Safety of Technogenic Environment

doi: 10.7250/ste.2013.002
2013 / 4

The Analysis of Fire Risk Assessment Methodology of Petroleum Product Transhipping Terminal

Vladimirs Jemeljanos[1], Jelena Sulojeva[2], Janis Bartusauskis[3], [1-3]*Riga Technical University*, Irina Ingelande, *Ltd Ventamonjaks Serviss*

Abstract. **Over time, disasters and consequences have made the society review the implementation of prevention measures at the facilities where large-scale emergency situations can potentially occur. The study examines data on causes and effects of fires and industrial accidents. Fire risk assessment methodology is based on the combined use of several techniques: checklist method, expert method and effect analysis method. The combination of methods allows carrying out both fire hazard qualitative and quantitative evaluation.**

Keywords: **Fire risk assessment, fire safety, oil product terminals.**

I. INTRODUCTION

Each year in disasters, accidents, fires, explosions and other accidents about 2 million people are killed; tens of millions of people are poisoned and gain different types of injuries. Accident, disaster, fire, etc. result in material losses of about 4–5 per cent of the gross world product. Material losses from fires constitute 0.25–0.3% of the gross world product in developed countries only [3]. Industrial accidents cause or may cause an uncontrolled chemical or technological process, uncontrolled activity or other adverse changes in the course of operation, such as technological or mechanical breakdown, intentional or unintentional incorrect operation, as well as other deviations from technological process mode or external factors [4], [21].

Industrial accident is characterized by massive hazardous substance spill, fire, or explosion in a company that either immediately or after a period of time poses a serious threat to the environment, human life, health or property in the company's premises or elsewhere [4]. Effect of industrial accidents depends on the nature of the emergency (disaster) kind, scale and type of an enterprise, in which an accident occurred, as well as on the scope and characteristics of an enterprise. Blasts in oil, gas and chemical companies are especially dangerous. Since 1556, when the first description of the manufacturing process safety appeared, to this day, world's specialists have been making a lot of observations and conducting extensive research, leading to the exploration of different aspects of security, as well as creating effective tools to struggle with fire, identifying the need for the management of safety ensuring processes [2]. At the same time, occasional fires, explosions, hazardous spills and other accidents in the world attest to the fact that technogenic and ecological safety issues and foremost safety of industrial processes are still far from their solutions [2].

Statistics of accidents shows that:

- major accidents in oil depots and gas stations are caused by oil product vapour outbreak, resulting from oil spills in the process of filling or draining operations [3];
- in oil refineries 90% of fires and explosions in open technological devices appear in case of uncontrolled combustible substance leakage into the atmosphere, gas presence in the territory, existence (presence) of source for fire and explosive mixture formation and ignition [12], [18].

Statistics for past 6 years shows that annually 2 major fires occur in world's oil refineries and oil depots [11]. It is estimated that 45% of emergency situations in nuclear power plants arise due to human error. In plane crash cases, 60% of accidents are caused by human error and in case of accidents at sea – 80% [9]. Possibility of accidents in large technological systems is increasing. That can be explained by the complexity of these systems, increasing capacity of aggregates and increasing concentration of dangerous objects in specific areas [9], [20].

Table I provides a brief overview of major industrial accidents and disasters. As this overview is very brief, it probably does not cover even the thousandth part of disasters worth mentioning.

II. STATISTICS AND FIRE RISK ASSESSMENT

During the time, experience in field of disasters and consequences made the society review the implementation of prevention measures at the facilities and first of all at those facilities, where large-scale emergency situations could potentially occur. Integral human hazard ratio shows a risk of injury or death caused by fires, explosions, accidents and other types of emergencies and disasters, as well as natural disaster; in Latvia over the past ten years this risk ratio is higher in comparison with other European countries. The risk of being killed in emergency situations is increasing not only in our country, but also in other developed countries around the world.

