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Aging Equipment in Facilities and Daily Maintenance – Latent Risks on Sites with Major-accident Hazards acc. Directive 2012/18/EU

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Since decades systematic safety analyses are well established methods to reduce the risks on sites with major-accident hazards acc. directive 2012/18/EU. In this time frame the methodologies have evolved as well as the depth of the analysis conducted. A special focus was also laid on aging equipment when sources of major accidents have been analyzed. However the focus here always has been safety on related parts of the plant i. e. vessels, reactors and other apparatus enclosing the hazardous substances or physical process parameters as well as related safety systems to eliminate or mitigate the risk. As part of the analyses the outage of facilities, energy and operating supplies was covered.
In the systematic safety analyses the potential impact of severe weather conditions including i. e. flooding and other impact caused by environment and neighborhood are discussed if reasonable to the location of the site. But what will happen if the source of flooding is internally? A crater is developing due to release of compressed gases and causes the hazard of structure instability of steelwork/platforms and buildings? Is it reasonable to consider facilities as a cause of this type of hazards?
Acc. to article 10 c) of the directive 2012/18/EU the safety report needs to demonstrate that adequate measures to reach safety and reliability have been taken into account in the design, construction, operation and maintenance of any installation, storage facility, equipment and infrastructure connected to operation and linked to major-accident hazards inside the establishment.
Based on selected examples the latent risk of aging facilities as well as human factors will be discussed showing that future safety analyses need to be more comprehensive to uncover these latent risks and to fulfill the requirements of article 10 c) in addition with annex II “Minimum data and information to be considered in the safety report referred to in Article 10”.

1. Introduction

Systematic safety analyses are well established in the process industry since the 70s of the previous century. In Europe , the European Directives on major-accident hazards detail the scope and have been transferred into national regulations, e.g. in Germany in the 12th ordinance to German Federal Immission Control Act (BImSchG) which is known as Hazardous Incident Ordinance (Störfallverordnung - StörfallV). To give more detail, the following considerations will use references to the requirements which are introduced in Germany. However this will also apply in other countries under EU legislation. Chapter 3 of the StörfallV requires the following principle rules for the company operating a major hazard site:

1. The operating company has to implement measures according to extent and kind of hazard to prevent accidents.
2. To comply with the requirement above the following hazards have to be considered
    a. In-plant and operational hazards
    b. Environmental hazards like earth quakes, floods and
    c. Unauthorized invasion

if they cannot be reasonably excluded.

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Supplemental to 1. additional measures have to be implemented to minimize the impact of major hazard accidents as much as possible.
Today's common practice focuses the systematic safety analyses to in-plant and operational hazards, environmental hazards, unauthorized invasion and reliability of facilities and all kind of energies and supplies. With regard to the reliability of the facilities and all kind of energies and supplies it´s common practice to evaluate the impact only if they are not available or not available within the required specification.
Most of the big industrial parks with agglomeration of process industry have grown over decades, a few even over centuries, due the interconnection of the products and material flows. Thus in mind it's evident that we will find aged equipment and installations in underground pipeline nets for water (process, cooling, waste water etc.) and pressurized air.
Maintenance, especially routine daily maintenance is considered in generalized statements and takes into account work permit systems and pre work hazard analyses to prevent negative impact to man and technical installations. To minimize the effort for hazard work analyses they are not considered individually but in categories and it´s a duty of the supervisor or the maintenance staff to perform a pre work hazard analysis as it is mentioned in the sites' management system process descriptions. Very often we rely on the qualification of the first line maintenance staff and their capability to oversee also very complex process plants with all their hazards.
Fortunately there have been only a few incidents yet, the author is aware of or was involved in the root cause analyses, but his discussions with employees of other operating companies not being already faced with incidents of such kind reveals a latent risk in the common practice of systematic safety analysis.

2. Examples of incidents based on aged equipment

The following incidents will show that aged equipment in facilities, all kind of energies and supplies can create hazards like i. e. an external flood.
The following incidents will show that aged equipment in facilities, all kind of energies and supplies can create similar hazards like e.g. an external flood.

