Normalisation of Risk

Insights from a large, escalating fire at the Shell Singapore Refinery

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Topics to cover

- What happened
- Causes of the fire & its escalation
- Observations and Insights
- Conclusion and Solution
- Discussion, Q&A

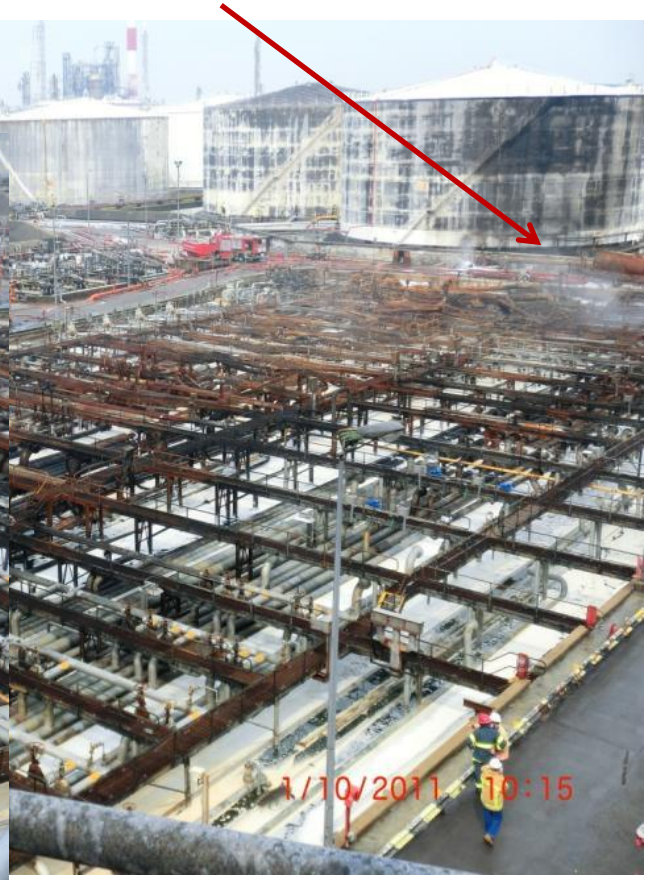
What Happened - Summary

- September 28th, 2011
- Fire started in a pump house area at a Shell-operated refinery
- Fire spread throughout the pump house
- The fire lasted 32 hours
- No serious injuries
- Significant damage to piping & equipment in the pump house
- Extended shutdown of refinery

What Happened – Pump House

Open area in Logistics (no roof on the 'house')
Contains pumps, piping, blending facilities