The main reason of this process is related to conditions and actions designed to ensure safety of people, which are one step behind the growth rates of hazards. In the Republic of Latvia, the development of the system to protect human life, health and environment, as well as the fruits of one's labour is in progress. When developing dangerous technologies, machinery and equipment as well as making decisions on project solutions, insufficient attention is devoted to the safety aspects [2].

TABLE I

OVERVIEW OF SOME MAJOR INDUSTRIAL ACCIDENTS AND DISASTERS [7] [COMPILED BY THE AUTHORS]

Year	Place	Description of an incident	The number of people killed	The number of people seriously injured
1	2	3	4	5
1906	*Courrieres,* France	The explosion in *Courrieres* mine – the worst mining accident in Europe.	1099	
1921	*Oppau,* Germany	In *BASF* factory there was the explosion of a shaft tower, which was intended to store 4,500 tons of ammonium sulphate and ammonium nitrate fertilizer mixture.	500–600	2000
1947	Texas, the USA	The explosion on the ship *Grandcamp*, which was placed in the dock. The cause of explosion was fire in the cargo compartment. Explosion of 3,200 tons of ammonium nitrate fertilizer led to further blasts and fires. It was considered that fire broke out due to a smouldering cigarette. As a result of explosion, within a radius of 40 km windows of houses were broken. Huge pieces of iron flew in the sky and landed 1.5 km further. This accident is recognized as the largest industrial disaster in America, caused by the ammonia nitrate explosion.	578	3500
1976	Seveso, Italy	Dioxin leakage into the atmosphere in *ICMESA* small chemical company. 3,000 domestic animals died, but afterwards other 70,000 animals were slaughtered to prevent transfer of dioxins into the food. As a result, the Seveso Directive was created.		193
1984	*Bhopal,* India	In *Union Carbide* enterprise, from damaged tanks poisonous methyl isocyanate leaked. This accident is considered the world's worst industrial disaster.	20000	
1988	*Piper Alpha,* the North Sea	Explosion and the resulting oil and gas fires on oil production platform. Total insured loss was about US$3.4 billion. This accident was the worst offshore oil disaster in terms of lives lost and industry impact.	167	
2000	*Enschede,* the Netherlands	The explosion of a fireworks storage depot, destroying the entire neighbourhood. Around 1,500 homes were destroyed and devastated. Property was damaged or destroyed to the extent of more than 300 million US$.	22	947
2007	*Qinghe Special Steel Corporation,* Tieling, Liaoning Province, China	Ladle used to transport molten steel separated from an overhead rail, felt down and turned over, all 30 tons of liquid steel, which was at a temperature of approximately 1,500 °C, was spilt.	32	6
2013	*Savar building collapse,* Savar Bangladesh	Eight-story commercial building, Rana Plaza, collapsed. It is considered to be the deadliest garment-factory accident in history, as well as the deadliest accidental structural failure in modern human history.	1127	2500

On the basis of data published by the Health and Safety Executive, the most common cause of accidents is equipment damage and defects accounted for 53%. Important factor leading to accidents is operator error that makes up 9% of all accidents, while emergency situations caused by the management systems account for 15% and 20% of accidents are related to violations of technological and production rules [10] [translated by the authors].

Research that has been made by the European Agency for Safety and Health at Work (EU-OSHA) pointed out that 67% of accidents, recorded in the Major Accident Reporting System database, occurred due to a low safety level and inefficient management system [10] [translated by the authors].

On the basis of the above-mentioned information, conclusions can be drawn that, despite statistical data difference for 10 years between the Health and Safety Executive and the company "J & H Marsh & McLennan", still major industrial accidents are caused by:

- ✓ equipment failure and defects;
- ✓ worker errors;
- ✓ control system failures.

Fire risk assessment is a safety control system component in high fire risk facilities. Fire risk assessment helps to increase company's fire safety, by ensuring timely detection and prevention of irregularities in fire protection requirements.

Fire risk assessment is carried out in the following way:

- ✓ identification of fire hazard factors;
- ✓ fire risk assessment;
- ✓ development of fire risk reduction measures.

