U.S. Chemical Safety and Hazard Investigation Board

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Public Meeting

Investigation of the March 23, 2005, Explosion and Fire at the BP Texas City Refinery

March 20, 2007

Incident summary

- March 23, 2005
- Explosion and fire
- 15 deaths
- 180 injuries
- Refinery process damaged and trailers destroyed
- Offsite property damage

Incident summary

- Occurred during startup
- Tower and blowdown drum overfilled
- Liquid hydrocarbon released
- Vapor cloud formed and ignited
- Explosion and fire

CSB investigation

- Most extensive investigation in CSB history
- Conducted 370 interviews
- Reviewed over 30,000 documents
- Tested equipment and instrumentation
- Worked with experts in distillation process modeling, relief system design, blast modeling, instrumentation, safety culture, and human factors

Presentation outline:

- Animation of the incident
- Vapor cloud explosion
- Human factors
- Process safety deficiencies
- Safety culture
- OSHA regulatory issues
- Recommendations

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Animation of ISOM Raffinate Section Startup

March 22 – 23, 2005

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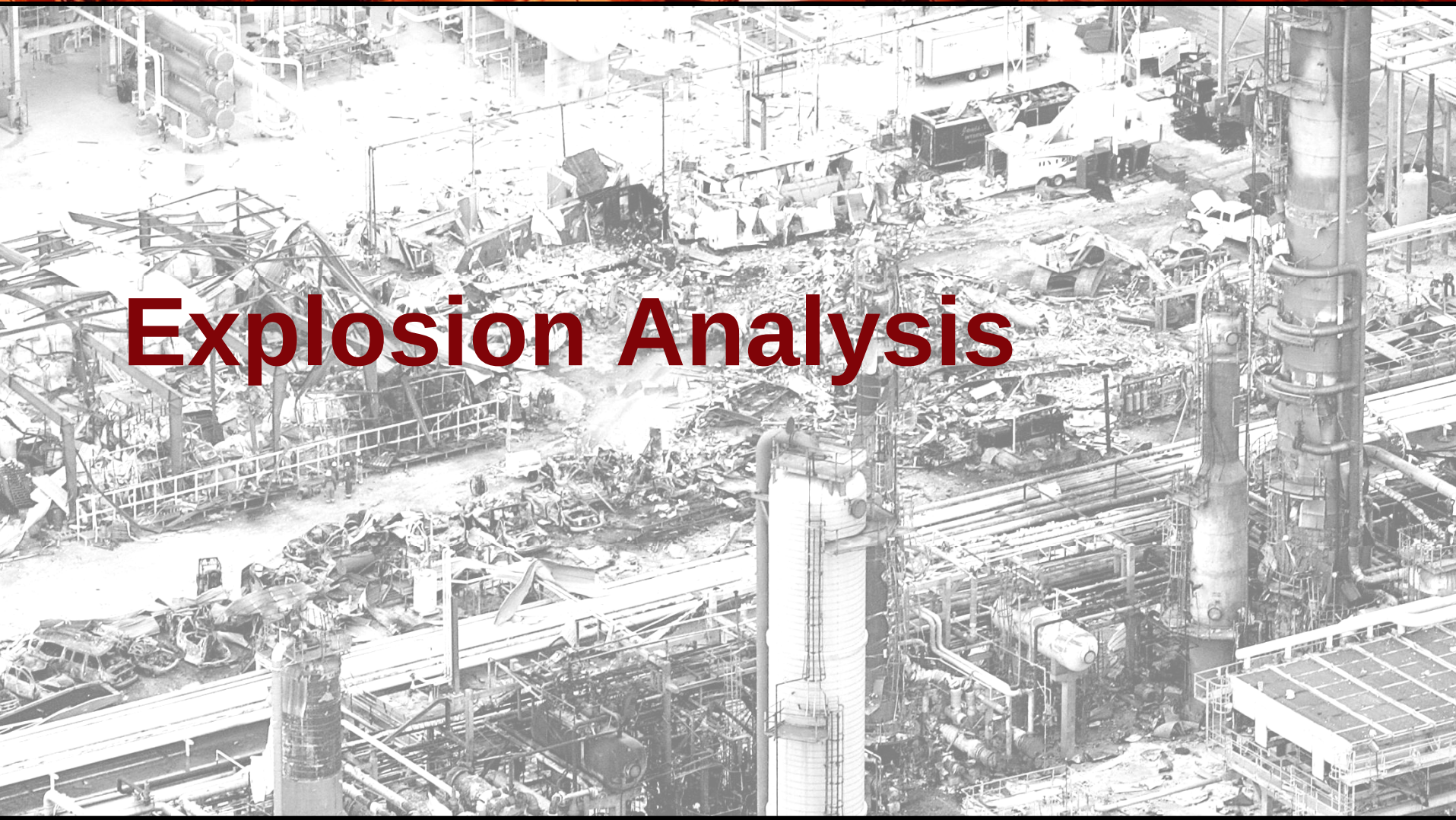
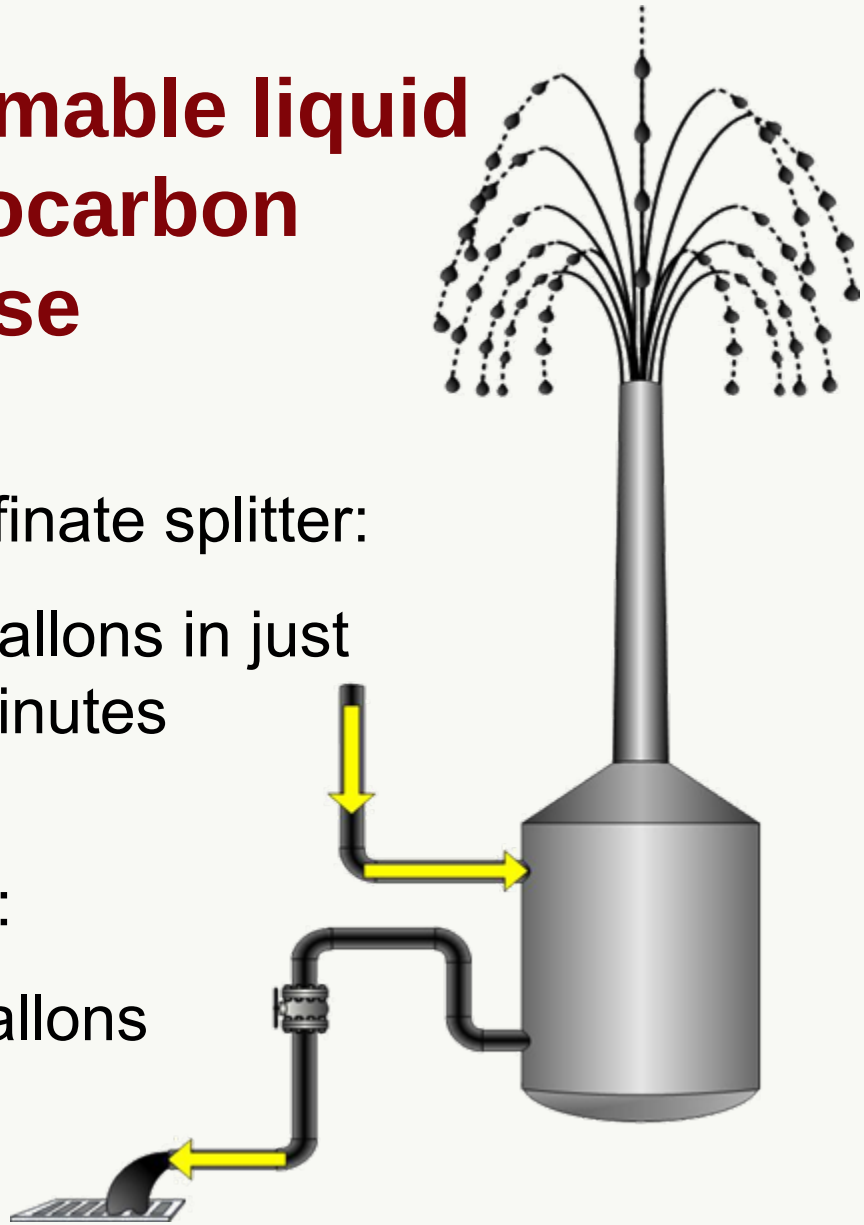