150 meters by 40 meters; approximately 2 meters below road at the West End



Post-fire photos

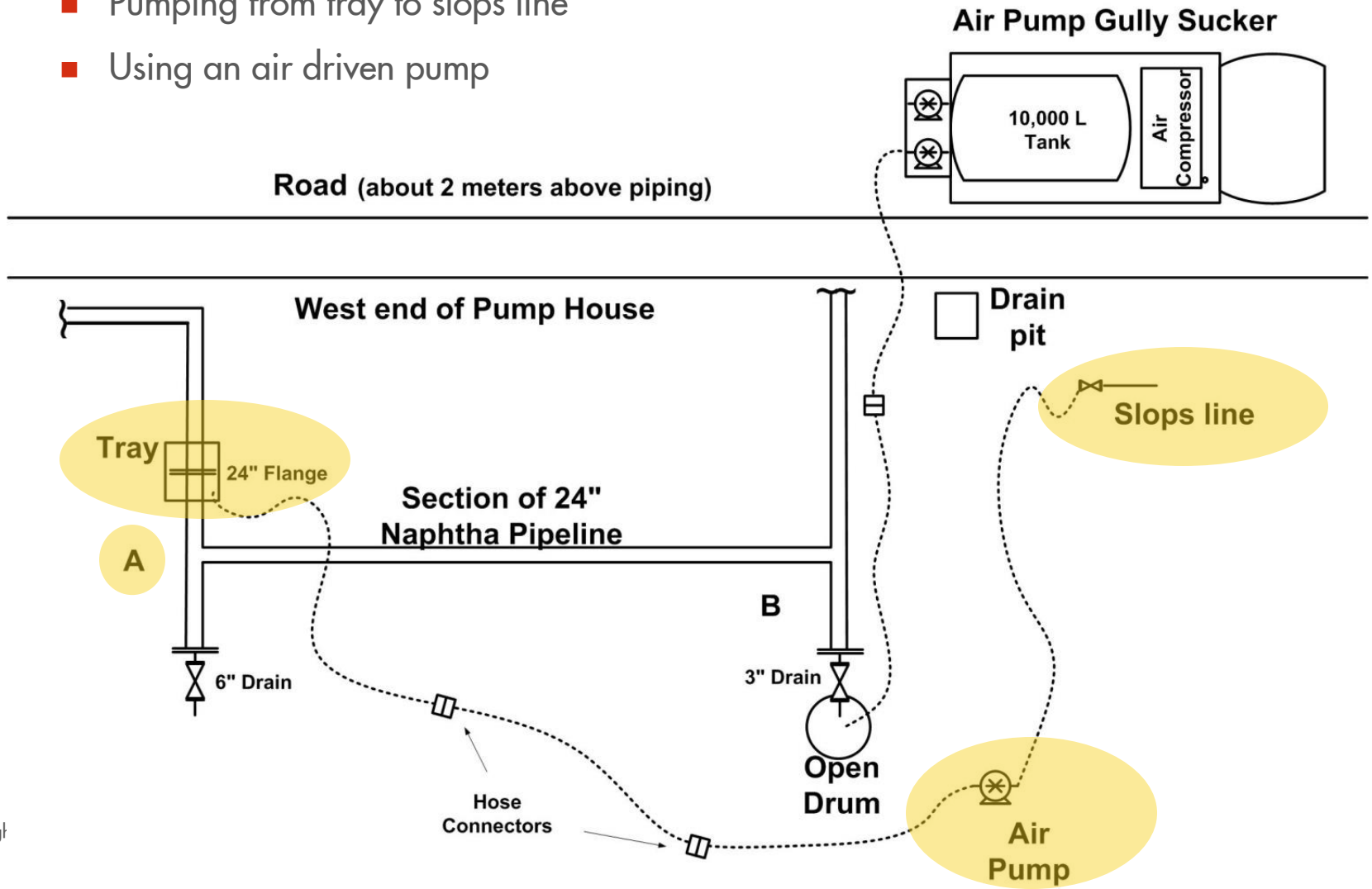
What Happened – The planned activity

- Preparing a light naphtha pipeline for maintenance
  - 24″ diameter piping
  - 560 meter section
  - 150 m^3 contents
- Shell & maintenance contractor had agreed to a decontamination plan involving draining, spading and flushing the line
- Operations had
  - Isolated the line (10 isolation points)
  - locked and tagged the isolation points
  - authorized the maintenance contractors to drain the line
- Contractors were following the agreed to decontamination plan

What Happened – Draining of Hydrocarbon (1)

Contractors were draining the isolated section of line at two drain points according to plan:

- Point A: draining from 24″ flange into metal tray
- Pumping from tray to slops line
- Using an air driven pump



