HAZARD IDENTIFICATION FOR LIQUID HYDROGEN IN TRANSFER OPERATIONS

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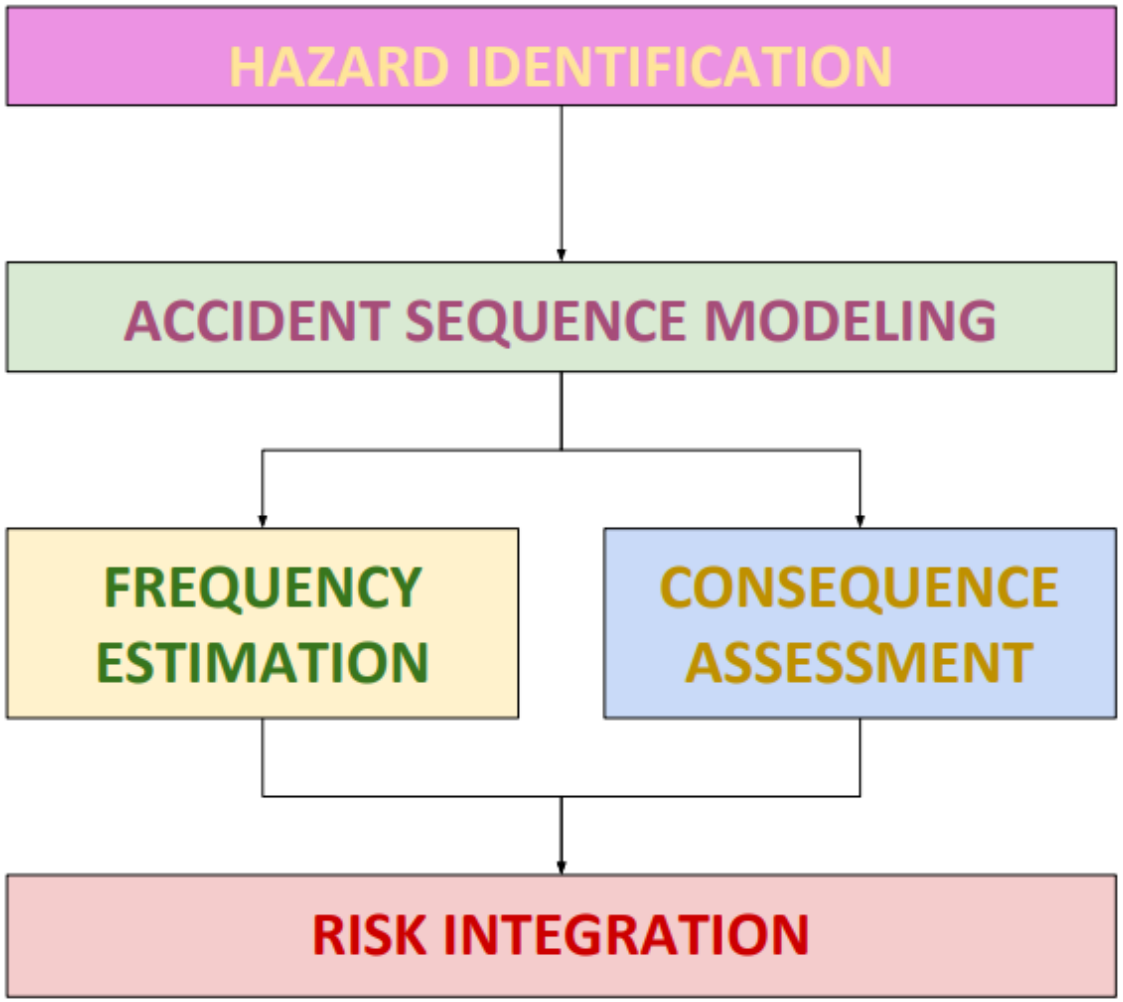
International Stakeholders' Seminar
Bologna 1 October 2024

OUTLINE

- Introduction
- Major Steps for QRA
- Hazard Identification
  - Initiating Events and Master Logic Diagrams
  - Accident Sequence Modeling
  - Damage States
- Case Study: Liquid Hydrogen Bunkering
- Conclusions

MAJOR STEPS FOR QRA



WHAT CAN GO WRONG?