Explosion Analysis

Flammable liquid hydrocarbon release



From raffinate splitter:

51,900 gallons in just over 6 minutes

To sewer:

12,200 gallons

Out the top of blowdown stack:

7,600 gallons in 1.8 minutes

To fill piping and equipment:

31,130 gallons in 4.2 minutes

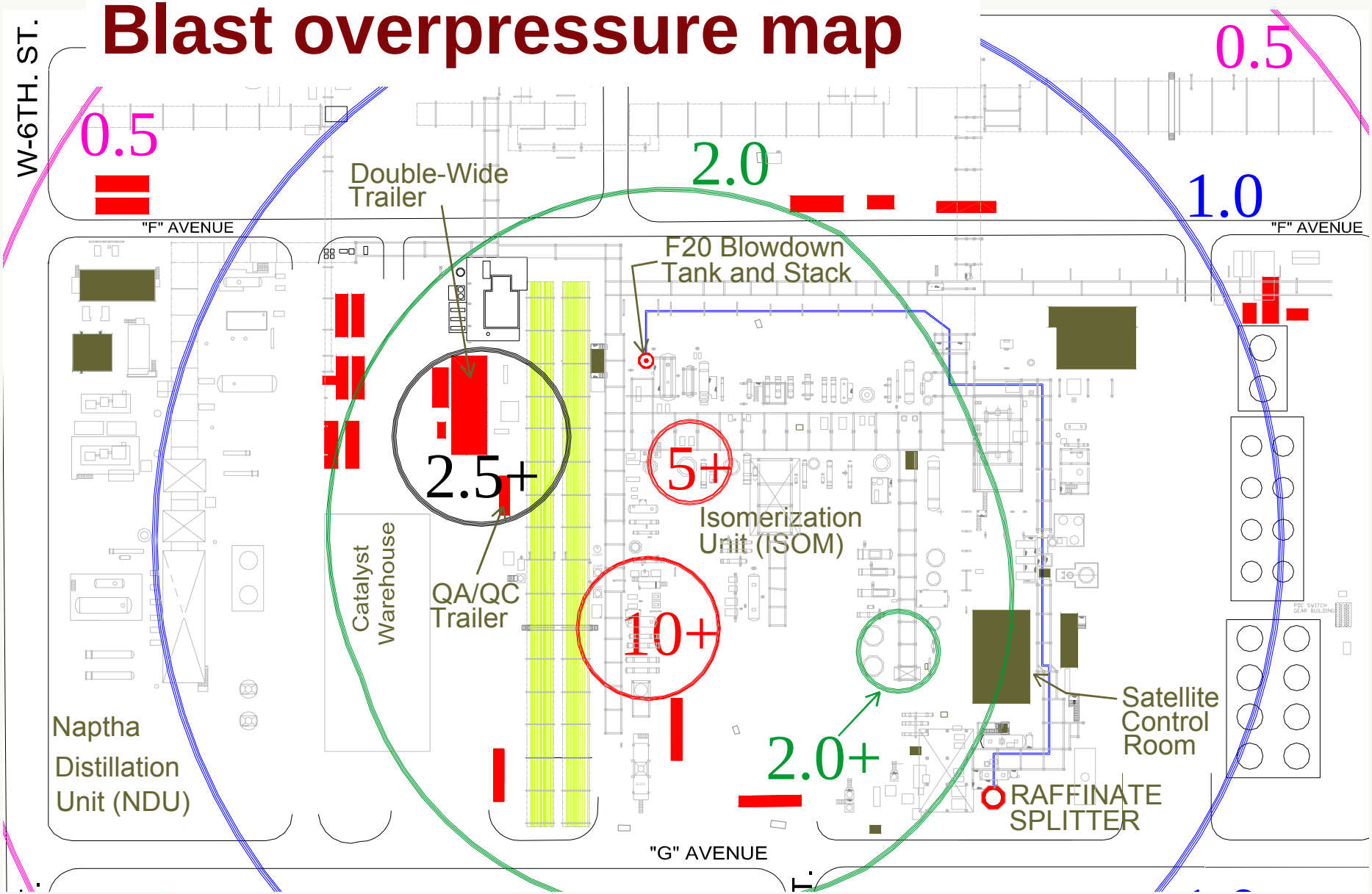
How did the vapor cloud get so large?

