IETI Transactions on Ergonomics and Safety
http://ieti.net/TES/

2018, Volume 2, Issue 2, 40-47, DOI: 10.6722/TES.201812_2(2).0006

CHECKLIST FOR FUEL TANK SAFETY ASSESSMENT

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Abstract Over the last four decades, a distinctive approach to hazards and failures that cause loss of life and property has been developed in the process industries. The modern approach to the avoidance of injuries and loss in the process industries is the outcome of various events. Central to this approach is leadership by management, starting with senior management, and creation of a safety culture that provides the appropriate environment for reduction of incidents and improvement of safety performance. Checklists can be a very powerful tool for hazards assessment methodology to identify the major contributors to risk, to improve safety measures and to assist the analysis in these aspects. This paper presents a systematic hazards identification methodology for fuel storage tanks, by applying a checklist technique on the accident causes and the relevant protection measures.

Keywords : Hazards assessment; storage tanks; checklist, accident.

1. INTRODUCTION

All Accidents at fuel tanks are relatively rare, which however, may lead unexpected consequences for the installation, the environment and the health of workers and neighbors. These accidents demonstrate not only the large-scale of destruction in the surroundings, together with the implication of potential environmental issues, but also the necessity to prevent similar accidents. Extensive study was made, by collecting reference and information through appropriate literature, with the aim to perform a statistical analysis of accident occurrence in storage tanks.

The management system is crucial to loss prevention and it is essential that this system itself be monitored. The management system may be audited in several ways. These include:

1. self-checking procedures, through checklists
2. internal audit, and
3. external audit.

In particular, there are checks on:

- Overall management attitude, policies, systems and procedures, and personnel selection;
- Plant level management, attitude, systems, training, and feedback;
- Incident reporting, investigation, and statistics.

The Qualitative Risk Analysis approach uses well known types of analysis, such as the Checklist, the Failure Mode and Effect Analysis (FMEA) and the Hazard and Operability analysis (HAZOP). Quantitative methods attempt to specify the safety level or the associated risk level of a system or an

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installation, through the well-established methods of Fault Tree (FTA) and Event Tree Analysis (ETA). Those methods could be lengthened with risk assessment methodologies tailor-made for offshore process facilities in seismic, for largescale oil export terminals, for fire management systems and for estimating the domino effect in petrochemical.

Checklist is the simplest tool of hazard identification in a chemical installation. It is impossible to envisage high standards in hazard control unless this experience is effectively utilized [1]. Checklists are applicable to management systems in general and to a project throughout all its stages. Obviously the checklist must be appropriate to the stage of the project, starting with checklists of basic material properties and process features, continuing on to check- lists for detailed design, and terminating with operation audit checklists.

1.1.Main types of storage tanks

Large liquid storage tanks are used in the petroleum and chemical industries for the storing of both raw material and intermediate or finished products in confined areas that are normally separated from the rest of the installation. The types of tanks for storing combustible or flammable liquid hydrocarbon fuel are classified in three main types by the Institution of Chemical Engineers (Figure 1) [2]:

1. Fixed or cone roof tanks.
2. Open top floating roof tank (simple pontoon or double deck).
3. Fixed roof tanks with internal floating roof.

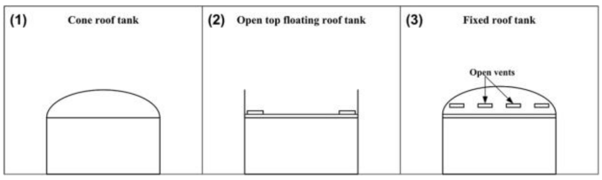

Figure 1. Types of tanks for fuel storage.

A fixed or cone roof tank is made of a vertical cylinder side and a fixed cone-shaped roof that is welded to each other. This type of tank usually contains “black” heavy products, such as fuel-oils, asphalt (bitumen) and vacuum or atmospheric residue. Hence, the use of insulation, steam or coil heating in these types of tanks is necessary for keeping of the content in a liquid state.

An open top floating roof tank is made of a vertical, cylindrical above ground shell similar to the conical roof tank. However, instead of a conical roof it has a pontoon type roof, characterized by the ability of the roof to rise and fall on the stored-fuel surface, in order to prevent the large volumes emittance of fuel-vapors. Moreover, there is a rim seal that covers the space between the floating roof and the tank shell, in the form of a rubber tube filled with kerosene, where most frequently a fire may start.

An internal floating roof storage tank is a combination of the above two types of tanks, as the tank consists of a conical roof with the addition of the internal floating roof or pan that floats directly on

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the fuel surface. Furthermore, internal floaters have the capability to decrease the potential of ignition and to prevent the initiation of tank fires.

The second and third categories of tanks are used for volatile liquid hydrocarbons such as crude oil and "white" light products (jet, diesel and gasoline).

1.2.Tank fire accidents scenarios

Potential fire scenarios that can be developed in a tank accident are (Figure 2):

1. Rim seal fire
2. Spill on roof fire
3. Full surface fire
4. Bund or Dyke fire
5. Pontoon explosion
6. Boilover

The most severe are the full surface fire and boilover. The scientific study confirms the lightning as the most frequent cause of tank accident, while fire and explosion constitute the 85% of total cases of tank accidents [3]. However, it is important to mention that sometimes a full surface fire can escalate to a boilover, even though it is accounted as a very rare incident.