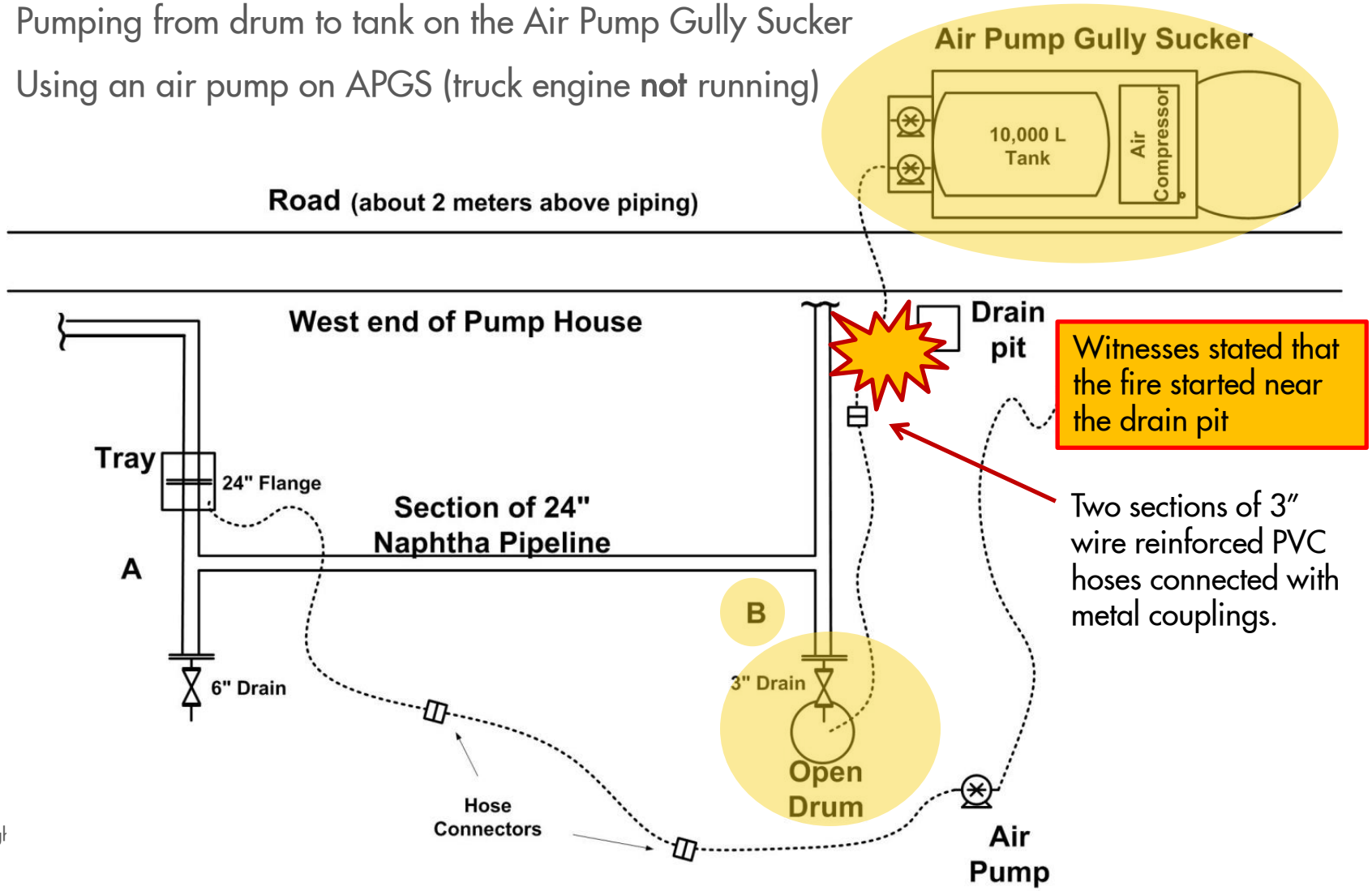
What Happened – Air Pump Gully Sucker

- Designed to collect light hydrocarbons; used instead of a regular Gully Sucker (Vacuum Truck) where there would be a concern
- Equipped with
  - 10 m^3 tank, 8 m^3 filling limit
  - two air driven pumps
  - an air compressor
  - grounding cable
  - flammable gas detector
  - spark arrestors on diesel engine exhaust and on the tank vapor outlet
- Experience
  - Numerous years of incident free deployment
  - Passed full inspection the previous month

