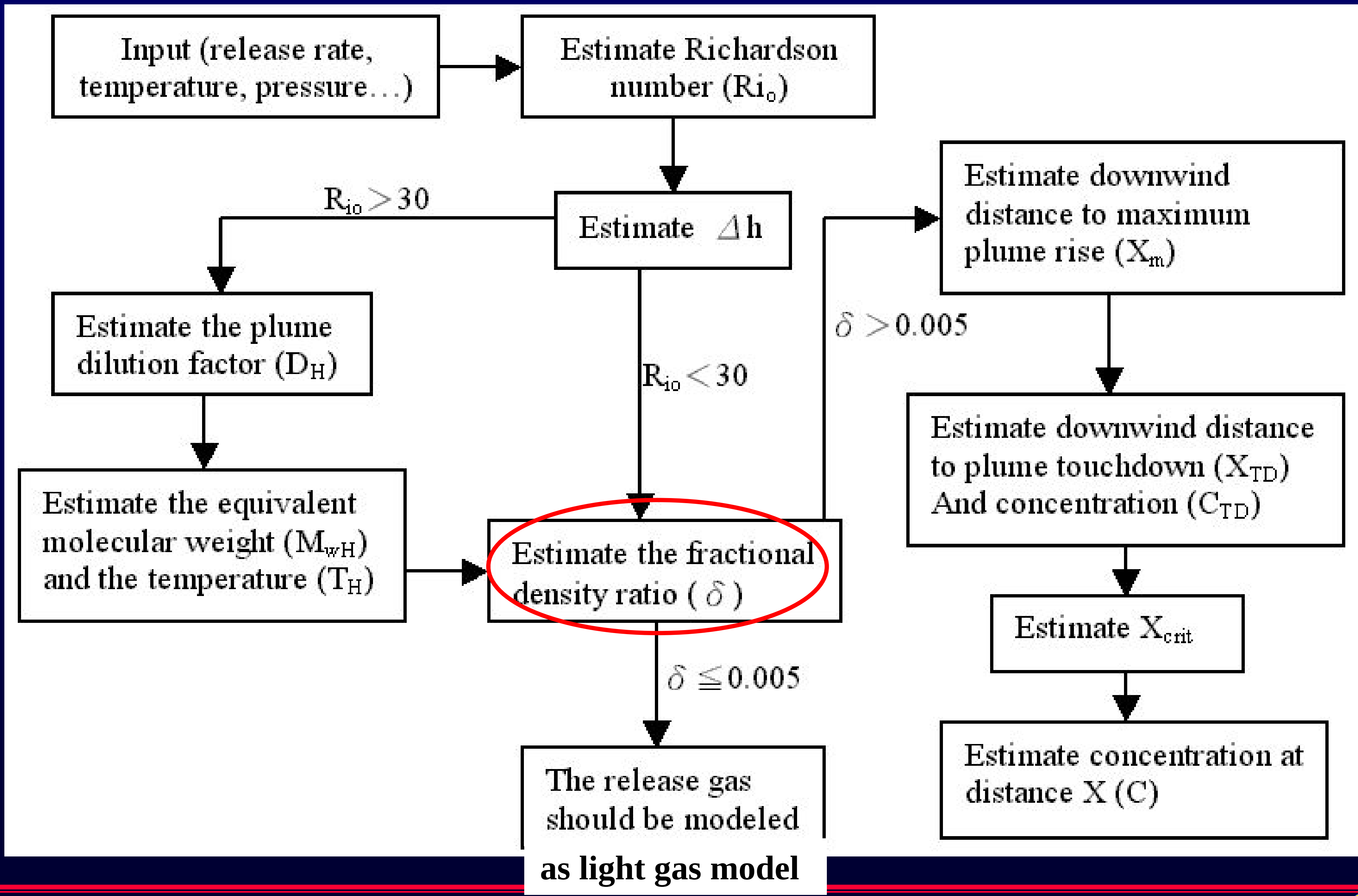
- Gas release from vessel/pipe
- Liquid release from vessel/pipe
- Two-phase release from vessel/pipe



