LEARNING FROM INCIDENTS: WHAT RISK ASSESSMENTS MAY NOT CAPTURE

IDENTIFYING HIDDEN RISKS IN NON-ROUTINE OPERATIONS

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PSRG OVERVIEW

- Established in 1997 (Houston)
- Premier, global Process Safety, Risk Management & Plant Reliability consulting and training firm
- Diverse staff of more than 100 technical professionals averaging 29+ yrs experience
- Diverse industry experience with more than 1000 customers in 90 countries
- EMEA Resources: France, Germany, Spain, Turkey, UK
- Member of AIChE CCPS, IChemE PSC, VPPPA, P2SAC, CHS




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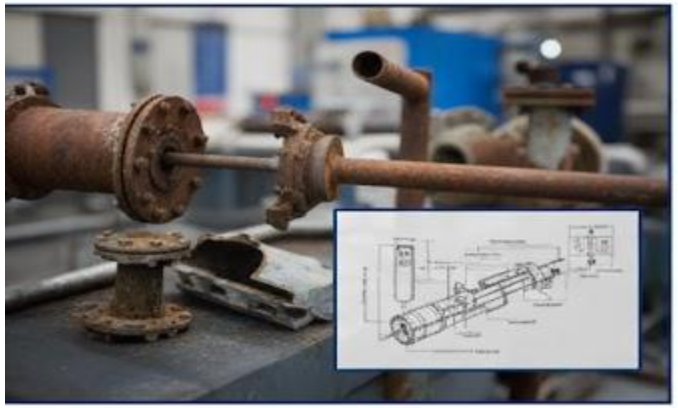
AGENDA

Why non-routine work creates hidden risks

Tank explosion case study

How the incident unfolded



What failed and why

Key learnings for Process Safety Management

Takeaways & discussion

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WHAT IS THE RISKIEST TIME DURING PLANT OPERATION?

- Most serious incidents do not occur during normal operation
- They tend to occur when the plant is in a non-routine or transitional state, such as:
  - Shutdown / start-up
  - Turnarounds
  - Unit modifications
  - Non-routine maintenance or repairs
  - Work performed while the plant is operating
  - Temporary or unconventional operating conditions

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WHY RISK ASSESSMENTS MISS THESE?

- Many incidents have precursors, such as:
  - Near misses
  - Normalization of deviations
  - Misclassified or recurring equipment failures

- Why HAZOP may not capture these risks:
  - Traditional HAZOP focuses on steady-state, routine operation
  - Non-routine conditions, degraded states, and unusual work practices often fall outside the study scope
  - Therefore, learning from past incidents and near misses becomes essential for identifying risks that formal assessments may overlook

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CASE STUDY: STORAGE TANK EXPLOSION DURING MODIFICATION

➢Incident Summary:

- A 300 m³ stainless-steel storage tank (steam coil heated) in a tank farm experienced an internal explosion, followed by a pool fire inside the secondary containment, generating heavy smoke

➢Consequences:

- Two contractors injured
- Significant structural damage
- Major business interruption
- Regulatory / authority investigation
- Long and difficult process to recover lost trust and anxieties in the organization

