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Fire Protection in the Chemical Industry

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A look on loss statistics of reportable incidents reveals that fire is the most important cause of major losses in the chemical industry. Therefore it pays off to think about how advanced fire precautions may help to minimize the risk of such damages.
This is the topic of the ProcessNet working group “Fire Protection in the Chemical Industry”. Experts from different chemical companies, consultant agencies, insurers and universities, who may contribute to the subject of fire precautions, cooperate and exchange experiences. It aims to establish a still more efficient risk fire management at chemical plants. Important working areas are: knowledge transfer between process safety and fire protection, evaluation and assessing the application of new technologies and learning from experiences.
One risk management methodology for the prevention of fire incidents describing protection measures in dependency of combustible components and of financial and social interests is described.

1. History

The original idea of the working group “Preventive Industrial Fire Safety” was initiated by discussions of the ProcessNet section Plant and Process Safety, where it became obvious that a broader approach to this important topic was needed. Up to that time fire protection was only a side activity of the section. In large chemical companies process safety and fire prevention are organized in different departments. So the topic fire prevention was seen oftentimes as a task of the fire brigade department and not as cornerstone of process safety work.
The records of the german major accidents reporting system – ZEMA (Zentrale Melde- und Auswertestelle für Störfälle und Störungen in verfahrenstechnischen Anlagen) shows consequences of major accidents in process engineering facilities for a time period from 2003 to 2013. It reveals that releases and fires are the most common consequences of accidents. In many cases the released substances are combustible and the releases could lead with an ignition source to a fire, too. Summarizing it can be stated that fire is the essential hazard of chemical production plants with respect to ZEMA accidents reports.
Information about likelihood of fire incidents in chemical or process plants are hard to find. For industrial buildings fire frequency is 6.4 * 10-6 [1/m²/a] referred to figures from Finland [Tillander K., 2003]. In comparison fire frequency of residential buildings is 4.7 * 10-6 [1/m²/a], which means fire probability is 25% lower related to area. Assuming the area of mid-sized chemical plant of 5000 m² the probability of fire is 2.5% per year or statistically every 40 years a fire incident hits the plant.

2. Learning form experiences

One of the most important success factors in the chemical industry is to implement new knowledge in a fast and efficient way. From this point of view the learning from experience is a key element in the safety methodology of this industry, which its inherent hazards.
There are a lot of examples:
Due to a fire in a warehouse in Switzerland in 1986 and the contamination of a part of the river Rhein in the consequence raised the issues of retaining fire fighting water and of safely storing of hazardous goods. The

related guidelines were developed by experts of the chemical industry and were implemented in a very short time period. Further examples of learned lessons are guidelines for handling of combustible materials, like liquids or powders or for fire hazards due to hot work.
The regular investigations of incidents and losses led to better understanding of process hazards and influenced best practice and legislation in a positive way.

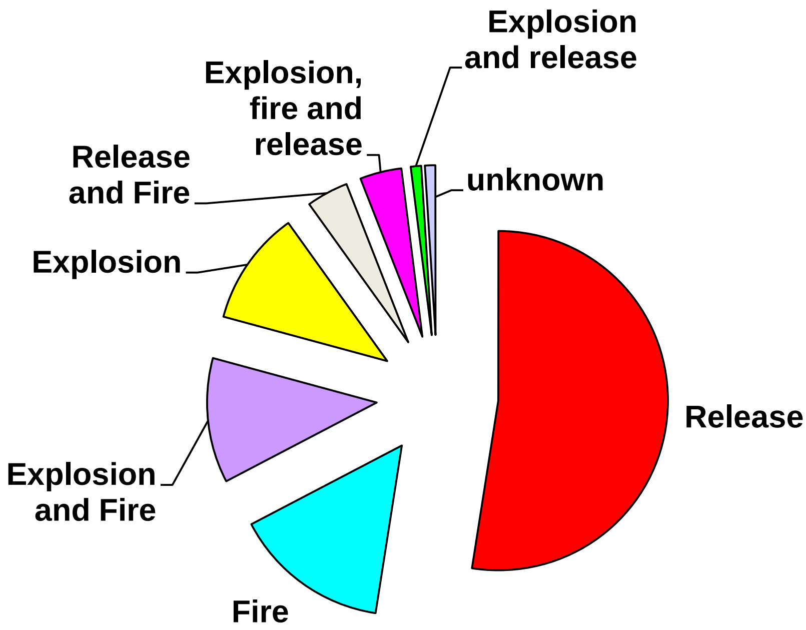

Figure 1: Consequences of major accidents in process engineering facilities [ZEMA data 2003 – 2012]

