Use of generic major accident scenarios for process safety management

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The « Perfect » PHA Study as Input for Process Safety Management

Before starting the PHA (=core of process safety)

- **Back to basics**: the design is performed according to good practices and recognized industry standards
- A review of experience information feedback information is performed to include the lessons learned in the design
- Inherent Safe Design principles were applied as much as possible

During risk assessment (= verification step)

- All risks of all installations are assessed, and all risks comply with company acceptance criteria
  - ✓ All hazards and risks are identified: there are no unknows!
  - ✓ All possible causes leading to undesired events (loss of containment,…) are identified
  - ✓ All possible scenarios and consequences are evaluated
  - ✓ All impact on people , environment and assets are known
  - ✓ All preventive and mitigating barriers are listed

Process Safety Improvement Plan

Step 1
Identify

Step 2
Action plan

Step 3
Promotion

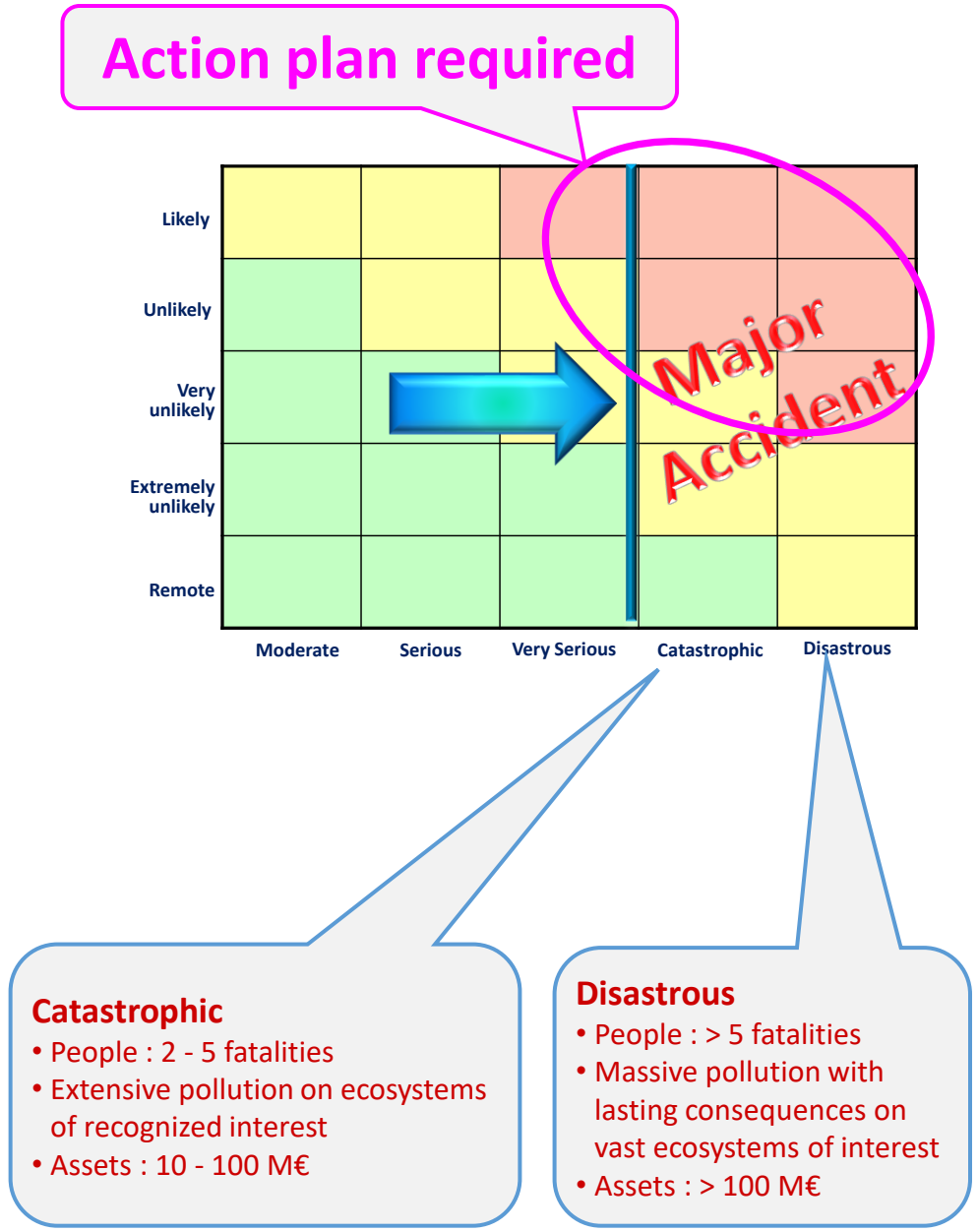
Step 4
Close the gap

Mature processes for PHA are existing in TotalEnergies…

But we want to get better…major accidents are not an option…

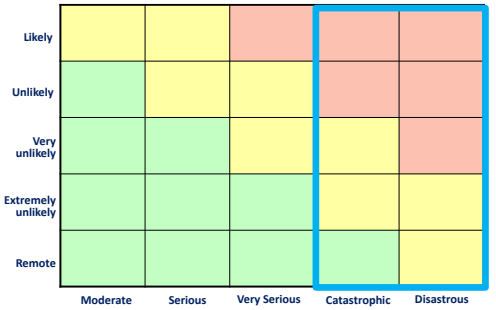
Step 1: Creation of a Major Risk Register

- Creation of central register with all major accident scenarios (Major Risk Register)
- The Major Risk Register includes all major accident scenarios with catastrophic and disastrous consequence potential in the TotalEnergies risk matrix
- The Major Risk Register is discussed periodically at board level of the company to increase transparency



Step 1: Creation of a Major Risk Register

- A benchmark study was performed (Q2 2018) of major accident scenarios reported by different sites for the same type of units in the Refining & Chemicals branch in TotalEnergies
- The table below gives a summary for some refinery and polymer units



