Property Risk Consulting Guidelines

A Publication of AXA XL Risk Consulting

PRC.8.0.1.1

OIL AND CHEMICAL PROPERTIES LOSS POTENTIAL ESTIMATION GUIDE

INTRODUCTION

AXA XL Risk Consulting develops potential loss estimates for each risk. One of these loss estimates is known as the Maximum Foreseeable Loss (MFL). This MFL is estimated assuming the most unfavorable conditions exist at the time of the loss with due regard to the size, location of the plant, construction, partial cutoffs, occupancy, protection of hazards, exposure protection installations, public protection, and any other factors pertinent to the risk involved.

Within the scope of this definition, MFLs are normally established for oil and chemical properties utilizing one of four types of potential incidents. These include:

- fires
- building explosions
- vapor cloud explosions
- vessel explosions

Of course, any risk may possess the potential for one or more of these incident types.

This AXA XL Risk Consulting Guideline describes the factors considered by AXA XL Risk Consulting when estimating the maximum foreseeable loss potential for oil and chemical properties. This AXA XL Risk Consulting Guideline should be used for property loss prevention purposes only and should not be used for designing or siting blast resistant buildings or for specifying personnel protection.

FIRES AND INTERNAL BUILDING EXPLOSIONS

Loss estimates based on vessel or vapor cloud explosions lend themselves to a rigorous analysis method. Fires, however, must be analyzed more subjectively. The guidance contained in this section is therefore limited to a listing of the factors which must be considered determining the potential loss scenario for a potential fire or internal building explosion incident, and the loss estimate based on that incident. Some factors which must be considered are:

- The largest amount of material which might be spilled and the reasons such a spill may occur such as a pump or piping failure.
- The physical properties of the material and the operating conditions of the process, such as temperature and pressure.
- The reactivity of process materials.
- Construction of the building.

- The passive protection features in the affected area such as:
  - Fireproofing of structural steel and vessel supports.
  - Drainage and diking in the area.
- Spacing between units or provision of blast-resistant walls.
- Past experience with similar units.

All of the factors above should be considered. Obviously, passive protection features, such as spacing, fireproofing, drainage and diking are not subject to impairment simultaneous with a loss so their affect on potentially limiting the size of the loss can be considered.

Generally speaking, where good drainage (more than one direction) or diversionary diking is utilized to prevent the spread of flammable liquid spills and the spacing is in accordance with PRC.2.5.2 the loss estimate should be based on major damage to the production units within the drainage/diking zone. Some damage would be expected to surrounding units due to exposure to the radiant heat of the fire.

As with analysis of a potential fire incident, internal building explosions cannot be rigorously analyzed. The release of flammable liquids or gases into a building, with subsequent ignition and explosion, will potentially result in destruction of the building. Possible damage to nearby buildings should be considered. Subsequent fires from broken piping would also be a factor. The degree of damage anticipated from a building fire with the sprinkler systems out-of- service and an internal building explosion with subsequent damage to the sprinkler system would be similar.

VAPOR CLOUD EXPLOSIONS (VCE)

Background

For many years, it was believed that in order for the combustion of flammable gases or vapors to create pressure, the combustion reaction must be confined. Therefore, it was considered only a fire problem to release quantities of flammable gases or hot flammable liquids in open areas. The potential for explosion was not considered even though a number of open-air vapor cloud explosions had occurred as early as 1948.

AXA XL Risk Consulting recognized, in the early 1960’s that the release of large quantities of flammable vapors could result in an open-air vapor cloud explosion that could cause damage due to overpressure to wide areas of plant properties. A method of calculating the approximate damage potential was formulated and used to establish MFL estimates for these potential losses. The original method was used for the release of flammable gases. A significant number of losses then showed there was a need to also consider the release of flammable liquids being processed above their boiling points. The initial incident is assumed to be the release of a significant quantity of flammable materials which forms a cloud and finds an ignition source.

Historically VCE scenarios have only considered liquids above their boiling point but this may be changing. Atmospheric flammable liquid storage hazards were thought to be limited to pool fires. This thinking may need to be reexamined in light of the Buncefield (2005), San Jose (2009) and Jaipur (2009) tank farm incidents. A spill of a liquid such as gasoline at a temperature lower than its boiling point may not immediately vaporize but if the pool remains long enough in the right conditions it could create enough vapors to lead to a VCE.

Assumptions

AXA XL Risk Consulting considers a reasonably simple vapor cloud explosion potential model. A number of papers have been written that examine the vapor cloud explosion phenomenon to a finer degree. These papers look at the effect of factors such as spill rate, wind velocity, wind direction, various atmospheric conditions, reactivity of the spilled material, congestion in the release area, and partial confinement within the cloud.