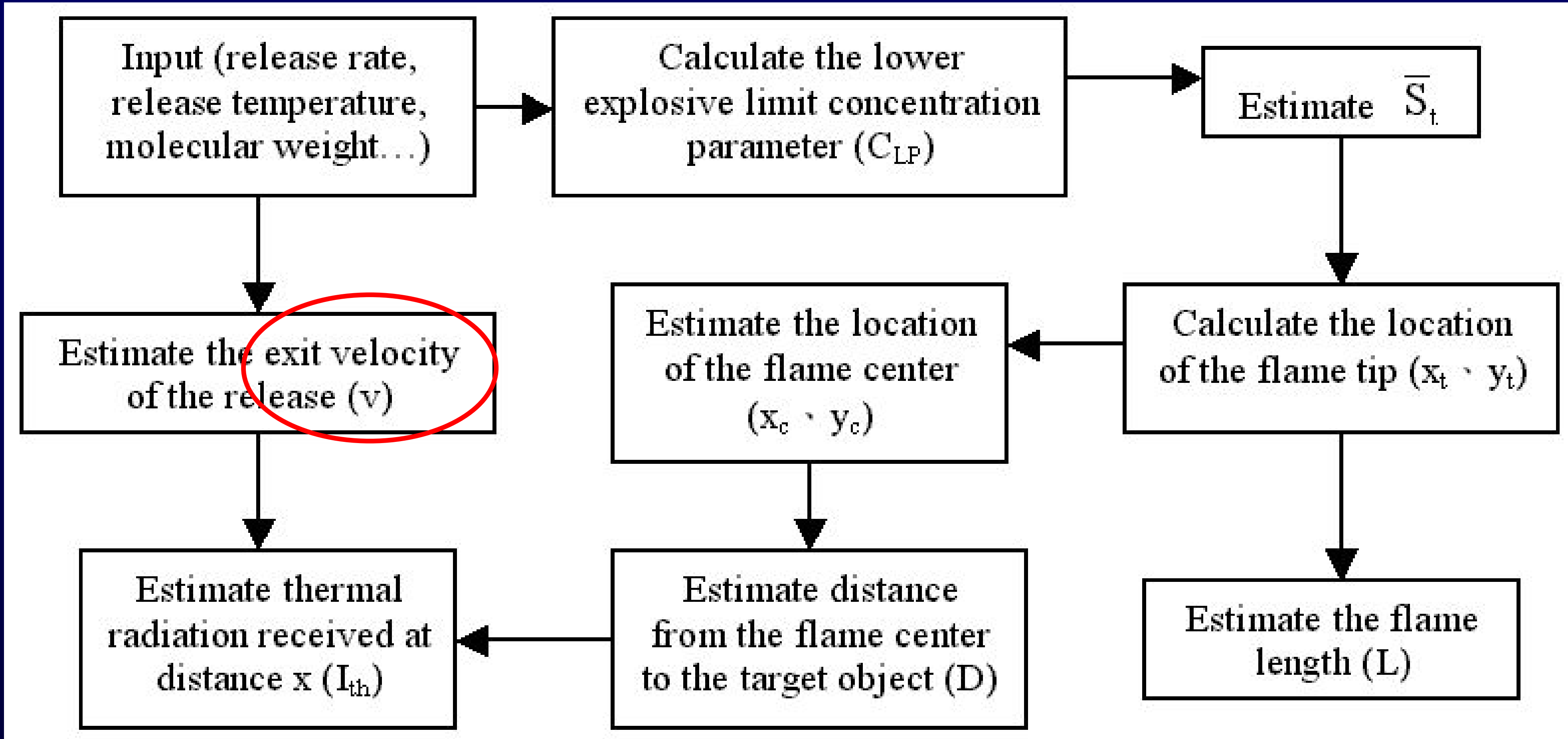
Gaussian Dispersion Puff/Plume Model



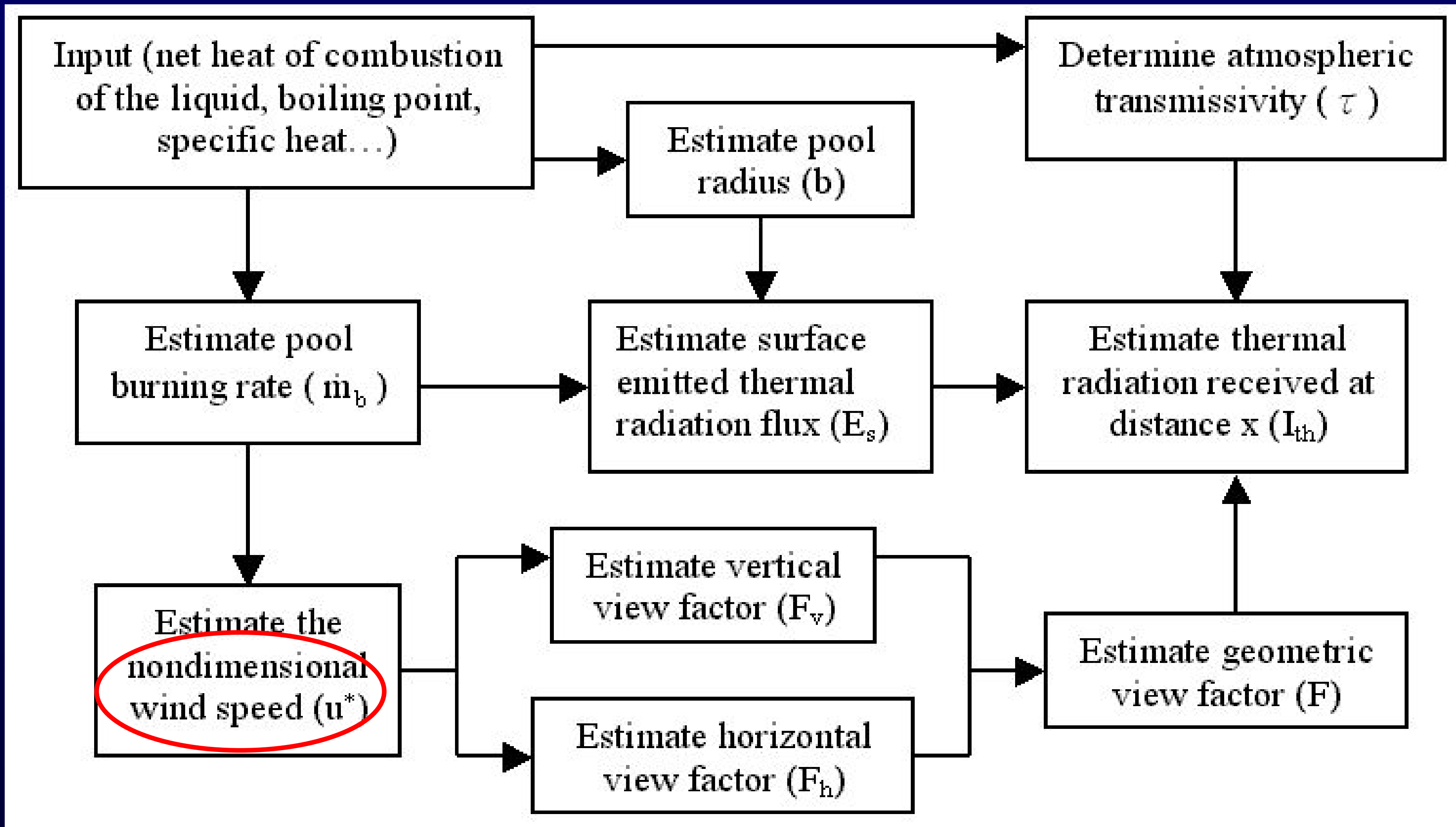
Heavy Gas Dispersion Model



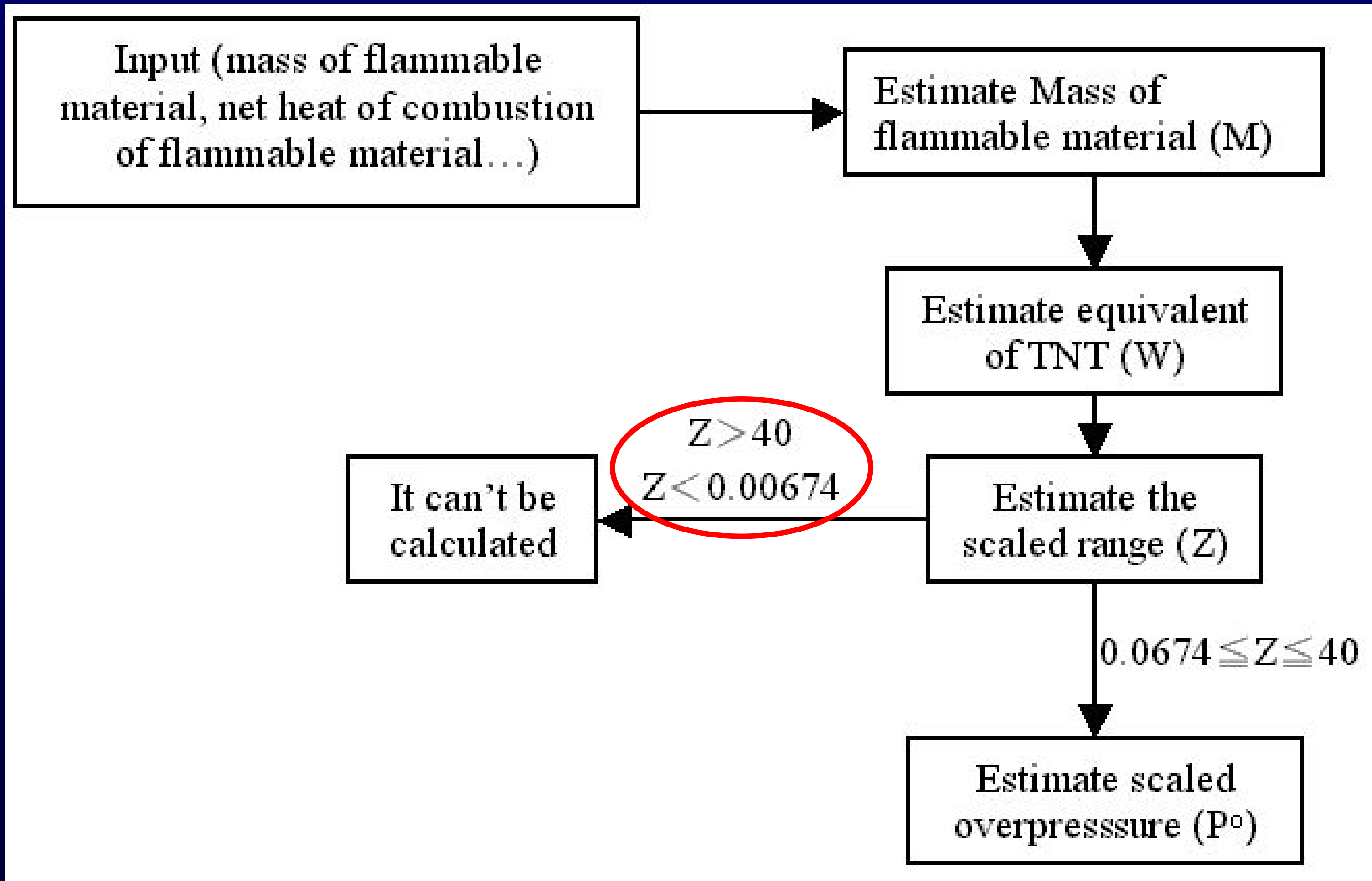
