Lessons Learned from the Texas City Refinery Explosion

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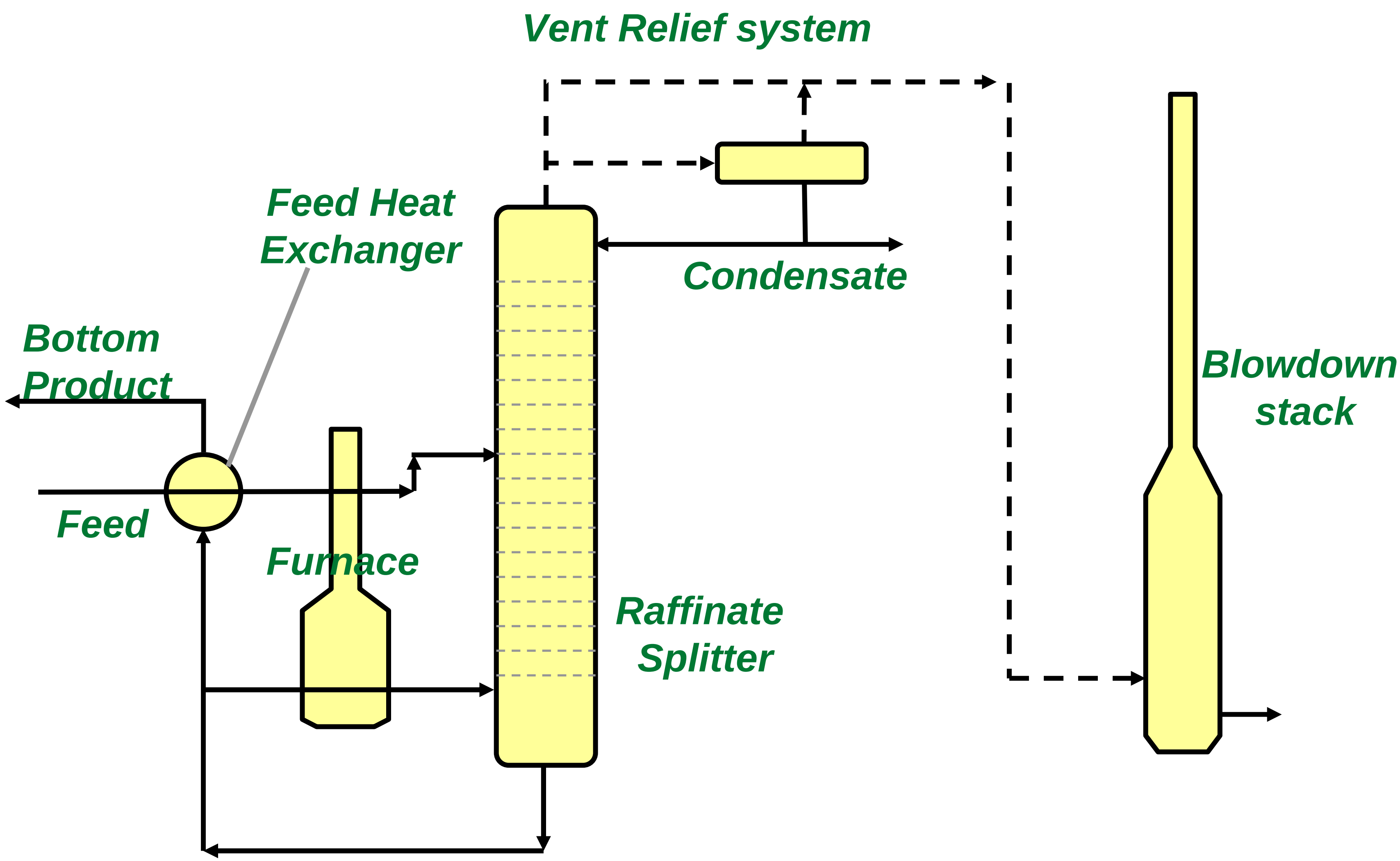
Texas City Refinery

- Texas City refinery is located 40 miles from Houston in Texas, USA
- 1600 people work at the refinery plus contractors
- It is one of the largest refineries in the USA, processing 460,000 barrels of crude oil/day, around 3% of gasoline US supplies

The accident

- An explosion and fire occurred at the refinery's isomerization unit
- The explosion happened at 13:20 (Houston time) on March 23, 2005
- 15 people died and many more were injured
- Note: The isomerization unit boosts the octane of gasoline blendstocks.