What Happened – Draining of Hydrocarbon (2)

Contractors were draining the isolated section of line at two drain points according to plan:

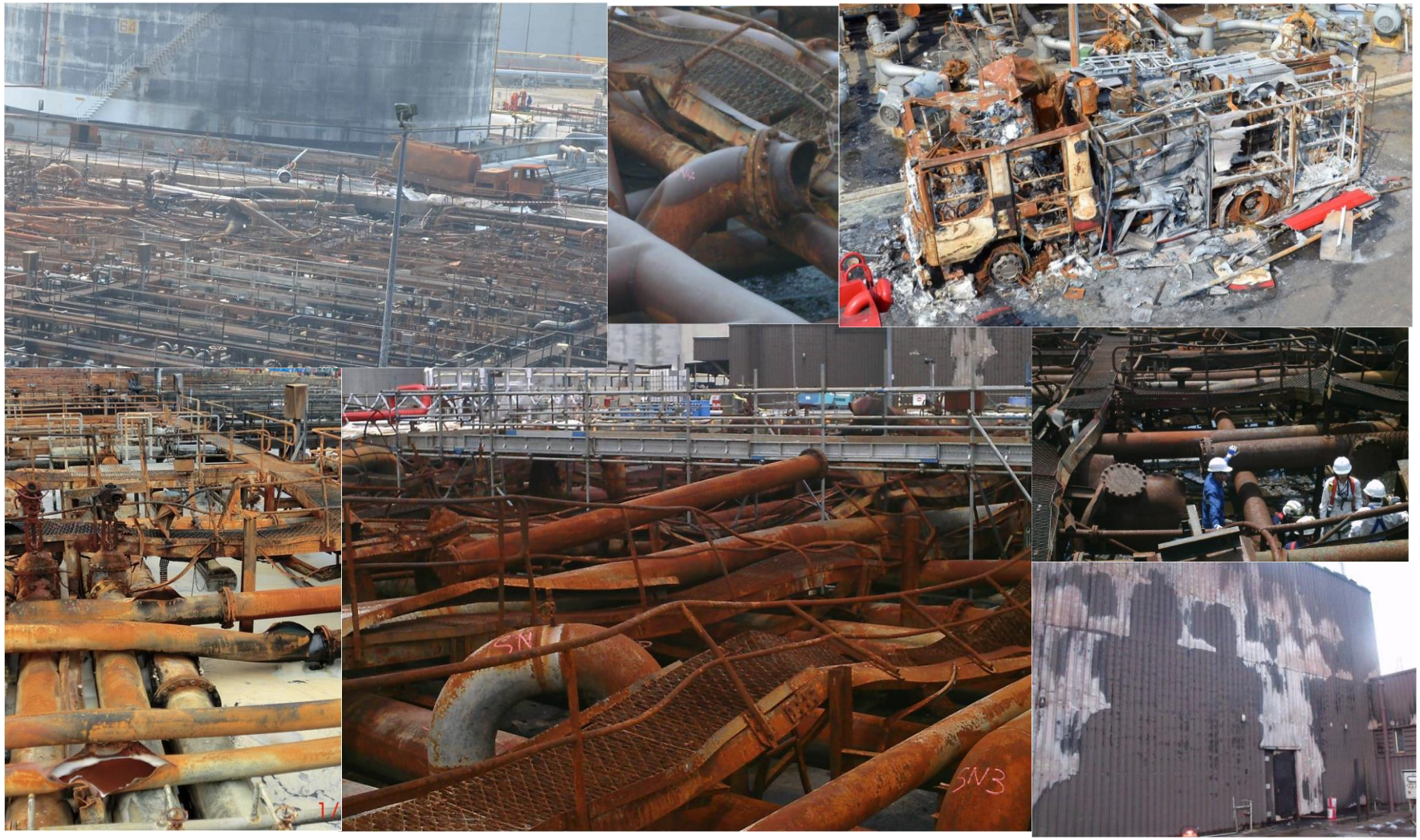
- Point B: draining from a 3″ drain into a plastic drum with the top cut off
- Pumping from drum to tank on the Air Pump Gully Sucker
- Using an air pump on APGS (truck engine **not** running)