Number of G4+G5 scenarios	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5	SITE 6	SITE 7	SITE 8
FCC	33	NA	**0**	44	396	ongoing	**17**	6
Distillation	21	139	130	72	109	ongoing	7	31
Naphtacracker	100 (2)	**50**	NA	NA	659	NA	NA	NA
Reformer+DHT	57	**0**	**0**	62	20	56	24	19
HDS units	23 (4 units)	0 (3 units)	17 (2 units)	35 (2 units)	120 (2 units)	ongoing	14 (3 units)	34 (3 units)
HF alkylation unit	7	NA	120	43	NA	173	NA	NA
Alkylation	NA	NA	NA	NA	152	NA	16	0
Aromatics	38	**0**	0	2	124	ongoing	1	5
Visbreaker	0	0	0	17	0	ongoing	0	NA
ARDS-DHC-MHC-unibon	87	**4**	NA	NA	NA	NA	NA	NA
Atm storage	21	33	38	35	487	56	0	14
TOTAL	**387**	**226**	**305**	**310**	**2067**	**285**	**79**	**109**

Many scenarios related to environment

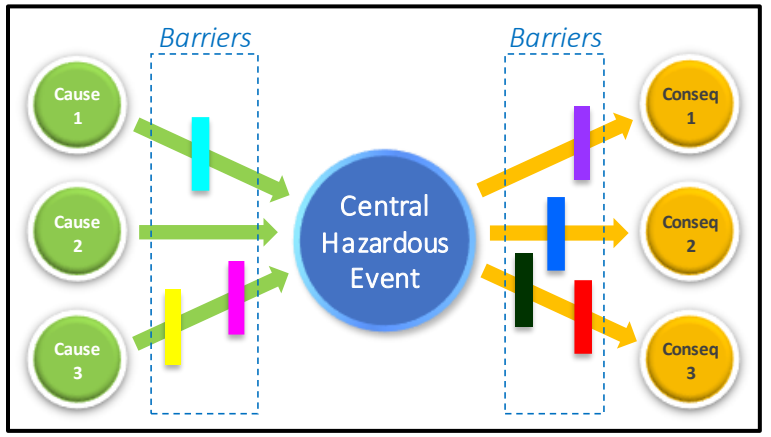
Very exhaustive (every manual valve is a possible cause)

	POL 1	POL 2	POL 3	POL 4	POL 5	POL 6	POL 7
PP	NA	25	133 (3 units)	809 (7 units)	NA	NA	NA
LDPE	NA	NA	NA	NA	NA	439 (2 units)	NA
HDPE	28 (3 units)	1 (1 unit)	21 (1 unit)	NA	NA	NA	NA
PS	NA	16	3	NA	4	23	3

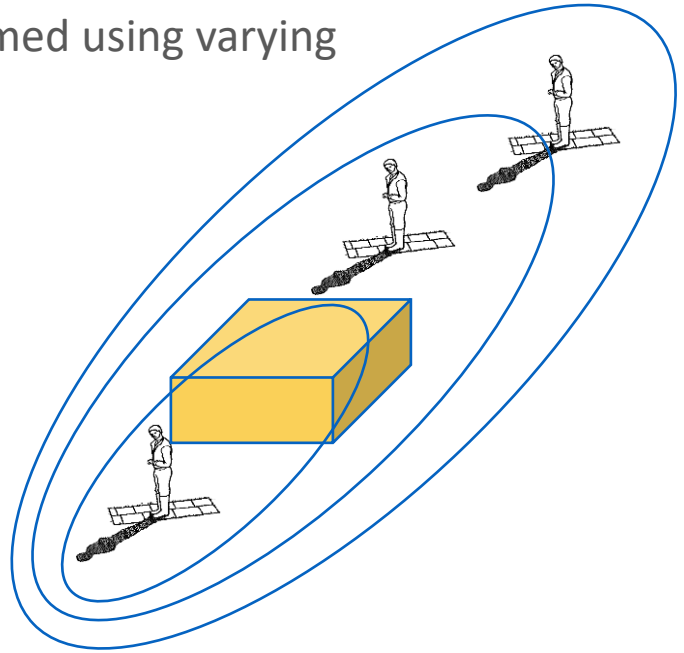
Step 1: Creation of a Major Risk Register

Some observations:

- Lack of consistency in the number and type of major accident scenarios reported by different sites for the same types of units:
  - ✓ Some scenarios are missing
  - ✓ Some causes were not treated



- The estimation of consequences is performed using varying approaches
  - ✓ Based on experience of the PHA team
  - ✓ Using different methodologies



Step 2: List of Generic Major Accident Scenarios for Typical Units

Inputs

- Process
- HSE
- Maintenan
- Inspection
- …

Expert Knowledge

- HSE
- Process
- Internal
- External
- …

Experience Feedback Information

- HAZOP
- HAZID
- CTA
- RBI
- ERA
- SCOP
- …

Risk Studies

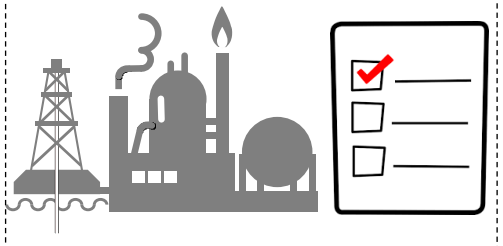
Observation 1: Lack of consistency in the number and type of major accident scenarios reported by different sites for the same types of units

Review by operations

Technical expertise

HSE expertise

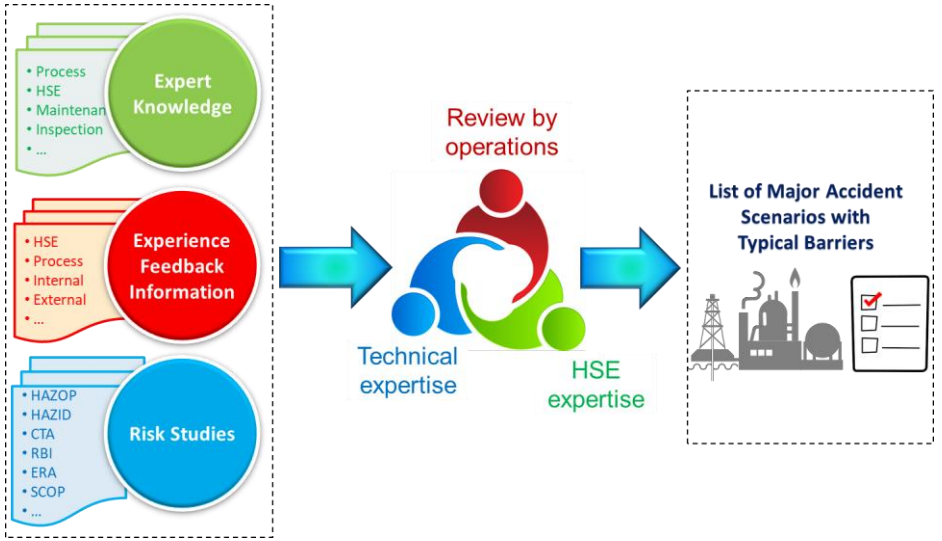
List of Major Accident Scenarios with Typical Barriers



