Semiquantitative Risk Evaluation Methods

An EPSC Working Group

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THE PROCESS SAFETY NETWORK

Agenda

- Information about the Working Group
- Basics of Semiquantitative Risk Evaluation (SQRA)
- Discussion of Risk Matrices from Members of Working Group
- Discussion of Risk Acceptance Criteria
- Example for Risk Assessment and SIL-Rating
- Conclusion

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Information about the Working Group

- Duration: 2015 – 2018
- Discussion based on Matrices submitted from EPSC members
  - 1st survey conducted in 2015
  - Update in 2017/2018 to reflect changed composition of working group
  - The data from 2017/2018 form the basis of the final document
- Documentation of results in EPSC Report

Organizations represented in the Working Group

AkzoNobel	DSM
Baker Risk	Dupont
BASF	Evonik
Bayer	Lyondell Basell
BG RCI	OMV Petrom
Centrica	Sasol
Clariant	TÜV Austria
Covestro	TÜV Süd

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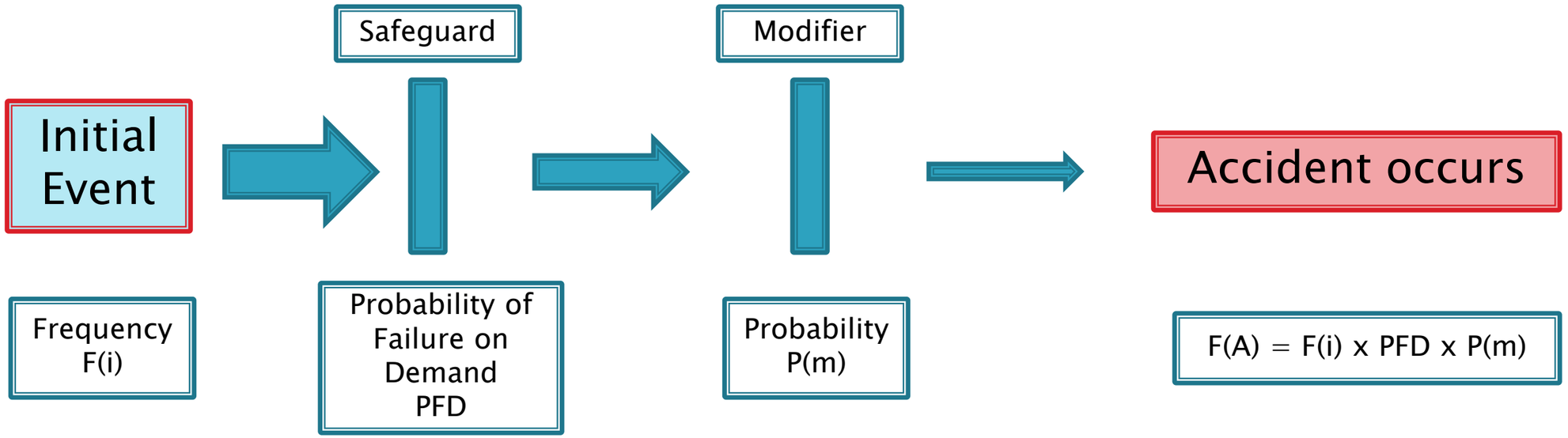
Chain of Events as Basis for SQ Risk Assessment



The Frequency of an accident F(A) is a result of

- **Frequency of the initial event F(i)**
- **PFD of the safeguards**
- **Probability factors P(m) of modifiers**

F(A) = F(i) x PFD x P(m)

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SQ Risk Assessment: Essential Steps

1) Describe the scenario as chain of events and determine the severity of final consequence
2) Determine the frequency of the initiating event (and further factors like modifiers if applicable)
3) Determine the existing countermeasures and their reliability (PFD = Probability of Failure on Demand)
4) Using the results from step 2 – 3, calculate the scenario frequency
5) Using frequency and severity of the scenario, determine whether the risk is acceptable