Jet Fire Model



Pool Fire Model



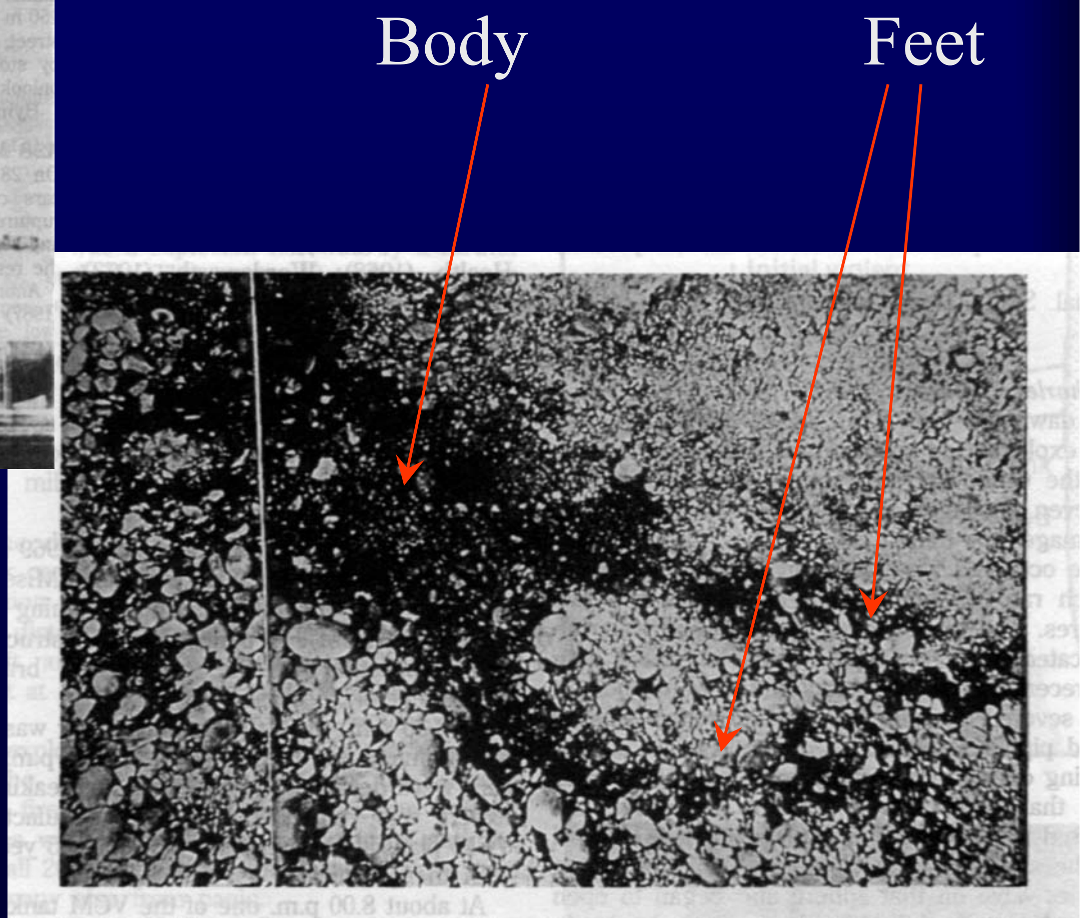
Vapor Cloud Explosion Model



BLEVE Effect

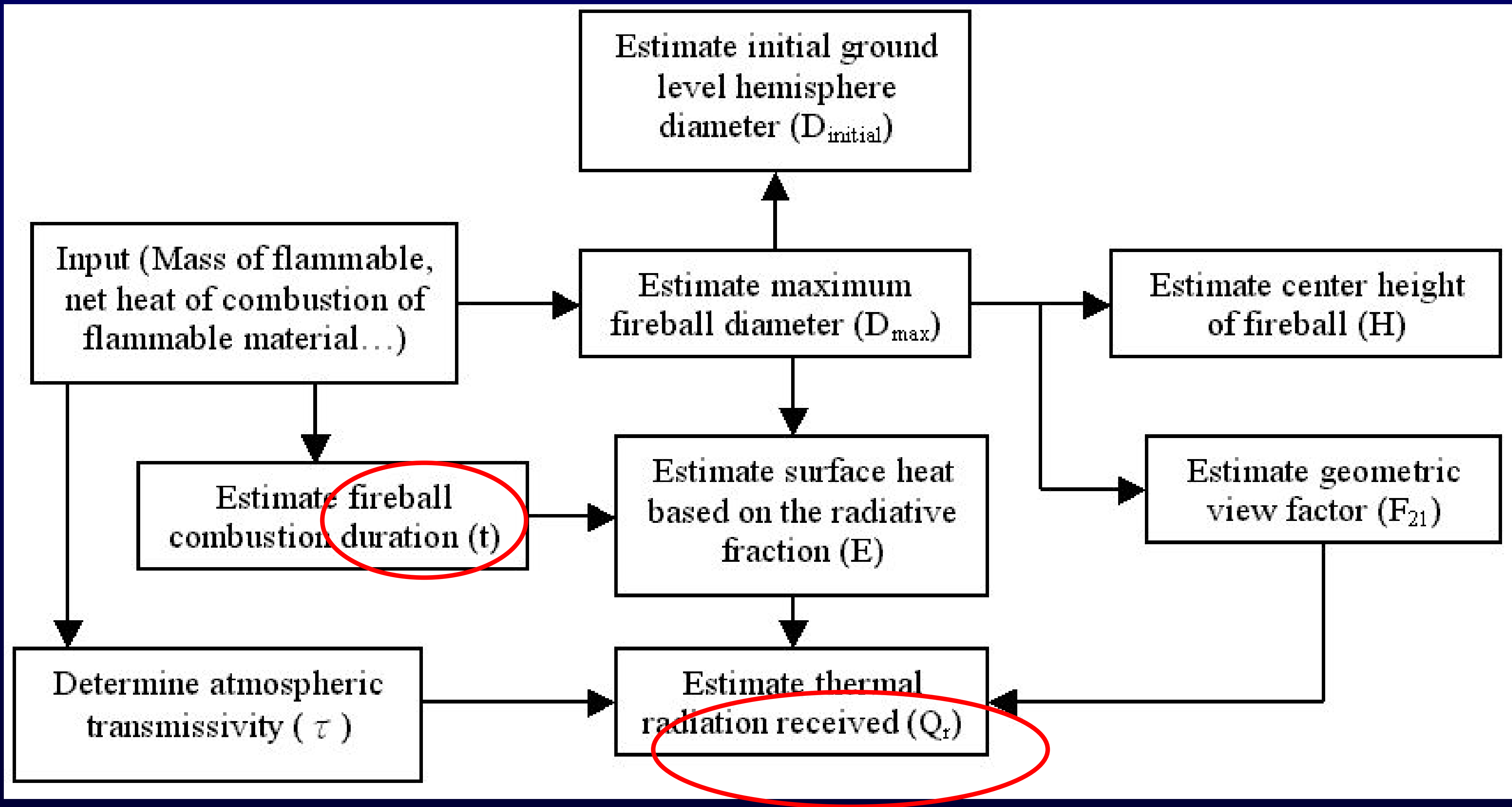
A boiling liquid expanding vapor explosion (BLEVE) often occurs when there is a sudden loss of containment for a pressure vessel containing a superheated liquid or liquefied gas.