These variables can vary from day to day such as weather conditions or may be difficult to determine such as confinement potential. With this in mind AXA XL Risk Consulting has chosen to take a conservative and practical approach toward determining the factors to be considered when conducting a VCE analysis. Therefore, the following assumptions are made:

- The spill is instantaneous and leak rate is not considered. The one exception to this is a spill from a pipeline rupture.
- The spilled material is instantaneously vaporized and a cloud is immediately formed. For example, spills of liquefied gases are assumed to fully vaporize instantaneously with no autorefrigeration of the liquid pool.
- The cloud formed is cylindrically shaped with a vertical axis as the cloud height. Wind distortion and distortion due to the presence of buildings or structures are not considered.
- The cloud composition is assumed to be of uniform composition with the vapor-air mixture being at the midpoint of the explosive range.
- A heat of combustion of 2000 Btu/lb (4648 kJ/kg) for TNT is used to convert the heat of combustion of the material to an equivalent weight of TNT.
- An ambient temperature of 70°F (21°C) is assumed.

Materials To Be Considered For A Potential VCE Include:

- The following materials are considered as having a vapor cloud potential:
- Liquefied flammable gases under pressure such as propane and butane.
- Flammable gases existing as a liquid because of refrigeration.
- Ordinary flammable liquids at temperatures above their atmospheric boiling point or under pressure such as cyclohexane and naphtha.
- Non-liquefied reactive flammable gases such as ethylene, ethylene oxide, and propylene.
- The following materials are typically excluded from this analysis:
- LNG and Natural Gas, as most natural gas has an ethane content of less than 15%
- Ammonia
- Gaseous Hydrogen
- VCEs with masses less than 1ton are not usually considered since no loss event has been reported involving a mass below that limit (Marshall, 1987)
- Miscellaneous flammable or combustible gases such as ammonia synthesis gas (a hydrogen/carbon monoxide mix), coal and blast furnace gases, methylene chloride, and trichloroethylene are excluded, because of low flame speeds and heats of combustion and lack of loss history
- Flammable liquids or gases processed above their autoignition temperature will immediately ignite on contact with air. A severe flash fire may occur but the delayed cloud ignition, necessary for development of significant overpressure, will not occur with these materials.
- Flammable liquids having a high viscosity (greater than 1×10^5 centipoise) will likely not present normal vapor formation and will form pools of non-vaporizing liquid rapidly.

CALCULATION CONSIDERATIONS

Choice Of A Credible Spill Scenario For The MFL Estimate

When estimating the MFL the following criteria should be used for estimating the size of the spill:

- The size of a spill is based on the contents of the largest process vessel or train of process vessels connected together and not readily isolated. Fire safe emergency isolation valves which are actuated both automatically and manually from a remote location may be considered in reducing the size of the estimated spill. The minimum spill source to be used is the largest process vessel. It should be noted the largest spill does not always present the largest vapor cloud potential, smaller spills of light products can create a larger vapor cloud and should also be considered.

- The existence of ignition sources may not be used in reducing the cloud size. The total amount which might be spilled must be used in estimating the cloud size. Loss experience has shown that large clouds may be formed without ignition by nearby ignition sources.
- If the flammable hold up in the process vessels is limited (i.e. flammable liquids react quickly or are immediately diluted in the reactor) then the failure of a process pipeline carrying the material may be considered. For this scenario it is standard practice to limit the discharge time to approximately 10 min. Experience shows that in most cases ignition occurs within this period.

CALCULATIONS AND RESULTS

For the actual vapor cloud calculations AXA XL Risk Consulting uses the SwissRe ExTool software. The amount of material which is expected to spill is entered into the program. The material expected to spill is also entered into the program which uses this information to determine the heat of combustion and yield factor to be used in its calculations. The software uses the information it is given to determine the cloud size and the energy released by the explosion which is normally expressed as a TNT equivalent.

Once the software completes its calculations the output includes the diameter of three pressure rings. These rings correspond to overpressures of 5 psig (34 kPa), 2 psig (13 kPa), and 1 psig (6.9 kPa).

Tables 1A, 1B, 1C, 1D and 2 show the type of damage that may be expected at the various overpressure levels. The expected damage within the 5 psig (34 kPa) ring is expected to be 80-100%, the damage in the 2 psig (13 kPa) ring is expected to be 40-50%, and the damage in the 1 psig (6.9 kPa) ring is expected to be 5-10%. AXA XL Risk Consulting typically uses the higher of the two values when calculating the loss estimate.

