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Of Belts and Braces

(Design of new and existing emergency relief systems.)

Ingo Ludwig, Principal Consultant – Process Safety, Design of new and existing Emergency Relief Systems

Of Belts and Braces

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An Incident with Property Damage from 2019

Incident Report ZEMA

An Incident with Property Damage from 2019

Some Information about the Company

The company is a family-owned business, specialized in the production of synthetic resins, used as raw materials for varnishes, paints and plastics.

- Country of Headquarters: Germany
- Industry: Base Chemistry
- Segment: Industry
- Year of Foundation: 1957
- Turnover: About 95,0 Mio. Euro (Estimation)
- Number of Employees: About 200

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An Incident with Property Damage from 2019

The Incident

8th of June, 2019

On June 8th, 2019, foaming of the mixture occurred in a reactor vessel during the execution of a post-reaction, initiated by the addition of peroxide. The employees noted that the behavior of the mixture is abnormal, i.e. a sharp increase in pressure was detected on the pressure gauge of the reactor. The shift supervisor has been informed. He immediately made the emergency call.

After this planned addition of the post-initiator, there was an increase in pressure and temperature in the reactor, followed by a relief of the vessel content via a rupture disc into a catch tank (having a volume of approx. 2.5 times of the one of the reactor) and from there via a further rupture disc venting into the atmosphere. The triggering of the rupture disc was indicated in the process control system.
Approximately 5,500 kg of ethyl acetate escaped and evaporated, with product components being entrained in the form of droplets. An area of approx. 60,000 m² north of the company ground was contaminated. Since the substance is not soluble in water, there is no water pollution (through the rain).

Process: Manufacturing of an acrylic resin in semi-batch operation
Duration of the event: 10 Minutes.

On-site Consequences

- One employee twisted his ankle during the evacuation, but was able to resume work.
- Costs incurred at the plant: About 20.000 € (Minor damages, replacement of the actuated rupture disc, repairs as well as cost for testing and cleaning.)

Off-site Consequences

- Fatalities: None
- Injuries: None
- Other Impairment: Bonded hair on a female.
- Damage on Property: Contaminated surface area within a 300 m radius NNE. Costs incurred for cleaning: Approx. 500,000 € (estimated).
- Environmental Damage: Very minor surface contamination with non-water-soluble acrylate resin for adhesives. Evaporation of 5,500 kg of ethyl acetate.

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An Incident with Property Damage from 2019

Root Causes

- **Operator Error:**
  Subsequently, it was reconstructed that at the beginning of the batch a tank mix-up had occurred, when solid peroxide was loaded, which first had to be dissolved with ethyl acetate. Employees of the 1st shift filled the solvent ethyl acetate into the correct pre-loading tank 1, and the solid peroxide into the wrong pre-loading tank 2. It should also have been filled into pre-loading tank 1. Therefore, the reaction didn´t start.

- **Improper Testing:**
  The 2nd shift then checked pre-loading tank 1 visually for the peroxide being in solution. However, just from that inspection it was not possible to determine the tank was only filled with the liquid ethyl acetate.

- **Monomer Pooling*:**
  As a result, the complete monomer conversion didn´t occur in the first reaction phase of the batch as expected. Instead, abruptly more material conversion occurred after adding the peroxide during the post-reaction phase, leading to the consequences as described previously.

* A monomer pool is an accumulation of unreacted monomers. When a monomer pool is initiated, a very powerful runaway reaction with an extremely high rate of energy release and catastrophic consequences can occur.

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Layers of Protection & Measures taken

Installed Layers of Protection:

- Reactor: Emergency relief system consisting of emergency relief valve & rupture disc, emergency relief line and catch tank.
- Catch Tank: Release via emergency relief valve and rupture disc into the ambient.

Measures taken:

- Alert of the volunteer fire department
- Evacuation of the production building
- Shut down of other processes in the production building.
- Air investigation by the fire brigade. (These took place after the accident: No impairments could be proven.)
- Warning of the population via radio: Close windows and doors in the surrounding area.

Similar Incidents:

- *Explosion Event in 2000: Extensive destruction of a part of the production building. (No reportable event according to StörfallV.)*

An Incident with Property Damage from 2019

Recommendations for avoiding similar Incidents

Precautions - Avoidance:

- Organisational Measures:
  - Optimization of the equipment labeling and designation for avoiding incorrect operation (in the field, in manufacturing instructions, process technology documentation, batch reports and so on.).
  - Critical review and revision of the manufacturing instructions.
  - Process Control Technology: Identification of short and medium-term replacement measures until finalizing the complete migration of the new PLS, which has been already installed to some processes.
  - Reassessment of the topic “Loading of solid materials into vessels containing flammable liquids“.
  - Determination of safety-related data for new manufacturing processes (e.g., thermal stability of reaction solutions, reaction enthalpies and so on).