- About half the liquid vaporized as droplets were ejected out the stack, dispersed by the wind, and fell to the ground
- Some falling liquid droplets contacted elevated process equipment producing multiple smaller droplets which then vaporized
- Liquid reached the ground, formed a pool and began to vaporize

Diesel truck was the ignition source

- Truck parked, but idling, about 25 feet from blowdown drum
- Eyewitness saw engine over-revving and backfiring sparks
- Blast damage analysis and explosion modeling ruled out other potential ignition sources

Blast overpressure map



Analysis of trailer damage

- Forty trailers were damaged
  - Thirteen were totally destroyed
- Occupants were injured in trailers as far as 479 feet from the blowdown drum
- Damage was noted in trailers almost 1,000 feet from blowdown drum

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Human Factors

Human factors

- Human errors led to the overfilling of the tower for 3 hours
- But individuals do not plan to make mistakes; they do what makes sense to them at the time
- Human errors are symptoms of underlying problems
- Must ask: *Why did the individuals take the actions that they did?*
- Numerous underlying conditions influenced operators' decision-making and actions

Human factors

- Procedures were not followed
- Ineffective communication during startup
- Operators were likely fatigued
- Instrumentation gave misleading information
- Unit was understaffed and not supervised
- Training was ineffective
- Control board display was poorly designed

Operators deviated from the procedure

- The procedure required that the tower level control valve be placed in automatic mode to control the level at 50% or at 6 ½ feet in the 170 foot-tall tower
- However, the board operator placed the tower level control valve in the manual mode and closed it completely
- To understand why he made these decisions, we reviewed what other board operators did in previous startups

Procedural deviations common in 19 startups of the unit from 2000 to 2005

- In a majority of the startups the tower was filled above the range of the level transmitter
- Swings in level experienced in 18 of these startups
- Operators frequently ran valve in manual instead of automatic
- None of these startups was considered abnormal or investigated to correct problems

Supervisors and managers did not correct procedural deviations

- Procedure did not reflect actual practice
- Procedural changes were allowed without management-of-change analysis
- Startup procedure lacked sufficient instructions for unique startup on March 23rd
- Hazards of high tower level were not identified in the procedures or safe operating limits