Basic task for the identification of fire hazard factors is to identify and specify all sources of fire, as well as describe the occurrence of undesirable events and their progression. This step is particularly important because undisclosed sources of fire are not subject to a further analysis. To evaluate fire safety for machinery, equipment and components, the following data must be used:

- ✓ details about the presence and amount of combustible material, its physical and chemical properties, flammability characteristics;

- ✓parameters of technological equipment (pressure, temperature, filling levels, etc.), pipeline (diameter, wall thickness, distance to closure fittings);
- ✓information about emergency protection system and automatic fire-fighting equipment actuators (device closing and opening time, reliability level, pumping capacity);
- ✓location of equipment and component parts in company's territories.

Listing of adverse events can be carried out in order to identify places and possible causes of emergency situations.

The most common adverse events in companies with fire hazards in the technological processes are:

- violations of technological regulations;
- unsealing of technological equipment, associated with exposure to mechanical, thermal or chemically aggressive environments;
- mechanical damage of equipment as a result of personnel errors (falling objects, imperfect repairs, delayed maintenance, low qualification, irresponsibility, work safety violations, etc.).

Fire risk assessment includes the following steps:

- ✓ the analysis of potential emergency situations;
- ✓ the impact assessment of the likely accidents and emergency scenarios;
- ✓ endangered zones that occur in different emergency scenarios;
- ✓ the exposure assessment of hazardous effects on humans.

In order to foresee the possibility and frequency for occurrence of fire hazard situations, the following information is needed:

- ✓ the structure of production enterprise, company's equipment spatial positioning;
- ✓ technological processes and their sequence in an enterprise, technological schemes;
- ✓ substances, products and materials that are used in an enterprise;
- ✓ hazards and threats that can exist in a specific enterprise;
- ✓ events that can lead to an accident;
- ✓ information about damage to equipment that occurred at a plant / enterprise in the past;
- ✓ manual for equipment safe operation and usage;
- ✓ workers' possible improper actions;
- ✓ local meteorological and geographical characteristics.

For the identification of emergency situations it is advisable to consider the processes and technological systems separately. Emergency situations are reviewed in the main technological equipment and auxiliaries. The possibility of fire should also be considered in administration buildings, warehouses, auxiliary equipment and machinery sheds, back rooms.

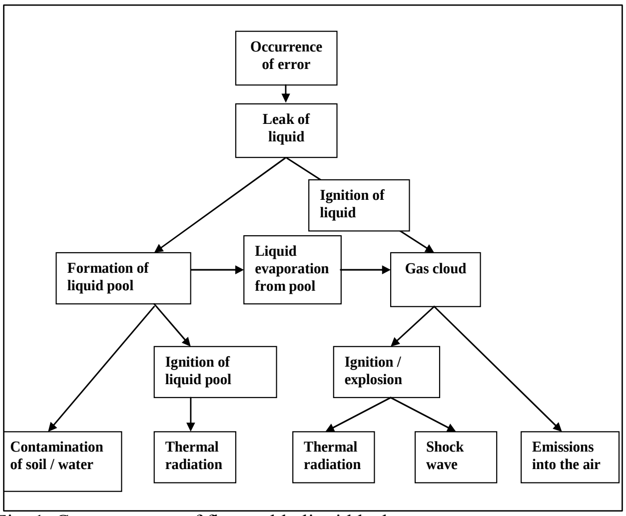

Fig. 1. Consequences of flammable liquid leakage.

During the analysis of emergency commitment to technological equipment unsealing, it is necessary to consider leakage for most diverse diameters (including the maximum – for equipment or pipeline complete breakdown).

When an accident is identified, it is necessary to determine the frequency of its occurrence. To check the frequency of occurrence of an accident, emergency statistical data or technical equipment safety component data can be used, which correspond to facility specifics.

Information regarding emergency frequency (including workers' errors), which is needed for risk assessment, can be obtained directly from observation data on the operation of an object or from data on operations of similar facilities.

In order to develop a whole range of accidents and emergency scenarios, a method of tree diagram can be used.