HOW OFTEN THIS CAN HAPPEN?

WHAT ARE THE POSSIBLE CONSEQUENCES?

HOW FREQUENT ARE THESE CONSEQUENCES?

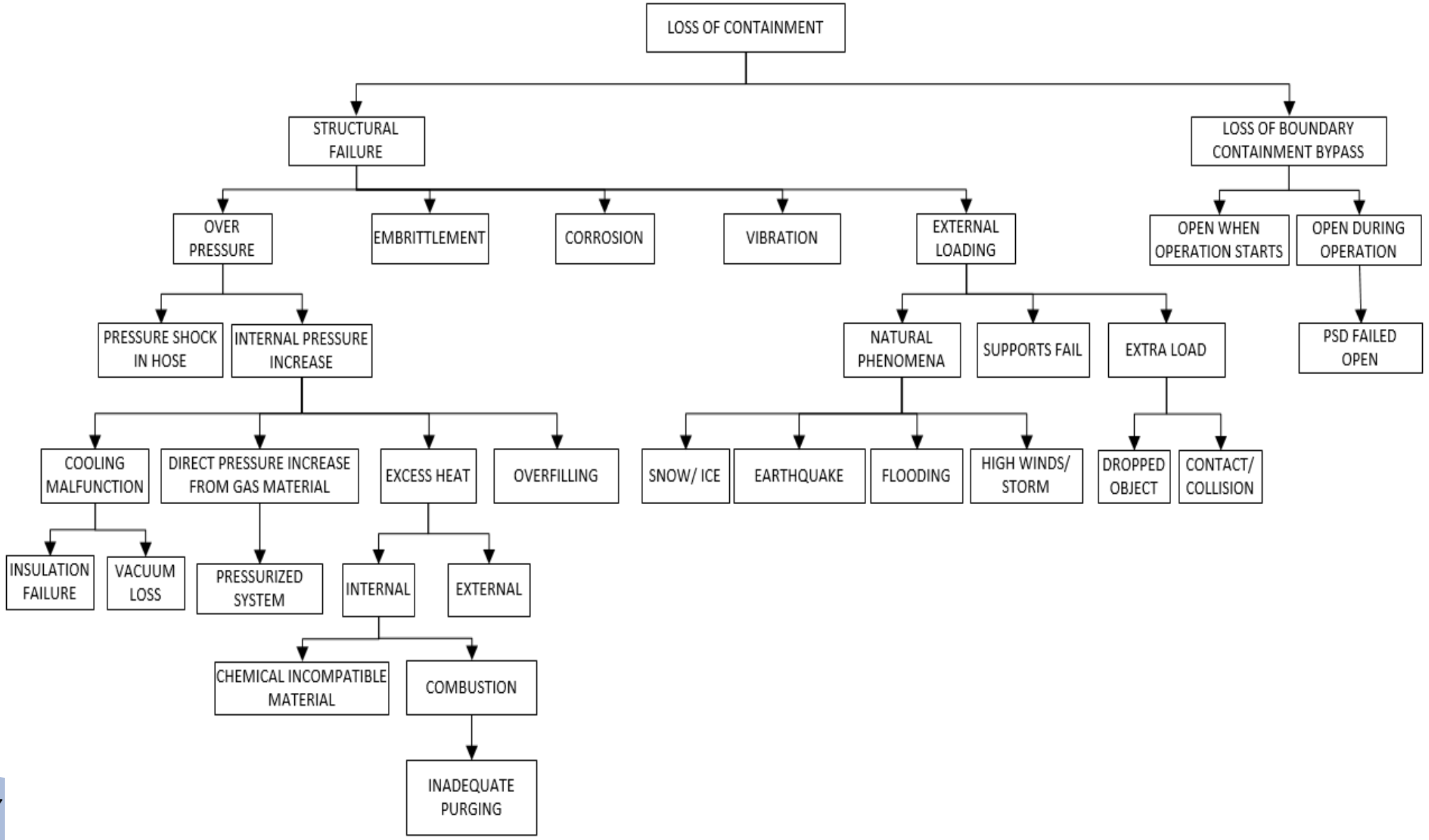
HAZARD IDENTIFICATION

Plant Familiarization	Hazard Source Identification	Initiating Events
• Description of installation • Document review, interviews • Systems, operations	• LH2 quantities, storage and transportation	• HAZOP • FMEA • Master Logic Diagrams • Accident Databases