Simplified block diagram of Raffinate Splitter



Raffinate Splitter and Blowdown Drum Stack

Raffinate Splitter Tower

Blowdown Drum Stack

Aerial Photograph of Isomerization Unit

What happened ?

Prior to Feb. 15	• Temporary trailers placed 150 feet from the Isomerization unit. They were being used by personnel preparing for a turnaround at another part of the refinery
Feb. 21	• Shut down part of the Isomerization unit to refresh the catalyst in the feed unit
March 22	• On the night shift, the raffinate splitter was being restarted after the shutdown. The raffinate splitter is part of the Isomerization unit that distils chemicals for the Isomerization process
March 23	• Splitter was over-filled and over-heated • When liquid subsequently filled the overhead line the relief valves opened • This caused excessive liquid and vapour to flow to blowdown drum and vent at top of the stack • An explosion occurred which killed 15 people and injured many others

Texas City Refinery March 23, 2005
15 People Killed
Many more injured
A community devastated

Incident

Isomerization Unit

Satellite Control Room

Inside Satellite Control Room

Cooling Tower

Trailer

Catalyst Warehouse

Storage Tank

Isomerization Unit

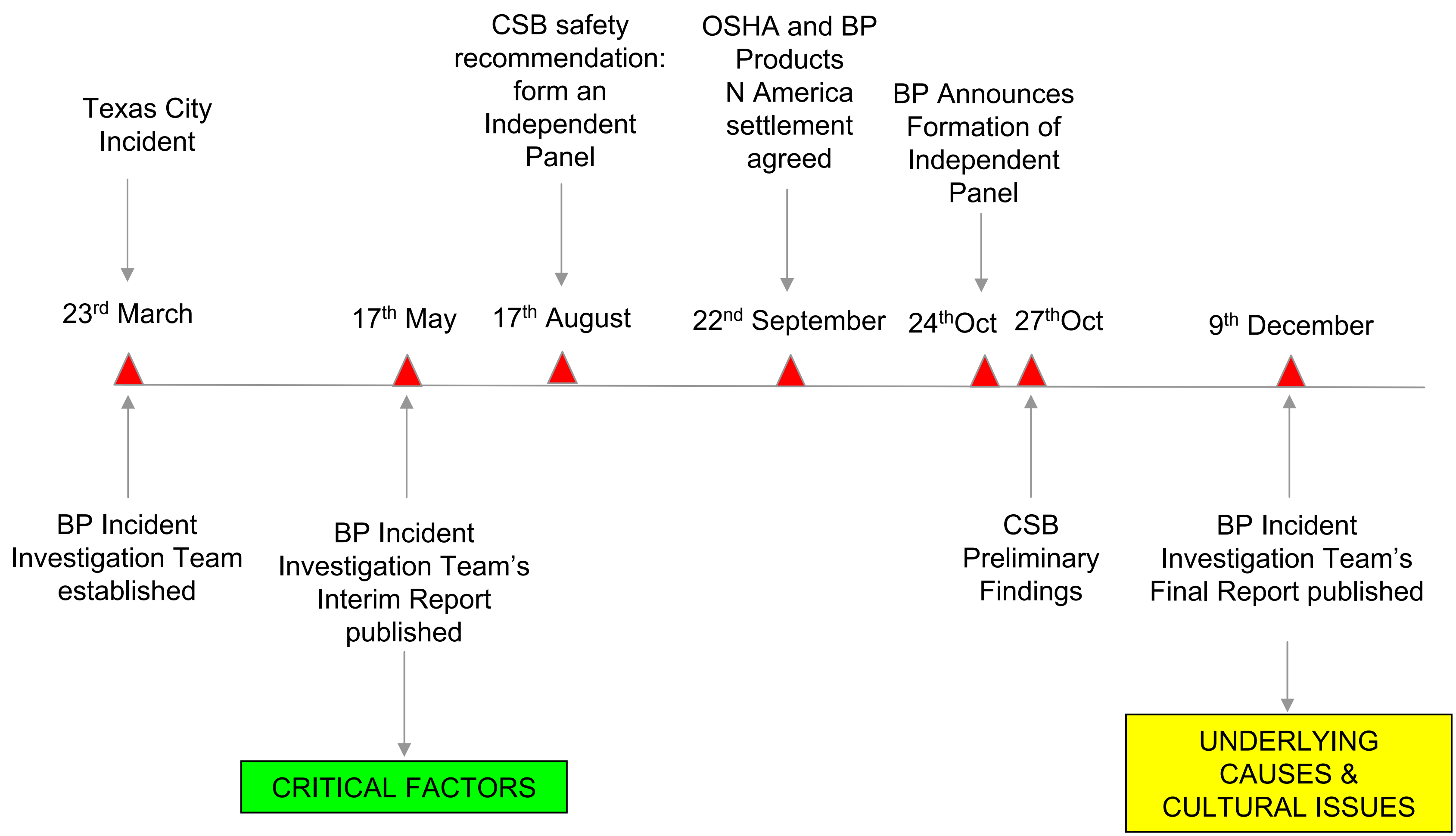
Double-Wide Trailer

Double-Wide Trailer

Key Issues

- Operator Inattention
- Following Procedures
- Supervisor Absence
- Communication – shift handover
- Trailers Too Close to Hazards
- Some Instrumentation Did Not Work
  - Tower Level Transmitter Worked as Designed
- Abnormal Start-ups