- Process Control System:
  - Optimization of the detection of the start of the reaction. (E.g., implementation of an automatic feed stop in the process control system, in case the start of the reaction was not actively confirmed by an employee).
  - Stop or slow down of a runaway reaction. (E.g., automatic addition of inhibitors by the process control system (PCS) when exceeding the associated temperature set point, instead of the current manual addition.)

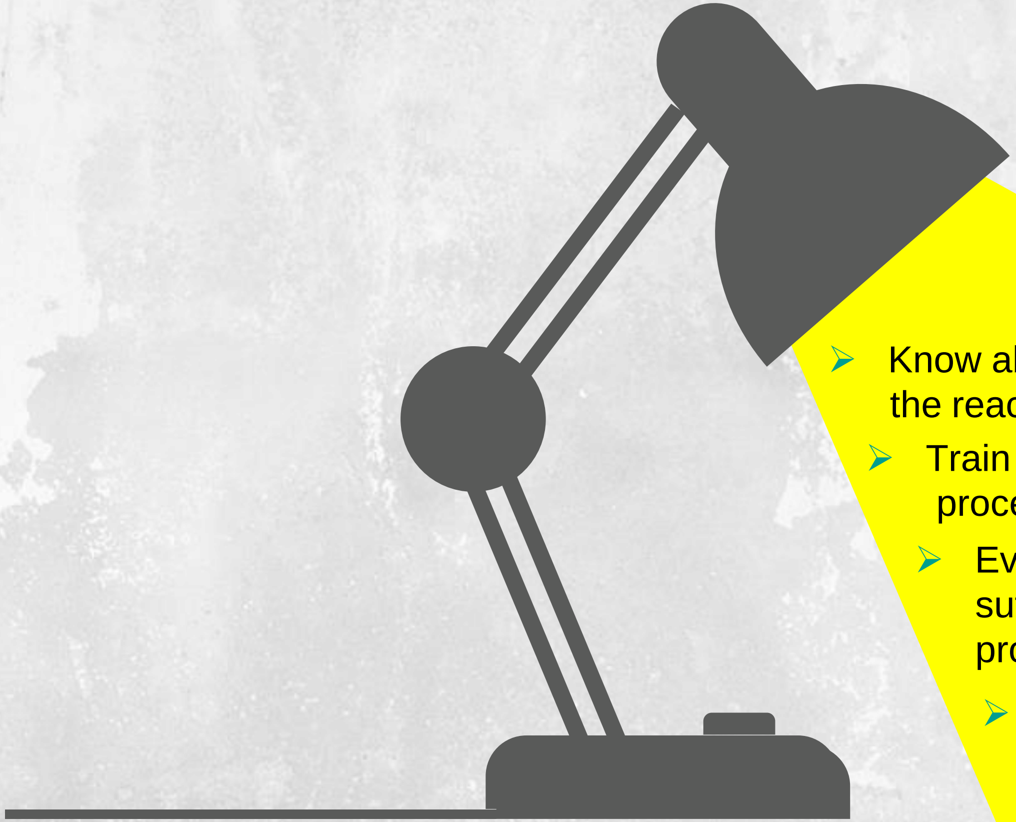
- Catch Tank:
  - Optimization of the liquid retention after actuating the pressure relief devices. (E.g., catch tank: Conversion of the inlet pipes into the tank to significantly improve the liquid separation and installation of a cyclone separator in the medium term.)

Precautions - Mitigation:

- Catch Tank:
  - Optimization of the catch tank with regard to liquid/gas phase separation.

An Incident with Property Damage from 2019

Lessons to be learned



- Know about and control the reactivity of the reaction.
- Train personnel about potential process hazards.
- Evaluate the risk and make sure sufficient and appropriate layers of protection are in place.
- Make sure all layers of protection are designed adequately.

Legal Requirements

Legal Requirements

PHA & Evaluation of Protection Layers / Germany

The following items represent just some examples of german legislative requirements and their core. In addition there are further documents, describing the german RAGAGEP. Beside those rules, regulations, information and leaflets, there are additional sources that must also be taken into account, depending on the specific application.

Process Hazard Analysis (PHA)

Betriebssicherheitsverordnung

§3 / 1 & 2: Prior to the use of any type of working equipment employers shall determine all potential hazards, associated with the operation of this equipment and identify appropriate protective measures.

§3 / 7: The risk assessment (PHA) shall be reviewed on a routine basis. When doing that, RAGAGEP shall be taken into account.
PHAs shall also be reviewed when (1) safety relevant changes have been made to equipment or operating conditions, (2) new information from incidents or occupational health requirements is present, or (3) the assessment of the effectiveness of the protective measures according to § 4 paragraph 5 has shown the specified protective measures are not effective or not sufficient.

§4 / 2: Technical protective measures have priority in comparison to organizational ones and those associated with personnel (PPE).