2.1. Aged main cooling water pipeline causing a Joukowski water hammer and flood

At a major industrial chemical park, a main cooling water pipeline (nominal width 1000 – 1400 mm) caused a Joukowski water hammer which led subsequently to the integrity loss of several smaller cooling water pipelines in the basement of a production building, resulting in flooding the entire basement and emergency shutdown of the process plant due to short circuits and water induced failures in instrumentation and control equipment.
It´s common knowledge, that closing a valve can cause a Joukowski water hammer depending on the closing velocity of the valve and the impulse of the media in the pipeline. But, what else can cause it, if you can exclude valves, pumps or collapsing big gas / vapour cavities as a root cause?
In the analysis we found, that the main cooling water pipeline was over 40 years old. The pipeline was manufactured from steel with a concrete liner. Occasionally the operator found some thin concrete pieces in the cooling tower and wondered, where they might come from because it´s a closed cooling water system and there was no information available about construction works with concrete. Following the analysis due to the age of the pipeline there was internal corrosion which led to a local separation of the concrete liner from the steel pipeline. The separation could lead to small concrete piece or even big pieces. In the considered case a big piece of the concrete liner blocked the pipeline at a smaller diameter internally of a valve. The thin piece of the concrete liner couldn`t withstand the impulse of the moving water mass and was destroyed immediately. But finally this short blockage of the pipeline caused a Joukowski water hammer which was confirmed by a simulation calculation and comparison with the pressure readings. When the results of the Joukowski water hammer calculations and pressure readings have been analyzed an additional cause was found (see figure 1 and 2). The maximum calculated pressure level of the Joukowski water hammer is lower than the allowable pressure for the pipeline classes which have been used for downstream cooling water supply in the production building and they could only fail with regard to wall thickness reduction caused by corrosion.
Before the incident, no visual inspection program of the cooling water pipelines has been in place due to their polyurethane foam coating for insulation and the extensive effort for inspection for corrosion under insulation or wall thickness measurements.
Even in water pipelines without concrete liner, massive scaling can occur, when the water has a high calcium / magnesium carbonate concentration over decades. The scaling might cause trouble, if corrosion combines with flaking pieces of the scaling.

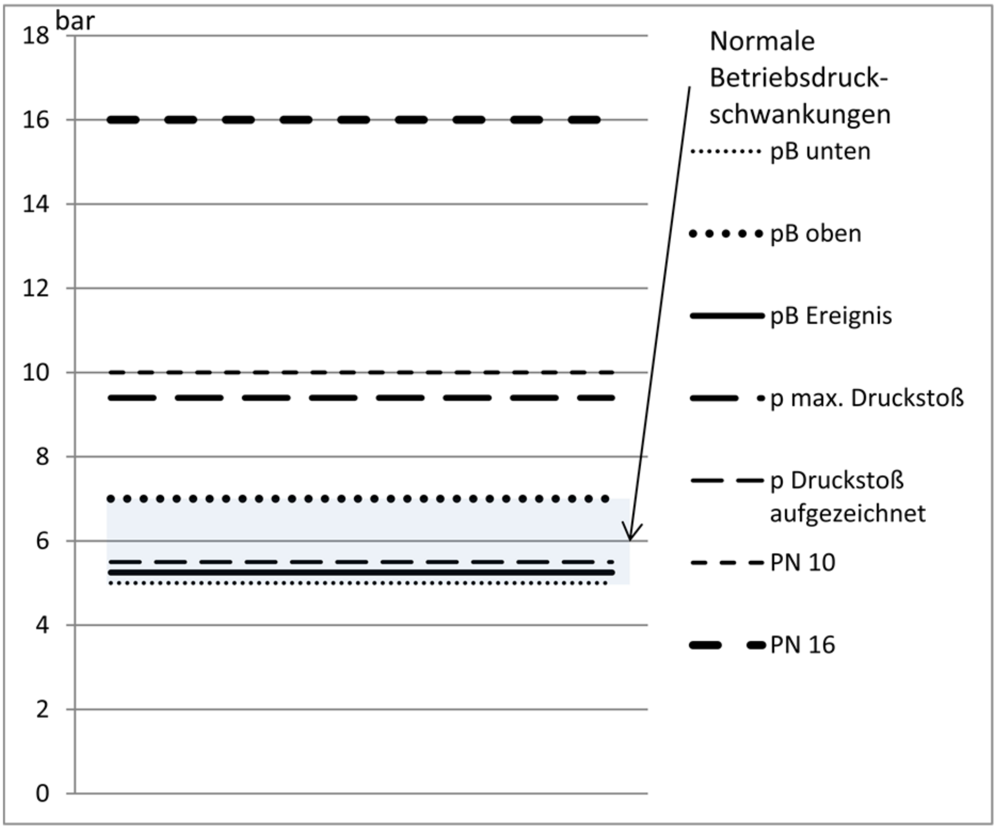

Figure 1: Shows different pressure levels. The lines "PN1"0 and "PN16" are allowable pressure for 2 different pipe classes. The lines "pB unten" and "pB oben" indicate the pressure range of the operating cooling water system. "pB Ereignis": Operating pressure before the incident. "p Druckstoß..": Pressure level of water hammer due to pressure reading with low resolution. "p max. Druckstoß": Calculated pressure level of water hammer.