BLEVE Effect



Feyzin, 1966: "shadow' of one of the victims (Courtesy of Compagnie Général d'Edition et

BLEVE Model



Estimate initial ground level hemisphere diameter ($D_{initial}$)
Input (Mass of flammable, net heat of combustion of flammable material…)
Estimate maximum fireball diameter (D_{max})
Estimate center height of fireball (H)
Estimate fireball combustion duration (t)
Estimate surface heat based on the radiative fraction (E)
Estimate geometric view factor (F_{21})
Determine atmospheric transmissivity (τ)
Estimate thermal radiation received (Q_r)

Probit Model

Physical Hazard Effect	Probit Equation
Overpressure Effect	$Y_1(x,y,z) = -77.1 + 6.91\ln\left(P_{max}(x,y,z)\right)$
Pressure Impulse Effect	$Y_2(x,y,z) = -46.1 + 4.82\ln\left(J_{max}(x,y,z)\right)$
Heat Radiation Effect	$Y_3(x,y,z) = -14.9 + 2.56\ln\left[\dfrac{t_e I_{max}^{4/3}(x,y,z)}{10^4}\right]$

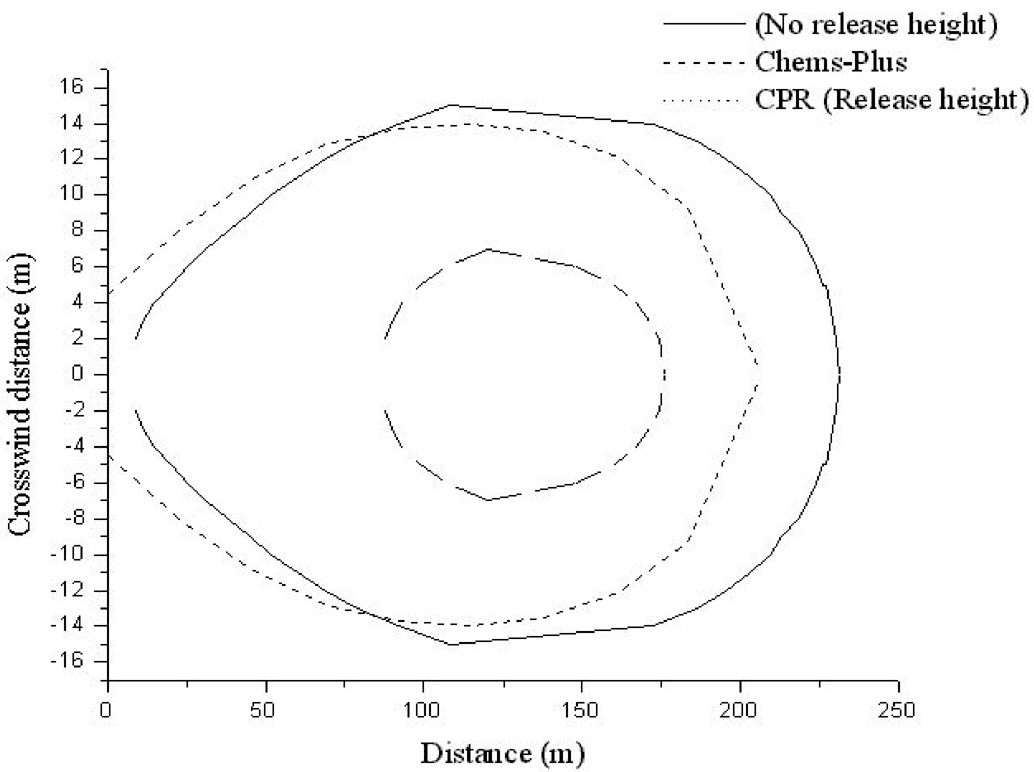
$$Y_i(x,y,z) = K_1 + K_2 \ln\left[F_{max}(x,y,z)\right]$$

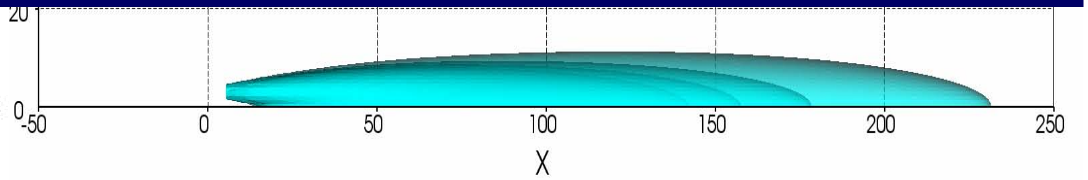
$$P_{D,i}(x,y,z) = \frac{1}{(2\pi)^{1/2}} \int_{-\infty}^{Y_i(x,y,z)} \exp\left(-\frac{u^2}{2}\right) du$$

Comparison of Gaussian Gas Dispersion Models

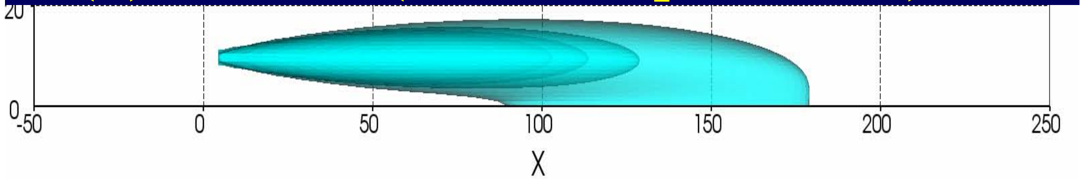
- Suppose methane was release from a tank under the following circumstances:
  - release mass flow rate, 2.4 kg/sec
  - release height, 3 m
  - rupture diameter, 0.15 m
  - atmospheric temperature, 29˚C
  - wind velocity, 5 m/sec
  - atmospheric stability, D
  - ground surface roughness, 0.03 m
- Estimate the potential hazard area of the vapor cloud on the ground with a concentration limit higher than 1250 ppm.