Company specific risk acceptance criteria are usually documented in a Risk Matrix

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Example Matrix with typical features of Group Member Matrices

	<10^{-5}/yr	10^{-5}/yr – 10^{-4}/yr	10^{-4}/yr – 10^{-3}/yr	10^{-3}/yr – 10^{-2}/yr	10^{-2}/yr – 10^{-1}/yr	10^{-1}/yr – 1/yr	> 1/yr
Catastrophic	**C**	**C**	**B**	**B**	**B**	**A**	**A**
Severe	**D**	**C**	**C**	**B**	**B**	**B**	**A**
Serious	**D**	**D**	**C**	**C**	**B**	**B**	**B**
Significant	**D**	**D**	**D**	**D**	**C**	**C**	**B**
Minor	**D**	**D**	**D**	**D**	**D**	**C**	**C**

Consequence category	Effect on Human Health
Catastrophic	Multiple fatalities
Severe	1 fatality / several severe injuries
Serious	Severe injury
Significant	Lost time injury
Minor	Minor injury without lost time

Risk level	Action required
A: very large, unacceptable risk	Process or design change required
B: Large, unacceptable risk	Risk reduction to reach at least risk level C
C: Undesirable (tolerable) Risk	Check if further risk reduction is possible („ALARP“)
D: Acceptable risk	Ensure that risk is maintained at this low level

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Consequence Categories

- Typically 5 Consequence Categories (Range from 3 – 6)
- Human health most frequently used, in some cases in addition environmental damage and financial loss
- Some companies do not differentiate between 1 fatality and Multiple fatalities
- Some companies differentiate between on-site and off-site effects
  - In this case an effect occurring off-site is classified one level more severe compared to the same effect occurring on-site

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Catastrophic	**C**	**C**	**B**	**B**	**B**	**A**	**A**
Severe	**D**	**C**	**C**	**B**	**B**	**B**	**A**
Serious	**D**	**D**	**C**	**C**	**B**	**B**	**B**
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Frequency Categories

- Typically 5 – 7 Frequency Categories
- Orders of magnitude
- 2 alternative definitions of frequency categories:
  - Range between 2 orders of magnitude, e.g. 10^{-2}/yr – 10^{-3}/yr
  - Full order of magnitude with rounding, e.g. 10^{-2}/yr
  - Mathematically this means a shift of one half order of magnitude
  - Not relevant in practice, because compensated by application rules like e.g. definition of initial event frequencies

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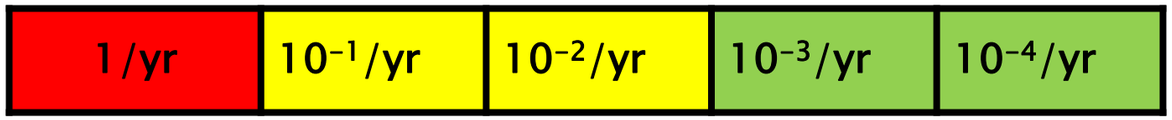
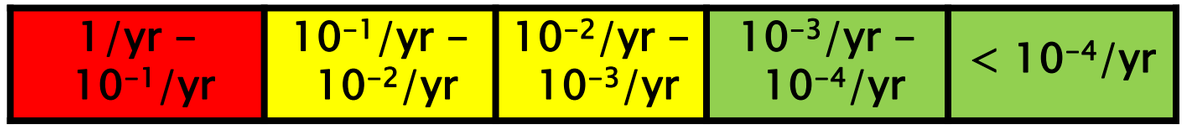
2 Alternative Definitions of Frequency Categories

