Liability Risk Assessment at Skarvik Port

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Abstract

The study focuses on a case of company X which owns an oil terminal and a depot in one of the Northern European countries. Company X's facilities are surrounded by the facilities of other oil companies. In case of an accident caused by company X there would be potential liability claims for property damage and business interruption. Insurance risk assessment is a well-developed approach for insurance of a company's own property; it is not normally used for liability risks. This study suggests methodology for determination of liability insurance values. Based on the obtained results and calculations of replacement values, the worst case scenario for company X was chosen. A new methodology was developed to determine liability insurance values in cases like that, including the total limit - maximum insurance value that can be claimed.

Keywords: Risk assessment, Liability risk, Insurance

1. INTRODUCTION

Accidents in oil and chemical industry might bring very large damages, both to the company where an accident happens and other companies if their facilities lie close to the place of the accident (hereinafter - 'neighbour-companies'). In this case the company may face huge legal liability claims.

For instance, after Buncefield oil depot explosion and fire, which severely damaged Maylands business park, the owners of the depot were found liable for the blast (Taylor, 2009) and had to pay damages of around 700 million pounds (Hemeltoday, 2009).

2. AIM OF THE STUDY

This study focuses on a case of company X that owns an oil terminal located in a port in one of the Northern European countries. Several companies operate in the port close to each other with activities such as storage, loading and unloading of petroleum products and chemicals to and from ships, rail cars and road tankers. The facilities of company X are situated closely to the neighbour-companies. This gives concern for damage claims if there is an accident at company X's facilities which brings destruction of property and business interruption to the neighbour-companies.

The study is conducted for insurance purposes. Based on the obtained results and calculations of replacement values, the worst-case accident scenario for the port was chosen and recommendations were made regarding the liability risk. Consequence modelling for insurance risk assessment is a well-developed approach for insurance of a company's own property. However it is not normally used for liability risks. Therefore a new methodology was developed to determine liability insurance values in cases like that, including the total limit - maximum insurance value that can be claimed.

3. THEORETICAL BACKGROUND

Focusing mainly on accidents with the biggest damage to property, the literature suggests several types of fires and explosions as the most common ones that can lead to such damage. Among them, the Vapour cloud explosion (VCE) occurs in a case of large release of flammable material in the atmosphere, which leads to forming a vapour cloud in the air that can be ignited in presence of an ignition source. In a case of VCE only a certain percentage of the substance released produces a burn, when an ignition source is present. Depending on where the explosion occurred, there are confined and unconfined VCEs. Even a slow combustion process generates overpressure in a case of confined VCE, and a small overpressure while burning, known as a flash fire, is produced in a case of unconfined VCE [Bjerketvedt et. al, 1993]. In order to have an extensive overpressure a sufficient amount of the vapour cloud must be within the flammable region of the material. A flammable region is considered to be the region of the vapour cloud that is between the point of release and the edge of the cloud.

Another very common type of explosion that can be caused either by flammable or non-flammable liquids is the Boiling Liquid Expanding Vapour Explosion (BLEVE). BLEVE is an explosion that occurs due to failure of vessel that contains liquid at a temperature significantly above its boiling point at normal atmospheric pressure [CCPS, 1994.]. BLEVE's effects are mostly determined by the conditions of the contents in the container and of its walls at the moment of the containers failure, mainly because BLEVEs are usually associated with release of flammable liquids from vessels as a result of external fire. That means that if the container with flammable liquid is heated, its metal will be heated too and it will lose its mechanical strength. The heat will be transferred to the liquid and liquid's temperature will rise. Reaching the liquid's boiling point vapour bubbles are formed at the active sites that occur at interface with solids, including vessels walls. A cloud of almost pure vapour and mist is formed due to the rapid vaporization, expansion and loss of containment. After the vapour is ignited it starts to burn at the surface where it's mixed with air. The combustion propagates to the centre of the cloud and a fireball is obtained. Accidents of this type, that include fireballs, are accompanied with a powerful heat radiation, known as heat flux.