Comparison of Gaussian Gas Dispersion Models (cont.)

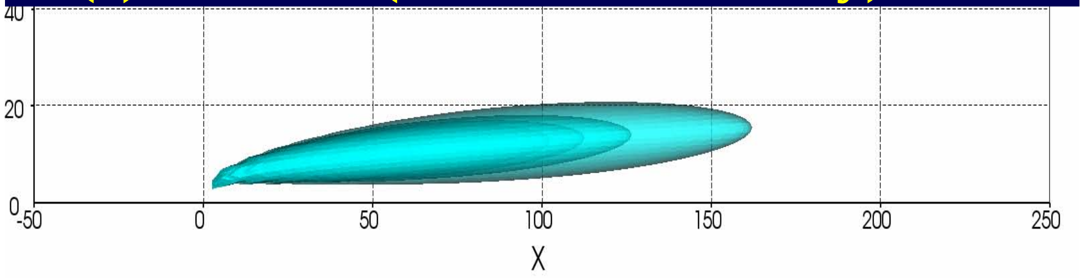




(b) CPR 2.0 (Set HE Equals Zero)



(c) CPR 2.0 (Consider HE Only)



(a) Comparison between CPR 1.0 and CHEMS-PLUS

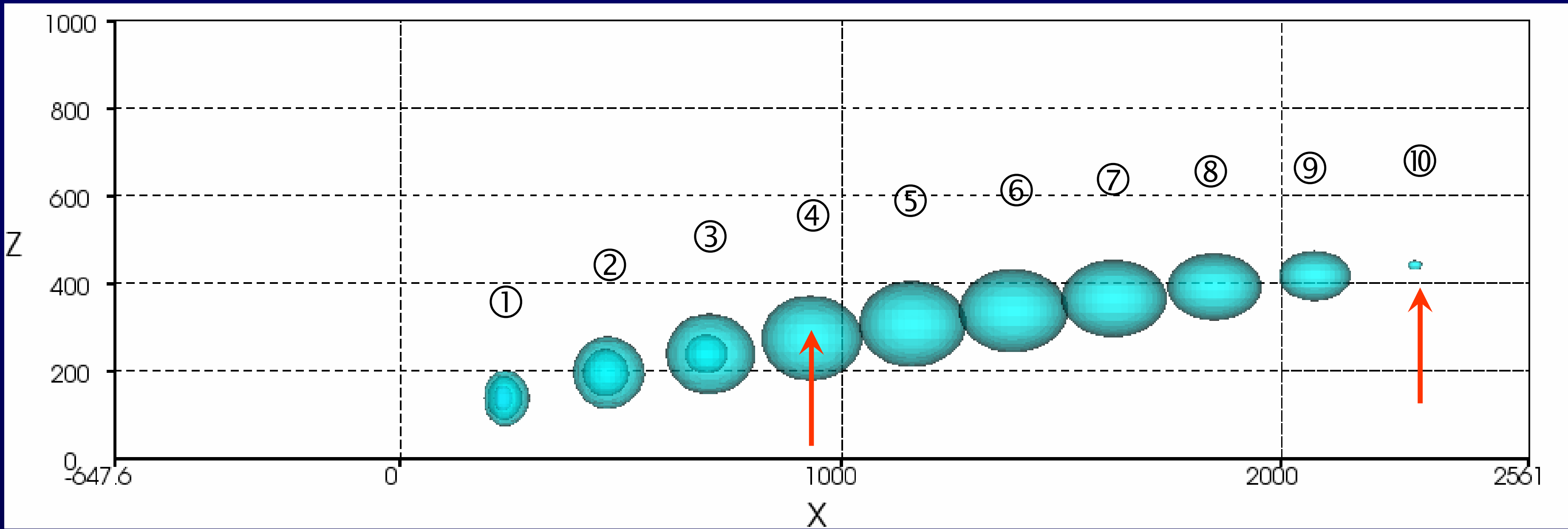
(d) CPR 2.0 (Consider HE with Buoyancy Correction)