3. Root causes for fires in the chemical industry

The fire statistic demonstrates that the primary protection level to reduce risk of harm for human and environment is reached nowadays [Altorfer F. et al., 2008].
The next step is to focus on the protection of the assets and thus of working places in the chemical industry in Germany and Europe. Therefore it will be important to analyze the root causes and the consequences of fire incidents.
Unfortunately the currently available information is scarce. A main task of the working group is to change this by collecting and analyzing incident root causes in a systematic way. A look to statistic of fire causes in a chemical/pharmaceutical company of the years 2005 – 2009 shows that no one single reason which leads to fire incidents.
With regard to fire incident investigation in the German Chemical Industry it can be stated that the causes of fires are complex and various.
Here are some examples:
• Frankfurt: Fire after a methanol vapor explosion caused by maintenance work
• Frankfurt: Fire due to welding
• Basel: A relief of a thermal decomposition leads to fire
• Frankfurt: Fire after leakage of an organic solvent
• Ludwigshafen: Fire due to a breakdown of a filter press

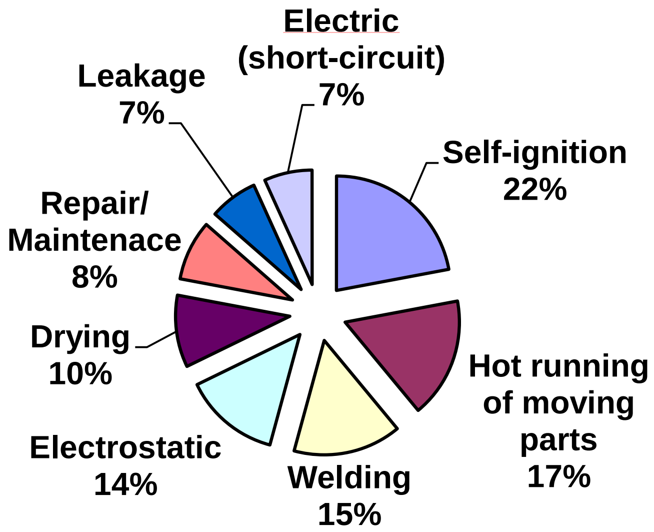

Figure 2: Causes of fire in chemical plants based on analyses of incidents of a chemical - pharmaceutical company [Wehmeier G., 2012]

All concerned companies had in place a safety management system. With regard to the loss time incident statistic they were better than the average of chemical industry (derived on the official figures of occupational accidents measured by the insurance association).
A simple finger pointing to the deficiencies of plant safety in the fire cases and the hint to optimize plant safety will not protect against a fire incident. A broader fire protection concept is needed, which tolerate single flaws in the plant safety of a chemical plant.

4. Fire Risk Evaluation

A first step of treating the potential hazard of a fire in a chemical plant is an evaluation of the risk, on which a proper protection level should be implemented.
The protection level is on one hand a measure of the danger to employees' life, the neighborhood, the environment and on the other hand of the business interests. Financial impact rises from business interruption, loss of sales or of market shares. The fixing of a protection level for a production plant begins with the definition of the worst case scenario. A process risk analysis, like HAZOP, or the risk assessment of an insurer delivers helpful information. All possible but realistic damage consequences including production interruption or business loss will be based upon this hazard identification.
Elementary fire protection measures are well established with respect to prevent harm to people or to environment. But the financial risk of fire incidents is oftentimes underestimated. The costs of business interruption can be multiple higher than the loss of assets itself.
The most critical issue is a fire load consisting of volatile organic solvents with low flash points. It is therefore the volume and processing of such solvents in manufacturing building which can give rise to an elevated fire risk. For a rough assessment of a risk one needs the largest individual quantity (LIQ) or the total volume of solvents (TV) in a plant with a boiling point below 150°C. Both figures, in addition to information on handling and processing will allow to define a fire protection level with respect to a guideline of the Expert Commission for Safety in the Swiss Chemical Industry [ESCIS, 2012]. It defines three protection levels: 1) basic protection measures, 2) additional fire protection measures and 3) supplementary measures.

Table 1: Definition of fire protection levels [ESCIS, 2012]

	Largest individual quantity in tons [LIQ]* (t), Total volume [TV]* (t)							
	<0,5 LIQ	<1 TV	<1 LIQ	1 - 10 TV	<5 LIQ	10 - 30 TV	<10 LIQ	>30 TV
Stored in tank, bulk, containers	1	1	1	1	2	2	3	3
The above and processed in reactors	1	1	2	2	2	2	3	3
The above and distilling, condensing	2	2	2	2	3	3	3	3
Processing under pressure above boiling point	3	3	3	3	3	3	3	3

At the end of the process should be a management decision, which answers the question: is the risk properly handled? That means are the fire protection measures adequate to the financial und social loss. If not, additional fire protection measures should be considered.

5. Fire Protection Measures

Basic protection describes the generally accepted and legally required measures like fire extinguisher, wall hydrants, manual alarm points, water supply, constructive fire protection etc. Additional and supplementary protection measures can be

- Reduction of fire load
- More stringent fire partition
- Automatic fire detection system
- Sensors for early warnings (smoke, heat, gas)
- Semi-fixed extinguishing systems
- Fixed extinguishing systems (sprinkler, water spray)
- Fire brigade.

The list defines menu items to choose from with respect to the potential (financial and social) impact. Especially sprinkler extinguishing systems fit the demands of the chemical industry due to short response time, design flexibility and robustness.