Type of fire that can be very often found in big accidents is the pool fire. Pool fire is a turbulent diffusion fire burning above a horizontal pool vaporizing flammable material, where the flammable material has zero or very low initial momentum [Cowley and Johnson, 1991]. In a case of pool fire the heat is transferred from the fire to the pool, which makes the rate of evaporation, fire size etc. to be influenced, or even controlled, by that feedback. Liquid fuels can burn either in a form of a spill or in an open storage container. The burning duration of a pool fire depends on the form of the fuel material as well as on the chemistry of the fuel. There are two types of pool fires, confined and unconfined.

When a gas has a higher specific weight than the surrounding ambient air, it's known as dense gas [Britter and Griffiths, 1982]. Since most of the flammable gases are denser than air, flammable dense gas cloud remains in the lower part of the atmosphere, largely spreads in lateral direction and do not disperse as fast as a light gas. Within the refinery industry many products are vapours under atmospheric pressure and therefore are stored, or transported as liquids, maintained in that phase at, or near, the saturation temperature at atmospheric pressure by refrigeration and insulation, or at ambient temperature by pressurization [Yellow Book, ch. 4.11]. For a risk assessment purposes three primary ways of release can be considered: rapid, continuous and combined.

All of these fires and explosions were included in the 6 scenarios that were selected for modelling. For the modelling aim it was used software called EFFECTS, based on the "Yellow Book" and "Green Book". The "Yellow Book" provides information about consequence analysis while the "Green Book" describes the relationship between physical phenomena and the resulting damage. For the modelling in this study it was used the latest version of the software, EFFECTS 8, suitable for handling large variety of chemicals due to the database containing toxic, flammable and thermodynamic properties, and because it offers calculation models for accidents with storage and transportation of chemicals [TNO, 2011. EFFECTS].

Since all of the fires and explosions mentioned above lead to hazardous events, in order to identify the consequences of them, Event Tree Analysis (ETA), a technique for risk assessment was used. This technique provides possibility to predict potential accident scenarios in a case of hazardous event, known as initiating event. ETA is an inductive technique because it examines all possible responses that can be cause from the initiating event.

4.METHODOLOGY

The study was completed in following phases:

Selection of the scenarios to model. Company X's safety report as well as the results of the literature review and interviews with Company X's staff and local Environmental Protection Office were discussed and analyzed. 'What-if' analysis, generic event tree analysis (ETA) and brainstorming techniques were used to select the final list of 6 scenarios for modelling. Event tree analysis was used to determine the chain of events leading to the accident.

Modelling of potential accidents at company X's facilities facilities in the port. The scenarios from the final list were modelled using software developed by the Netherlands Organisation for Applied Scientific Research (TNO), called EFFECTS 8.1. Methods of calculation of physical effects ('Yellow Book') and EFFECTS manual were used to calculate necessary input values. Some additional manual calculations were performed.

Assessment of potential liability claims from the neighbour-companies and review of available mitigation strategies Calculation of replacement values for neighbour-companies' tanks, structures etc. was conducted using the data from Company X's Insurance Valuation done by the insurance broker and Summary of property values provided by one of the neighbour-companies.

5. MODELLING

The final list of scenarios was modelled using a software developed by the Netherlands Organisation for Applied Scientific Research (TNO), called EFFECTS 8.1. Methods of calculation of physical effects ('Yellow Book') and EFFECTS manual were used to calculate necessary input values as follows.

Explosion damage contours:
- Total destruction (> 83 kPa)
- Heavy damage (35 - 83 kPa)
- Moderate damage (17 - 35 kPa)
- Minor damage (3.5 - 17 kPa)
The damage is thus dependent upon the overpressure. (TNO Built Environment & Geosciences, 2010)

Table 1 – Thermal radiation damage contours (Dreher, 1999).