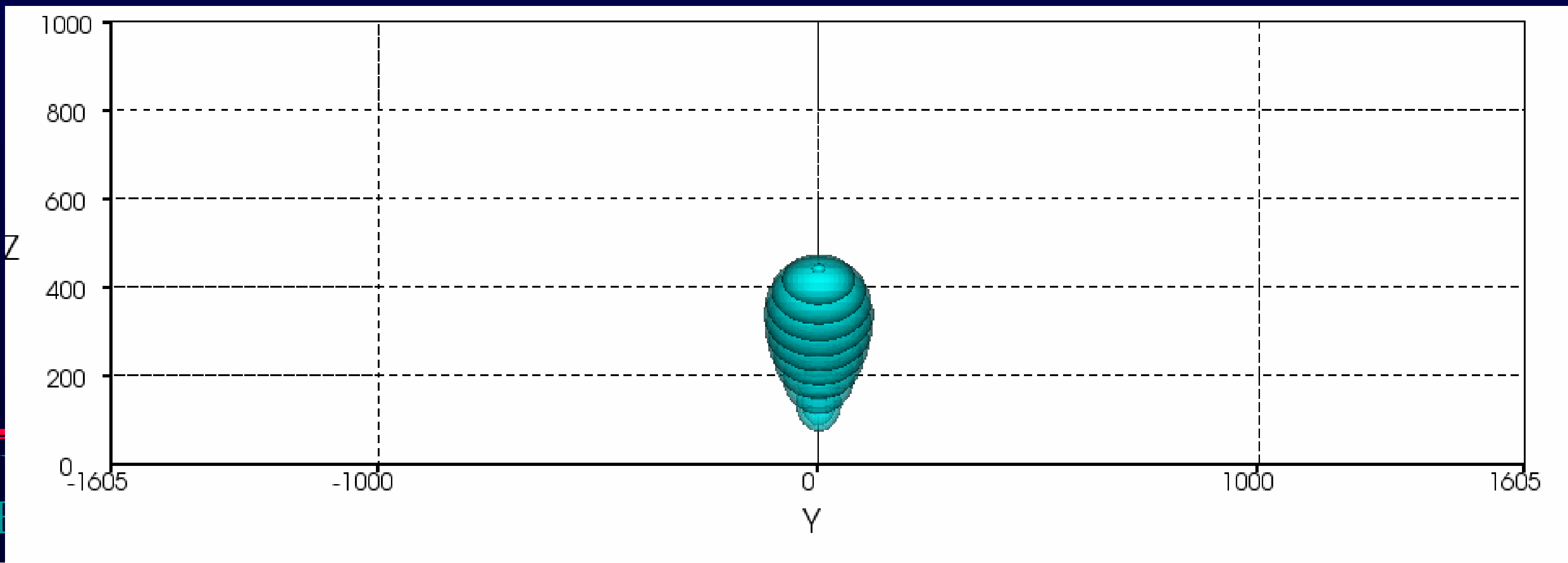
Figure 10: Ground Contours and Side-Views of a Methane Gas Cloud with a Boundary Concentration of 1250 PPM

Comparison of Gaussian Gas Dispersion Models

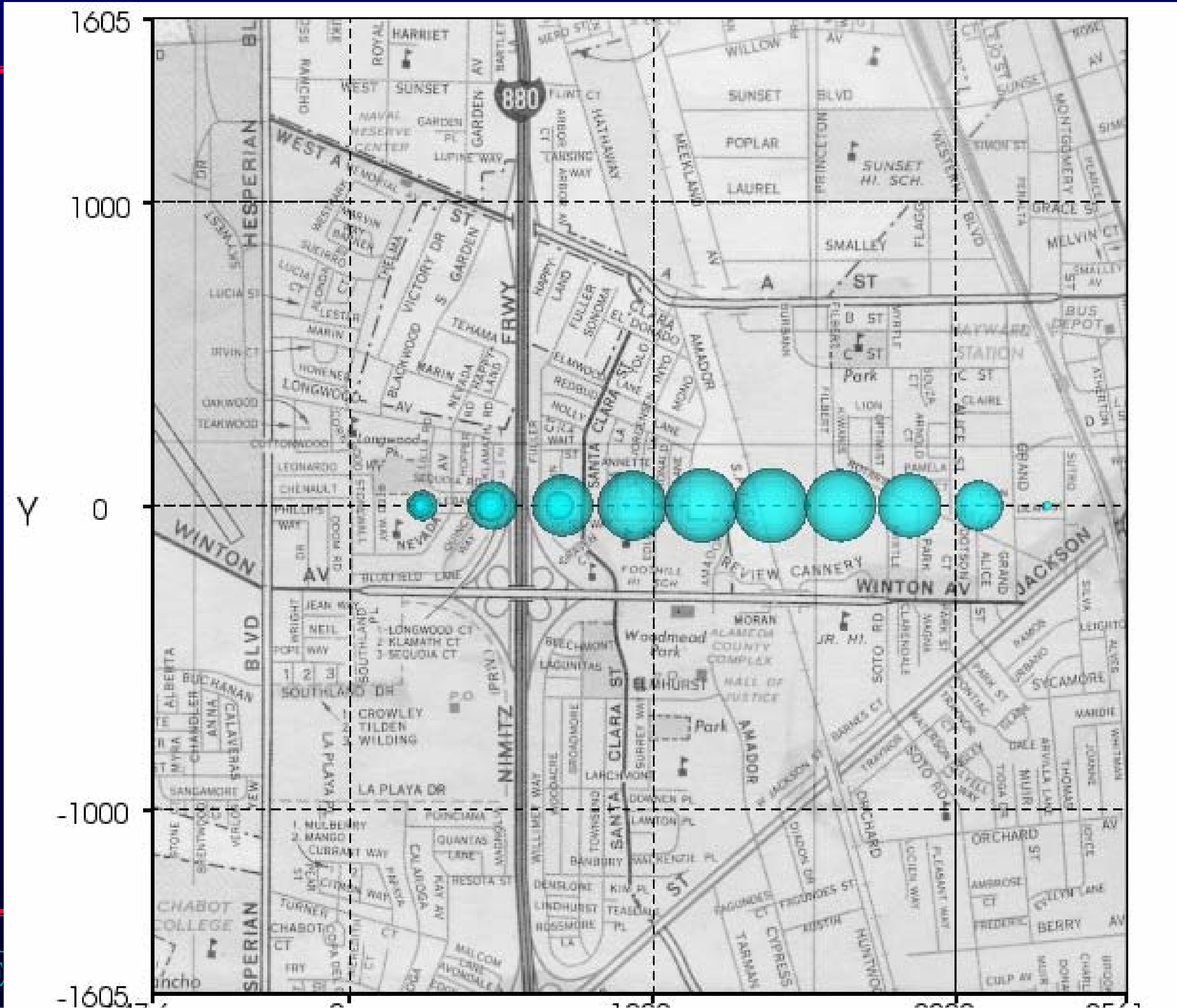
- Suppose 50 kg methane puff suddenly released from a site locates 10 m above ground level, all the other conditions are similar to the previous case study, they are:
  - atmospheric temperature, 29 °C
  - wind velocity, 5 m/sec
  - atmospheric stability, D
  - ground surface roughness, 0.03 m
- Estimate the potential hazard trajectory and the size of the vapor cloud with the concentration as 1000, 100, and 10 ppm respectively.