- Investigation of Previous Incidents
- Blowdown Drum Vented Hydrocarbons to Atmosphere
- Opportunities to Replace Blowdown Drum
  - Evaluation of Connection to Flare

Key events timeline - 2005



BP incident investigation team reports

The Interim Report identified 4 critical factors; the Final Report confirmed the critical factors and identified underlying cultural issues:

CRITICAL FACTORS:

- Start-up procedures and management oversight
- Loss of containment
- Design and engineering of blowdown unit
- Control of work and trailer siting

UNDERLYING CULTURE:

- Insufficient business context
- Safety as a priority
- Organizational complexity
- Inability to see risk
- Lack of early warning indicators

Underlying Cultural Issues

Business Context

- Motivation
- Morale
- PAS Score

(Process) Safety as a Priority

- Emphasis on Environment and Occupational Safety

Organizational Complexity & Capability

- Investment in People
- Layers and Span of Control
- Communication

Inability to See Risk

- Hazard Identification Skills
- Understanding of Process Safety
- Facility Siting
- Vehicles

Lack of Early Warning

- Depth of Audit
- KPI’s for Process Safety
- Sharing of Learning / Ideas

Technical Lessons Learned

Many Lessons from Texas City

- Level Indication
- Blowdown Systems
- Relief Systems
- Facility Siting

Level Transmitter

Design typical of many in the industry

Displacer type instrument

Not faulty – worked as designed before, during and after the incident

Trending downwards (but other data available)