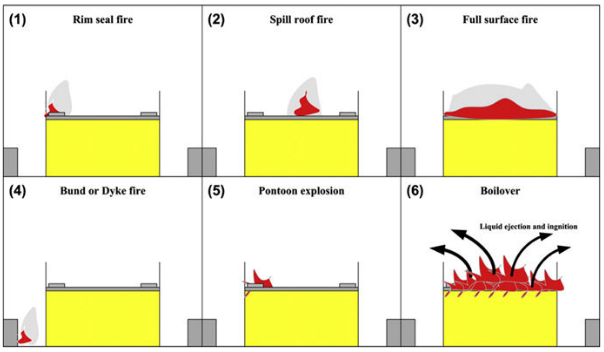

Figure 2. Potential tank fire scenarios.

Vapour cloud explosion

In fact the investigation of explosion accidents in the vicinity of liquid hydrocarbon storage tanks led to significant conclusions, such as

a) the explosion always follows a leakage of gasoline,
b) tank overfilling is the major cause,
c) the cloud ignition happens in nearby sites
d) the delay of the ignition ranges from 20 to 90 min from leakage onset,
e) almost windless conditions prevail before the accident, and
f) there is significant recurrence of this type of accident (though not as destructive), almost every 5 years around the world.

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All these make obvious that an explosion accident after the release of a hydrocarbon vapour cloud, as a result of tank overfilling has a significant occurrence probability and needs to be further investigated, especially in non-properly safeguarded commercial tank farms.

2. HAZARD IDENTIFICATION FOR LIQUID FUEL TANKS

General steps for hazard identification for liquid fuel tanks are based on:

- Description of the local area, including a general map;
- Sufficient knowledge of the hydrogeological, hydrographical and meteorological data of the area together with any protected environmental zones;
- Sufficient meteorological data with heavy snow and heavy rain frequencies;
- List of the hazardous installations in the surroundings;
- Ground plan of the plant and/or tank farm together with process flow diagrams;
- Description of production processes for every location of the plant;
- Characteristics of chemical substances (Material Safety Data Sheets - MSDS).

The present checklist is based on a catalogue of causes that could lead to the failure of the tank, together with a list of preventive and protection measures that can avert the occurrence of an accident in a storage tank. These two lists derive from past experience of tank operation and maintenance, and are to be considered as prerequisite conditions to avoid problems in safety. If an installation satisfies these criteria, then the accident potential is very low without banning risk totally.

The most common initiating events or failure causes for fixed/cone and floating roof tanks are grouped in the general headings presented in Table 1.

Table 1. Immediate causes of accidents.

1. Operational errors
Tank overfilling Drain valves left open accidentally Vent closed during loading/unloading Oil leaks due to operators' errors High inlet temperature Drainage ducts to retention basin obstructed
2. Equipment/instrument failure
Floating roof sunk Level indicator Discharge valve rupture Rusted vent valve does not open
3. Lightning
Poor grounding Rim seal leaks Flammable liquid leak from seal rim Direct hit
4. Static electricity
Rubber seal cutting Poor grounding Fluid transfer

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Improper sampling procedures
5. Maintenance errors
Welding/cutting Non explosion-proof motor and tools used Circuit shortcut Transformer spark Poor grounding of soldering equipment Poor maintenance of equipment both normal and blast proof
6. Tank crack/rupture
Poor soldering Shell distortion/buckling Corrosion
7. Piping rupture/leak
Valve leaking Flammable liquid leak from a gasket Piping failure Pump leak Cut accidentally Failure owing to liquid expansion
8. Miscellaneous
Earthquake Extreme weather Vehicle impact on piping Open flames/smoking flame Escalation from another unit (domino) Accident caused by energy/fuel transportation lines Arson (intentional damage)
9. Safety supporting systems
Electric power loss Insufficient tank cooling Firefighting water loss Firefighting water in piping freezing

For all the above mentioned causes there are certain protective measures aimed at limiting or preventing their occurrence and are presented in Table 2.

Table 2. Protective measures.

1. Design
Following engineering standards and regulations Modification of tank top design to prevent overfilling Site inspection Safe distance Dikes, bunds Defining tank capacity
2. Maintenance
Routine inspection Periodic proof testing of overfill prevention system/ Corrosion resistance Preventive checking of venting equipment Use proper equipment Use explosion-proof tools

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Maintenance of both normal and blast proof equipment Hot work permit Checking of successful work completion
3. Equipment
Following engineering standards Handling static electricity during tank loading Lightning protection system High-integrity automatic operating overfilling prevention system Arrangements to ensure that the receiving agent has ultimate control of tank filling Remotely operated and fire-safe shut-off valves Protection against fluid expansion in piping Temperature monitoring
4. Safety supporting systems
Fire detection and alarm system Firefighting network Foam supply and production system Tank cooling system Spare firefighting water tank/diesel driven pump Anti-frost protection Connection of gas detection with the overfilling prevention system CCTV equipment Emergency response plan
5. Miscellaneous
Safeguarding Electrical supply of tanks added to critical utilities No smoking/good house keeping Protection against extreme weather phenomena Protection from vehicle bumping Protection of piping from mechanical stress Protection from DOMINO effects Protection from areal electric power lines Proper labelling and traffic signing Appropriate management of oily waste Appropriate management of firefighting water Appropriate management of rain water

