UNIT III

Introduction to Consequence Analysis - Fire and Explosion models: Radiation - Tank on fire - Flame length –Risk analysis- Radiation intensity calculation and its effect to plant, people & property, UCVCE -Explosion due to - Deflatration - Detonation - TNT, TNO & DSM model - Over pressure. Methods for determining consequences effects: Effect of fire-Effects of explosion - Risk contour - Flash fire - Jet fire - Pool fire - BLEVE - Fire ball.

INTRODUCTION TO CONSEQUENCE ANALYSIS:

Modeling the consequences of hazardous fluids releases is an integral part of any process hazard management program. For most applications within the oil, gas, and petrochemical industry the potential outcomes of a hazardous fluid release fall into categories:

- flammable vapor cloud
- toxic vapor cloud
- torch (jet) fire
- pool fire
- BLEVE fireball
- vapor cloud explosion

Each of these consequence analysis types can be computed using Quest’s CANARY software package, which was designed by Quest engineers and built around a multi-component thermodynamics package. From a list of over 250 components, process streams can be accurately simulated and used in the consequence calculations.

We begin our consequence analysis by calculating the rate of release of the fluid and its thermodynamic state after depressurization to the atmosphere. If the release begins as liquid, we determine the amount of material that falls to the ground or becomes vapor or aerosol. For vapor cloud hazards, we predict the dispersion of the released material in the atmosphere. If ignition of a flammable material is assumed to occur, the release model provides information to the fire radiation models in order to determine the thermal radiation impacts. A vapor cloud explosion (VCE) model can be used to determine the impact of overpressure, should a flammable vapor cloud be ignited.

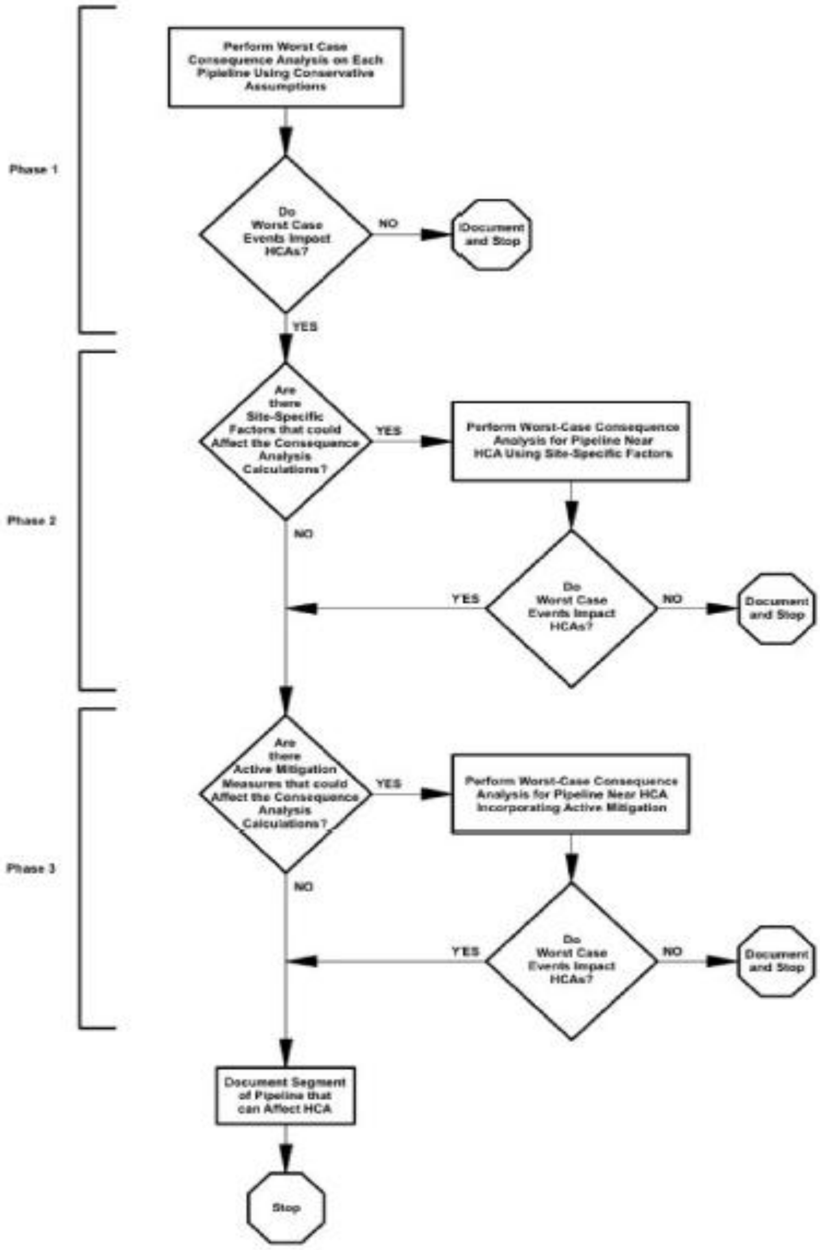
In addition to CANARY, Quest engineers draw on a number of other consequence models for specific purposes. These include the use of public-domain consequence models (e.g., DEGADIS or LNGFIRE for LNG) or Computational Fluid Dynamics models to solve complex problems.