Heat flux, kW/m2	Damage level, %
4,7	10%
8	30%
12,6	50%
18	80%
23	100%

Heat radiation levels are also taken from Dreher, 1999:

Table 2 – Thermal radiation effects

Heat flux	Observed effect
35-37,5 kW/m2	Sufficient to cause damage to process equipment. Cellulosic material will pilot ignite within one minute's exposure.
23-25 kW/m2	Spontaneous ignition of wood after long exposure. Unprotected steel will reach thermal stress temperatures which can cause failures. Pressure vessel needs to be relieved or failure will occur.
12,6 kW/m2	Thin steel with insulation on the side away from the fire may reach a thermal stress level high enough to cause structural failure. Minimum energy required for piloted ignition of wood, melting of plastic tubing.

These values have been translated into damage to structure in accordance to Table 1.

Damage to structures (empirical) at Xd is the damage suffered by a structure if it was situated at the point of study (TNO Built Environment & Geosciences, 2010; Empirical damage to structures).

19 different situations can be found:
The supporting structure of a round storage tank has collapsed (100 kPa)
Brickstone walls (20-30 cm) have collapsed (50 kPa)
Displacement of a cylindrical storage tank, failure of connecting pipes (50-100 kPa)
Loaded train carriages turned over (50 kPa)
Collapse of a pipe-bridge (40-55 kPa)
Displacement of a pipe-bridge, rupture of piping (35-40 kPa)
Damage to a fractioning column (35-80 kPa)
Plating of cars and trucks pressed inwards (35 kPa)
Breakage of wooden telephone poles (35 kPa)
Cladding of light industry building ripped-off (30 kPa)
Collapse of steel frames and displacement of foundation (20 kPa)
Industrial steel self-framing structure collapsed (20-30 kPa)
Cracking in empty oil-storage tanks (20-30 kPa)
Slight deformation of a pipe-bridge (20-30 kPa)
Large trees have fallen down (20-40 kPa)
Walls made of concrete blocks have collapsed (15-20)
Minor damage to steel frames (8-10 kPa)

Connections between steel or aluminium ondulated plates have failed 7-14 kPa)
The roof of a storage tank has collapsed (7 kPa)

6. RESULTS

6 serious scenarios were identified as follows:

Scenario 1, 'Buncefield-type' scenario (see above). Tank with gasoline overfills for 15 minutes, while pump flow is 800 m3/h. It is assumed that 10% of leaked mass turns into vapour, as reported during Buncefield accident (Buncefield Major Incident Investigation Board, 2008).

Scenario 2, BLEVE at LPG storage. Pipe rupture during transfer of LPG to the tank may cause leak of propane, propane ignites and heats the other tank. This eventually triggers BLEVE.

Scenario 3, Leak from a hole in gasoline tank. In this scenario tank starts to leak, the leak is assumed to be detected in 15 min. Estimated fraction of product to turn into vapour is 10%, similar to Buncefield accident (Buncefield Major Incident Investigation Board, 2008).

Scenario 4, Dense gas explosion due to the leak of LPG tank. In this scenario propane is assumed to leak from the bottom of the tank which leads to explosion.

Scenario 5, Rupture of propane vessel. In this scenario it is assumed that propane vessel ruptures from metal fatigue of flanges.

Scenario 6, Diesel pool fire

The selected scenarios were modelled in EFFECTS 8.1 with a custom-made selection of input parameters. Since EFFECTS 8.1 does not have an option for calculating replacement costs, in order to determine the worst-case scenario, manual calculations were conducted. Having in disposal the replacement values for groups of tanks of company X, the replacement costs for neighbour companies' facilities were calculated as following.

The replacement value for one tank was calculated by dividing that value to the number of tanks in the group. Because of the fact that each tank has different volume, the replacement value per unit of volume was obtained by dividing the replacement value per tank by the volume of the tank. Since company X has tanks with different types of roofs, after calculating the replacement values per unit of volume for all the tanks, the average value was calculated for the tanks with the same type of roof and that value was considered to be the replacement value per unit of volume for that type of tank. The procedure was repeated for the other tanks with same type of roof. At the end, from all the values that were obtained the average value was calculated used as a replacement value per unit of volume. That replacement value multiplied with the volume of the tanks that were destroyed gave the replacement value for those tanks.

Having information about the contents of neighbour companies' tanks, the replacements values of the products inside of the tanks and a replacement values for clearance of debris and fire fighting were also included in the calculations.