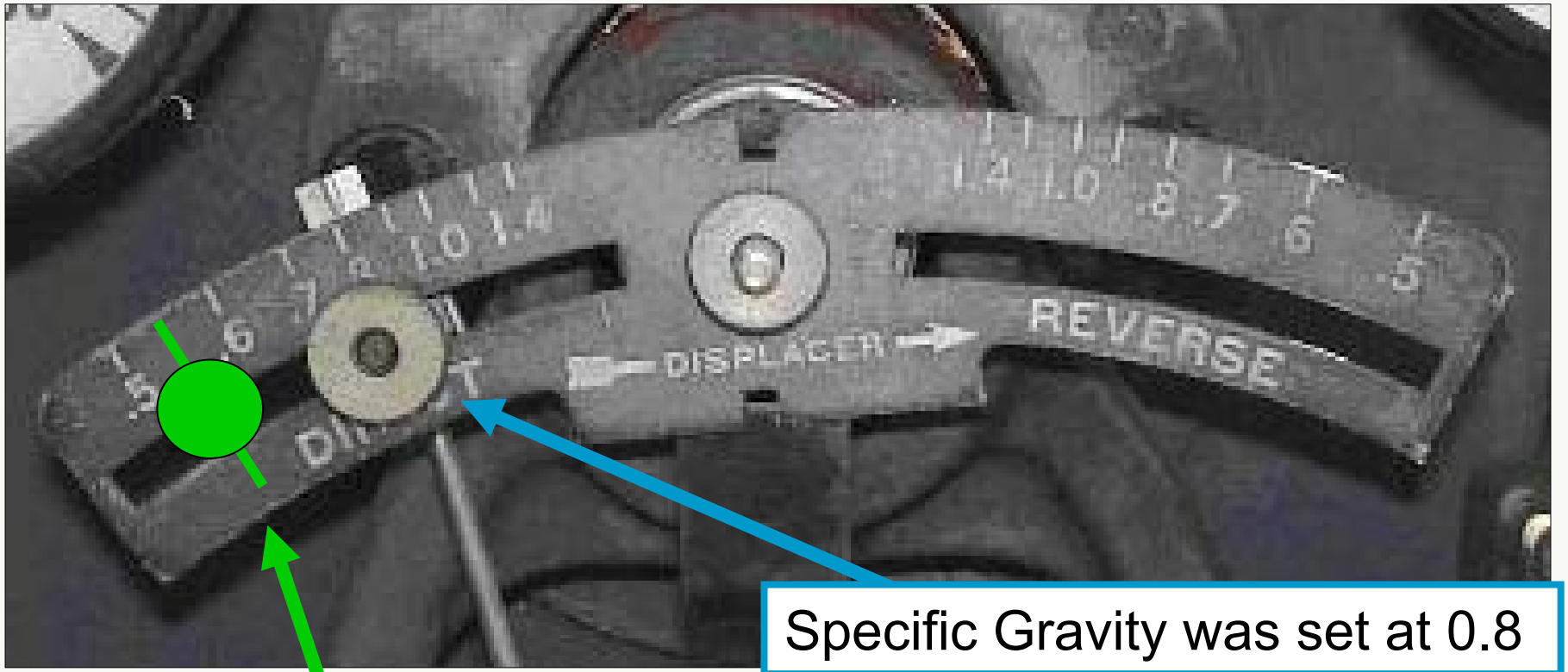
Communication was ineffective between operations personnel

- Multiple critical miscommunications occurred
  - Instructions for routing feed led to the level control valve being closed
  - The condition of equipment was not communicated from one shift to the next
- BP had no policy for effective communication between operations personnel

Tower instruments malfunctioned

- Miscalibrated level transmitter gave operators false readings that the tower level was declining
- Dirty level sight glass on the tower was unreadable
- The redundant high level alarm failed to sound
- No other indication of level was available to operators

Level transmitter was miscalibrated



Operators were likely Fatigued

- Operators worked 12-hr shifts, 7 days-a-week, 29+ days
- Acute sleep loss and cumulative sleep debt resulted
- BP has no corporate or site-specific fatigue prevention policy or maximum shift work regulations
- No fatigue prevention guidelines widely used in refining industry

March 2005						
~~27~~	~~28~~	~~1~~	~~2~~	~~3~~	~~4~~	~~5~~
~~6~~	~~7~~	~~8~~	~~9~~	~~10~~	~~11~~	~~12~~
~~13~~	~~14~~	~~15~~	~~16~~	~~17~~	~~18~~	~~19~~
~~20~~	~~21~~	~~22~~	~~23~~	24	25	26
27	28	29	30	1	2	3