CONSEQUENCE ANALYSIS SOFTWARE

Because of the importance of accurately determining hazard extents, Quest developed a consequence analysis application, the CANARY software package. This powerful application is capable of addressing a variety of hazards. For example:

- Plant and siting of hazardous material facilities
- On and offsite emergency response
- Location of permanent and portable buildings (API 752/753)
- Location and h(API 521)

- Development of hazard zmaps for Quantitative Risk Analysis use
  Quest has considerable experience using Consequence Analysis to complete pipeline integrity management using worst case modeling, site-specific factors, and mitigation options. Quest completes this process according to this flow chart.
  For additional information concerning Consequence Analysis in general or the CANARY consequence modeling application, please contact Quest.



DEFLAGRATION:

Deflagration (Lat: de + flagrare, "to burn down") is subsonic combustion propagating through heat transfer; hot burning material heats the next layer of cold material and ignites it. Most "fires" found in daily life, from flames to explosions, are deflagrations. Deflagration is different from detonation, which propagates supersonically through shock waves. This means that when a substance detonates, it decomposes extremely quickly instead of deflagration. Black powder is an example of a substance that deflagrates when it is ignited.

DETONATION:

Detonation (from Latin detonare, meaning 'to thunder down') is a type of combustion involving a supersonic exothermic front accelerating through a medium that eventually drives a shock front propagating directly in front of it. Detonations occur in both conventional solid and liquid explosives,[1] as well as in reactive gases. The velocity of detonation in solid and liquid explosives is much higher than that in gaseous ones, which allows the wave system to be observed with greater detail (higher resolution).

EFFECT OF FIRE:

EFFECTS OF EXPLOSION:

Explosions create high-pressure, high-temperature gases that can cause:

1. Mechanical failure due to pressure or blast waves or internal pressure build-up.
   - Permanent deformation or equipment or structures
   - Rupture or tearing of metal or building components
   - Creating flying fragments or missiles.
   - Blast, fragment or impact injury
2. Thermal failure due to heat transfer from fireball or hot combustion products.
   - Softening of metal structures
   - Ignition of building materials, electrical insulation, plastic or paper products
   - Burn injuries to skin and eyes
3. Combination of fire and explosion, thermal and mechanical effects often occur.

MECHANICAL EFFECTS FROM HIGH PRESSURE

• Expansion of combustion products due to conversion of chemical to thermal energy in combustion and creation of gaseous products in high explosives
• Expansion ratio for gaseous explosions depends on thermodynamics
• Expansion rate depends on chemical kinetics and fluid mechanics
  - Flame speeds
  - Detonation velocity

THERMAL EFFECTS FROM HIGH TEMPERATURE

Hot gases radiate strongly in IR, particularly for sooting explosion like BLEVE.
– Fireballs cause injury (skin burns) and secondary ignition of structures
• Internal explosions create high-speed gas and convective heat transfer in addition to IR radiation
– Heat up equipment, ignite flammable materials

FRAGMENT EFFECTS FROM STRUCTURAL FAILURE

Primary fragments
– Created by rupture of vessel or structure
– Some fraction of explosion energy transferred to fragment
– Follows a ballistic trajectory
• Secondary fragments
– Created by blast wave and following flow
– Accelerated by flow, eventually follows a ballistic trajectory

• Both lift and in determining trajectories drag important

RESPONSE OF A LARGE STRUCTURE IS COMPLEX!

• Blast effects cause a small number of columns and slabs to directly fail
• Increased load on other structural elements leads to progressive collapse
• In Murrah Building, 40% of floor area destroyed due to progressive collapse, only 4% due to direct blast.
• Factors in progressive collapse
– Building design (seismic resistance can help)
– Fires can weaken structural elements (WTC)
• Detailed analysis and testing is needed to understand or predict response

RISK CONTOUR:

Individual risk results are typically reported as likelihood of death (or dangerous dose) per year, and can be presented in the form of risk contours

FLASH FIRE:

A flash fire is a sudden, intense fire caused by ignition of a mixture of air and a dispersed flammable substance such as a solid (including dust), flammable or combustible liquid (such as an aerosol or fine mist), or a flammable gas. It is characterized by high temperature, short duration, and a rapidly moving flame front.

JET FIRE:

A jet or spray fire is a turbulent diffusion flame resulting from the combustion of a fuel continuously released with some significant momentum in a particular direction or directions. Jet fires can arise from releases of gaseous, flashing liquid (two phase) and pure liquid inventories.

POOL FIRE:

A pool fire is a turbulent diffusion fire burning above a horizontal pool of vaporising hydrocarbon fuel where the fuel has zero or low initial momentum. Fires in the open will be well ventilated (fuel-controlled), but fires within enclosures may become under-ventilated (ventilation-controlled).