Störfallverordnung

§9 / 1.2: Operators of applicable assets shall create a report, showing that hazards from major incidents and associated scenarios have been determined and all required measures have been taken, making sure those events and their impact to human health and the environment will be avoided.

Appendix 3 / Paragraph 2b: This appendix talks about the „Safety Management System“ and makes sure, processes for the systematic identification of the hazards of both, normal and abnormal operation, including subcontracted activities, as well as the associated estimation of the probability and severity of such incidents, have been developed and are followed.

Gefahrstoffverordnung

§6 / 1: Part of the PHA shall be the assessment, whether employees are operating hazardous substances, or whether those substances can be generated or released while they are running a process. If so, employers shall evaluate all resulting hazards, impacting the health and safety of those employees. Items of that evaluation shall be „the option for substitution„ and the evaluation of the effectiveness of the protectivbe measures to be taken.

§6 / 4: Employers shall determine, whether there is a potential interaction between process material and process equipment, including process conditions, which can lead to fire or explosion, even if recommended protective measures are in place. Items to address: (1) Presence of hazardous amounts or concentrations of hazardous substances and mixtures, including their physical hazards, which can lead to those events.
(2) Presence of ignition sources or conditions, which can enable those events.
(3) Potential impact from those events to health and safety of employees.

§7 / 7: Function and effectiveness of technical protective measures shall be tested on a routine bases, not exceeding every 3 years.

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Legal Requirements

PHA & Evaluation of Protection Layers / Germany

Process Hazard Analysis (PHA)

Arbeitsschutzgesetz

§4: When taking occupational safety measures, the employer shall take into account the following principles:

- The work is to be designed in such a way that a risk to life, as well as physical and mental health, is avoided as far as possible and the remaining risk is kept as low as possible.
- Threats are to be combated at their source.
- Measures are in compliance with RAGAGEP.

§5 / 3: Hazards can result especially from:

- Physical, chemical and biological effects.
- The design of working- and manufacturing instructions.
- Insufficient qualification and training of personnel.

Arbeitsstättenverordnung

§3 / 1: According to the result of the PHA, the employer shall determine measures to protect employees in accordance with the requirements of this document, its appendix, and based on RAGAGEP and requirements from occupational health.

RAGAGEP

SFK-GS-41 („Bericht "Risikomanagement im Rahmen der Störfall-Verordnung") & KAS-55 („Leitfaden - Mindestangaben im Sicherheitsbericht"):
Deals i.a. with techniques for risk determination and must be taken into account when considering RAGAGEP. The last-mentioned document also talks about the "Layers of Protection Analysis" (LOPA) as a recognized semi-quantitative risk determination method, which is based on the initiating event frequency of a failure scenario and the probability of failure on demand of the associated layers of protection.

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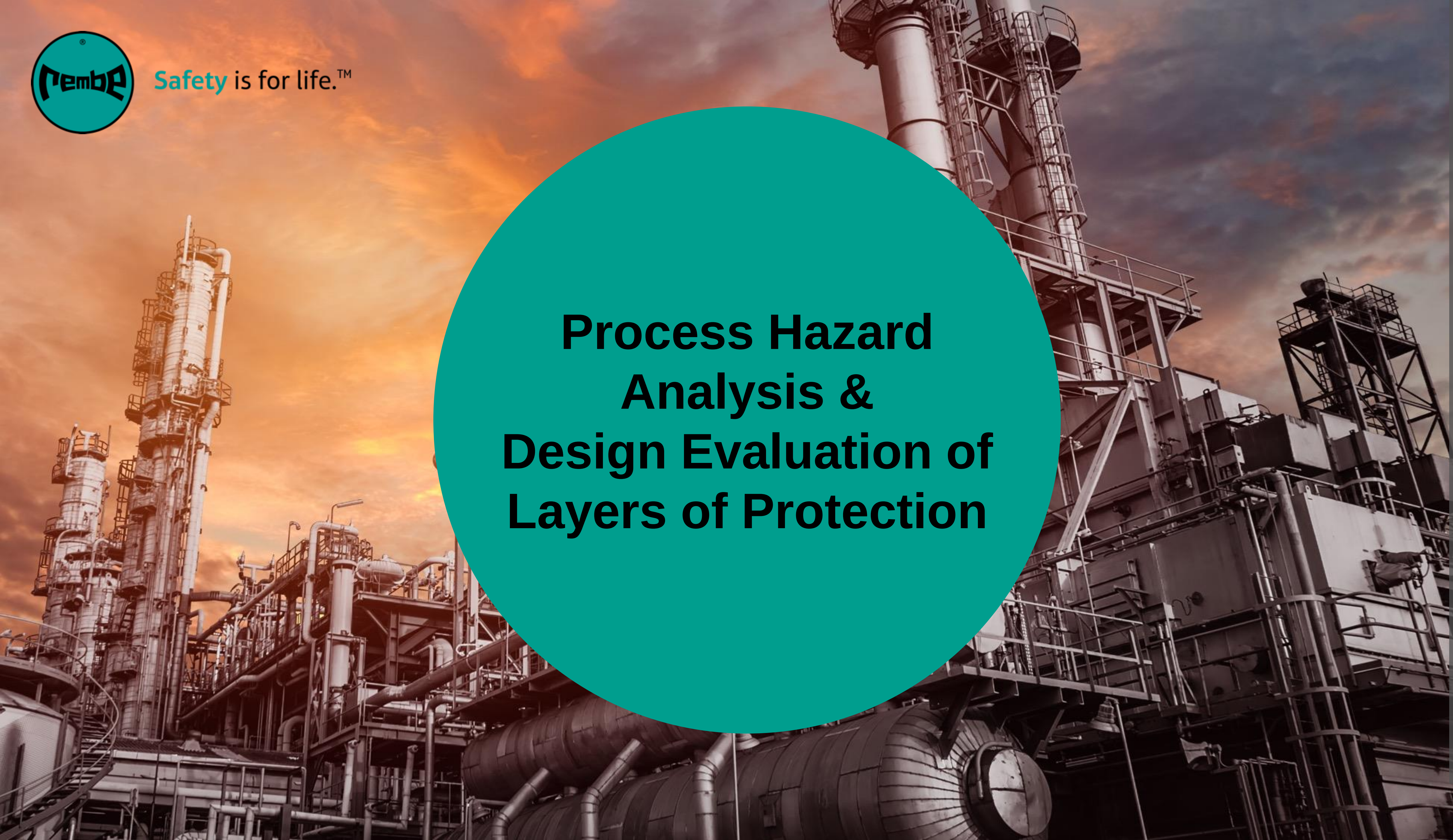
Legal Requirements