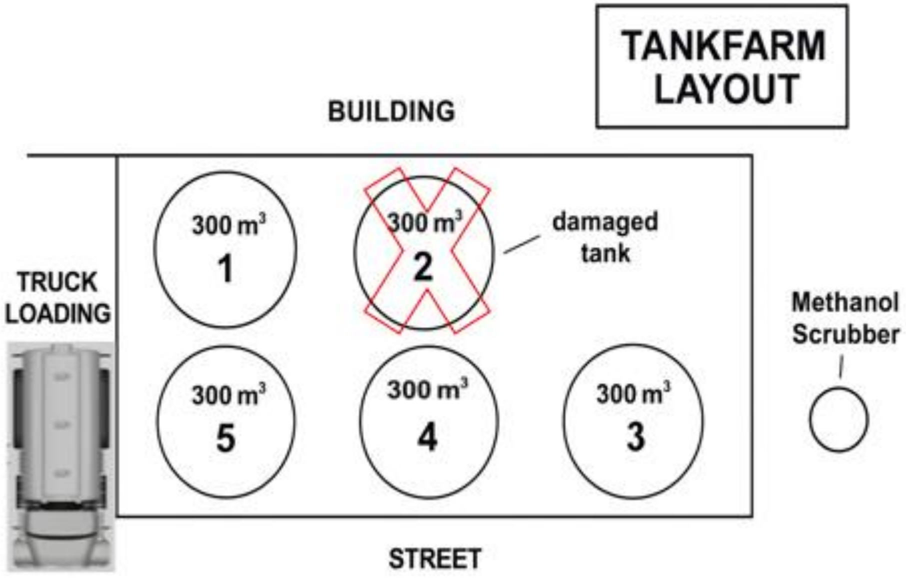

Figure: Tank Farm Layout Showing Damaged Tank (Tank 2)

PRODUCT CHARACTERISTICS RELEVANT TO THE INCIDENT

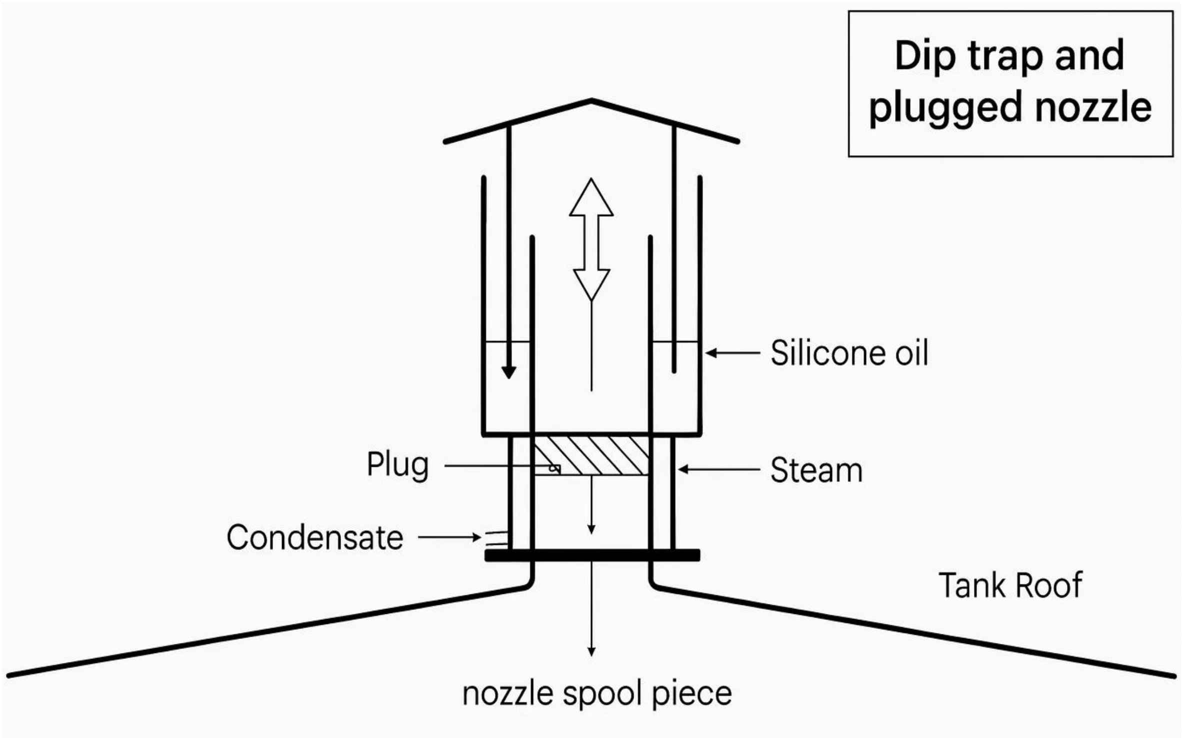

Figure: Dip Trap Assembly Showing Plugged Nozzle and Silicone Oil Seal

- Monomer for polymer manufacturing
- Melting point: 142°C
- Tendency for high sublimation, leading to crystal formation in vapor spaces
- Contains 0.5–1% methanol, contributing to flammability