Step 2: List of Generic Major Accident Scenarios for Typical Units

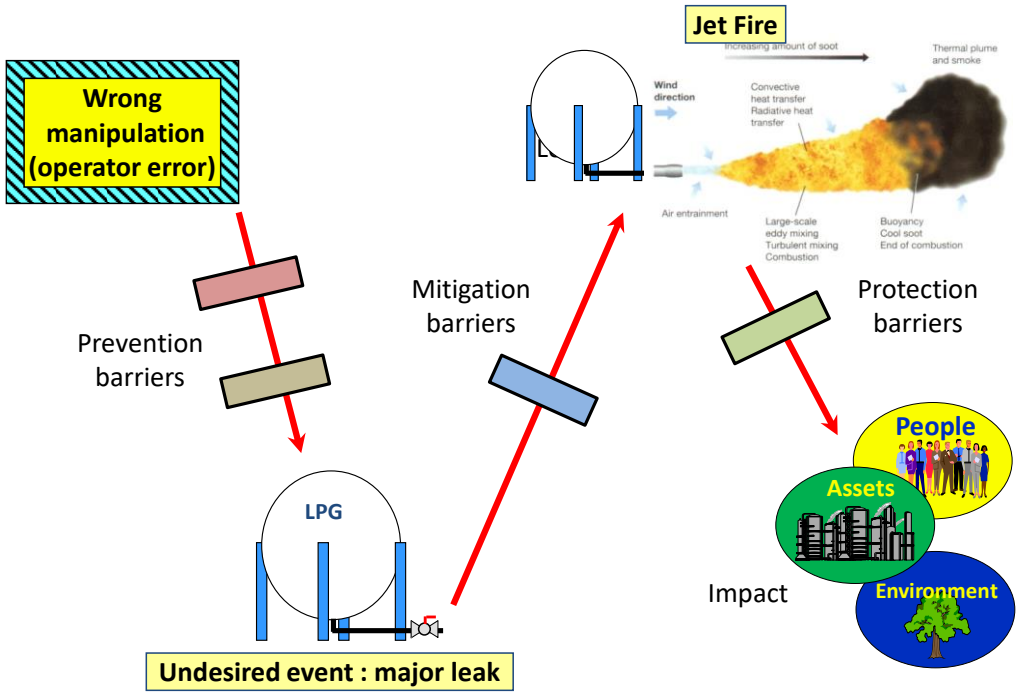
- Priority was given to process units with high HAZARD potential
  - ✓ HF Alkylation: isobutane and butene feedstock with as a catalyst toxic HF to produce gasoline component iso-octane: unit with LPG and light products
  - ✓ Fluid Catalytic Cracker : feedstock is cracked at high temperature with catalist into light products
  - ✓ Poly-propylene unit: feedstock is propylene
  - ✓ Naphtha-Cracker: naphtha, butane or ethane as feedstock , products are LPG and light products
- The analysis includes
  - ✓ Identification of process causes.
  - ✓ Non-process causes are integrated only if specific to the unit (product characteristics, process parameters…).
  - ✓ Typical barriers for prevention, mitigation and protection are listed.
  - ✓ Frequency estimation was done in a second step to prioritize scenarios and barriers

Observation 1: Lack of consistency in the number and type of major accident scenarios reported by different sites for the same types of units



Step 2: List of Generic Major Accident Scenarios for Typical Units

- Estimation of Consequences
  - ✓ Internal tools and guidelines are being developed to assure consistency in the estimation of consequences related to the release of flammable and/or toxic substances
  - ✓ A task force involving representatives of all branches in TotalEnergies is in charge of developing these guidelines & tools to increase consistency of results
  - ✓ The guidelines and tools include all phases of a consequence calculation
    - Definition of source terms
    - Dispersion of vapors/gases
    - Estimation of physical effects (pressure, heat radiation)
    - Impact of physical effects on people, assets, environment

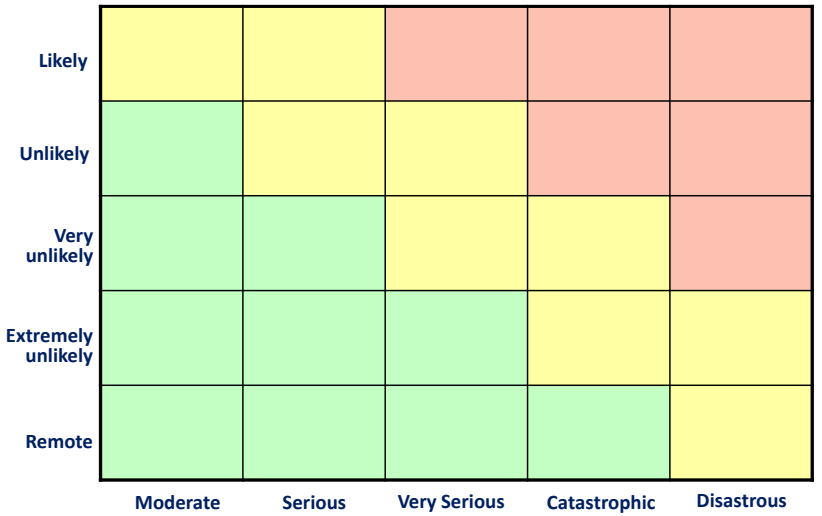


Observation 2: The estimation of consequences is performed using varying approaches