Main dangers of oil product transhipment terminals are associated with flammable substances. Possible crash scenarios for leakage of flammable liquid are shown in Fig. 1 [6].

In order to organize production processes with flammable and explosive substances, **it is needed to ensure that within a year the possibility of hazard influence on people would not exceed 10^{-6}**.

It should be pointed out that this facility security parameter depends on failures of certain object parts, and it is very difficult to assess their impact importance. It becomes evident when considering the fact that during the assessment of adverse events and their conditions, some of the information that describes technical and equipment failures that do not lead to extreme situations, inevitably disappears. At the same time, when assessing the impact of failures on the whole security of the object, not only the events that cause fires, explosions, injuries must be taken into account, but also those situations that create conditions for these reactions [1], [19].

The development of fire risk reduction recommendations is the last stage of risk assessment process. The recommendations consist of justified guidance of risk minimization. This guidance is based on the object fire risk analysis, fire aversion, fire prevention and protection system performance evaluation and results of risk assessment. In the process of developing the recommendations, it is necessary to consider detected deficiencies in fire safety systems and observe measures that minimize these deficiencies in accordance with technical requirements of regulations [1], [19]. Guidance on risk reduction can be both technical and organizational. When choosing risk reduction measures, overall effectiveness and efficiency, as well as costs for implementation of these methods must be taken into account.

III. Conclusions

With industrial development, the society's need for various fire risk assessment methods has increased. Complex calculations are required to estimate probability and consequences of fire with maximum possible accuracy. There are no general methods to assess the risk of fire for each building and all operations. Several methods are available. Some of them can be used to show the effect of preventive measures in terms of risk level reduction. Research on fire risk is extremely important for industrial companies, warehouses, hospitals, schools, hotels and public buildings [1].

During the development of fire risk assessment methodology of petroleum product transhipment terminal, the so-called "consequence analysis method", which is a checklist method, has been used, as well as overpressure and thermal radiation calculation has been performed for explosive vapour – air mixture from oil products in terminals, pump stations, wharf, and also potential risk areas for people, equipment, buildings and structures have been assessed.

This method is simple, effective and less time-consuming for assessing fire safety in facilities with a well-known technology (a prepared form can be used to facilitate the analysis and presentation of results). Checklist should include questions and answers for the terminal according to the fire safety requirements and guidance on how to meet these requirements. Checklist method differs from the method of "what if ...?" with more background information and wider and deeper understanding of effects that can lead to a security breach, but the "approximate analysis" method is used for the planning of new industrial projects at an early stage.

Checklist questions were developed on the basis of the legal requirements of the Republic of Latvia, as well as of the European Union and other regulatory requirements for petroleum product transhipment terminal in compliance with fire safety requirements. The checklist was designed to be able to give two types of answers: affirmative ones, in which case it is necessary to tick "YES", which indicates that preventive measures have been taken and the situation is under control; and negative responses, by ticking "NO", which indicates that these preventive measures have not been taken, or if they have been taken, they have been insufficiently implemented and the situation is not satisfactory. This means that the necessary adjustments should be made to improve the situation. A sample of checklist form for the fire risk assessment of petroleum product transhipment terminal is shown in Table II.

Listing of adverse events is carried out in order to identify possible causes and locations of emergency situations. The list of adverse events, which can cause temporary or sustained oil leak and fire, as well as safety and preventive measures taken and the likely consequences will be summarized in Table III.

TABLE II

Checklist Form for Fire Risk Assessment of Petroleum Product Transhipment Terminal

No.	Fire safety requirements	Answer		Expert evaluation (I-V)	Comments
		"Yes"	"No"		
1	2	3	4	5	6

TABLE III

List of Adverse Events

Fire hazard factor	Safety measures	Preventive measures	Possibility	Consequence
1	2	3	4	5

IV. Proposals

1) The developed methodology for the fire risk assessment of oil product transhipment terminal can be used in practice for fire risk assessment in similar enterprises.

2) The developed checklists can be used to carry out fire safety inspections in oil product transhipment terminals.