Supervisor and Operator Staffing was Insufficient

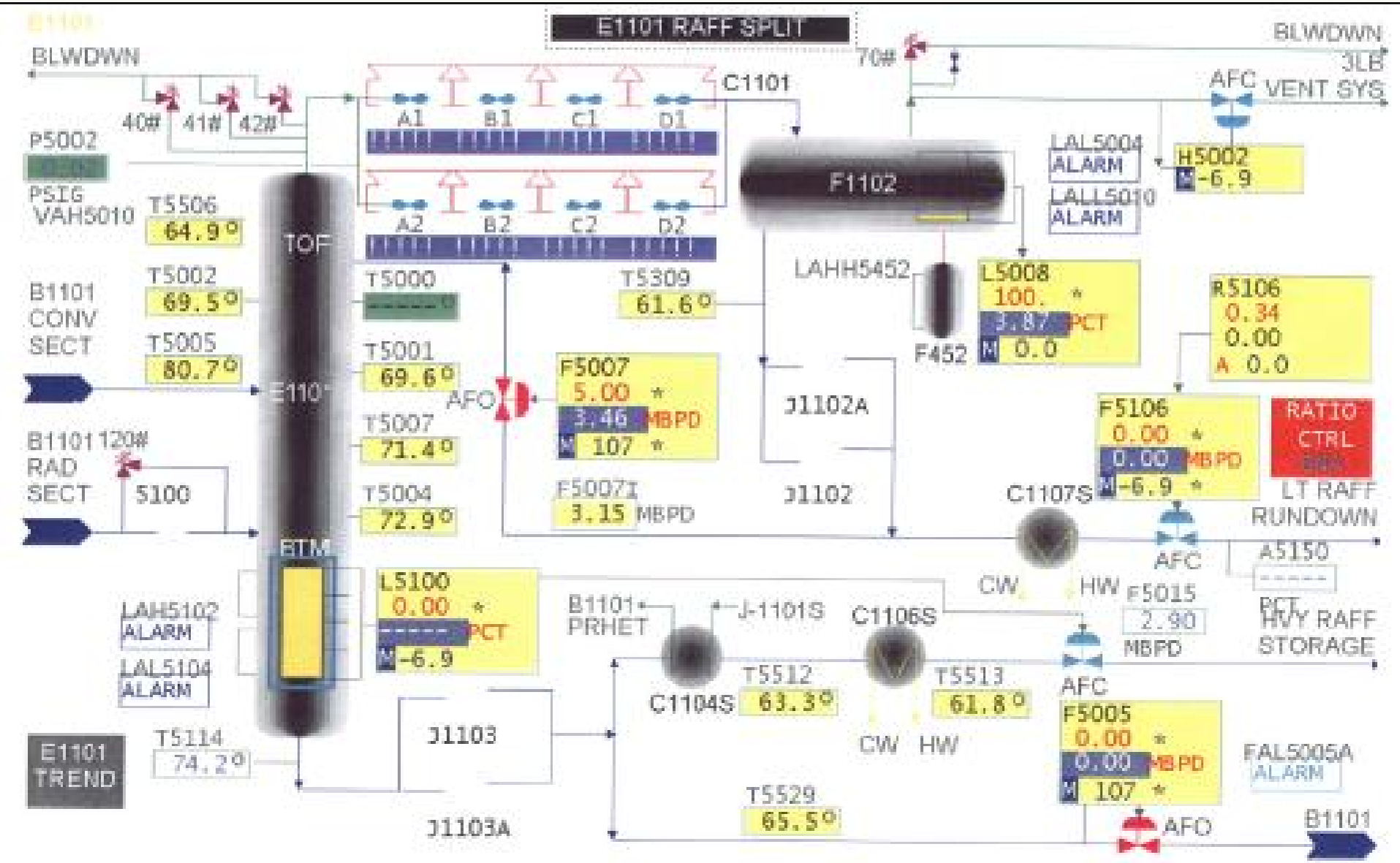
- Unit Startups are especially hazardous
- No supervisor or technically trained person with ISOM experience assisted with startup
- A hazard review recommended two board operators during all unit startups, but this was not done
- 25% budget cut target in 1999 led to ISOM staffing cuts - control room consolidation reduced two board operators to one; additional workload added in 2003

Operator Training was not effective

- No effective training for abnormal situation management
- No effective verification methods of operator competency
- No simulation technology made available
- From 1998 to 2004 central training staff cut from 28 to 8; move to computer-based training "was a business decision driven by cost"
- Audits and reviews from 2002 - 2005 identified on-going deficiencies in operator competency

Design of Control Board Display Provided Insufficient Data

- Display lacked adequate indication of how much liquid was in the tower
- Two different screens used to display to operator how much liquid entering and leaving the unit


E1101 RAFF SPLIT
BLWDWN
40#
41#
42#
P5002
PSIG
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64.9°
T5002
69.5°
B1101
CONV
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LAHH5452
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RATIO CTRL
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STORAGE
70#
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3LB
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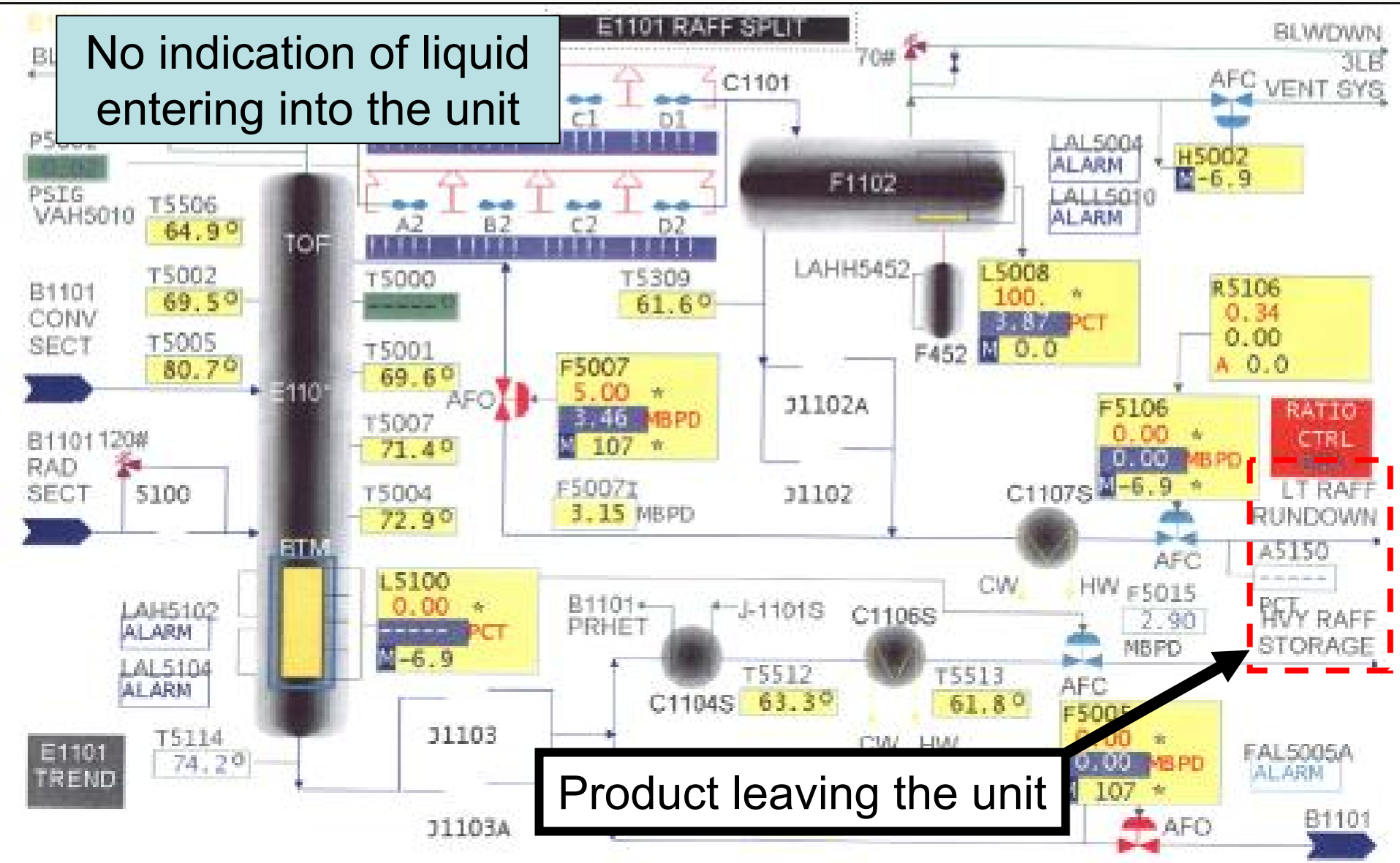
No indication of liquid entering into the unit
E1101 RAFF SPLIT
C1101
C1
D1
A2
B2
C2
D2
F1102
TOF
BTM
E1101 TREND
T5506 64.9°
T5002 69.5°
T5005 80.7°
T5000
T5001 69.6°
T5007 71.4°
T5004 72.9°
T5309 61.6°
T5114 74.2°
B1101 CONV SECT
B1101 RAD SECT
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LAL5104 ALARM
LAL5004 ALARM
LALL5010 ALARM
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R5106 0.34 0.00 A 0.0
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A5150
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HVY RAFF STORAGE
C1107S
C1106S
C1104S
CW
HW
F5015 2.90 MBPD
T5512 63.3°
T5513 61.8°
L5100 0.00 PCT -6.9
B1101 PRHET
J-1101S
FAL5005A ALARM
B1101
Product leaving the unit