Lessons Learned

- Functionality changed when top tap flooded

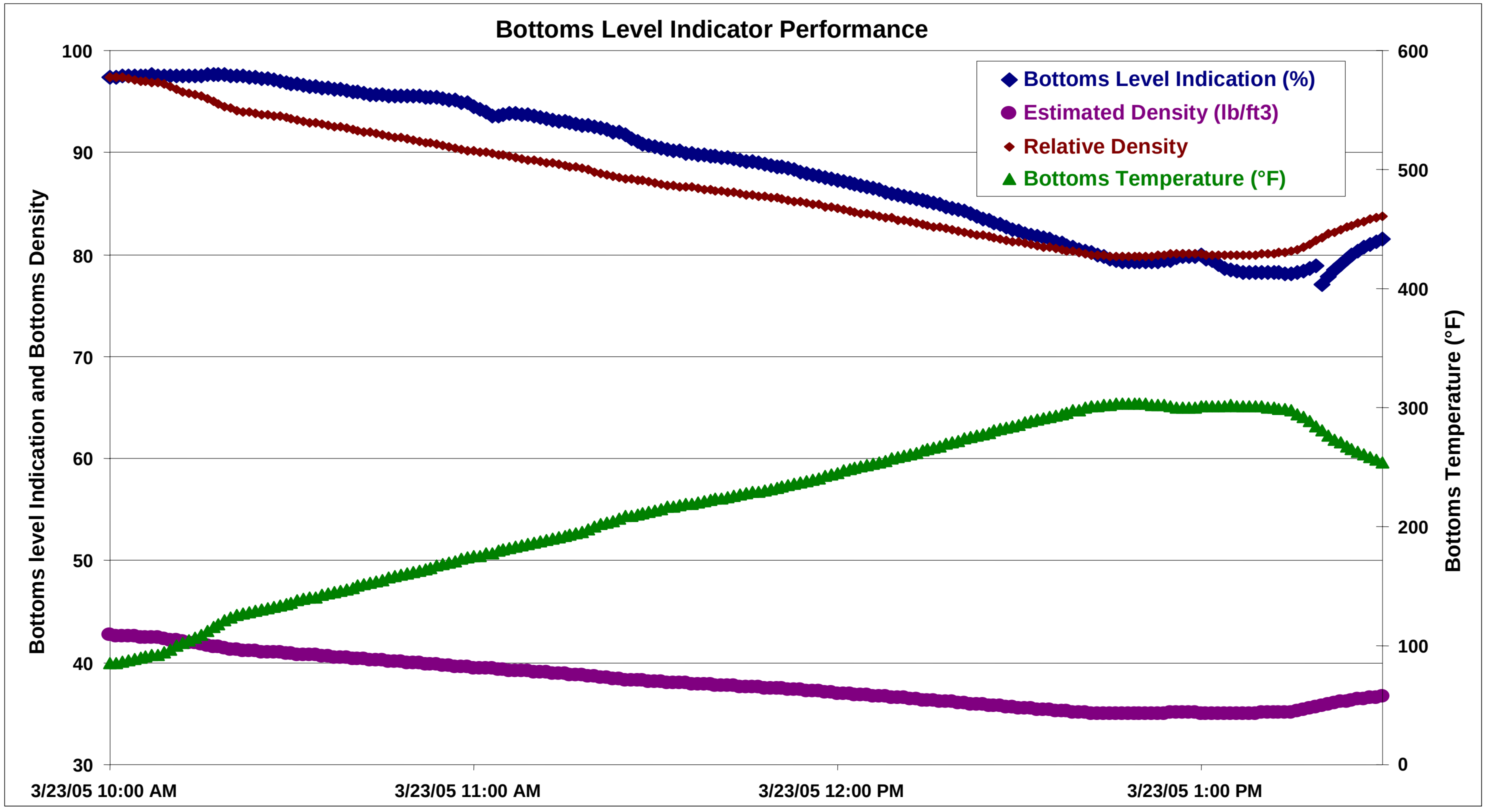
Raffinate Splitter Bottoms Level

Level instrument submerged early with cold raffinate

Instrument output changed from reading liquid level to indication of buoyancy

As raffinate temperature went up (green), density decreased (purple)

''Level'' output on the DCS screen decreased (blue)



Level Transmitter

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Design typical of many in the industry

Lessons Learned

- Functionality changed when top tap flooded
- Critical high level alarms/trips ? LOPA
- Robust testing procedures and documentation of instrument testing

Blowdown Systems

- Commitment to replacing blowdown drums on light hydrocarbon duty
- Survey all sites

Lessons Learned

- Design basis sometimes unclear – mods. over time
- Some have flammable liquids (flash < 100˚F)
- Limited understanding of vapor dispersion
- Drums may be too small
  - inadequate liquid holdup
  - vapor/liquid disengagement
- Discharge to sewers sometimes not well understood
- Quench designs may be ineffective
  - Lack of contacting internals
  - Inadequate or non-existent controls
  - Potential for steam explosions
- Potential for stack fire/explosion due to inadequate purge

Blowdown Systems

Wider Issues

- Atmospheric Relief
  - Variable practice
  - More common in USA
- Vent Pipe Design
  - Dispersion adequacy ?
  - Possibility of liquid under upset conditions ?

Relief System Studies

Design

- Sites generally have some design basis documentation
  - Some very good practices in place
  - Completeness and format vary widely, no common framework
  - Some not updated for current operation
- ACTION: Implement common practice for relief system documentation
- ACTION: Improve MOC process to capture relief system changes

Accountability

- Some sites have no accountable person for relief systems process design
  - Expertise and technical knowledge of pressure relief systems is limited
- ACTION: Appoint SPA's