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TANK FARM LAYOUT / PFD OVERVIEW

➢Tank Farm Operation:

- Five storage tanks connected to a common overhead vapor line
  - DN200, steam-jacketed
  - Vented through a methanol scrubber
- Common product outlet header, with two pumps serving all five tanks
- Each tank equipped with a steam-heated dip trap filled with silicone oil
  - Purpose: prevent over-pressure / under-pressure
  - Operating tolerance: ±100 mm H_2O ((≈ ±0.98 kPa or 0.01 bar)
- Tanks maintained under a low-positive nitrogen blanket

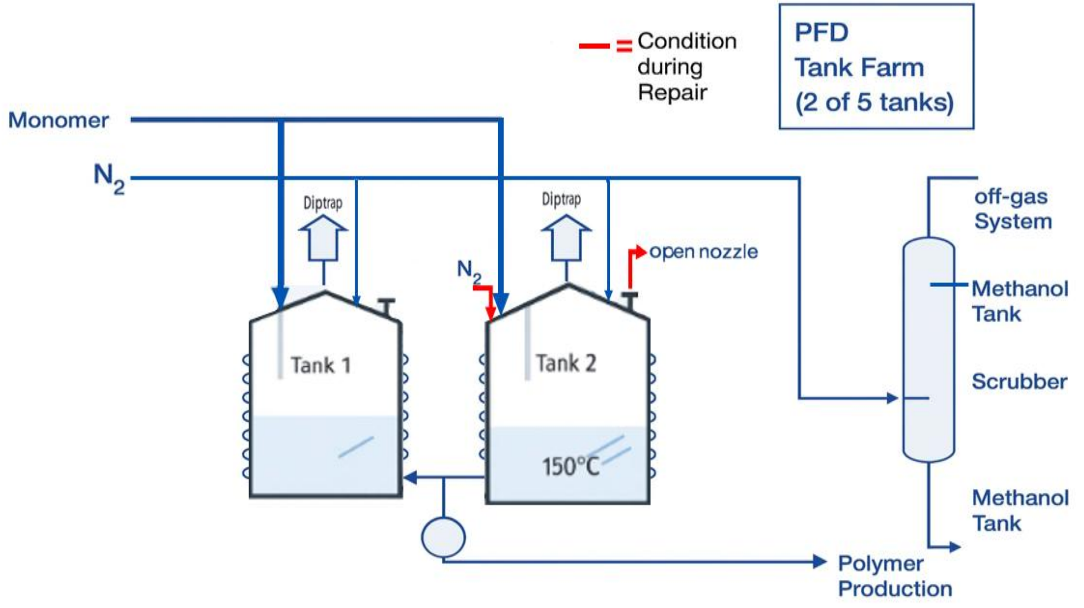

Figure: Simplified PFD of Tank Farm

DESIGN PROBLEM - MAINTENANCE JOB

➢Why Maintenance Was Required:

- Nozzle between tank and dip trap plugged regularly due to crystal (sublimate) buildup at cold spots
- Plugging created risk of tank overpressure or vacuum damage

➢Scope of the Maintenance Job:

- Replace spool piece with a better heated design
- Adjust steam and condensate lines to improve heat distribution
- Perform modification on all five tanks, sequentially
- Work stretched over several months (treated as low-priority "filler work")

STATE OF THE TANK BEFORE JOB

➢Work Preparation:

- Each job operated under a daily extended work permit, renewed over several days
- Tank was isolated from the overhead vapor system using a blind

➢Tank Condition:

- Tank was considered "empty," but 5–10 m³ of product remained at the bottom
- Tank heating remained ON
- The DN 200 top nozzle was opened to vent to atmosphere
- Nitrogen flow was increased to ensure continuous flow through the open top nozzle