PHA & Evaluation of Protection Layers / Germany

Evaluation of Protection Layers

Störfallverordnung (Seveso Directive)	European Directive 2014/68/EU (Pressure Equipment)	RAGAGEP
§4 / Item 3: The operator shall install reliable process & control equipment to processes of applicable assets. If for safety reasons required , multiple equipment, which is different and independent from each other, must be installed.	From Appendix 1, Paragraph 2.3: Control equipment of pressure vessels shall be designed in such a way, that its operation doesn´t create any reasonably forseeable risk. Special attention shall be applied to „Dangerous venting from pressure relief valves“!	RAGAGEP is provided by i.a. Technical Guidelines, which can be categorized in TRGS (Technical Guidelines for Hazardous Substances), TRBS (Technical Guidelines for Operational Safety) and TRAS (Technical Guidelines for Process Safety). Special attention might be given to TRAS 410 (Erkennen und Beherrschen exothermer chemischer Reaktionen), TAA-GS-06 (Leitfaden zur Rückhaltung von gefährlichen Stoffen aus Druckentlastungseinrichtungen) and ISO 4126- Series (Safety devices for protection against excessive pressure). In addition, norms for designing and testing of safety interlocks, such as IEC 61511-1 (Functional safety – Safety instrumented systems for the process industry sector), but also SFK-GS-41 (Bericht “Risikomanagement im Rahmen der Störfall-Verordnung“), which deals i.a. with techniques for risk determination, must be taken into account when considering RAGAGEP. The last-mentioned document also talks about the "Layers of Protection Analysis" (LOPA) as a recognized semi-quantitative risk determination method, which is based on the initiating event frequency of a failure scenario and the probability of failure on demand of the associated layers of protection. (Also true for KAS-55 (Leitfaden - Mindestangaben im Sicherheitsbericht.)
§6 / (1) / 1 & 2 : Operators shall verify the construction and operation of safety relevant equipment and constantly monitor and maintain safety relevant processes of applicable assets. Maintenance and repair shall be done according to RAGAGEP.		
From Appendix 3 / Paragraph 1: The safety management system is appropriate to the hazards, activities and the complexity of the business organization and is based on a risk assessment.		



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Process Hazard Analysis & Design Evaluation of Layers of Protection

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Process Hazard Analysis

Design Evaluation of Layers of Protection

Definition – Independent Protection Layer (IPL): A device, system, or action that is capable of preventing or mitigating the impact of a scenario from proceeding to the point where the undesirable consequence occurs.

- **Specific:** Shall be specific to certain scenarios, shall not have an operational function. (E.g. an electronic safety interlock that interrupts the process in case the pressure gets too high so that it doesn´t increase any longer. However, this interlock shall not be used for maintaining or indicating the desired operating pressure.)
- **Independent:** Must be independent from the initiating event and other IPLs. (Shall not depend on other IPLs, nor have any impact to their function.)
- **Reliable/Available:** Must be available when needed. (May only be changed or switched off by authorized personnel ("Access restriction“). Must be independent from the required auxiliary energy. Must not be prone to failure. Must be adequately sized. Must be fast enough. Must be effective enough. (e.g. Concentration or amount of a stopper or quench solution.) In case of human intervention: Document the expected human action in form of procedures & train staff regularly.
- **Auditable:** Needs regular testing & inspection. All procedures, as well as all data and information about the layout and design changes made, and inspection & test results must be fully documented.