3) For the unambiguous understanding of safety issues and the avoidance of thought sharing by officials, the laws of the Republic of Latvia (regulations, laws relating the prevention of civil and industrial accidents) should introduce precise terms, such as "accident", "technogenic accident".

References

[1] *Bīstamības avotu noteikšana un novērtēšana vietējā sabiedrībā* / UNEP IE/PAC APELL. Programmas izdevums ārkārtējo situāciju apzināšana un gatavība tām vietējā līmeni - Rīga: 1994. – 87 lpp.

[2] Jemeļjanovs, A. *Civilā aizsardzība. Rūpniecisku avāriju risku novērtēšanas kartība un to pazemināšanas pasākumi: mācību līdzeklis* / O. Jemeļjanovs. Ē.Pālītis. – Rīga: RTU Izdevniecība, 2004. – 103 lpp.

[3] *Metodiskie norādījumi drošības pārskatu sagatavošanai, lai izpildītu noteiktas Direktīvā 96/82/EC, kurā grozījumi izdarīti ar Direktīvu 2003/105/EC (Seveso II)* / Iedzīvotāju aizsardzības un drošības institūts (Institute for the Protection and Security of the Citizen). – Eiropas Komisijas ģenerāldirektorāts, Joint Research Centre, 2005. – 46 lpp.

[4] *Noteikumi par rūpniecisko avāriju riska novērtēšanas kārtību un riska samazināšanas pasākumiem*: LR MK 19.07.2005. noteikumi Nr. 532 / „Latvijas vēstneša" tiesību aktu vortāls. [Online]. Available:// http://www.likumi.lv/doc.php?id=113700 [Aceessed: Mart, 19, 2009].

[5] *Pašvaldības, komersanta un iestādes civilās aizsardzības plāna struktūra, tā izstrādāšanas un apstiprināšanas kārtība:* LR Ministru Kabineta 26.06.2007. noteikumi Nr. 423 /„Latvijas vēstneša" tiesību aktu vortāls. [Online]. Available: http://www.likumi.lv/doc.php?id=159545:// [Accessed: Nov. 28, 2008].

[6] *SIA „Ventall Termināls" drošības pārskats* (3. redakcijā). – Ventspils, 2007. – 96. lpp.

[7] *Industrial disasters/Wikipedia, the free encyclopedia*. http://en.wikipedia.org/wiki/List_of_industrial_disasters [Online].

[8] *Bezopastnostj v crezvucainah situacijah.* Tehnologiji chrezvichainix situacij (Техногенные чрезвычайные ситуации.) Termini i opredelenija (Термины и определения.)

[9] *Klasifikacija Klassifikacia chrezvychajnyh situacij tehnogennogo haraktera i ih harakteristika/Ohrana truda i požarnaâ bezopasnost*. [Online]. Available: http://otipb.ucoz.ru/publ/8-1-0-471

[Accessed: Nov. 29, 2012].

[10] *Kievskaja ocenka: Proekt glavy po tehnolgicheskim i estestvennym opasnostyam /*Organizacija Obedinennyh nacij. Ekonomicheskij i Socialnyj Sovet. Evropejskaja ekonomicheskaja komissii. Komitet po ekologicheskoj politike. [Online]. Available:// - http://www.unece.org/env/documents/2002/cep/ac.10/cep.ac.10.2002.31.r.pdf [Accessed: Sep. 27, 2012].

[11] *Mirovaja statistika registriruet 2-3 krupnye avarii na predprijatijah ezhegodno.* [Online]. Available:// http://www.rosinvest.com/news/209452/ [Accessed: July, 6, 2012].

[12] *Prognozirovanie obrazovanija i rasseivanija pozharo- i vzryvoopasnyh smesej na neftepererabatyvajuschih predprijatijah / Nauchno-prakticheskij informacionnyj zhurnal «Rostehnadzor».* [Online]. Available:// http://www.energopress.ru/allmaterials/991/ [Accessed: Sep. 20, 2012].

[13] *Big Industrial Fires HVAC Building Control Fire Safety*. [Online]. Available:// http://www.iklimnet.com/hotelfires/big_industrial_fires.html [Accessed: Mart, 14, 2012].