Competency

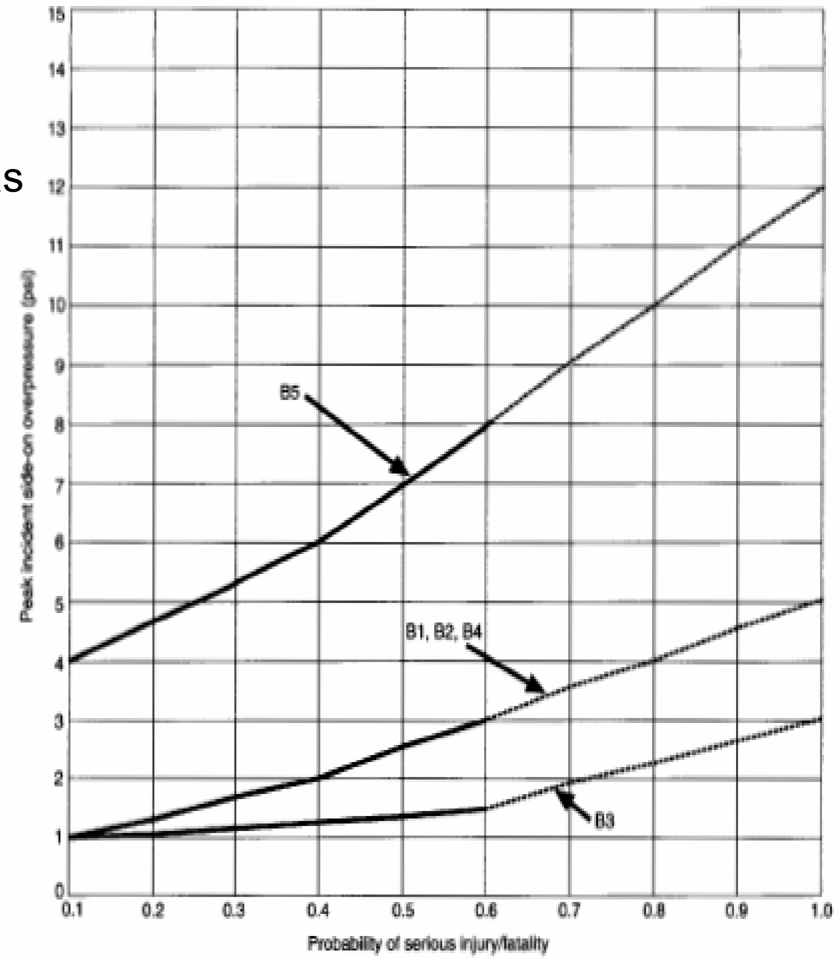
- Operator training is critical to understanding relief system operation and for emergency response
- ACTION: Enhance program of training and drills

Facility Siting

Trailers used as temporary buildings

Local practice based on API RP 752 used for siting

- Adopted own occupant vulnerability correlation as allowed by API RP 752
- Predicts lower vulnerability than CCPS



Note: Figure taken from CCPS, *Guidelines for Evaluating Process-Plant Buildings for External Explosions and Fires* (work in progress).

Figure C-1—Sample Overpressure Versus Vulnerability

Predicted Side-On Pressure Contours (in psi)

Facility Siting

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- Predicts lower vulnerability than CCPS

Overpressure at trailers: 2.5psi peak side-on

430 psi.ms impulse

- At 2.5 psi (side) CCPS/API predicts 50% vul.

Lessons Learned

- CCPS vulnerability correlation may not be conservative
  - Long impulse duration ?
- API RP 752 may not be as conservative as thought and is currently under review
- BP commitment – no trailers in h-c areas