3.CHECKLISTS ANALYSIS

Hazard identification consists of the identification of serious incidents which may result in danger to employees or the public or environment or in financial loss. Fundamental methods can be used to identify the underlying root causes which can lead to the undesired consequences, as well as to identify those incidents which could lead to problems related to operability, maintainability and other problems.

From a perspective of completeness. it is important that the most important undesired consequences have been identified and taken into account in the hazard evaluation or risk assessment. Completeness depends on how sophisticated the identification technique is and how well known the hazards are. For an existing technology, the hazards may be known form past experience and a simple identification technique will be sufficient to identify the important hazards.

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A checklist analysis uses a written list of items or procedural steps to verify the status of a system. Checklists contain possible failures and causes of hazardous events. Checklists are based on operating experience and are often used in risk analyses. Traditionally, checklists vary widely in their level of detail and are frequently used to indicate compliance with standards and practices.

Checklists are limited by their author's experience; therefore, they should be developed by authors with varied backgrounds who have extensive experience with the system they are analyzing. Frequently, checklists are created by simply organizing information from currently relevant codes, standards and regulations. Checklists should be considered as living documents and should be audited and updated regularly.

The Checklist Analysis is easy to use. But it should be clear that the use of checklists depends critically on the expertise and judgement of the engineer selecting and applying the checklist. As a result, decisions taken by the engineer with regard to the checklist selected, and any additional or superfluous questions, should be fully documented and justified.

Given the availability of experience in the field of application, the use of checklists is straightforward and uncomplicated.

3.1. Checklist for tank safety assessment

This checklist has the form of Tables 1 and 2, and it is expended with additional space for "Evaluation" and "Comments" regarding the awareness of failure causes and the implementation of protection measures by tank farm owners. These remarks are filled out by the person who performs the tank inspection. More specifically, in column "Evaluation" the inspector must complete each cell of the table with the appropriate letter (A, B, C or X). The explanation of each letter is as follows:

- A: Full description (the safety study describes the specific failure cause or protective measure with full details),
- B: Insufficient description (the safety study does not describe the specific failure cause or protective measure with the appropriate detail),
- C: Inefficient (the safety study does not include or there is inefficient description of the specific failure cause or protective measure), and
- X: Inapplicable (the specific failure cause or protective measure is inapplicable to this installation).

The "Comments" column contains any comment of the inspector that is important to be referred for the specific failure cause or protective measure.

Based on issues mentioned in Tables 1 and 2, findings of the literature gave rise to some additional remarks and suggestions:

- The protection against lightning is considered vital, so the existence of a very effective grounding system is deemed indispensable for every separate tank combination with lightning conductors positioned at sufficient height and distance from the tank farm.

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- A rim seal fire is considered as the most frequent fire cause for floating roof tanks containing petrol, crude oil and kerosene, as the first one burns out quickly, while the last two produce significant thermal load while burning.
- Venting devices placed on the top of fixed roof tanks should be regularly checked, as they may be easily blocked, because of a variety of reasons, such as the intrusion of birds.
- The systematic maintenance of blast proof equipment is underlined, so that its blast proofing quality is preserved.
- The sinking of the floating roof must be avoided through regular maintenance of the pontoons and the rim seal and drainage system integrity checking (easy to happen).
- Extreme weather phenomena, such as an abrupt and heavy precipitation, can cause flooding of the drains for oily residuals resulting in the spreading of hydrocarbons to the environment.

4. CONSLUSION

A checklist should be used for just one purpose only - as a final check that nothing has been neglected. Items on the checklist should only be inspected by individuals knowledgeable of and familiar with structure of fuel tanks. The frequency of inspections is the minimum standard recommended by the committee. Other factors affecting the frequency of inspection could include such things as monthly throughput, climatic conditions, applicable environmental rules and regulations, manufacturers' recommendations, experience with component performance, or other extenuating circumstances. Some fuel-dispensing system components must be inspected according to requirements established by environmental, fire safety, and other authorities having jurisdiction over fuel tanks.

Acknowledgements

This paper was supported by projects III43011, III43012 and III43014 of the Ministry of Education and Science of Republic of Serbia.

References

[1] Brissaud D., Tichkiewitch S., and Zwolinski P., 2006, Innovation in Life Cycle Engineering and Sustainable Development, Dordrecht: Springer Netherlands.
[2] IChem^{E}, 2008, Liquid hydrocarbon storage tank fires: prevention and response: a collection of booklets describing hazards and how to manage them.
[3] Chang J. I., and C.C. Lin, 2006, A study of storage tank accidents, *J. Loss Prev. Process Ind.*, vol. 19, no. 1, pp. 51–59.