[14] *COUNCIL DIRECTIVE 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances* / Major *Accident Hazards Bureau.* [Online]. Available:// http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31996L0082:EN:NOT. [Accessed: Dec. 13, - 2012]

[15] Directive 2003/105/EC of the European Parliament and of the Council of 16 December 2003 amending Council Directive 96/82/EC on the control of major-accident hazards involving dangerous substances. / Major Accident Hazards Bureau. [Online]. Available:// http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32003L0105:EN:HTML.[Acecessed: Dec. 20, 2012].

[16] Fire statistics. Report N 11 /International Association of Fire and Rescue Services, Center of Fire Statistics. – Moscow: National committee CTIF of Germany, 2006. – June. – 72 lpp.

[17] Bezrodnyj, I., *Tushenie nefti i nefteproduktov* / A. Giletich, V. Merkulov, V.Molchanov, A.Shvyrkov. – Moskva, 1996. – 214 lpp.

[18] Rasbash, D., Kandola, B., Ramachandran, G., Law, M., Watts, J. *Evaluation of Fire Safety*, Wiley, 2004. http://dx.doi.org/10.1002/0470020083

[19] Rausand, M. *Risk Assessment: Theory, Methods and Applications (Statistics in Practice)*, NJ Wiley, 2011.

[20] Ridley, J., Channing, J. *Safety at Work*, Elsevier Ltd., 2007.

[21] Marc Assael, J., Kakosimos Konstantinos, E. *Fires, Explosions, and Toxic Gas Dispersions: Effects Calculation and Risk Analysis*, CRC Press/Taylor in Author, 2010.

Vladimirs Jemeljanovs, Professor of the Institute of Labour Safety and Civil Defence at Riga Technical University, the Faculty of Engineering Economics and Management. In 1997 he was awarded a Degree of Doctor of Engineering Sciences (Dr.sc.ing.) by Riga Technical University. He delivers lectures on civil defence and fire fighting. He specialises in work safety, improvement of civil protection, fire prevention system efficiency and fire fighting efficiency.
Address: 6 Kalnciema Street, Riga, LV–1048, Latvia
E-mail: Vladimirs.Jemeljanovs@rtu.lv

Jelena Sulojeva, Assistant Manager for the Study Process at the Institute of Labour Protection and Civil Defence and Lecturer at Riga Technical University. In 2011 she was awarded a Degree of Doctor of Economics (Dr.oec.) by Riga Technical University. She was a member of the board at SVD Group, Ltd. (2010–2011), Assistant Professor and Head of Business Department at the Latvian Business College (2008–2010).
Address: 6 Kalnciema Street, Riga, LV–1048, Latvia
E-mail: Jelena.Sulojeva@rtu.lv

Janis Bartusauskis, Lecturer and Head of Civil Defence Laboratory at the Institute of Labour Safety and Civil Defence, Riga Technical University, the Faculty of Engineering Economics and Management. He received a Master's Degree in Labour Safety from Riga Technical University in 2007. He delivers lectures in the field of labour safety. He specialises in work safety and aspects of labour protection, as well as risk assessment.
Address: 6 Kalnciema Street, Riga, LV–1048, Latvia
E-mail: dcai@rtu.lv, mob. ph.: +37122023337

Irina Ingelande, Occupational Health and Safety Specialist at Ventamonjaks Serviss Ltd. In 2009 she was awarded a Professional Master's Degree in Labour Safety by Riga Technical University, the Faculty of Engineering Economics and Management, Institute of Labour Protection and Civil Defence. Since 2007 she has been working at JSC Latvijas Gāze.
Main fields of research include risk assessment in oil refinery and transfer terminals, fire safety risk assessment, fire hazard factors, as well as development of methodology in the field of risk assessment and minimization.
Address: 66 Dzintaru Street, Ventspils, LV–3602, Latvia
E-mail: i.irina@ventamonjaks.lv, mob. ph.: +371 26835582