What Happened – Fire and escalation

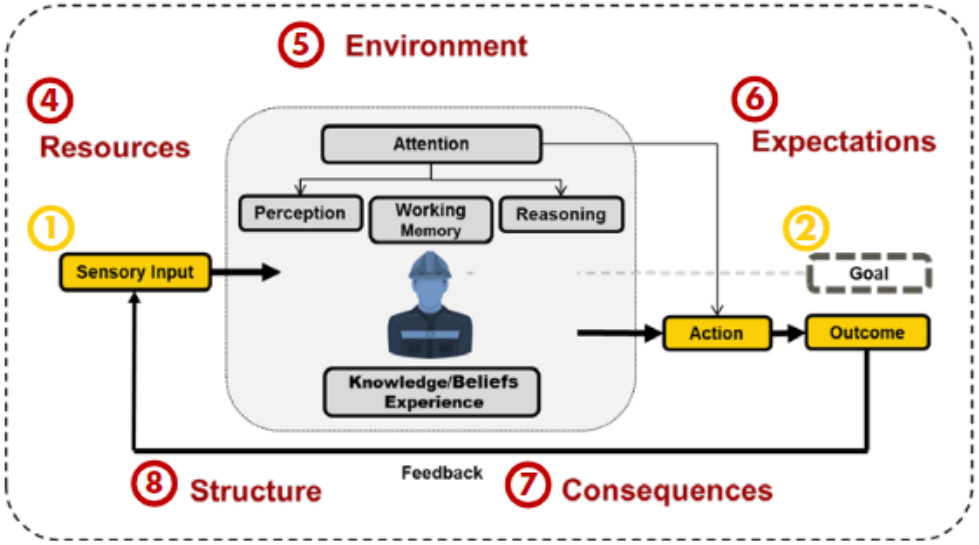
- Fire fighters used fixed & portable foam & water application devices
- Operations were isolating fuel sources to the pump house
- Piping near the fire failed
- Initial fire grew spread through the pump house
- More piping overpressured and added fuel to the fire.
- Two fire escalations caused evacuation of the fire scene
- Fire lasted 32 hours

Damage



Causal Learning

Causal learning looks at how the system, within which individuals work, allowed them to do what they did and why they believed this would achieve the desired outcome.



Human Behaviour Model: From the Causal Learning Methodology

O – I – C:

Observation

(Deeper) Insight

Conclusion

Planned result

Safe decontamination of the piping system to allow cutting, rotation and inspection of a section of pipeline.

Actual result

A flammable mixture was created that ignited by an ignition source after which the resulting fire severely escalated.