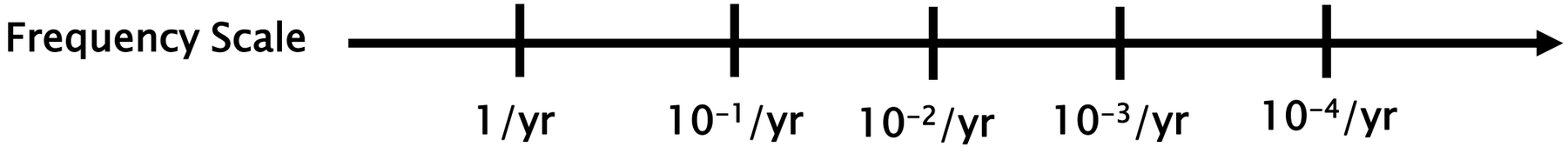
Mathematically there is a shift of one half order of magnitude between the 2 frequency categories
Not relevant in practice, because compensated by application rules like e.g. definition of initial event frequencies

Risk classes for frequency categories as full power of 10



Risk classes for frequency categories as range between 2 powers of 10





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Example Matrix with typical features of Group Member Matrices

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Catastrophic	**C**	**C**	**B**	**B**	**B**	**A**	**A**
Severe	**D**	**C**	**C**	**B**	**B**	**B**	**A**
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Significant	**D**	**D**	**D**	**D**	**C**	**C**	**B**
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Risk Levels

- 3 risk levels as minimum
  - Acceptable (green)
  - Tolerable (yellow, “ALARP”)
  - Unacceptable (red)
- Some companies further differentiate within the unacceptable or tolerable region
  - 3 – 6 risk levels in available matrices
- Each risk level has a clear description of the risk and the action required for risk reduction

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Conditional Modifier / Enabling Condition

- Conditional Modifier:
  - Probability factor expressing the possibility that a chain of events can end up with different consequences
  - Most frequently used:
    - Probability of ignition of a released vapor cloud
    - Probability of people being present in the area affected by an accident
- Enabling Condition:
  - Probability factor for scenarios that occur only under special circumstances or states of operation
  - Example:
    - A cooling failure in a batch process results only in a runaway if it occurs during the exothermic reaction (no hazardous consequence during workup steps)

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Use of Modifiers and Enabling Conditions

- 8 members of the working group participated in a survey on the use of modifiers and enabling conditions
  - **4 members use them**
  - **4 members do not use them**
- Reasons for not using them:
  - To be on the conservative side and to keep SQ risk assessment as simple as possible
- Most frequent field of use:
  - Personnel presence
  - Probability of ignition
  - Campaign production (different processes) with higher and lower risk

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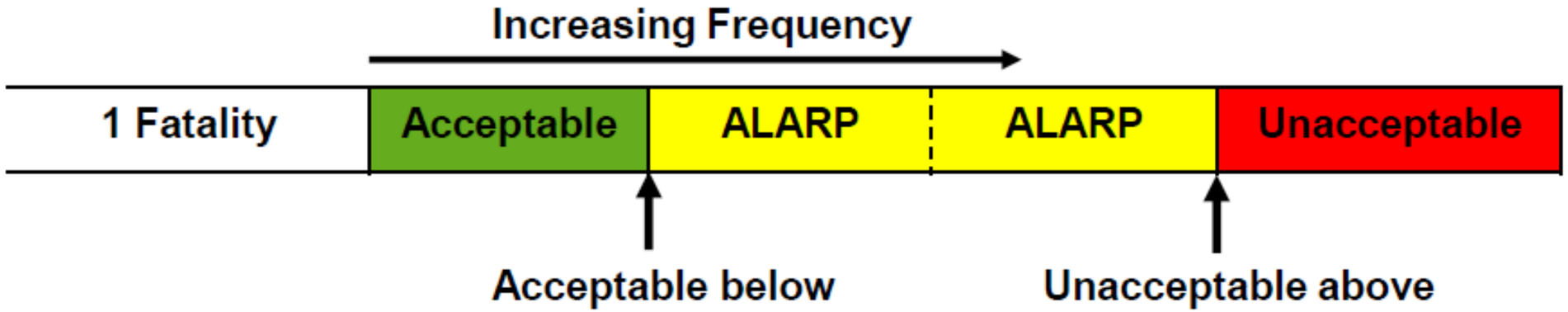
Risk Acceptance Criteria for 1 Fatality