TABLE 1A

Summary of Blast Damage To Structures

Over-pressures (psi)	Controlhouses		Crude Units				
	Steel Roof Decking and No Frame	Precast Concrete Roof and Steel Frame	Steel Frame bet. Vessels	Atmos./Vacuum Towers		Fractionator Towers	
				Rectangular Conc. Frame	Octagonal Conc. Frame	Rectangular Conc. Frame	Mounted on Conc. Pedestal
0.5	Windows shatter	Windows shatter					
1.0	Roof collapse (switchgear room)	Frame deformation					
1.5	Roof collapse (control room)	Roof collapse (all rooms)					
				NOTE: Atmospheric Vacuum Towers	**NOTE:** Vacuum Towers only		
3.5	Conc. block walls fail	Conc. block walls fail	Conc. brackets fail causing frame collapse				
4.5							Anchor bolts yielding
5.0							
5.5				Conc. frame cracking		Conc. frame cracking	
7.0				Conc. frame collapse	Conc. frame cracking	Conc. frame collapse	Vessel & foundation overturn
7.5					Vessel anchor bolts fail causing frame collapse		
8.0							
8.5							
10.0		Steel frame collapse					
12.0							
16.0							

Source: *Minimize Damage to Refineries From Nuclear Attack*, National And Other Disasters, The Office Of Oil & Gas, U.S. Dept. Of The Interior; February 1970

SI Units: 1 psig = 6.9 kPa

TABLE 1B

Summary Of Blast Damage To Structures

Over-pressures (psi)	Fluid Catalytic Cracking Units (FCCU)				
	Regenerator Tower		Reactor Tower		Fractionator Tower
	Rectangular Steel Frame	Rectangular Conc. Frame	Rectangular Steel Frame	Rectangular Conc. Frame	Mounted on Conc. Pedestal
00.5					
01.0					
01.5			**NOTE**: Reactor & Fractionator supported by same frame		
03.5					
04.5					
05.0	Leeward columns buckle				Anchor bolts yielding
05.5					
07.0	Overturns		Leeward columns buckle.		Overturns Anchor bolts fail
07.5					
08.0				Concrete frame cracking	
08.5		Conc. frame cracking			
10.0					
12.0			Steel frame overturns	Conc. frame collapse	
16.0		Conc. frame collapse			

Source: *Minimize Damage to Refineries From Nuclear Attack*, National And Other Disasters, The Office Of Oil & Gas, U.S. Dept. Of The Interior; February 1970

SI Units: 1 psig = 6.9 kPa

TABLE 1C
Summary Of Blast Damage To Structures

Over-pressure (psi)	Light Ends Units		Furnaces - Pipe Still		Maintenance Building	Water Cooling Tower	Flares	
	Deisobutanizer	Vapor Recovery Unit						
	Mounted on Pedestal and Large Footing	Rectangular Steel Frame	Atmospheric	Vacuum			Tower Supported	Guyed
00.3					Corrugated Asbestos Siding fails	Corrugated Asbestos Louvers fail		
01.5			Moves slightly from original position	Moves slightly from original position				
02.0								
03.0					Steel frame deformation		Steel frame overturns Blast diagonally oriented.	
03.5						Tower collapses		
04.0							Steel frame overturns. Blast squarely oriented	
05.0					Brick walls collapse. Severe frame deformation.			
06.0		Steel frame collapse.	Stacks collapse	Stacks collapse	Steel frame collapses			
06.5			Steel frame collapse	Steel frame collapse				
07.0								
07.5								
09.0								
09.5	Vessel overturns							
10.0								
10.5								
11.0								Collapse above middle collar
15.0								Complete collapse
20.0								

Source: *Minimize Damage to Refineries From Nuclear Attack*, National And Other Disasters, The Office Of Oil & Gas, U.S. Dept. Of The Interior; February 1970