Side-View (top) and Front View (bottom)

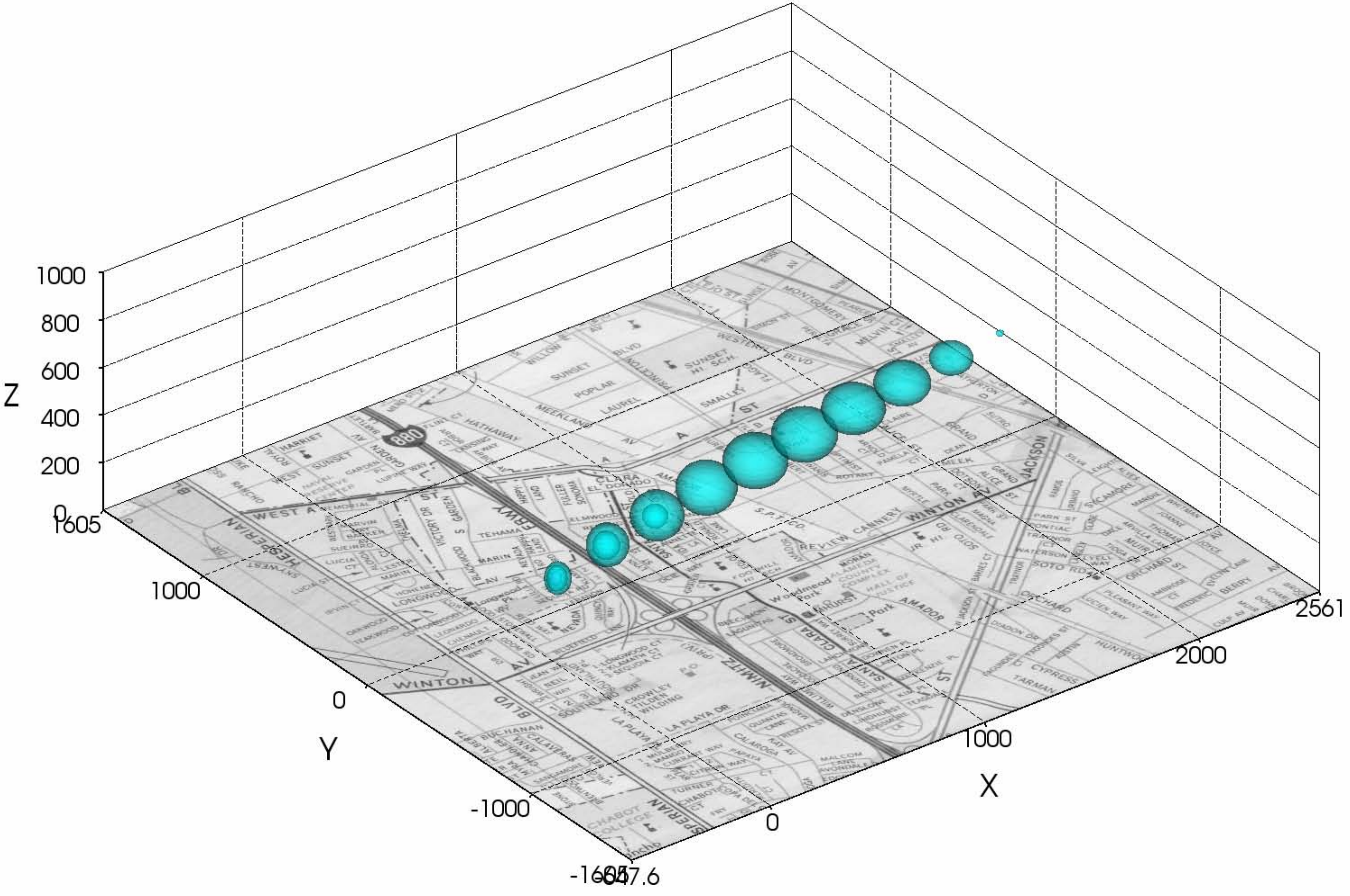




Projective View



3D Isometric View



Conclusions

- After comparing CPR with the CHEMS-PLUS software through different case studies, one can really understand the characteristics of different models and their limitations. A series of model improvements can also be implemented through the validation process.
- In conclusion, the characteristics of the CPR software is as followings:
  - An "all Chinese" user environment (all the figures have been translated into English in this paper) makes it more acceptable and easy to be understood by the local people. A reviewable inquiry input method makes it easier to be learned by the beginners.
  - The "effective release height" and "wind effect" has been taken into consideration for the corresponding gas dispersion and fire models.
  - A "probit model" has been added into the software to manifest the relative severities of different incident outcomes.

Conclusions (cont.)

- All the source codes are reachable thus users can modify the software according to their own purpose.
- CPR 2.0 can vivid provide the whole pictures of an incident to the audiences. The 3D/2D gas dispersion contours superimposed on a local map can clearly show hazardous gas dispersion trajectory, its end point, and the possible impact area from any view angle.
- The transient function and transparent layer of each gas contours can further facilitate the emergency-planning project.

- It is foreseeable the CPR 2.0 can not only be employed as a consequence simulation/emergency planning tool for the novice but can also be used as a platform for developing a more complicated risk assessment software.

Thank you for your attention!

Acknowledgement

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