- Comparison of 8 Risk Matrices from working group members
- 1 Fatality as reference scenario
- Target frequencies for the “Acceptable” and “Unacceptable” range as limit values towards the “Tolerable” range (yellow)
- The “Tolerable” (ALARP) range is defined as the range between these 2 values and comprise one or more orders of magnitude



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Risk Acceptance Criteria for 1 Fatality

Matrix No.	Acceptable at or below (1/yr)	Unacceptable above (1/yr)	Remarks
1	**10^{-6}**	**10^{-4}**	
2	**10^{-4}**	**10^{-3}**	
3	**(10^{-6})**	**10^{-4}**	No Acceptable region for fatalities. The limit 10^{-6}/yr is used in practice
4	**10^{-7}**	**10^{-4}**	
5	**-**	**10^{-4}**	No Acceptable region for fatalities
6	**10^{-5}**	**10^{-4} or 10^{-5}**	Unacceptable limit depends upon raw risk
7	**10^{-6}**	**10^{-4}**	
8	**10^{-6}**	**10^{-3}**	

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Risk Acceptance Criteria for 1 Fatality – Alternative Representation

Matrix No.	Acceptable Range (1/yr)	Unacceptable Range (1/yr)	Remarks
1	**≤ 10^{-6}**	**≥ 10^{-4}**	
2	**< 10^{-4}**	**≥ 10^{-3}**	
3	**(≤ 10^{-6})**	**≥ 10^{-4}**	No Acceptable region for fatalities. The limit 10^{-6}/yr is used in practice
4	**< 10^{-7}**	**≥ 10^{-4}**	
5	**-**	**> 10^{-4}**	No Acceptable region for fatalities
6	**≤ 10^{-6}**	**≥10^{-3} or ≥10^{-4}**	Unacceptable limit depends upon raw risk
7	**≤ 10^{-6}**	**≥ 10^{-3}**	
8	**≤ 10^{-6}**	**> 10^{-3}**	

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Risk Acceptance Criteria for 1 Fatality – Comments

- Target frequencies differ only by one order of magnitude in most cases
- Risk level depends not only on target frequencies but also on application rules like e.g. use of modifiers
  - **Example 1: Target frequency of 10^{-4}/yr (conservative) with use of modifier (less conservative)**
  - **Example 2: Target frequency of 10^{-3}/yr (less conservative) without use of modifier (conservative)**
- Example 1 and 2 will often result in a comparable risk level
- Further factors influencing risk level: Values used for **initiating fault frequencies**