Step 2: List of Generic Major Accident Scenarios for Typical Units

Case study: Generic Scenarios for FCC Units

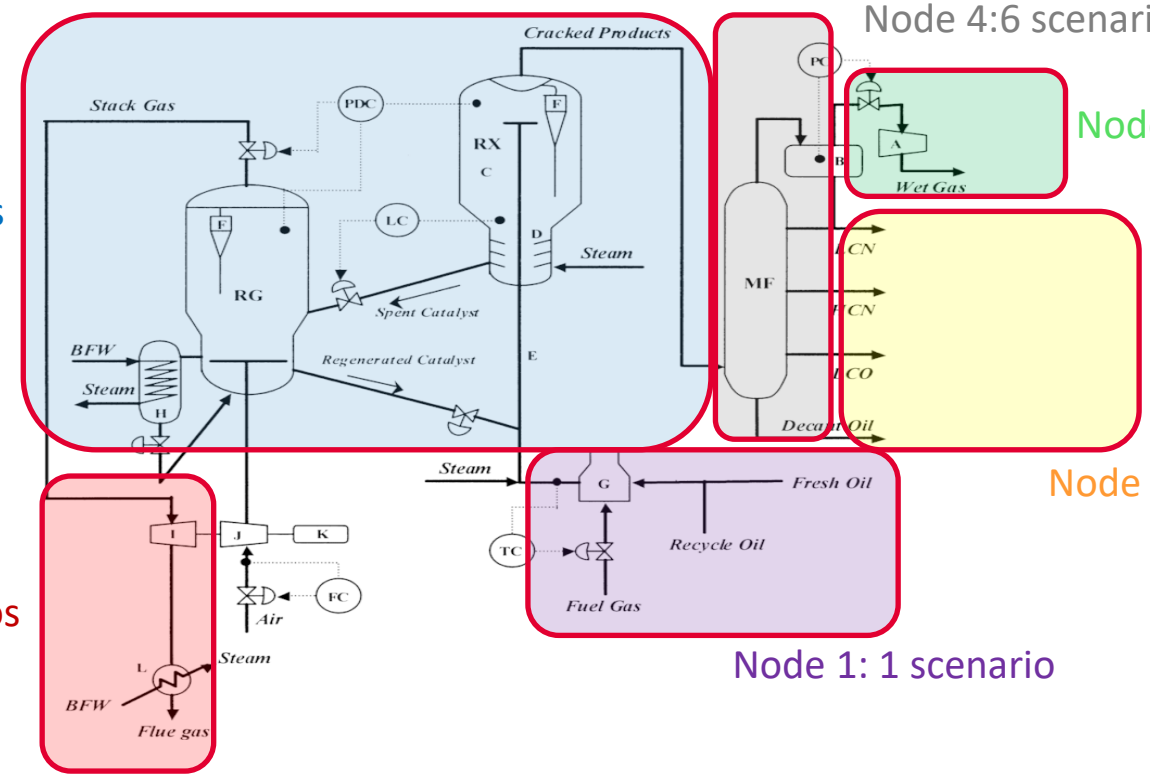
- The frequency was estimated based on simplified part counts based on typical P&ID
- Focus on "first priority" scenario according to TotalEnergies (without any barrier installed)
- In total 47 priority generic scenarios were identified for an FCC unit



Node 4:6 scenarios

Node 5,6: 21 scenarios

Node 2: 11 scenarios



Node 7,8,9,10: 6 scenarios

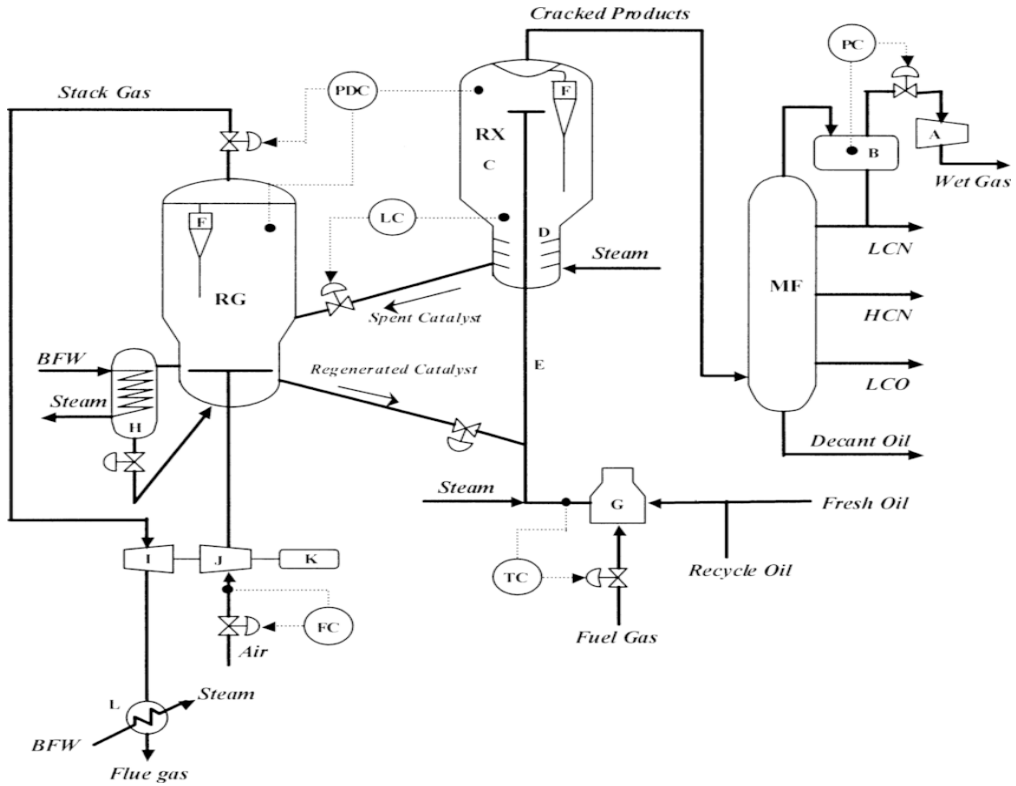
Node 3: 2 scenarios

Node 1: 1 scenario

Step 2: List of Generic Major Accident Scenarios for Typical Units

Example of a scenario sheet for the FCC unit

Scenario nr		N2-Sc15		
Description		Internal damages / fire and major leak on regenerator		
System		* Node 2 : Reaction section * Equipment function : Regenerator * Operation : Normal		
Cause(s)		RCVS fails to open due to temperature control malfunction		
Sequence of events		* Feed continues to flow to the reactor riser. * Without the catalyst to vaporize and crack the feed, the oil will fill up the riser, overflow into the stripper and soak the catalyst, then enter the regenerator through the spent catalyst slide valve. * Oil burns resulting in extremely high temperature (> 1000°C) * Explosion at stack and shockwave back into the system * Leakage up to major leak * Flammable risk		
Severity level	Human	Major leak : G4		
	Asset	G4		
	Environment			
Safety barriers	Description	* High temperature alarm on flue gas and Operator action.	* Low DeltaP (PDSLL) across SCSV Safety (PDSLL) will initiate Reactor S/D (stop feeds, close slide valves, steam dispersion in reactor, "inverted regen/reactor DP" and "ESP deenergized")	* Low temperature safety (TSLL) and reactor S/D
	Type	Alamr and operator action	SIF	SIF
Comments				