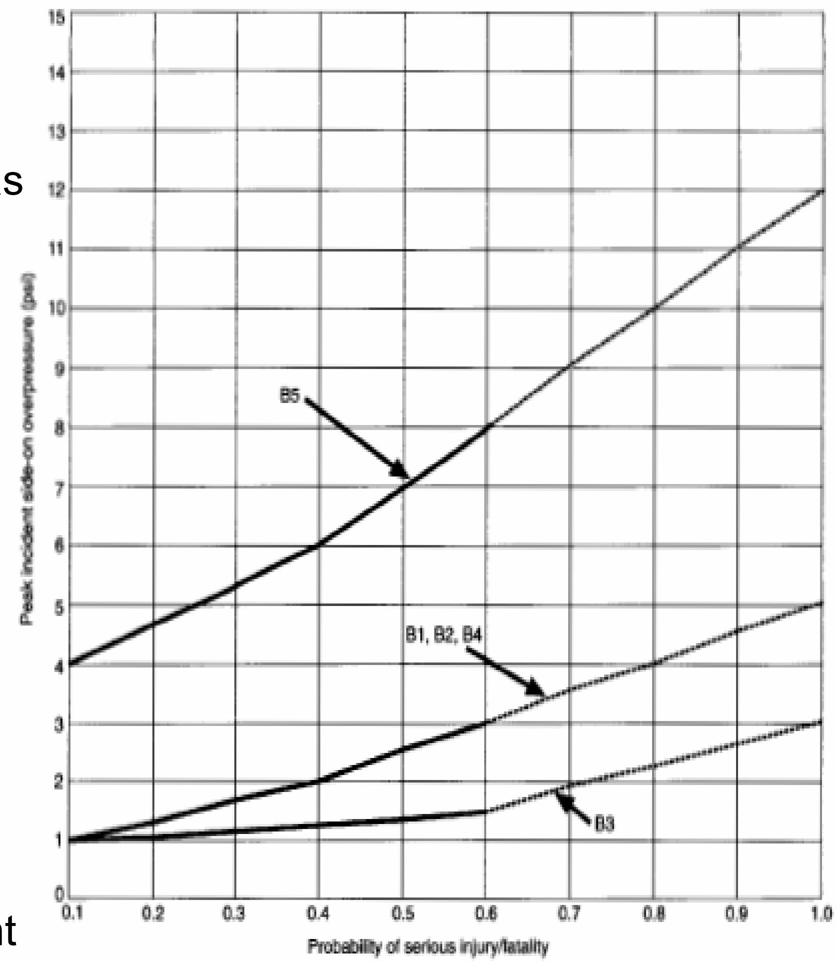

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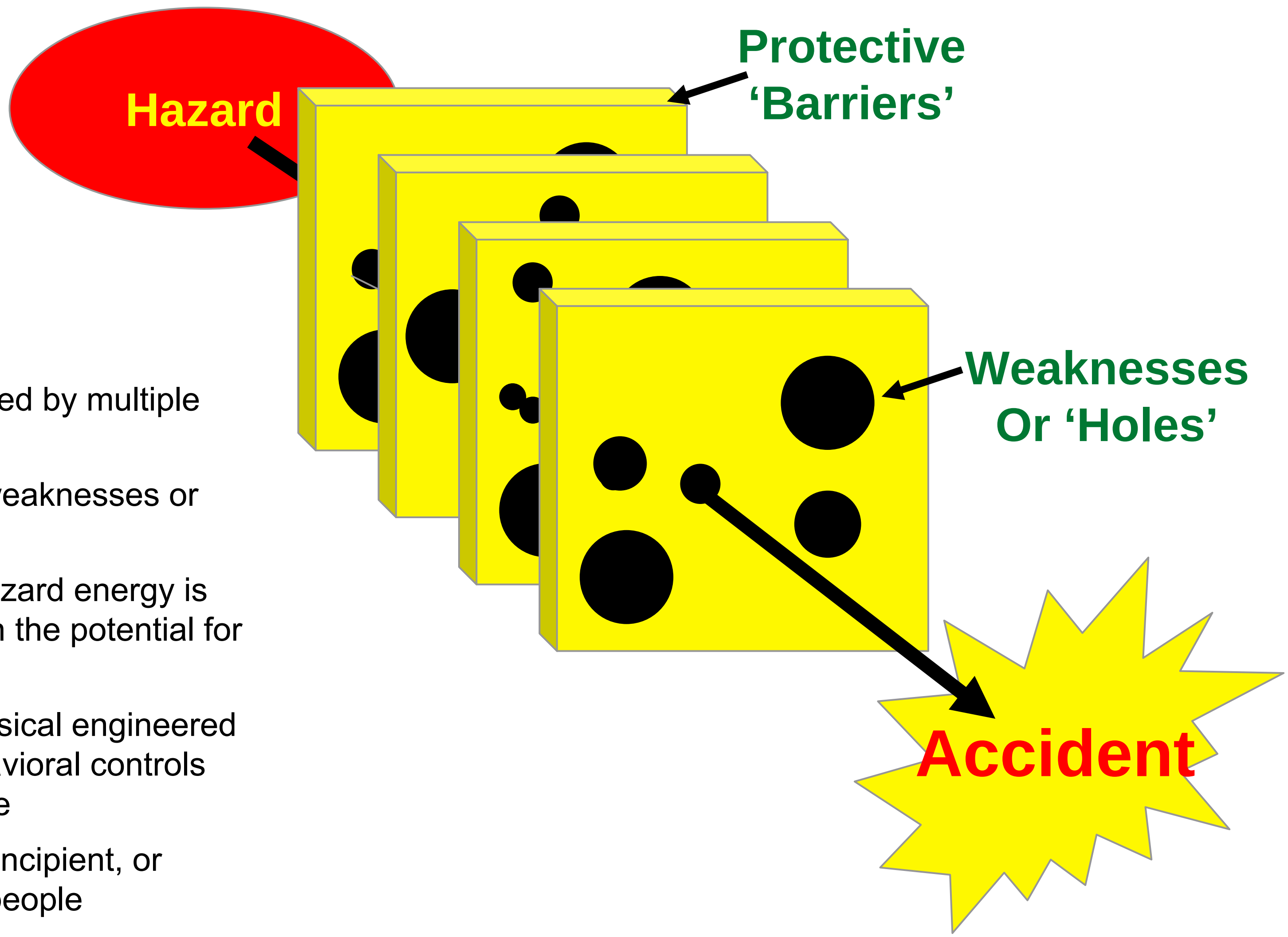
Figure C-1—Sample Overpressure Versus Vulnerability