PURGING & WORK SETUP

- Work Performed:
  - Spool piece under the dip trap was replaced with a jacketed, heated spool piece
  - Steam and condensate lines were reconnected and welded to the new jacketed spool piece
- Work Permit Requirements:
  - Permit required testing for explosive atmosphere around the job area (top of tank)
    - Tests showed no flammable signal
    - However, tests did not represent internal tank conditions
- Missed Opportunity:
  - No decision to perform the hot-work modification in a workshop
    - Job continued in the field despite potential hazards

MOMENT OF INCIDENT AND DAMAGE SUMMARY

- What Happened During the Job:
  - A few minutes after welding on the jacket, a violent internal explosion occurred inside the tank
    - Both contractors working on top nearly fell off the roof
  - The tank lifted ~1 meter and struck the adjacent tank, causing
    - ~200 m^3 of monomer to leak into secondary containment
    - Vapors ignited, resulting in a pool fire
  - Contractors escaped via a vertical ladder
  - The explosion pressure wave shattered over 50 windows and damaged nearby structures
  - Firefighting teams extinguished the fire within ~30 minutes

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ROOT CAUSE 1: CHANGE IN OPERATING CONDITIONS

RISK ASSESSMENT / MOC

➢ What Happened:

- Heating for this specific tank was turned down, causing the tank to cool
  - Foreman wanted to reduce visible vapor emissions from the open nozzle during cold weather
- As the tank cooled, the volume contraction exceeded the nitrogen purge flow, causing **air ingress** into the tank
  - Tank **cooled to ~64°C** (the boiling point of methanol), creating a **sensitive condition**
- The operating change was noted in the shift log - but nobody recognized the hazard created

➢ Key Issue:

- A change in operating conditions occurred **without a proper risk assessment**

ROOT CAUSE 2: INADEQUATE JOB RISK ASSESSMENT

➢ **Job Risk Assessment was not evaluating backflow of air into the tank. Some key problems identified:**

- Nitrogen purging via an open vent nozzle was completely inadequate
  - No verification of the tank's internal atmosphere
  - Plant was fortunate the same method did not create incidents in the other four tanks

- Risk of forming a potentially explosive atmosphere was overlooked
  - Hot Work Permit did not require checking internal tank atmosphere
  - Permit assumed the tank was oxygen-free without measurement

- No defined procedure for a safe tank shutdown existed
  - Operators followed informal practices instead of a controlled procedure

ROOT CAUSE 3: PERMIT-TO-WORK WEAKNESSES

➢ **Operating permit was renewed the day before to allow early start of work. Key weaknesses identified:**

- Changes in operating conditions were not recognized
  - These changes occurred after the permit was renewed, and no reassessment was triggered
- Multiple permit extensions reduced risk awareness
  - Over time, permit issuers relied on previously "known" conditions rather than re-evaluating hazards
- Low authorization level for hot work
  - Permit writer and issuer roles lacked appropriate seniority or process safety competence

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STILL GOING WRONG / CASE HISTORY EXAMPLES

- **Seven Key Lessons to Prevent Worker Deaths During Hot Work In and Around Tanks - General News - News | CSB**
  - Multiple CSB-investigated hot-work explosions showed that workers were killed when welding ignited flammable vapors in tanks that were not gas-tested or properly cleaned
- **2015: ExxonMobil Torrance Refinery Explosion | CSB**
  - During non-routine maintenance, hydrocarbons entered the Electrostatic Precipitator, which exploded and nearly struck a tank containing large quantities of modified hydrofluoric acid
- **2010 E. I. DuPont De Nemours Co. Fatal Hotwork Explosion | CSB**
  - Hot work on a piping system containing residual flammable vapor triggered an explosion, killing one operator and injuring others
- **2009 Packaging Corporation Storage Tank Explosion | CSB**
  - Workers welding on top of a waste storage tank ignited flammable vapor inside, causing an explosion that killed three contractors
- **2007: Partridge Raleigh Oilfield Explosion and Fire | CSB**
  - Workers were conducting welding on or near a tank containing flammable hydrocarbons, which ignited and exploded, killing three workers