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Process Hazard Analysis

The Incident from 2019 as PHA/LOPA-Scenarios

	Scenarios	Quantitative Evaluation -> (LOPA)												
				onditional Modific		Consequence Category			Layer of Protection				Result LOPA	
Scenario Title / Description	Scenario Number (from PHA)	SeverityLevel	Initiating EventFrequency	Probability of Ignition	Unmitigated Event Frequency	Frequency Category	Risk Score I oder II > LOPA	Actions Recommended	4	9	Risk Tolerance	Mitigated Event Frequency	**Result ok**	Recommendation
	Szenario Nummer (from PHA)	Grad des Ereignisses	Ereignis Häufigkeit	Möglichkeit einer Entzündung	Gesamtwahrscheinlichkeit des Ereignisses	Frequenz Kategorie	Risikofaktor	Empfohlene Aktionen	IPL Additional Mitigation, Dikes, Pressure Relief Device	Future Upgrade	Grenzwert Ereignis SOLL	Wahrscheinlichkeit Ereignis IST	**Ziel erreicht**	Empfehlung
IFT-1	**Szenario 1**	**C4**	1,50E-01	3,00E-01	4,50E-02	**F4 Likely**	I	> Proceed with LOPA	1,00E-02	1,00E-02	<10-5	**4,50E-04**	**No**	
Main Feed Phase		Feed of monomers and solvents into the reactor: Monomer Pooling. During the post-polimerization phase feeding of initiator into the monomer pool: Exothermic runaway reaction & pressure increase in the reaktor. (> MAWP) Reactor starts leaking, a vapor cloud gets released & ignited. Consequence: Explosion and multiple fatalities.	Assumption! Operator error: Initiator not loaded. (Frequency: Experience from the past.)	30% chance of ignition source.					Emergency relief system: Pressure relief valve, Rupture disc. Catch Tank together with pressure relief valve & rupture disc	1) Optimization of the detection of the start of the reaction via BPCS. 2) Stop or slow down of a runaway reaction via a stopper system independent from the BPCS (SIL1). 3) Catch Tank: Optimization of the liquid retention after actuating the pressure relief devices. *(Not relevant for this scenario!)*				Caution: This risk evaluation assumes the entire emergency relief system, including the rupture disc, the relief line and the catch tank, is correctly dimensioned and designed for this scenario!

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Process Hazard Analysis

The Incident from 2019 as PHA/LOPA-Scenarios

	Scenarios	Quantitative Evaluation -> (LOPA)												
				onditional Modific		Consequence Category			Layer of Protection				Result LOPA	
Scenario Title / Description	Scenario Number (from PHA)	SeverityLevel	Initiating EventFrequency	Probability of Ignition	Unmitigated Event Frequency	Frequency Category	Risk Score I oder II > LOPA	Actions Recommended	4	9	Risk Tolerance	Mitigated Event Frequency	**Result ok**	Recommendation
	Szenario Nummer (from PHA)	Grad des Ereignisses	Ereignis Häufigkeit	Möglichkeit einer Entzündung	Gesamtwahrscheinlichkeit des Ereignisses	Frequenz Kategorie	Risikofaktor	Empfohlene Aktionen	IPL Additional Mitigation, Dikes, Pressure Relief Device	Future Upgrade	Grenzwert Ereignis SOLL	Wahrscheinlichkeit Ereignis IST	**Ziel erreicht**	Empfehlung
IFT-1	**Szenario 2**	**C4**	1,50E-01	3,00E-01	4,50E-02	**F4 Likely**	I	> Proceed with LOPA	1,00E+00	1,00E-04	<10-5	4,50E-06	**Yes**	
Main Feed Phase		Feed of monomers and solvents into the reactor: Monomer Pooling. During the post-polimerization phase feeding of initiator into the monomer pool: Exothermic runaway reaction & pressure increase in the reaktor. (> MAWP) The reactor content gets directed into the catch tank, a vapor cloud gets released from the catch tank stack & ignited. Consequence: Explosion and multiple fatalities.	Assumption! Operator error: Initiator not loaded. (Frequency: Experience from the past.)	30% chance of ignition source.						1) Optimization of the detection of the start of the reaction via BPCS. 2) Stop or slow down of a runaway reaction via a stopper system independent from the BPCS (SIL1). 3) Catch Tank: Optimization of the liquid retention after actuating the pressure relief devices.				