Reminder of the 'Swiss Cheese Model'



Hazards are contained by multiple protective barriers

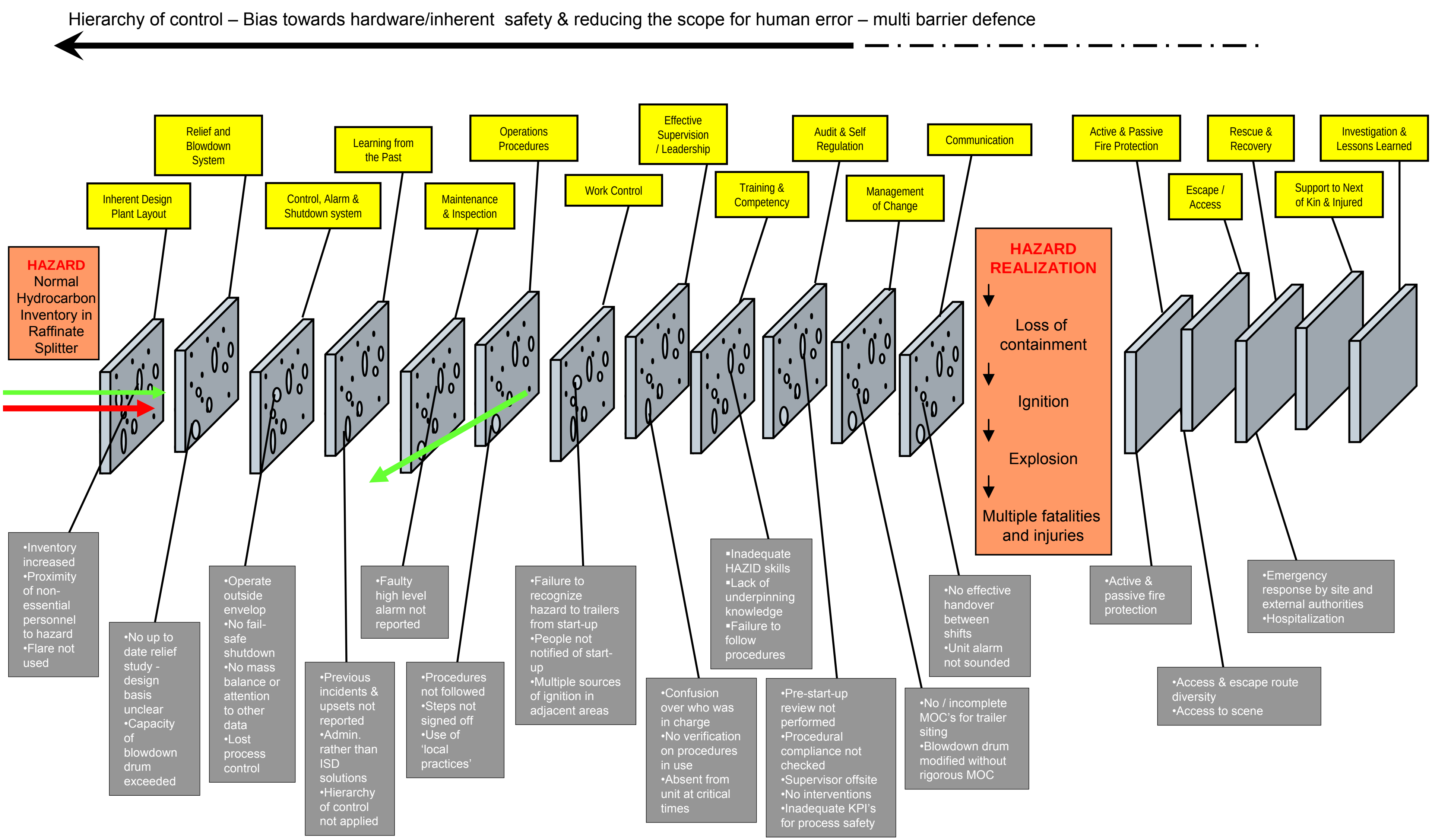
Barriers may have weaknesses or 'holes'

When holes align hazard energy is released, resulting in the potential for harm

Barriers may be physical engineered containment or behavioral controls dependent on people