SI Units: 1 psig = 6.9 kPa

TABLE 1D

Summary Of Blast Damage To Structures

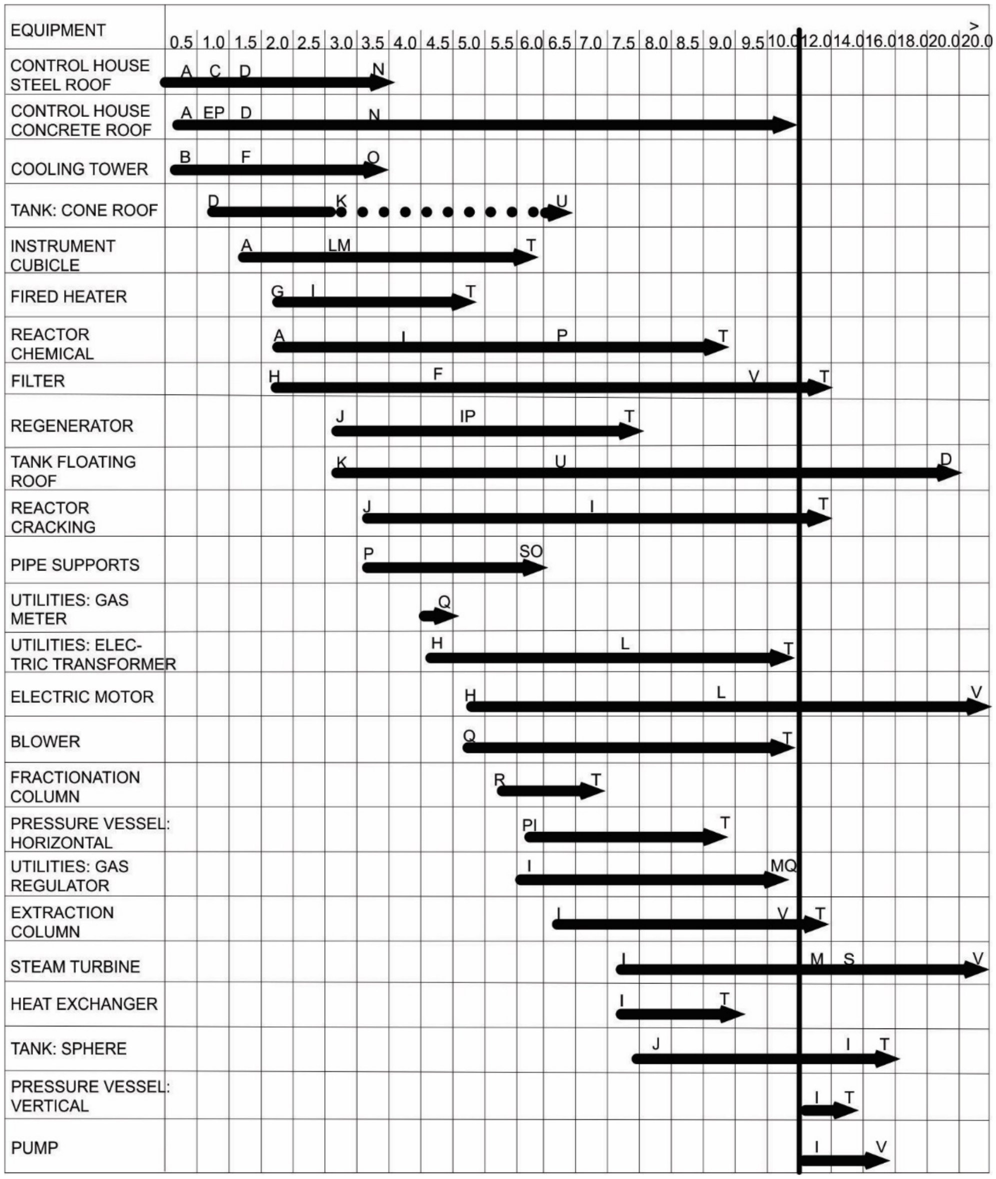
Over-pressure (psi)	Pipe Bands		Boiler Stack F.C.C. Unit	TEL Building	Bulk Terminal	Storage Tanks		
	Steel Frame	Concrete Frame				Cone Roof	Floating Roof	Spherical
00.3								
01.5				Tile walls fail	Roof of Admin. Bldg. collapses. Cone roofs of tanks collapse	Empty tank uplift	Empty tank uplift	
02.0								
Bulk Terminal 03.0						Tanks 0.5 & 0.9 filled) uplift over this range depending on height-to-diameter ratio and diameter of tank.		
03.5	Steel frame deformation	Concrete frame cracking						
04.0								
05.0		Concrete frame collapse						
06.0	Steel frame collapse							
06.5			Stack and foundation overturn		Tanks uplift (0.5 to 0.9) filled)			
07.0				Steel frame deformation				Support deformation (full) support
07.5								Support deformation (empty)
09.0								Overturns (full)
09.5				Steel frame collapse				Overturns (empty)
10.0								
10.5								
11.0								
15.0								
20.0							Roof collapse	

Source: *Minimize Damage to Refineries From Nuclear Attack*, National And Other Disasters, The Office Of Oil & Gas, U.S. Dept. Of The Interior; February 1970

SI Units: 1 psig = 6.9 kPa

TABLE 2

Blast Overpressure Effects On Vulnerable Refinery Parts



Code

A. Windows and gauges break
B. Louvers fall at 0.3-0.5 psi (2.1-3.4 kPa)
C. Switchgear is damaged from roof collapse
D. Roof collapses
E. Instruments are damaged
F. Inner parts are damaged
G. Brick cracks
H. Debris-missile damage occurs
I. Unit moves and pipes break
J. Bracing fails
K. Unit uplifts (half-filled)
L. Power lines are severed
M. Controls are damaged
N. Block walls fail
O. Frame collapses
P. Frame deforms
Q. Case is damaged
R. Frame cracks
S. Piping breaks
T. Unit overturns or is destroyed
U. Unit uplifts (0.9 filled)
V. Unit moves on foundation