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Process Hazard Analysis

The Incident from 2019 as PHA/LOPA-Scenarios

	Scenarios	Quantitative Evaluation -> (LOPA)												
				onditional Modific		Consequence Category			Layer of Protection				Result LOPA	
Scenario Title / Description	Scenario Number (from PHA)	SeverityLevel	Initiating EventFrequency	Probability of Ignition	Unmitigated Event Frequency	Frequency Category	Risk Score I oder II > LOPA	Actions Recommended	4	9	Risk Tolerance	Mitigated Event Frequency	**Result ok**	Recommendation
	Szenario Nummer (from PHA)	Grad des Ereignisses	Ereignis Häufigkeit	Möglichkeit einer Entzündung	Gesamtwahrscheinlichkeit des Ereignisses	Frequenz Kategorie	Risikofaktor	Empfohlene Aktionen	IPL Additional Mitigation, Dikes, Pressure Relief Device	Future Upgrade	Grenzwert Ereignis SOLL	Wahrscheinlichkeit Ereignis IST	**Ziel erreicht**	Empfehlung
IFT-1	**Szenario 3**	**C4**	1,50E-01	1,00E+00	1,50E-01	**F4 Likely**	I	> Proceed with LOPA	1,00E+00	1,00E-04	<10-5	1,50E-05	**No**	
Main Feed Phase		Feed of monomers and solvents into the reactor: Monomer Pooling. During the post-polimerization phase feeding of initiator into the monomer pool: Exothermic runaway reaction & pressure increase in the reaktor. (> MAWP) The reactor content gets directed into the catch tank, a vapor cloud gets released from the catch tank stack & contaminates the surroundig off site ground. Consequence: Mayor incident, because of soil and groundwater contamination.	Assumption! Operator error: Initiator not loaded. (Frequency: Experience from the past.)							1) Optimization of the detection of the start of the reaction via BPCS. 2) Stop or slow down of a runaway reaction via a stopper system independent from the BPCS (SIL1). 3) Catch Tank: Optimization of the liquid retention after actuating the pressure relief devices.				

Design Basis for Emergency Relief Piping

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Emergency Relief Piping

Design Basis

<u>Basic Thoughts – Emergency Relief System:</u>

- <u>Vessel:</u> Which vessels do need an emergency relief system?
- <u>Emergency Relief Device:</u> Rupture disc and/or Pressure relief valve? Dimensioning? Material of construction? Pressure and temperature design? State of aggregation / Phasing of the flow? Accuracy? Location of installation? (Process and inspection) Direction of installation?, Required inspections?, and so on…
- <u>Emergency Relief Piping:</u> See next chart.
- <u>Catch Tank:</u>
  - Location: As close as possible to the process. Inside, or outside from closed buildings? Neigborhood buildings and plants under the light of the prevailing wind direction.
  - Which vessel pipes must be connected? (Emergency relief pipes, breathing pipes…)
  - Vessel: Size? Pressure and temperature design? Material of construction? Phase separation: Impact to the total volume, Specific height of the pipe entrances? Protection agains flame propagation? „Quenching“ ? Required inspections (Draining of material – Frame work of the vessel - Statics, Required entrance- and inspection ports & their accessability via stairs and platforms)
  - Stack: Statics / Stability? Required diameter & Height? Exhaust air (Plume) and potential consequences?
  - Interaction with a thermal gas incinerator?