Holes can be latent/incipient, or actively opened by people

Texas City Explosion – Hazard Management Diagram

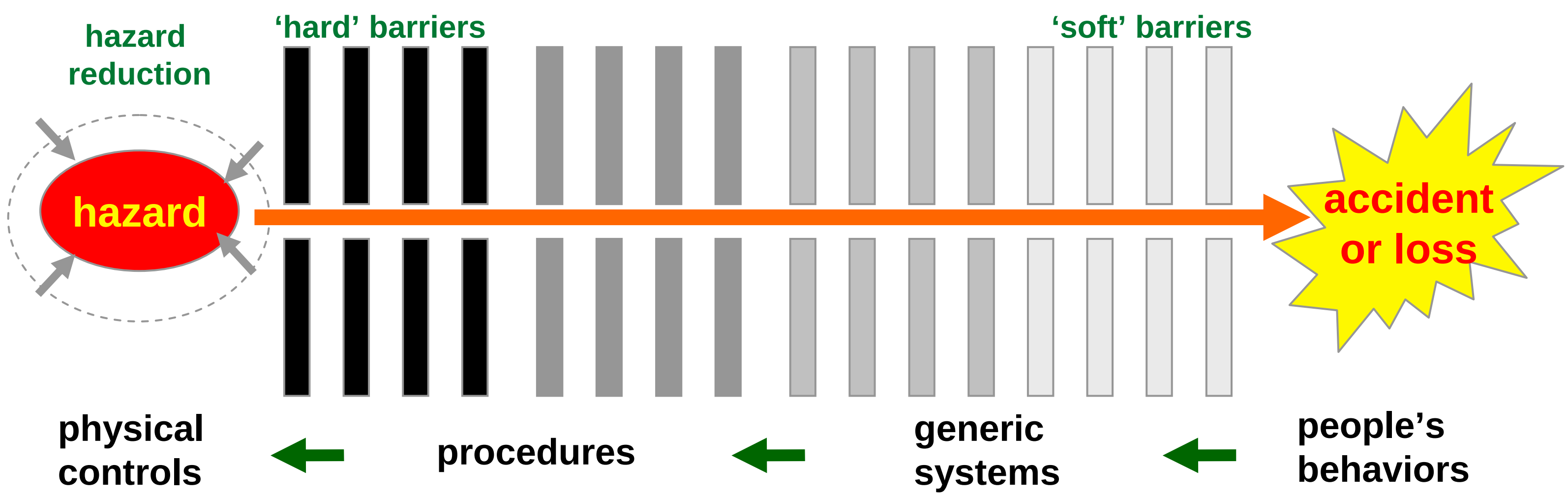


Strategic concepts

In order to reduce the potential for future major incidents and losses, three layers of protection are to be considered:

- **plant** – engineering hardware, control systems, and layouts to eliminate, control and mitigate potential hazards to people, and improve productivity
- **processes** – management systems to identify, control and mitigate risks, and drive continuous operational improvement
- **people** – capability of our people in terms of leadership skills, relevant knowledge and experience, and the organizational culture they create

In layers of protection, 'hard barriers' are more reliable than 'soft barriers', but all rely on people



Principal actions

Plant

- No trailers or temporary accommodation to be placed inside areas (of refineries) containing hydrocarbons, even if the assessment of risk is negligible
- Blowdown stacks used for light hydrocarbon to be phased out as quickly as possible

Process

- Operating procedures to be clear, appropriate for their purpose, and always followed

People

- Build capability for operational leadership, supervisors, and technicians

Other Actions

Texas City

- Organization, accountabilities, communication,
- $1 billion investment program, off-site offices, facility siting study, trailers removed, reduced vehicles, blowdown stacks in light h-c duty being removed, engineering studies (relief systems and SCE),
- Supervisory oversight, operator training.

BP Group

- Safety & Operations organization,
- Assessment of temporary buildings, removal of blowdown drums, engineering studies of atmospheric vents
- Review of operating procedures,
- Development of OMS, implementation of CoW and IM standards,

External

- Assisting API, sharing lessons learned

Other BP Activities Associated with the Response

Government Agencies

- Continue to cooperate with government agencies and proactively share reports and findings

US Chemical Safety Board

- Continue discussions with CSB incident investigators in an effort to achieve a common understanding of the facts

Independent Panel

- Voluntarily appointed an independent panel, comprised of world renowned experts, chaired by Former US Secretary of State James Baker

What can we learn from this incident ?

Many lessons that can be learnt from Texas City, including:

- Temporary building siting is a critical step in managing flammable / toxic risks
- Atmospheric venting needs careful design and operation
- Procedures are ineffective if they are not up-to-date and routinely followed
- Competency and behaviors of Operations leadership, supervision and workforce are fundamental to safe operations

Other lessons involve management visibility and accountability, hazard identification, hazards of startup operations, performance measures for process safety, emergency drills, etc.

Incident investigation report available at: www.bpresponse.org