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MANAGING SIMULTANEOUS OPERATIONS (SIMOPS)

- **A Methodology for Controlling Overlapping Maintenance & Operational Risks**
  - SIMOPS assesses whether two activities can safely occur at the same time
  - Helps define which activity combinations are:
    - Allowed – Restricted – Prohibited
  - Restricted or prohibited activities require higher-level approval
    - E.g., Plant Manager / VP Operations
  - SIMOPS supports, but does not replace job-specific risk assessment
    - Each task still needs critical thinking and competency

- **Relevance to the incident:**
  - Welding on a tank with flammable material would have been prohibited or escalated to plant manager / VP Operations level
  - SIMOPS would have flagged this activity pairing long before work began

PSM IMPROVEMENTS (PART 1)

- Routine PHAs / HAZOPs focus on normal operation and may miss non-routine risks
- Conduct targeted risk assessments for critical equipment during non-routine activities
- Include:
  - Past operating issues + industry lessons
  - Maintenance log insights or damage mechanisms
  - PHA / HAZOP as baseline, expanded with full PSI
  - Your most experienced operators in the review

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PSM IMPROVEMENTS (PART 2)

- Develop SOPs for Shutdown / Start-up of Tank Farms & Hazardous Equipment
  - Ensure risks are understood and preparation is complete before work begins

- Key Actions:
  - Create predefined maintenance work packages for frequent or recurring jobs
  - Pre-define critical procedures:
    - Inerting / purging
    - LOTO plans
    - Temporary bypass procedures (when applicable)
  - Integrate these procedures into the Permit-to-Work process
  - Train operators, maintenance teams, and contractors on SOPs and risks

- Key Message:
  - START PLANNING BEFORE YOU NEED IT!

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KEY LEARNINGS FROM THE SAFE WORK PERMITTING PROCESS

➢Key Takeaways:

- Permit issuers must understand PHAs, HAZOPs, and key risk assessments
- The permit is the final output, not where risk assessment begins
- A permit functions as a contract between Ops, Maintenance, and Contractors
- Mitigations must be defined jointly, not only by Operations
- Once issued, a permit is “frozen”- changes require re-approval
- Authorization levels must reflect competence and accountability

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WHAT RISK ASSESSMENTS MAY NOT CAPTURE

- Non-Routine Work Risks
  - PHAs / HAZOPs often miss risks from non-routine operations
- Need for Strong Shutdown / Start-Up SOPs
  - Procedures must reflect PHA / HAZOP learnings and past incidents
- Critical Equipment Requires Specific Risk Assessments
  - Ensure job plans and LOTO procedures exist for hazardous equipment, including auxiliary items
- Permit-to-Work as Final Defense
  - A robust PTW system must verify conditions before work begins

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WHY MAINTENANCE ERRORS ARE COSTLY: INSIGHTS FROM MARSH'S 100 LARGEST LOSSES

- Major incidents during maintenance, shutdown, or startup have caused losses of hundreds of millions to over $1B.
- 43% of losses are linked to mechanical integrity failures, often exposed during non-routine work
- Inadequate hazard identification and risk assessment during maintenance/start-up are recurring root causes
- Permit-to-Work (PTW) and shift handover failures directly contributed to disasters

➢ Bottom Line: **Maintenance-related risks are among the most financially impactful failures in the hydrocarbon industry. PTW discipline and proper preparation directly protect assets and people**

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FINAL TAKEAWAYS

- Non-routine work carries the highest risk
- Always verify tank atmosphere, never rely on assumptions
- Work permits must drive real risk thinking, not routine approval
- Every change needs evaluation, even “minor” ones can be major
- Auxiliary equipment can create serious hazards if overlooked

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THANK YOU!

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