The secondary damage was also considered, which means that the possibility of an escalation, spreading of fire etc. that increases the risk other tanks which are about 1 diameter away from the last tank that is damaged to be affected, was considered. As a result of all those calculations, the worst-case scenario was obtained.

The results of the study showed that Scenario 1 could be considered a worst-case in terms of liability risk. (See Table 1).

It should be noted that risk of damage to the environment and people is very important but in this study the scope was limited to the damage to property of the neighbour-companies.

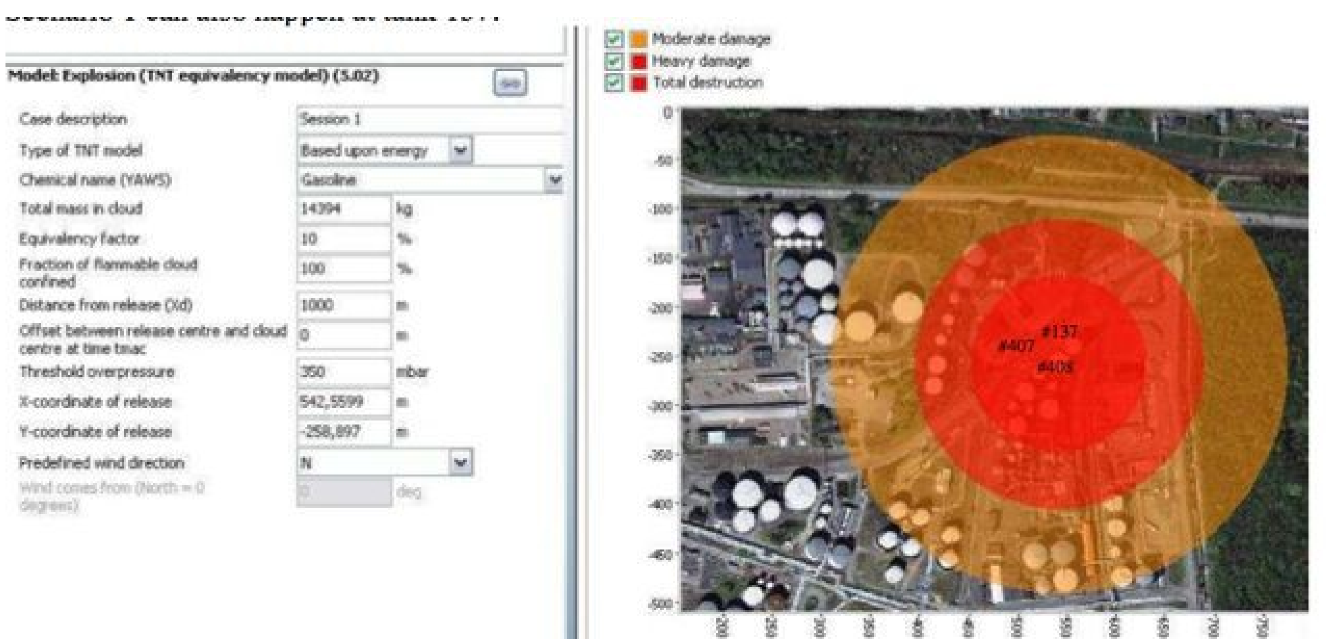

Figure 1 – Worst-case scenario on terms of liability risk.

7. CONCLUSION

Methodology to determine the liability risk was developed and tested using EFFECTS 8.1.

The suggested methodology includes the study of previous accidents, 'what-if' analysis, event tree analysis, modelling of the most probable scenarios in EFFECTS 8.1 and manual consideration of domino effects. Some parameters for the modelling, like fraction of flammable cloud confined, were also calculated manually.

Using the developed methodology worst-case scenario was chosen.

It can be reasonably assumed that Scenario 1 can lead to BLEVE at LPG storage (Scenario 2). But since it is impossible currently to establish the replacement values of BLEVE consequences – Scenario 1 remains the worst-case in terms of liability risk (≈260 million Euro).

The similar methodology can be used for the assessment of liability risk in chemical and oil industries as well as to determine the insurance value of a company's own property.

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