MASTER LOGIC DIAGRAM FOR HAZARD IDENTIFICATION

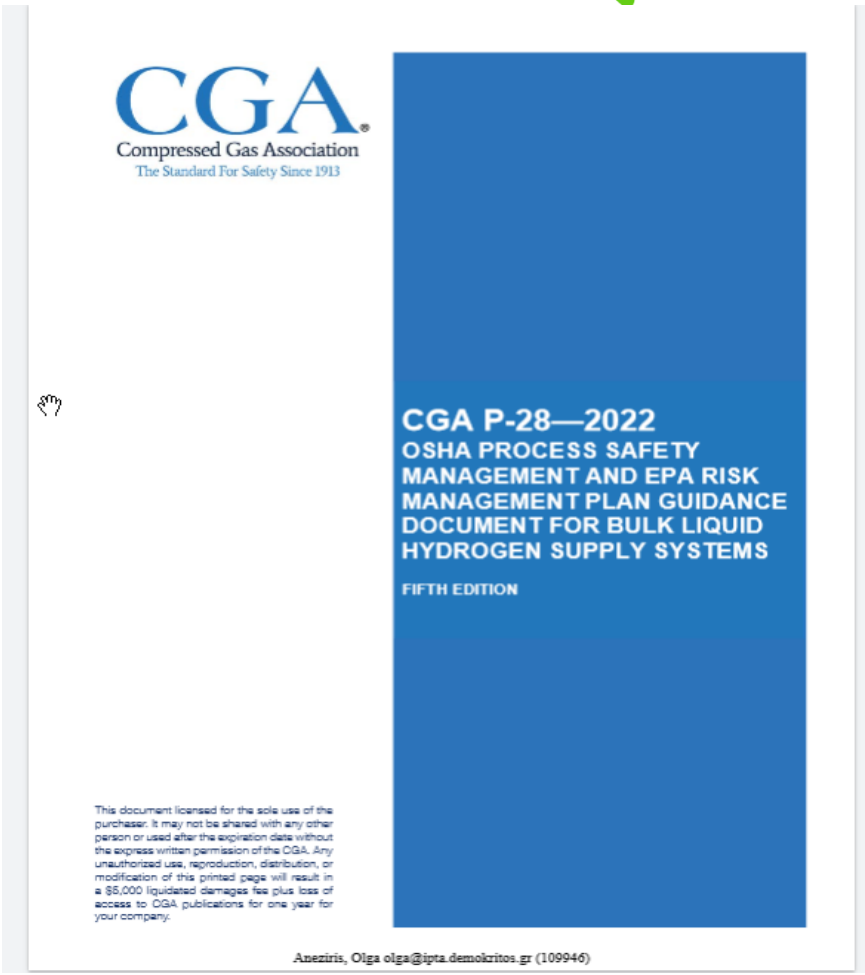
- It is a **Logic Diagram** that starts with a Top Event, considered undesirable
- The top event is the “Loss of Containment”
- It continues decomposing into simpler events until events challenging safety systems are identified
- These are the initiating events

MLD FOR LOSS OF CONTAINTMENT OF LH_2 SYSTEMS



HAZOP CGA REPORT

Publication of the Compressed Gas Association "CGA P-28-2022 OSHA Process management and EPA risk management plant guidance document for Bulk Liquid Hydrogen supply systems"



PAST ACCIDENTS FROM DATABASES

- Material defect, e.g embrittlement, corrosion, material incompatibility
- External fire in the vicinity of a tank or truck
- Safety disc failures
- Air in system owing to inadequate purging
- Loss of vacuum (insulation failure)
- Leakage from valves, welds, isolation and sealing failures, during disconnection of loadings arms or connection during transfer of hydrogen
- Operator errors related to containment by-pass (valves left open or closed)
- Overpressure created in tank and malfunction of PSVs (left open)
- Overpressure in pipes owing to inadequate emptying of pipes
- Natural phenomena (e.g snow, heavy rain)
- External load (collision, vibration, e.t.c)
- Plugged LH2 tank, owing to vent failure
- Hydrogen accumulation in pipes