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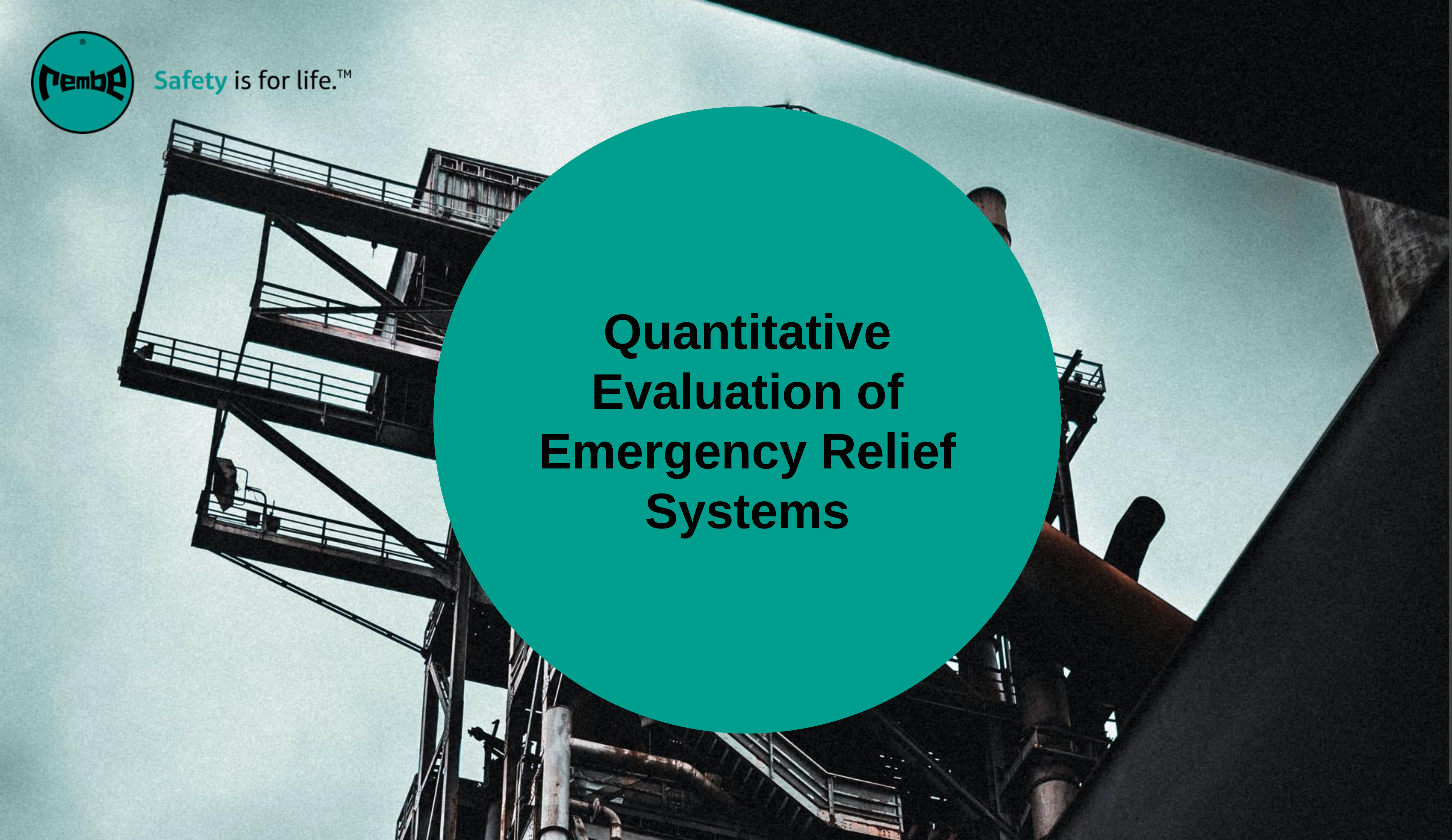
Emergency Relief Piping

Design Basis

Design Basis – Emergenc Relief Piping:

- Design Basis:
  - What is my „Worst Case“? (…or are there more than just one?)
  - State of aggregation / Phasing of the flow? (1-Phase, 2-Phase)
  - What should be the material of construction for the piping or for some parts of it?
  - Starting point of the piping? (e.g. Vessel Dome: Independent from other components of the process!)
  - Diameter of the piping? (At least as big as the diameter of the emergency relief device(s))
  - Shut-off valves? (In general should be avoided. Only to be used under certain conditions.)
- Routing of the Piping:
  - Lenght, Height, Number and type of changes of direction (Goal: Lowest possible pressure drop.)
  - No accumulation of process material (Immediate climb to the highest point, no "U-Sections”, constant decline.)
  - No „abrupt“ changes of direction“
  - Connection of multiple emergency relief lines to a single collection line (Location, direction and angle of the connection flanges)
- Miscellaneous:
  - Maintenance (Tightness, plugging, corrosion) / Consider inspection and cleaning of emergency relief lines during the design phase, especially on the entrance side of emergency relief devices. (Accessibility, number of pipe pieces…)
  - Recommendation: Separation between emergency relief lines and breathing lines.



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Quantitative Evaluation of Emergency Relief Systems

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Emergency Relief Systems

Quantitative Evaluation

Although taking into account the basis for the right design of emergency relief systems and their associated pipe work, not all requirements for an appropriate layout have been considered yet. Open points, which should also be considered for generating an adequate design, include:

- How much Energy will be generated during emergency relief cases from worst case scenarios of the applicable process?
- Which type of mass flow and associated physical conditions (Pressure, Temperature, Flow Velocity) will we have to expect in the different pipe segments?
- Is the Emergency Relief Device appropriately designed for the type of flow and flow rate of the worst case mass flow to be expected?
- Which static and which dynamic forces act on the individual sections of the pipe over the duration of the emergency release and can pipe supports hold the pipe under those worst case conditions?
- Has the thermodynamic impact from an emergency release to the pipe been considered?
- Are the nozzles connecting the emergency relief pipe with both, the process vessel and the catch tank, designed, so that they will withstand the forces from a worst case release?
- In case of an emergency release, is there a negative interaction with other connected process vessels?
- Is the Catch Tank designed for the maximum pressure to be expected inside the tank during a potential emergency release?
- Is the Catch Tank designed, so that the plume released during an emergency relief case doesn´t cause any inacceptable secondary events?