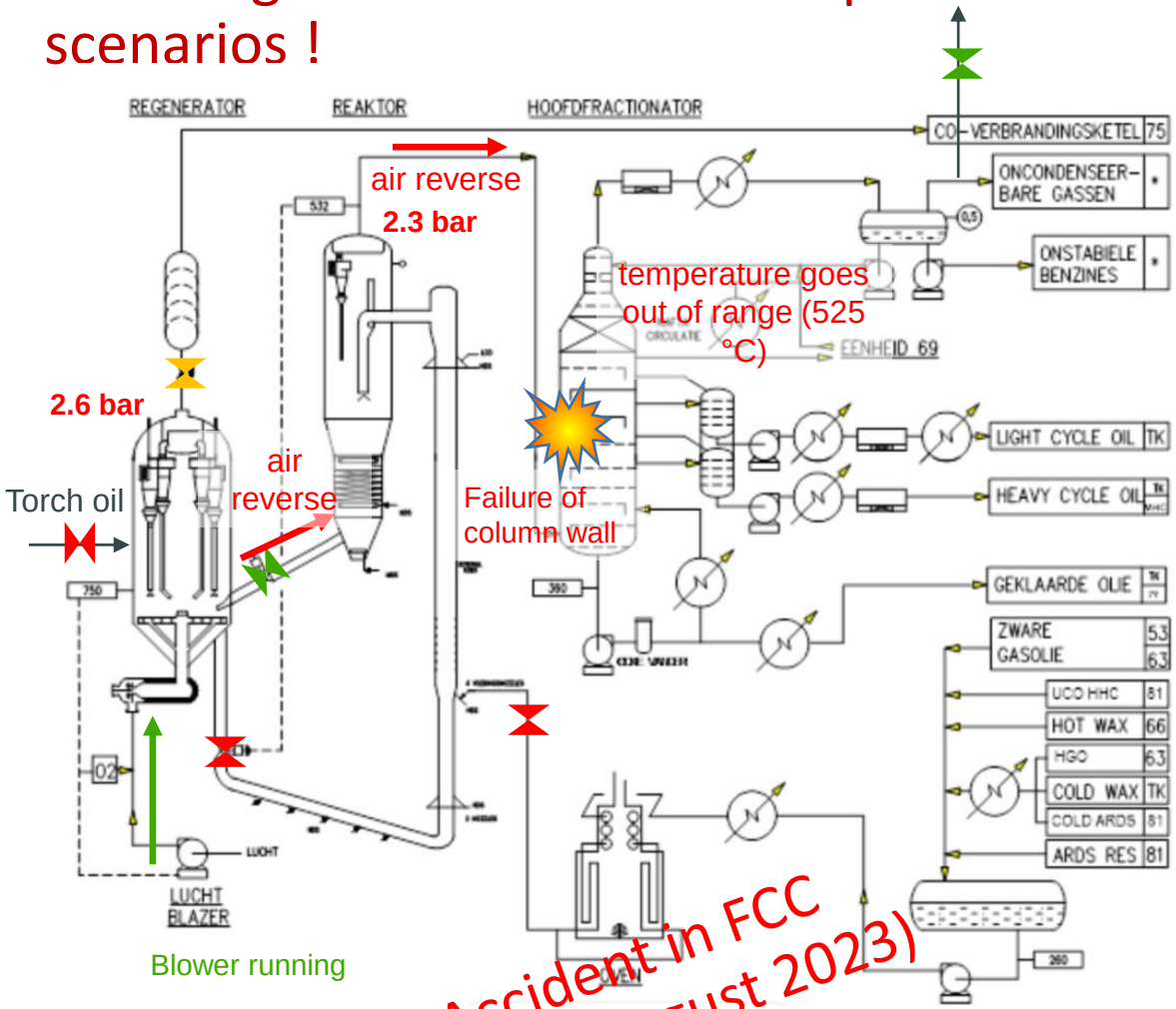


Step 2: List of Generic Major Accident Scenarios for Typical Units

- Total, La Mède, France (9/11/1992)
- Major VCE
- 6 Fatalities

Step 2: List of Generic Major Accident Scenarios for Typical Units

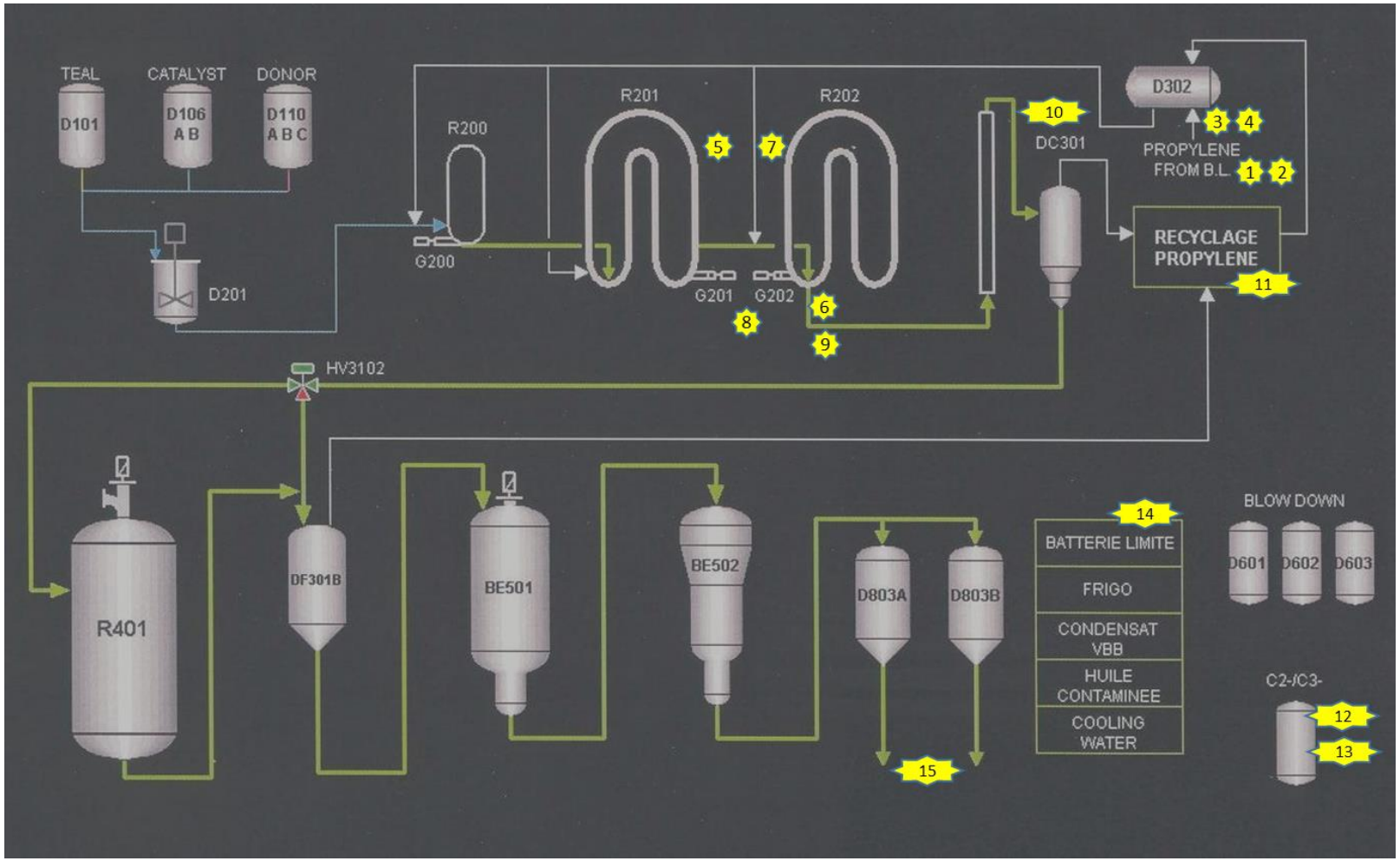
- Dynamic Approach !