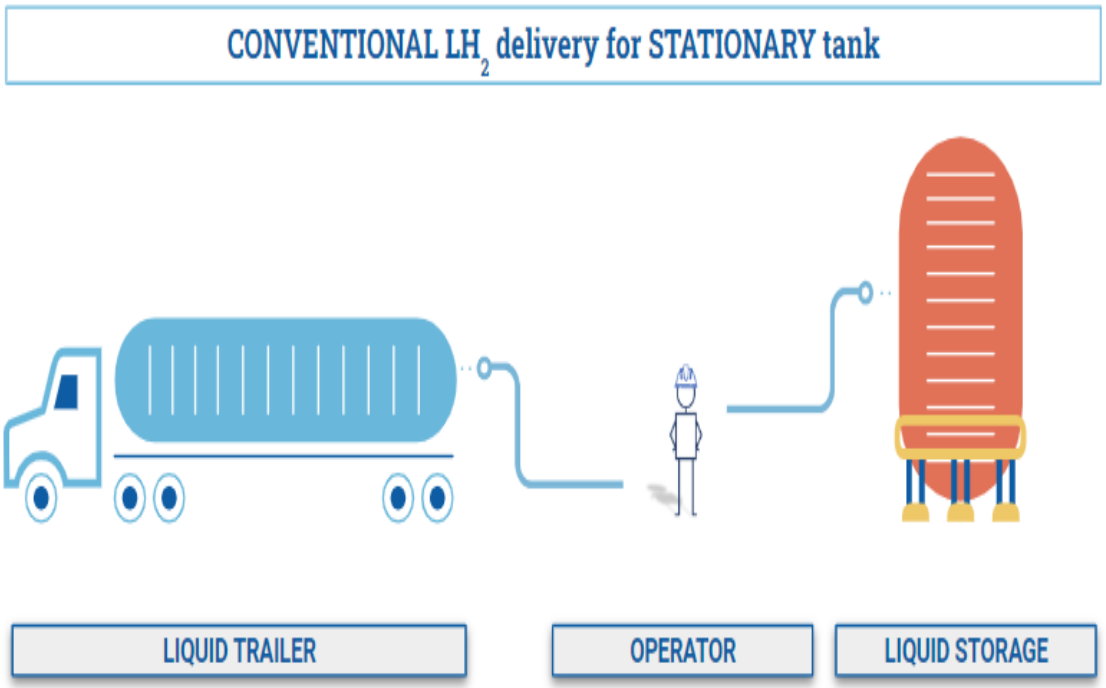
DAMAGE STATES: ACCIDENT SEQUENCE MODELLING