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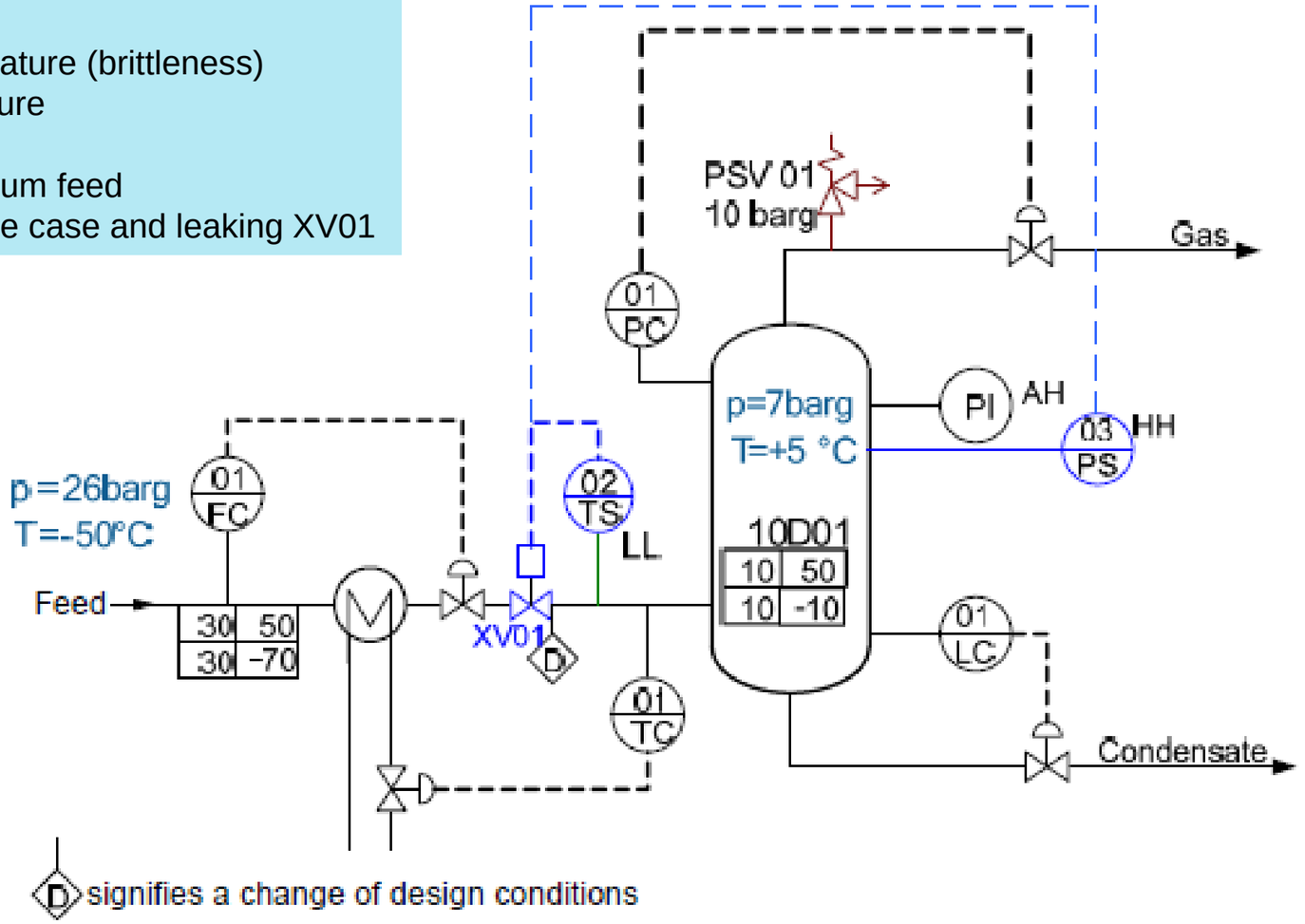
Example for Risk Assessment and SIL Rating (1)

Hazards:
- TS02 (LL) protects from too low Temperature (brittleness)
- PS03 (HH) protects from too high pressure
  - PSV variants: 2 different sizes
    - Variant 1: PSV is sized for maximum feed
    - Variant 2: PSV is sized only for fire case and leaking XV01



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Example for Risk Assessment and SIL Rating (1)

- 7 Members of the working group participated
- Task: SIL classification for TS02 (LL) and 2 variants of PS03 (HH)

The number of participants reaching a specific SIL classification is given in the column „Number“								
Results for TS02 (LL)			Results for PS03 (HH) – Variant 1			Results for PS03 (HH) – Variant 2		
	Number			Number			Number	
SIL 1	0		SIL 1	5		SIL 1	0	
SIL 2	1		SIL 2	1		SIL 2	1	
SIL 3	6		SIL 3	1		SIL 3	6	

Comparison of Risk Matrices: Summary and Conclusion

- Variations in frequency and severity categories and risk classes
- But: Risk acceptance criteria differ only by one order of magnitude (reference scenario: 1 fatality)
- Risk level obtained with a matrix is further influenced by factors like use of modifiers and values for initiating fault frequency
- These factors can compensate each other resulting in the same requirements for safeguards for different matrices
- Example case for SIL rating confirms that in most cases the same results were obtained
- **Comparable risk level of risk matrices and SQRA tools of working group members**

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Thank You for your Attention!