Why It Happened - Observations

Open draining

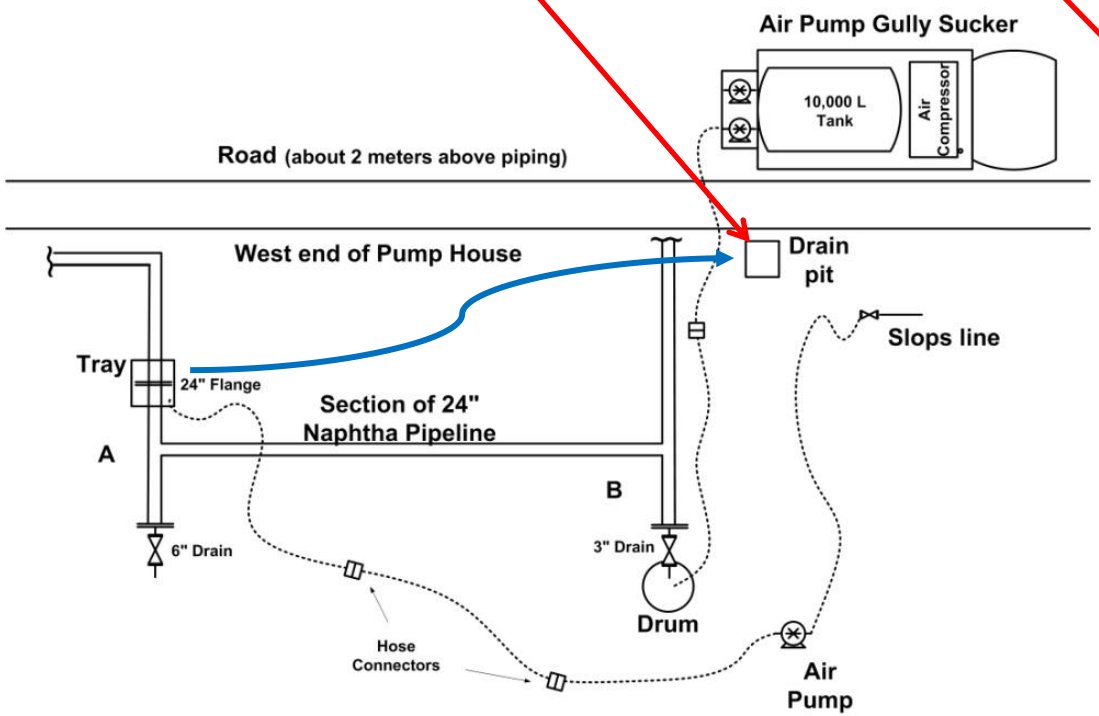
Static Electricity

Emergency Response

Observation – Flammable Mixture

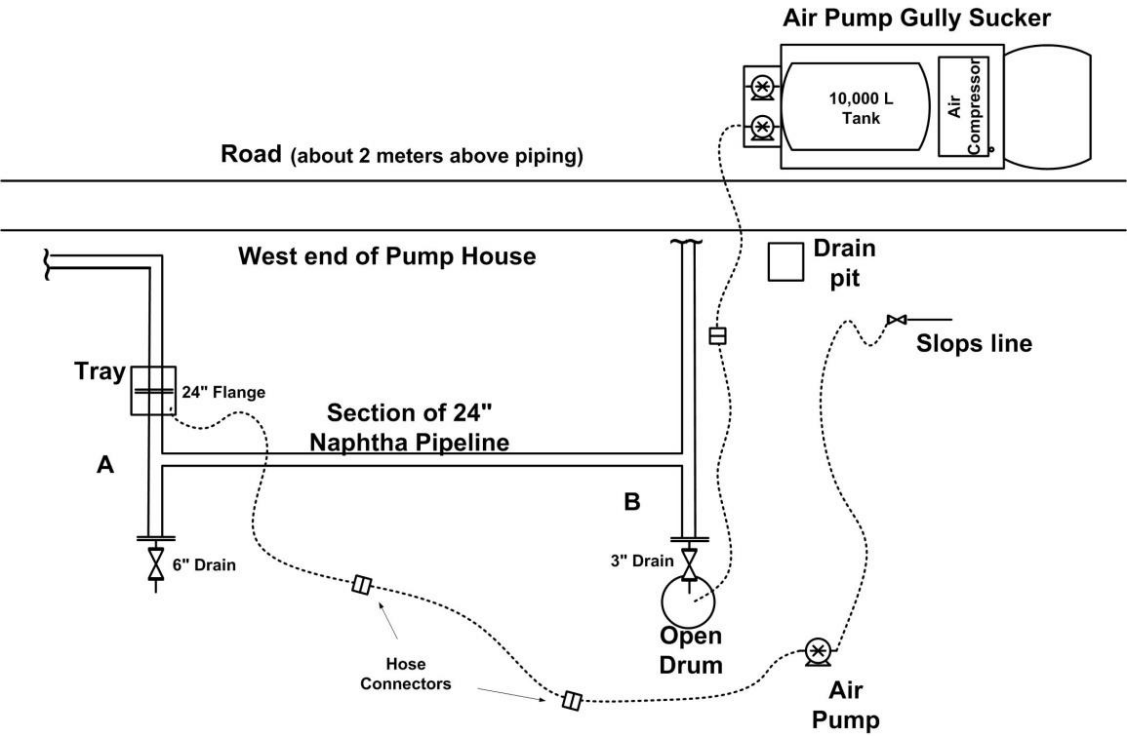
Draining the light naphtha into the open containers produced vapours mixed with air to form a flammable vapour mixture