CASE STUDY
Identification of critical areas

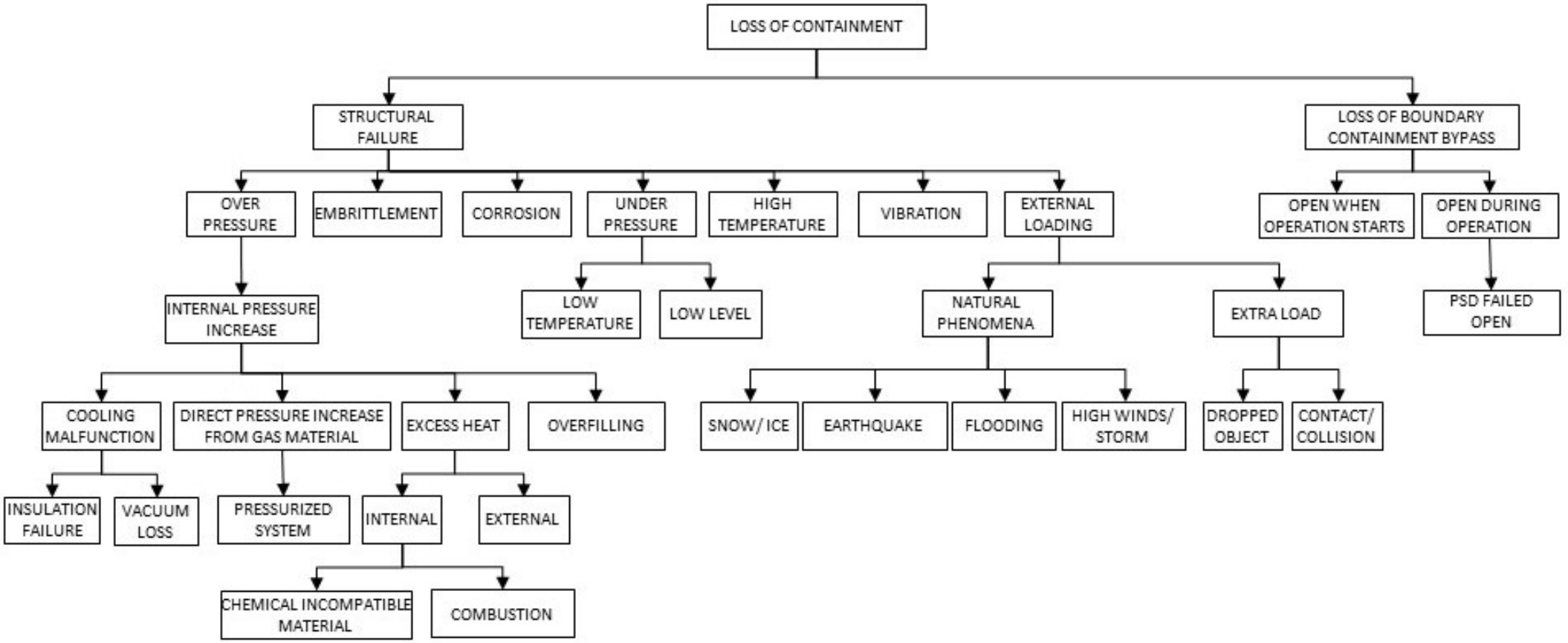
a) Trailer area with capacity up to 57m³ LH_2

b) The transfer hose from the stationary trailer to the stationary tank

c) LH_2 stationary tank - A storage tank with capacity about 80 m³ LH_2



CASE STUDY: MLD of LH_2 trailer



CASE STUDY
Initiating events to be quantified

LH_2 Trailer
Trailer tank insulation failure or vacuum loss
Excess external heat owing to nearby external fire
High pressure in trailer, owing to vaporiser malfunction
Embrittlement, corrosion
PSD failed open
LH_2 hose
Embrittlement, corrosion
Excess external heat owing to nearby external fire
Pressure shock in pipelines (Inadvertent valve closure during unloading)
Inadequate purging or cooling of hoses
Containment bypass during loading (e.g. premature disconnection of hose)
LH2 storage tank
Embrittlement, corrosion
Tank insulation failure or vacuum loss
Excess external heat owing to nearby external fire
High Pressure, owing to vaporizer malfunction
IEs corresponding to trailer, hose and tank
Extra loads; e.g. a) heavy objects drop on trailer, b) other vehicle collides with trailer or equipment, c) trailer leaves with hose still connected
Natural phenomena (earthquake, snow, floods, high winds)

Safety Functions and systems of LH_2 trailer

Safety Functions	Safety Systems
Avoid overpressure owing to boil off/ hydrogen gas	High pressure control system
Manual pressure reduction through blow down valves	Procedures for manual pressure reduction
Provide overpressure protection	PSVs, Bursting discs, vent
Provide vacuum and insulation protection	Insulation of tank, vacuum of insulation
Maintain structural integrity of Pressure Boundary under normal pressure conditions	Procedures for structural integrity
Avoid Boundary containment by-passing	Procedures for Containment bypass protection
Corrosion and embrittlement protection	Procedures for corrosion protection
Fire protection	Fire protection system, sprinklers
Collision and extra load protection (external impact)	Restriction of traffic and warning signs. Tow away interlock system

ACCIDENT SEQUENCE MODELING

SAFETY SYSTEM FOR INITIATING EVENT: "Trailer tank insulation failure)"

- Pressure Safety Valves (PSVs, rupture disks, vent stack)