- Including recent events to complete the list with generic scenarios !



Step 2: List of Generic Major Accident Scenarios for Typical Units

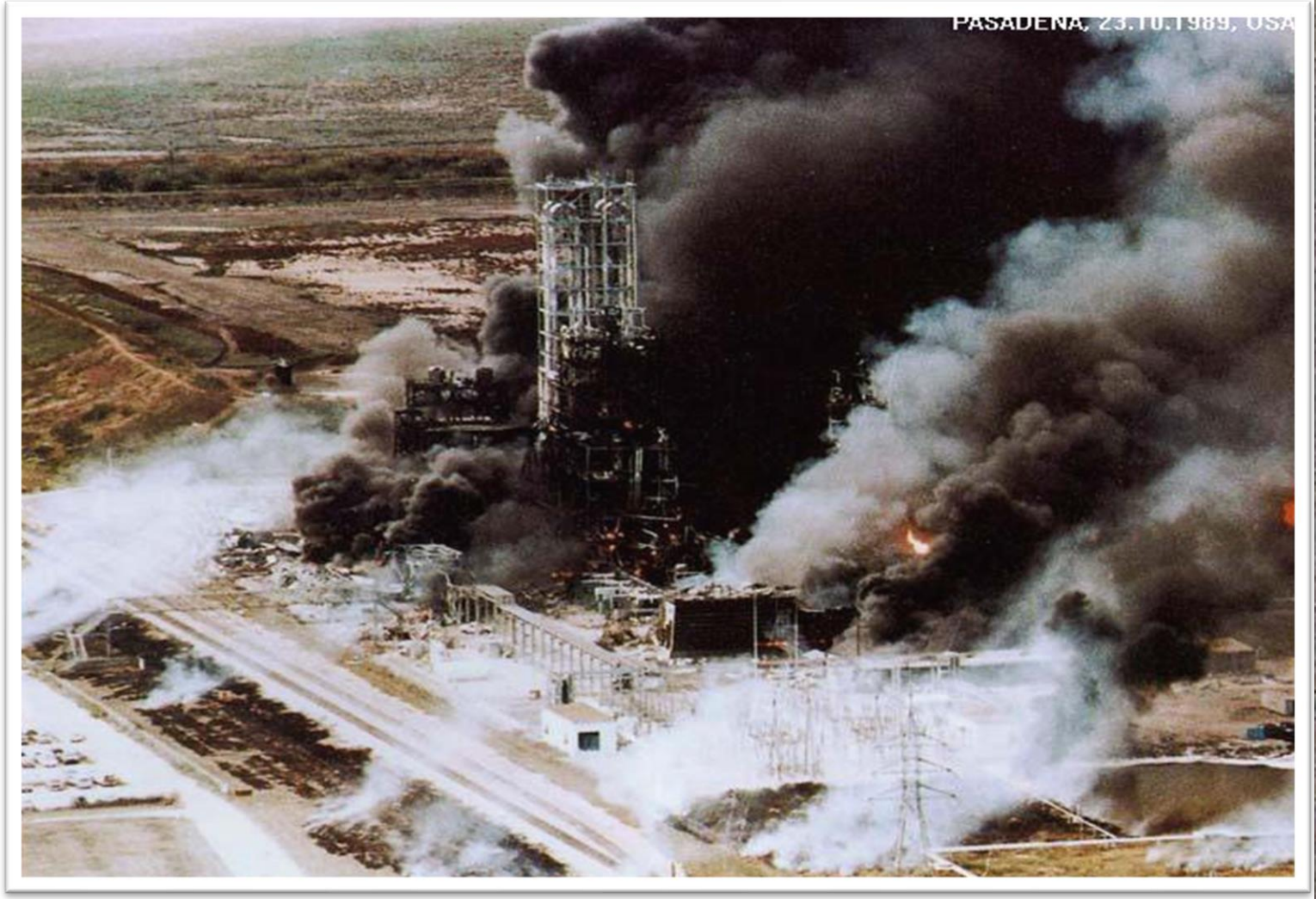
- Case study: Generic Scenarios for a Polypropylene Unit (PP).
- In total 15 priority generic scenarios were identified