6. Example of Implementation

In a midsized chemical production site a deeper fire risk evaluation was done. The site runs a well trained and equipped fire brigade. At first the amount of volatile organic solvents with low flash points was checked in each plant. Most chemical plants had a higher hold up of flammables solvents with respect to the defined thresholds. The installed fire protection measures, well described in industry standards, were sufficient to prevent a hazard for people and environment, but did not consider the financial risks. These were checked as sum of property damage, loss of sales due to business interruption and loss of market shares. In case of intermediates the losses of whole production network has to be considered.

The detailed look on potential loss due to fire revealed an unknown or at least an unaware financial risk. Consequently, the plants with higher fire load were equipped in-house with sprinkler systems and outside with automated activated deluge systems.

7. Cost benefit ratio

A comprehensive fire protection concept primarily considers financial aspects. This means minimizing losses due to business interruption and threatening market shares. Simple production processes could be transferred to other sites or the product could be purchased, which means the costs due to production loss were low. For specialty chemical production it is oftentimes no option to transfer the production in adequate time or to purchase the product. In the example the business interruption costs were calculated 8-12 times higher than the replacement costs of building and equipment. Especially, a fire could cause extremely high losses in a plant that produces an important intermediate in a production chain.

Installation costs of sprinklers and automation deluge systems vary form 50-180 €/m² (basis 2010) depending on size and complexity of the chemical production. In our example, the cost ratio of financial fire risk to the investment in technical fire protection is 250.

For a specialty chemical plant, the payback time of the investment in technical fire protection is calculated to be less than one month (The calculation is based on the industrial fire frequency figures from Finnland [Tillunder K., 2003]).

8. New demands and need for research

The increased level of advanced process control and multivariable control has led to more efficient and especially to safer operations. This trend will continue in future years. Cost pressure and demographic change will bring new ideas of automation. On the other side, there will be less staff on the shop floor, which checks the plant by walking around to detect leaks or other process faults. Henceforth, sophisticated sensors for early warnings of vibrations, gas or heat will detect process deviations like irregularly running pumps or slightly leaking flanges.

Research in fire prevention will be based on the development of active monitoring systems. The smart combination of various types of detectors in the production area and on production equipment will lead to a higher level of safety.

Passive fire protection is another field of research. It includes compartmentalization of the overall building through the use of fire-resistance rated walls and floors. An important research topic is cable coating, which means application of fire-retardants. These are either endothermic or intumescent, to reduce flame spread and smoke development of combustible cable-jacketing.

New developments in active fire protection research concerns water mist systems. They use very fine water sprays (i.e. water mist). The small water droplets allow the water mist to control, suppress or extinguish fires by cooling, displacing oxygen and attenuating radiant heat. The advantages are less water damage and, thus, shorter downtimes.

9. Topics of the working group

The focus of the working group is divided into four sections:

Active fire prevention:
fire detector, gas detector, design of sprinkler systems, use of line detectors, design of deluge systems (water spray, water mist, sprinkler), design of gaseous extinguishing systems (carbon dioxide, inert gas, steam)

Passive fire protection:
permanent inertization of warehouses, support for pipe racks, fireproofing cabling, use of fire resistance cable coating, protection of tank farms

Repair and maintenance:
thermal oil heat exchanger, deluge systems (gas, vapor, sprinkler)

Discussion of worst-case scenarios:
case studies, fire statistics, fire propagation (numerical calculations)

10. Conclusion

The overall target is to minimize the risk and to reduce the figures and severity of fire incidents by adjusting process safety, work place safety and preventive fire protection in a holistic way. The derived methodology for a proper fire protection concept in dependency of combustible components and financial and social interests can give hint for additional protection measures.
One important task of the ProcessNet working group “Preventive Industrial Fire Safety” is to deeply analyse the causes and effects of fire incidents and to derive from that knowledge requirements of a preventive fire protection concept. Until nowadays information and statistics about fire incidents in chemical industry are rare.

The working group members are from the following companies and institutions:
- BASF SE, Ludwigshafen
- Currenta GmbH & Co. OHG, Leverkusen
- HDI-Gerling Sicherheitstechnik GmbH, Essen
- Inburex Consulting GmbH, Hamm
- Infracor GmbH
- Linde AG, Pullach
- Lord Germany GmbH, Hückelhoven
- Lonza AG, Visp/Schweiz
- Merck KGaA, Darmstadt
- Munich RE, München
- Otto-von-Guericke Universität Magdeburg
- Sanofi-Aventis Deutschland GmbH, Frankfurt
- VDS Schadenverhütung, Köln
- vfdb e.V., Lippetal
- Wacker Chemie AG, Burghausen

The partners have the common interest on a safe and undisturbed (chemical) production. Preliminary conditions are on one hand low risks and on the other hand competitive costs of production. The combination of these both targets requires a differentiated approach.
All members of the working group contribute their outstanding expertise to reach a common understanding for a proper fire prevention methodology in the chemical industry.

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