Similar contributory cause found in 1994 UK Texaco Milford Haven refinery incident

- Process equipment overfilled with hydrocarbon; explosion and fire resulted
- Display screens did not provide all critical information, including how much liquid was entering and leaving the unit
- Recommendation was made to UK refining industry to ensure display systems be configured to provide such information

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Process Safety Deficiencies

BP Texas City incident investigations were ineffective

- Eight serious ISOM blowdown system incidents occurred between 1994 and 2004
- Only three incidents were investigated
- External audits in 2003 and 2004 identified problems with the Texas City refinery incident investigation system

Poor design of tower level indication

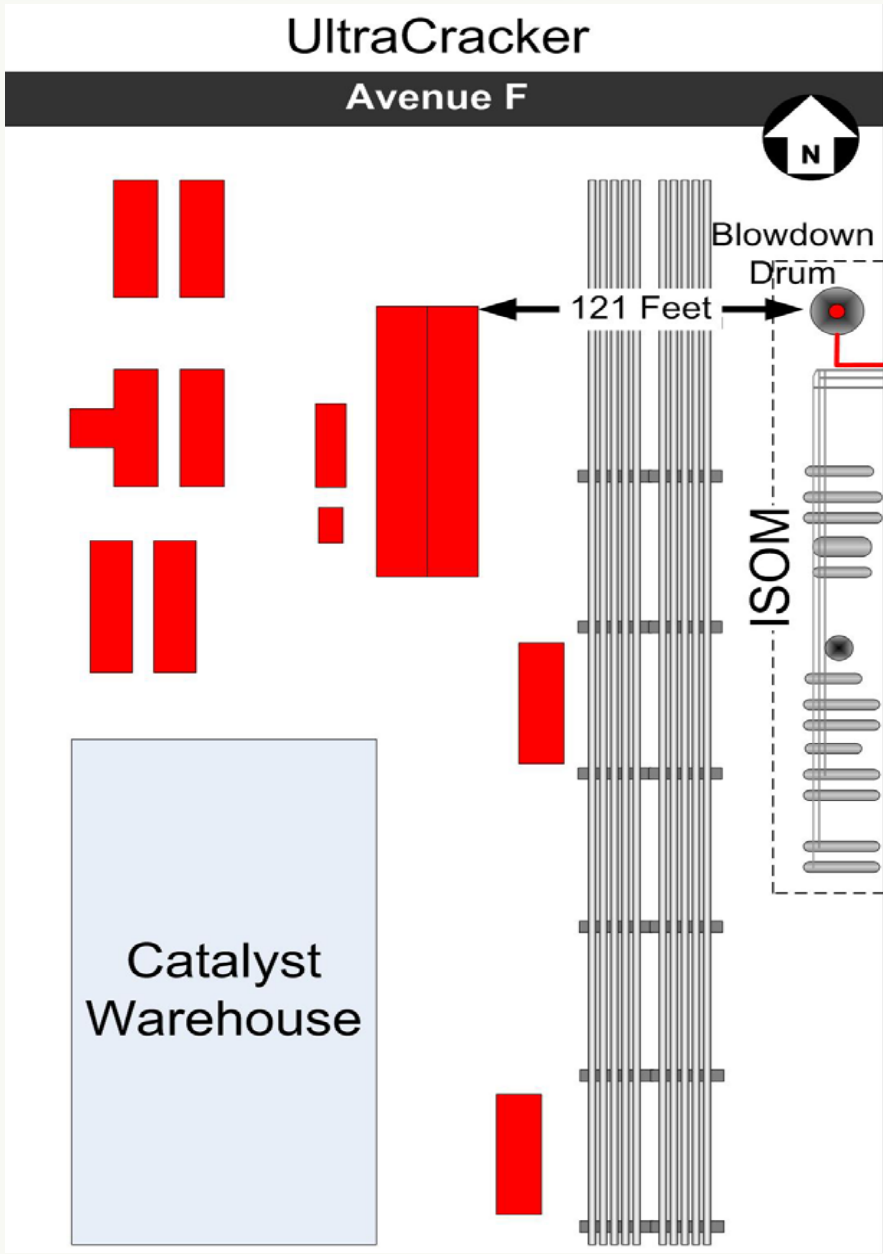
- None of the instruments showing the level in the tower were working properly on March 23, 2005
- Another ISOM tower had been previously overfilled in 1994 under similar circumstances
- Faulty level measurement and control are the primary causes of high level events based on 900 cases histories of tower malfunctions
- Tower was not equipped with automatic safety shutdowns or safety interlocks triggered by high level