Nr	Central Hazardous Event
1	Medium leak in raw materials pipeline (ethylene, propylene, hydrogen)
2	Pipe rupture of raw materials pipeline (ethylene, propylene, hydrogen)
3	…
4	…
5	…
6	…
7	…
8	…
9	…
10	…
11	…
12	…
13	…
14	…
15	……



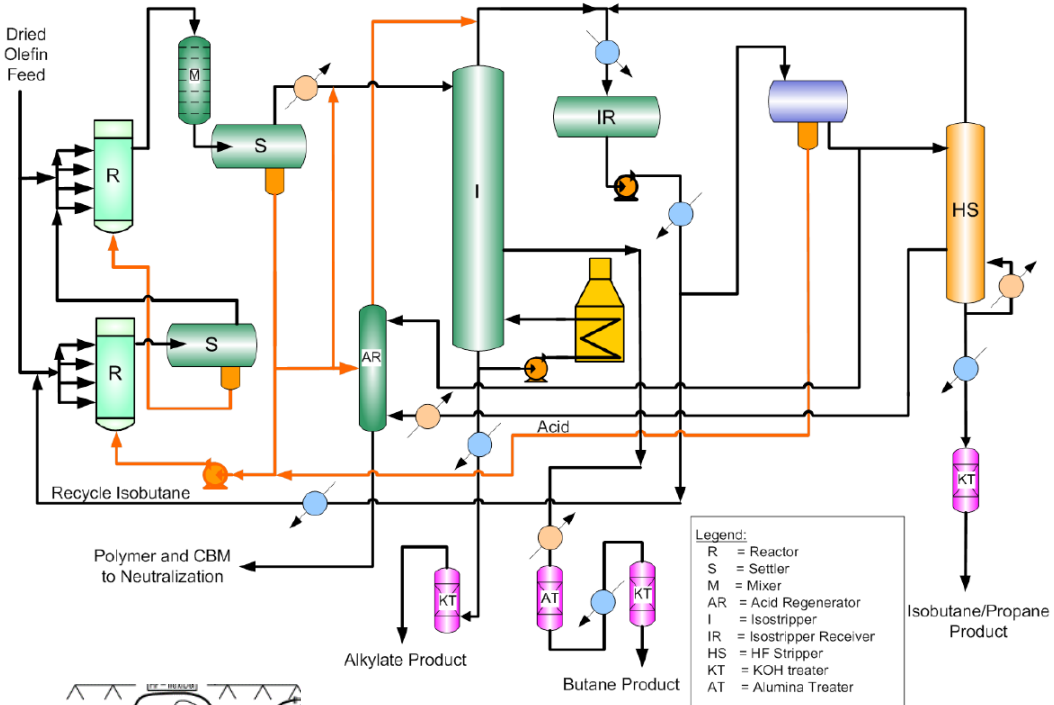
Step 2: List of Generic Major Accident Scenarios for Typical Units

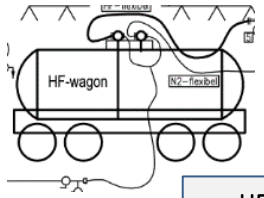
- Phillips Petroleum, Pasadena, Texas (23 October 1989)
- Major VCE
- 23 Fatalities



Step 2: List of Generic Major Accident Scenarios for Typical Units

- Case study: HF Alkylation Unit
- In total 17 priority generic scenarios were identified





HF Unloading

1	Loss of containment of HF during unloading operation (rupture of hose/unloading line).
2	Loss containment following loss of cooling of the reaction (with continued feed of olefinic C_4). All causes for loss of cooling water need to be considered (trip of pump, valves closed, plugging,….). Possibility to have HF in cooling water circuit with rapid corrosion of other exchangers with risk of loss of containment.
3	…
4	…
5	…
6	…
7	…
8	…
9	…
10	…
11	…
12	…
13	…
14	…
15	…
16	…
17	…

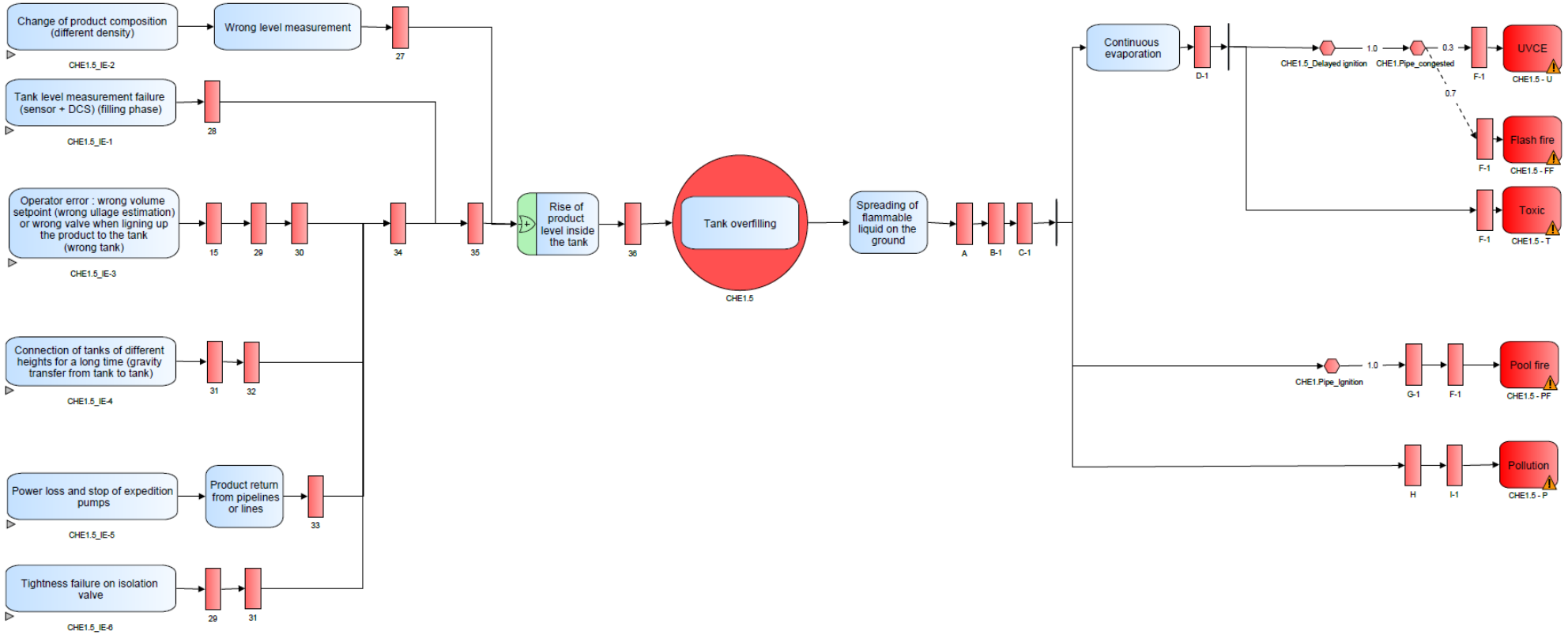
Step 2: List of Generic Major Accident Scenarios for Typical Units