Emergency Relief Systems

Quantitative Evaluation

The clear description of the content of a dynamic stress analysis and its adjustment to the calculations offered by potential service providers requires a lot of experience and a comprehensive understanding about both, the processes to be considered, and the methodology and instruments used by the service provider. Therefore, the following items should be taken into account:

Items for the Evaluation of released Energies:

- Systematic Screening of all potential processes enabling the identification of all potential worst cases.
- Evaluation of the energy release of all potential worst cases and priorization by experts.
- If applicable, adequate transfer of these cases into calorimetric trials, so that their results do correctly reflect the consequences of each worst case.
- Determination of the quallity of raw materials to be used in calorimetric trials.

Emergency Relief Systems

Quantitative Evaluation

The sudden opening of an emergency relief devices during an overpressure event causes an accelerating flow of partially still reacting process material through the pipeline of an emergency relief system. (That opening of an emergency relief valve or a rupture disc often takes place in just a few milliseconds.) That often generates significant forces acting on the pipe work. The mass flow then gets transfered into a catch tank.

Items for the Evaluation of the Piping:

- Type of resulting mass flow (Vapor-Like Systems: Overpressure due to increasing vapor pressure with evaporative cooling of solvents, gas-generating systems, or hybrids of the two.)
- Imbalance of forces on the pipeline due to rapid change in momentum of current.
- The occurrence of fluid- and thermodynamic loads together with other applicable static loads (e.g. dead weight and thermal expansion) must be combined and considered in the system design.
- The pressure distribution within the pipe line and its impact to other process vessels connected to it, must be determined.
- The duration of the relief case and its impact to the above mentioned items.

Emergency Relief Systems

Quantitative Evaluation

This process can cause large reaction forces at bearing points and bending stress in the pipeline. Here, dynamic stresses can increase to a multiple of the static stress, if the pressure relief process triggers a resonance frequency of the entire system ending up in a temporarily occurring resonance vibration.

Items for the Evaluation of Pipe Supports:

- Execution of a Dynamic Stress Analysis: Fluid forces are entered into an associated program (e.g. Finite Element Method).
- Analysis of pipe support installation points.
- Analysis of type / layout of pipe supports.
- Analysis of the structural support the pipe supports are connected to (Beams, scaffolding, walls, suspensions etc.), determining their suitability for absorbing the forces that arise.

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Emergency Relief Systems

Quantitative Evaluation

A complete evaluation or redesign of an emergency relief system also includes a dispersion model, including the re-evaluation of the catch tank, if applicable. The dispersion model calculates the dimensions of the plume, as well as its potential for toxicity and ignitability. The data generated by an adiabatic reaction calorimeter in combination with the calculated flow velocities can be used for this type of analysis.

Here the following items, among others, are relevant:

- Layout of the catch tank.
- Height of the stack.
- Elevation profile of the surrounding area.
- Identification of the hazards resulting from an emission based on the relevant raw material data.
- Identification of critical / relevant „Points of Exposure“.
- Different meteorological conditions.

Emergency Relief Systems

Quantitative Evaluation

However, the bending stresses caused by the reaction forces don´t only have an impact the holding points of the pipeline, but also to their connection points. Often connection nozzles are becoming weak points. Therefore, also at thoses locations the mecanical integrity has to be maintained, so that the tightness of the entire emergency relief pipe is also given in a relief case.

Items for the Evaluation of Pipe Connection Points:

- Pipe Code - Nozzle.
- Material of construction und wall thickness of nozzles.
- Condition and design of the connection between the nozzle and the associated process vessel. (weld seam)

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Emergency Relief Systems

Quantitative Evaluation

Summary:

In order to correctly evaluate the design of an emergency relief system and thus its reliability, a full dynamic stress analysis is recommended.

And…

The right partners, a detailed purpose of job description and a complete process technology package are the key factors for a successful study!

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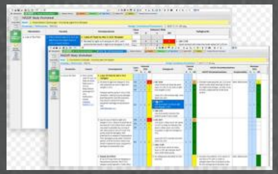
REMBE Safetyneering

5 Elements for maximum Safety

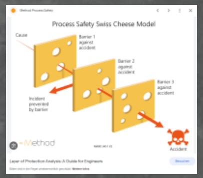
Overall REMBE® Safetyneering provides companies with five elements, supporting them with the implementation of their safety goals. From the overall consideration of a safety management system, through the execution of process hazard analysis and semi-quantitative risk determinations, to the revalidation and testing of the design of protection layers, a complete package is offered that can help to significantly improve the process safety of plants.

Process Safety Management (PSM)

Process Hazard Analysis (PHA)



Layers of Protection Analysis (LOPA)



Protection against Hazards from Plants with an increased Potential for Risk

Evaluation of Protection Layers

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Thank you for your Attention

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