- Draining from a flange into a tray
- Draining from a valve into a drum
- Any spillage could run across the floor of the pump house to the open drain



Observation – Static Electricity (1)

The most likely source of ignition - a static electricity discharge in the pump house associated with removal of hydrocarbon from drain valve through the drum.



- Vapours were heavier than air
- Possible flammable vapour mixture was near the floor of the pump house
- Air Pump Gully Sucker was considered as a potential ignition source, but it was located on the road about 2 meters (6.5 feet) above the pump house floor

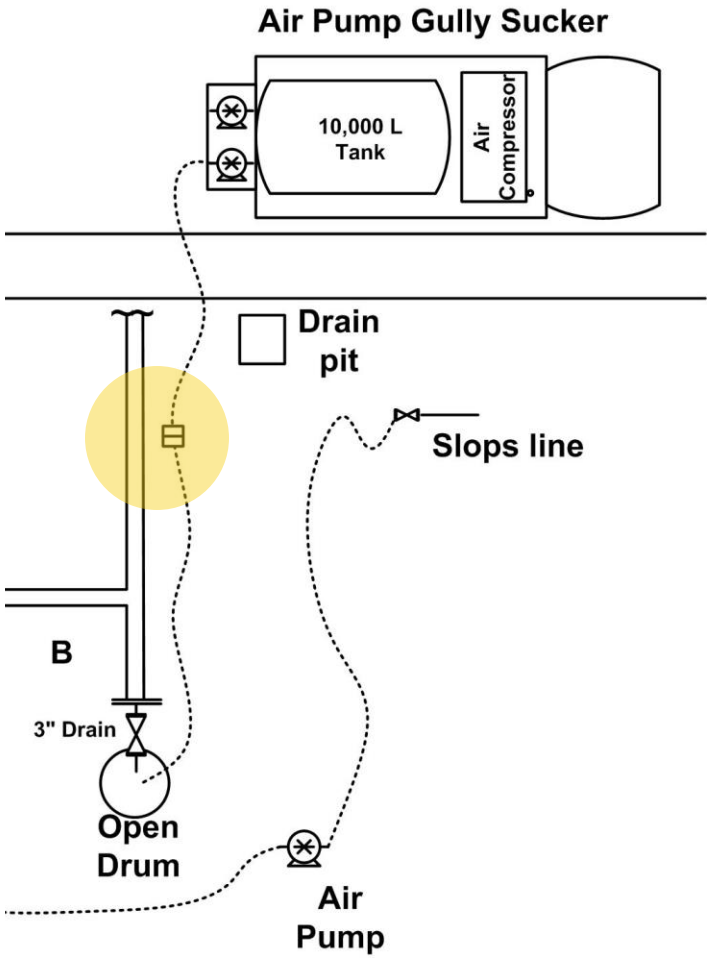
Observation – Static Electricity (2)

- Static Charge was **generated** because:
  - Light naphtha has a low conductivity
  - Draining into the open drum and flowing through the hose into the APGS tank generated separated charges

- Static Charge **accumulated** due to low conductivity of the equipment created by one of more of the following:
  - Drum was non-conductive plastic
  - Hose was not fully bonded to the connector
  - Low conductivity through the APGS earthing (to ground) cable attached to the railing alongside the pump house.