BLEVE:

A boiling liquid expanding vapour explosion is an explosion caused by the rupture of a vessel containing a pressurized liquid that has reached temperatures above its boiling point.

Mechanism:

There are three characteristics of liquids which are relevant to the discussion of a BLEVE:

- If a liquid in a sealed container is boiled, the pressure inside the container increases. As the liquid changes to a gas it expands - this expansion in a vented container would cause the gas and liquid to take up more space. In a sealed container the gas and liquid are not able to take up more space and so the pressure rises. Pressurized vessels containing liquids can reach an equilibrium where the liquid stops boiling and the pressure stops rising. This occurs when no more heat is being added to the system, either because it has reached ambient temperature, or because a steady-state equilibrium has been reached between the heat received from the heat source and the heat lost to the environment, or because it has had a heat source removed (in this latter case both the temperature and the pressure will fall if heat is allowed to leave the system).

- The boiling temperature of a liquid is dependent on pressure - high pressures will yield high boiling temperatures, and low pressures will yield low boiling temperatures. A common simple experiment is to place a cup of water in a vacuum chamber, and then reduce the pressure in the chamber until the water boils. By reducing the pressure the water will boil even at room temperature. This works both ways - if the pressure is increased beyond normal atmospheric pressures, the boiling of hot water could be suppressed far beyond normal temperatures. The cooling system of a modern internal combustion engine is a real-world example.
- When a liquid boils it turns into a gas. The resulting gas takes up far more space than the liquid did.

Typically, a BLEVE starts with a container of liquid which is held above its normal, atmospheric-pressure boiling temperature. Many substances normally stored as liquids, such as CO2, propane, and other similar industrial gases have boiling temperatures, at atmospheric pressure, far below room temperature. In the case of water, a BLEVE could occur if a pressurized chamber of water is heated far beyond the standard 100 °C (212 °F). That container, because the boiling water pressurizes it, is capable of holding liquid water at very high temperatures.

If the pressurized vessel, containing liquid at high temperature (which may be room temperature, depending on the substance) ruptures, the pressure which prevents the liquid from boiling is lost. If the rupture is catastrophic, where the vessel is immediately incapable of holding any pressure at all, then there suddenly exists a large mass of liquid which is at very high temperature and very low pressure. This causes a portion of the liquid to "instantaneously" boil, which in turn causes an extremely rapid expansion. Depending on temperatures, pressures and the substance involved, that expansion may be so rapid that it can be classified as an explosion, fully capable of inflicting severe damage on its surroundings.

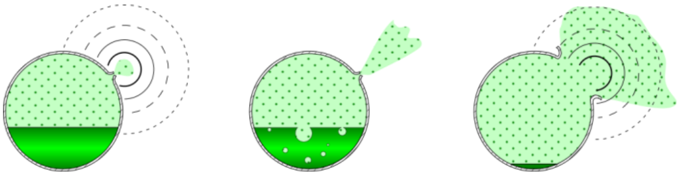
Water example

For example, a tank of pressurized liquid water held at 204.4 °C (400 °F) might be pressurized to 1.7 MPa (250 psi) above atmospheric ("gauge") pressure. If the tank containing the water were to rupture, there would for a brief moment exist a volume of liquid water which would be at atmospheric pressure, and a temperature of 204.4 °C (400 °F).

At atmospheric pressure the boiling point of water is 100 °C (212 °F) - liquid water at atmospheric pressure does not exist at temperatures higher than 100 °C (212 °F). At that moment, the water would boil and turn to vapour explosively, and the 204.4 °C (400 °F) liquid water turned to gas would take up significantly more volume (~1,600-fold) than it did as liquid, causing a vapour explosion. Such explosions can happen when the superheated water of a steam engine escapes through a crack in a boiler, causing a boiler explosion.

BLEVEs without chemical reactions

A BLEVE need not be a chemical explosion—nor does there need to be a fire—however if a flammable substance is subject to a BLEVE it may also be subject to intense heating, either from an external source of heat which may have caused the vessel to rupture in the first place or from an internal source of localized heating such as skin friction. This heating can cause a flammable substance to ignite, adding a secondary explosion caused by the primary BLEVE. While blast effects of any BLEVE can be devastating, a flammable substance such as propane can add significantly to the danger. While the term BLEVE is most often used to describe the results of a container of flammable liquid rupturing due to fire, a BLEVE can occur even with a non-flammable substance such as water,[2] liquid nitrogen,[3] liquid helium or other refrigerants or cryogens, and therefore is not usually considered a type of chemical explosion. Note that in the case of liquefied gasses, BLEVEs can also be hazardous because of rapid cooling due to the absorption of the enthalpy of vaporization (e.g. frostbites), or because of possible asphyxiation if a large volume of gas is produced and not rapidly dispersed (e.g. inside a building, or in a trough in the case of heavier-than-air gasses), or because of the toxicity of the gasses produced.



FIRE BALL:

A somewhat spherical mass of fire