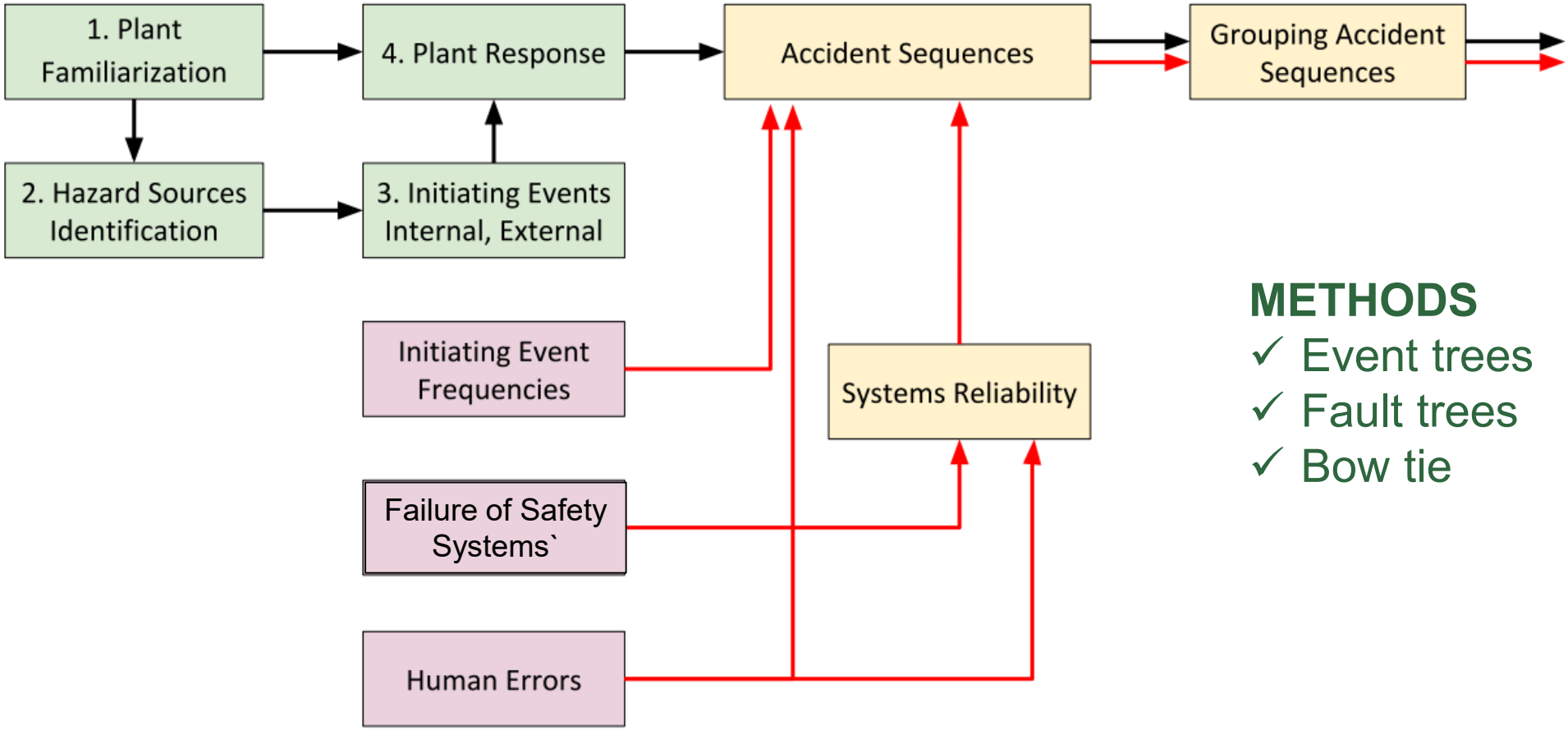
Trailer Tank Insulation Failure or Vacuum Loss	Pressure Safety System (PSVs, rupture disks and vent stack)		
IE-1	PSV	No.	Consequence
		1	RELEASE FROM PSV
		2	TRAILER TANK RUPTURE

DAMAGE STATE

CASE STUDY 1
Damage states to be quantified

- ✓ Trailer rupture
- ✓ Hose rupture (Liquid phase)
- ✓ Tank rupture

TASKS OF QUANTITATIVE RISK ASSESSMENT



METHODS

- ✓ Event trees
- ✓ Fault trees
- ✓ Bow tie

Frequency Assessment of Damage States

Data and Parameter Assessment

- ✓ Estimate frequencies of the initiating events, component unavailability, probabilities of human actions
- ✓ Data Gathering and parameter value assessment

Accident Sequence and Plant damage State Quantification

- ✓ Calculate frequency of occurrence of accident sequences and Damage states using the event trees of the logic model.