Observation – Static Electricity (3)

- The static electricity **discharged**
  - one of the hose connectors most likely came in contact with piping in the pump house due to the pulsating movement of the hose created by the air pump



Observation – Escalation of fire

- Initial pool fire spread because:
  - Fixed foam system dispensed both water and foam
  - Water sprays further dispersed foam
  - Other piping was exposed to fire and ruptured

- Fire continued to spread throughout the pump house
  - Pump house drainage system capacity exceeded
  - Burning and unburned hydrocarbon migrated across the pump house.

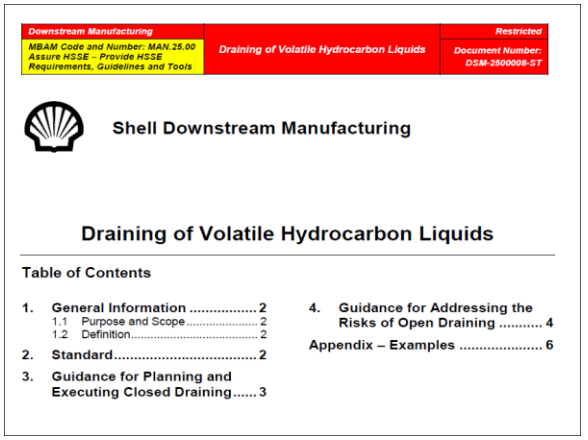
- Escalations led to large fire balls
  - Piping failures added large volumes of hydrocarbon due to line sizes and location of isolation points

Insights: beliefs contributing to normalization of risk

- Design aspects
  - Design of the piping allows only draining to atmosphere
  - Design of the piping requires cut and 180° rotation to inspect
  - Gully sucker design is specific for safe use for light hydrocarbons
  - Design intent of pump house drain system is functional (draining from West to East)
- The safety barriers have proven effective risk controls during previous decontaminations of light hydrocarbon systems
- Expertise and experience
  - Static electricity is only important for rail and road car loading activities
  - Own personnel has the expertise and experience to manage the risk of this type of activity – solid training and handover periods
  - Contractors demonstrated many years of experience in performing the decontamination activities safely – no need for operations to stand by
  - Emergency response capability adequate (own and authorities)

Conclusion

- Causal Learning identified many major and minor issues, leading to *normalisation of the risk* involved
  - Each had recommendations for improvement (strengthen existing safety barriers, introducing new safety barriers)
  - Cumulatively, implementation would be a mammoth task
  - *And still did not guarantee that people can make a mistake safely!*
- Controlling static electricity as an ignition source is difficult
  - Thus tackle the fire triangle at avoiding a combustible mixture
- *The only real solution is to eliminate the need to drain hydrocarbons to atmosphere and reinstate the original design !!!*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Shell Downstream Manufacturing

Draining of Volatile Hydrocarbon Liquids

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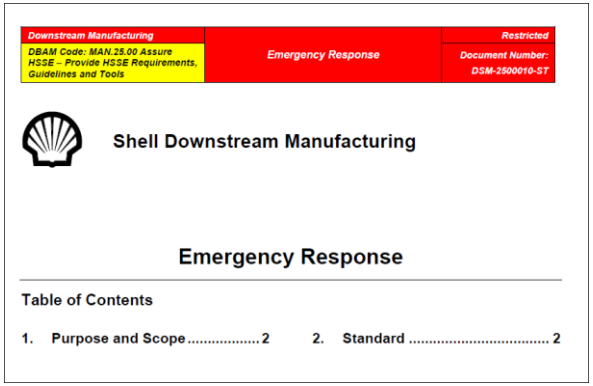
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Emergency Response

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