Inadequate design of pressure relief and disposal system equipment

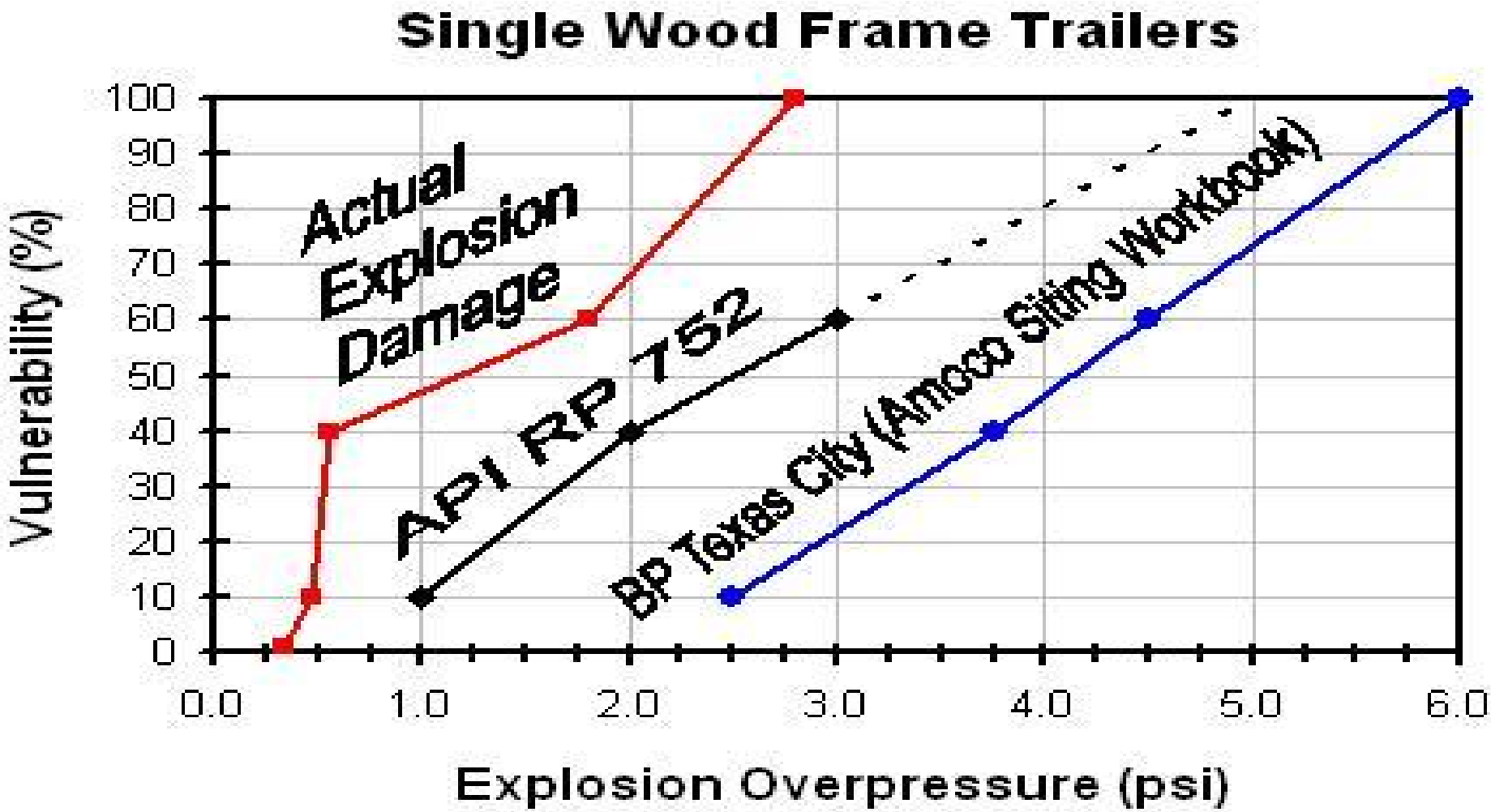
- Blowdown drum and relief valve disposal piping were undersized
- Amoco and BP safety and engineering standards were not followed
- Relief valve and header study was not completed; 13 years overdue
- Previous attempts to remove blowdown drum were cancelled