Figure 2: Samples of downstream cooling water pipelines in the production building showing significant corrosion and reduction of wall thickness.

2.2. Aged main pressurized air underground pipeline causing an explosion

The following example shows a main pressurized air pipeline right behind the compressor leaving the compressor building. Due to condensates at lowest point (pipeline bend), corrosion was induced and reduced the wall thickness over time (figure 3 and 4). The underground pipeline was not periodically inspected and an inspection even not considered, because of an air drying step right after the compressor. The pipeline itself is crossing a interplant traffic way for people and vehicles. The compressor building is located close to production plants and the explosion crater close to / partially in the traffic area (figure 5 and 6). The explosion crater caused some minor damages to the grounding and settlements of the compressor building. In case of traffic major injuries would be the result. If the incident area would have been closer to a production plant the blast and debris could have led to a significant impact.

Figure 3: View in the main pressurized air pipeline

Figure 4: Detail view on the corroded area

Figure 5: Detail view on the explosion crater

Figure 6: Close environment of the explosion crater

3. Examples of incidents and hazards based on routine daily maintenance

3.1. Change of a traced control valve for acid product

The change of a traced control valve is a routine daily maintenance task, managed via work permit system and following line breaking procedures, especially if the design is according state of the art (figure 7). In this specific case the pipelines and valves have been traced (approx. 150°C) because the acid product will solidify at ambient temperatures. The control valve is a failsafe close type, which closes when power is disconnected. The tracing was still in place when the operators started with draining and flushing, disconnecting the power supply to the control valve. In sequence, when the power was disconnected, pressure built up in the blocked intake segment of the pipeline, which is opposite of the control valve with no connection to the drain / flush line, and accidentally released as a vapour blast together with residual acid liquid. The range of the vapour blast was about 5-6m. Two employees wearing the required personal protective equipment (operator: full body chemical protection suit, helmet and face shield. Supervisor in approx. 6 m distance: Helmet and safety glasses, working garment with limited, temporary chemical protection) have been hurt (temporary eye and face/throat chemical burn requiring medical treatment in hospital). In the hazard analysis for the work place as well as in the safety analysis the replacement of valves has been considered in general, work permit system and line breaking procedures have been followed. The weak point was that not all valves are of the same failsafe type, what might lead to a specific hazard.

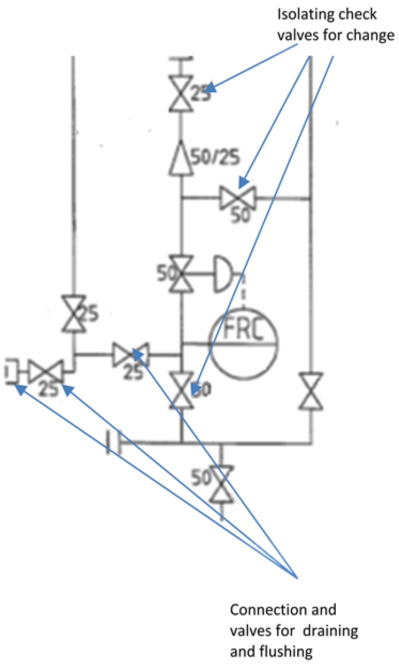

Figure 7: Sketch of the considered installation of the control valve

3.2. Other hazards based on routine daily maintenance

Other hazards might be created if for maintenance tasks bypasses are necessary and the set-up is not documented using a work permit or line breaking procedure which makes sure, that after completion of the task and the bypasses are switched of and installation is handed over in proper operation condition. In case of changing metering equipment for catalyst dosing this can lead to runaway processes with fatal consequences. Also the use of blanking disks in maintenance and leaving them after completion of the tasks is a common failure which can lead to critical situations i. e. if emergency cooling systems or pressure relieve valve are inoperable and require specific maintenance procedures and consideration in systematic safety analysis.

4. Conclusions

These few examples - and there is for sure a higher number of unreported incidents - show the latent hazard of aging and aged facilities and as well of routine daily maintenance and potential impact to the safe operation of a major hazard accident site. These cases reported have been neither considered in detail in the systematic safety analyses of the site where they happened, nor in safety analyses, the author was involved in as an authorized expert. With regard to improve the safe operation of major hazard accident site it is highly recommended to consider not only reliability of facilities and all kind of energies and supplies but also incidents like ruptures and explosions leading to an negative impact on the site, which is scope of the analysis itself. Especially this will apply for major industrial sites with a history back to the 80s and earlier.

Reference

EEC (European Economic Community), 1982, Council Directive 82/501/EEC of 24 June 1982 on the major-accident hazards of certain industrial activities

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