- Philadelphia Energy Solutions (PES) Refinery, Philadelphia (US)
- 21 June 2019
- 750 M$ property damage
- Release of about 2000 kg of highly toxic hydrofluoric acid (HF) and about 300.000 kg of hydrocarbons

Step 2: List of Generic Major Accident Scenarios for Typical Units

Generic Bow Tie Diagrams

- Developed per equipment type by a team of subject matter experts
- In line with available design specifications and allows to communicate more easily about major accident scenarios
- Allows to compare available design with “optimum” design meeting design specifications
- Possibility to remove non-existing hardware barriers and organizational barriers to verify the impact on risk profile
- Drives consistency and quality in risk assessment since use of common starting point



Step 2: List of Generic Major Accident Scenarios for Typical Units

MARISTO — Major Risk Scenarios in TotalEnergies

Disclaimer

The information included in this document is obtained from sources believed to be reliable and is based on technical information and experience currently available inside and outside the TOTAL group at the date of the publication of this document. While PSR/HSE/RM recommends reference to or use of its publications by industrial sites of TOTAL, such reference to or use of its publications by TOTAL sites or third parties are purely voluntary and not binding. Therefore, PSR/HSE/RM makes no guarantee of the results and assumes no liability or responsibility in connection with the reference to or use of information or suggestions contained in its publications. PSR/HSE/RM has no control whatsoever as regards, performance or non performance, misinterpretation, proper or improper use of any information or suggestions contained in its publications by any person or entity and HSE PSR/HSE/RM expressly disclaims any liability in connection thereto. Publications of PSR/HSE/RM are subject to periodic review and users are cautioned to obtain the latest edition.

Use

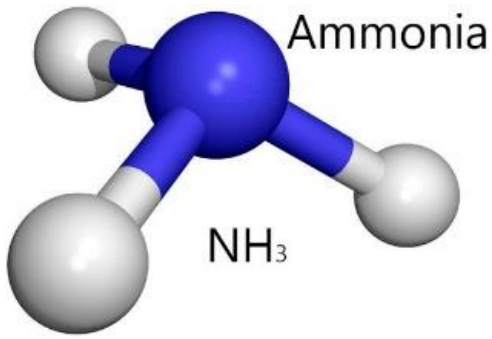
The intention of this tool is to help in the consistency of the output of risk studies of activities presenting major accident risks Group. The focus is on accident scenarios with a catastrophic or disastrous impact on people, environment or assets according to CR-GR-HSE-301.
The use of the listed typical scenarios and associated preventive and mitigating barriers in this tool should increase the quality of the output of risk analysis studies. The use of this list includes:
- As starting document for Hazard identification and Risk Assessment specific to a new project with major accident potential,
- As a starting document for Hazard identification and Risk Assessment specific to existing units with major accident potential
- As a reference list of scenarios for existing Hazard Identification and Risk assessment studies to identify missing scenarios in units with major accident potential
- As as guideline for the severity estimation of typical scenarios in units with major accident potential
- As a guideline for typical barriers installed on unit with major accident potential

The scenarios listed in this tool are based on the analysis information found in available studies, experience feedback information and discussions with subject matter experts in TOTAL.

Warnings

This tool is not a replacement for conducting a full Technological Risk Analyis according to principles explained in CR-GR-HSE-301 and GS-GR-HSE-312.
The list does not include scenarios linked to an unsafe isolation of process equipment. For a safe isolation of a piece of equipment, CR-RC-HSE-028 (isolation rules for sources of hazardous substances) refers.
The frequency of the scenarios has been evaluated by available information in the CHARAD 7.1 database, guidelines from TOTAL and experience feedback information.
This study includes the potential risk evaluation (gravity and frequency) in a general context.
Typical prevention and mitigation barriers are proposed and prioritized to reduce the risk to a generally considered safe or reasonable as per TOTAL CR-GR-HSE-301 criteria. However, barriers may be

Step 2: List of Generic Major Accident Scenarios for Typical Units



Step 3: Promotion. Get Everybody On Board !

1. Promotion by Major Risk Division of Corporate HSE

- Promotion of guidelines within process safety network
- Yearly corporate process safety network meeting for all branches
- Training to process safety experts and operational personnel
- Promotion on TotalEnergies intranet
- Review in 3-yearly mandatory corporate audits

2. Technology experts of branches promote safe operation within industrial sites:

- Giving training to operation people with chapters dedicated to
  - ✓ The specific risks of a given unit
  - ✓ Emergency procedures
- 6 monthly network meeting for the process engineers, HSE is present

Step 4: Closing the Gaps

- Provide feedback on guidelines to improve development of generic list for other typical units
- Perform gap analysis based on guidelines
- Assure incorporation of the generic list of major scenarios in the 5 yearly PHA review and close the gap
- Yearly update of the Major Risk Register for all industrial sites by the Major Risk Division of Corporate HSE
- Assistance to industrial sites
  - ✓ To perform the gap analysis
  - ✓ To assure that the 5-yearly PHA study update includes the list of major accident scenarios

Conclusions

One step closer to the “perfect” Technological Risk Study by

- Development of a generic list of major accident scenarios for typical process units, involving experts covering all disciplines in TotalEnergies:
  - ✓ Provides a list of credible major accident scenarios based on expert knowledge: best information as we know it today
  - ✓ Provides guidelines for the consequence estimation based on expert knowledge and REX: best knowledge of today
  - ✓ Provides typical barriers that are installed in similar units
- A centralized Major Risk Register is monitoring the yearly improvement
- The Major Risk Register and associated action plans are discussed up to board level of the company

Questions