CONSEQUENCE ANALYSIS

Pool fire

Jet fire

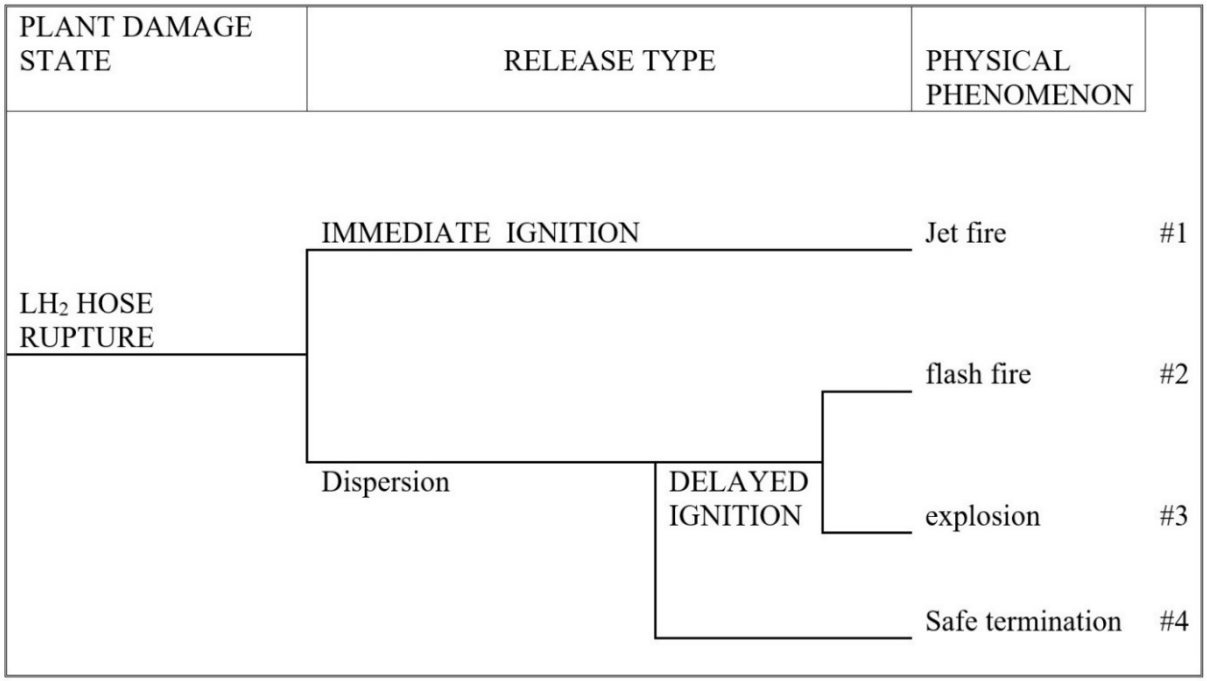
Fireball

Deaths

Burn Deaths from Flash Fire
Burn Deaths from Pool Burning
Deaths from Lung Haemorrhage
Deaths from Impact

Damage

Structural Damage



- ✓ Hose rupture –jet fire
- ✓ Hose rupture - flash fire
- ✓ Hose rupture - explosion

CONCLUSIONS

- Hazard identification for Liquid Hydrogen transfer operation was presented in case of bunkering from a trailer to a storage tank
- It is the first phase of a QRA and focuses on determination of :
  - Initiating events
  - Safety systems
  - Accident sequences
  - Damage states
- QRA estimates the risk level of Liquid Hydrogen transfer operations
- QRA provides information to decision makers and assists risk reduction strategies in hazardous installations

Thanks for your attention

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