Siting of trailers was unsafe

- Sited for convenience
- Management of change (MOC) procedures were not followed
- Siting methodology was flawed



BP and API siting methods were inadequate



Maintenance program was deficient

- Level indicator on tower was not listed as critical equipment
- Instrument data sheet was out of date
- Formal testing and maintenance procedures were not established
- Computerized maintenance management system was not fully implemented

Additional process safety system problems

Process hazard analysis

- Serious fire and explosion risks in ISOM unit were not identified
- Previous incidents with catastrophic potential were not examined

Management of change (MOC)

- Numerous changes made to processes, equipment, procedures, buildings and personnel were not reviewed

Additional Process Safety System Problems

Auditing

- Many process safety management problems were identified by audits, but not resolved

Pre-startup safety review

- No review was conducted in the ISOM unit prior to the startup

Vehicle traffic control

- Policy did not effectively control vehicle traffic into hazardous process areas

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Safety Culture

Safety culture – Organizational causes

The March 2005 ISOM disaster was an organizational accident

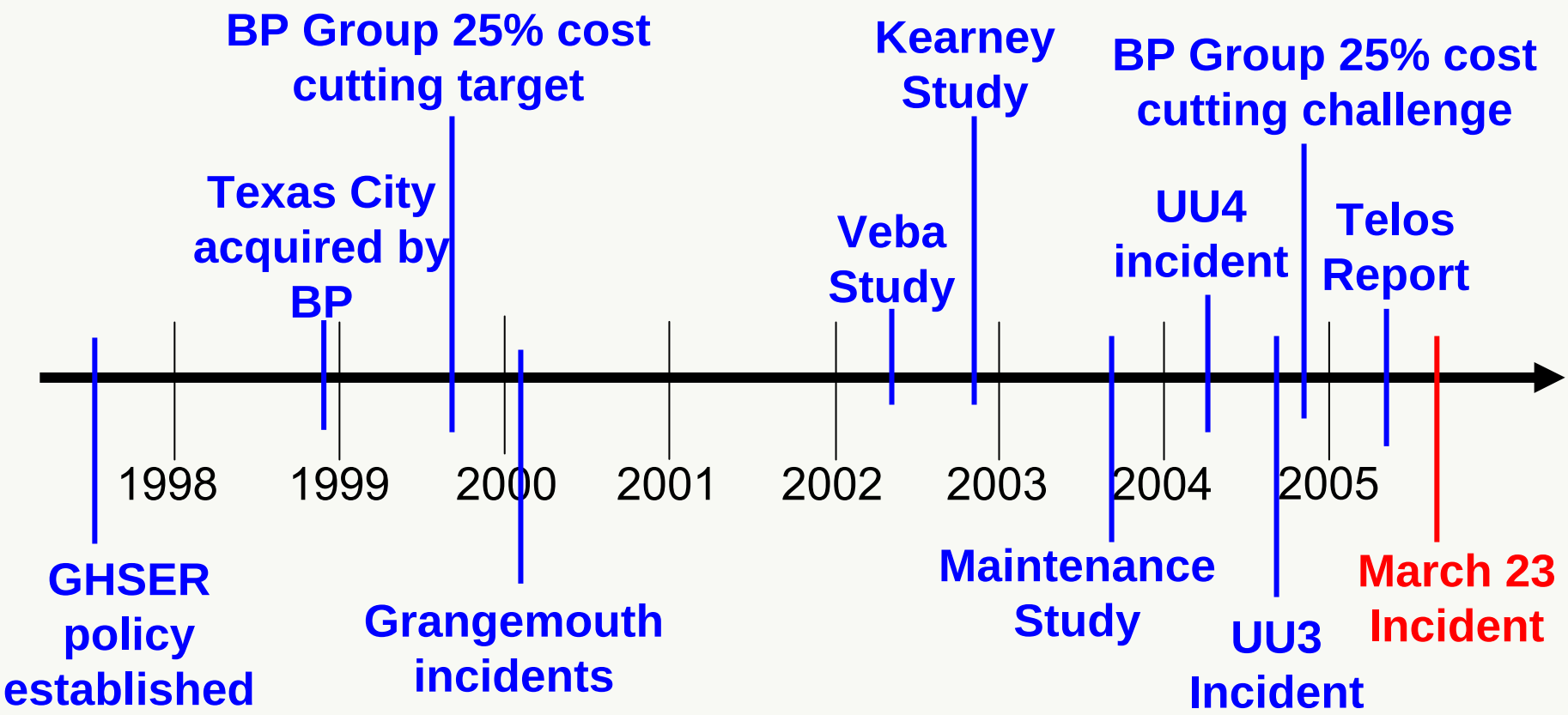
- Causes extended beyond the ISOM unit to actions of people at all levels of the corporation
- Multiple safety system deficiencies were found
- Causes were embedded in the refinery's history and culture – plant history of fatality incidents

Safety culture - History of major accidents

In the previous 30 years, the Texas City site experienced multiple major accidents and 23 fatalities

- In 2004, three fatalities occurred
- From 2004-2005 the refinery experienced four major mechanical integrity-related incidents including two after ISOM incident

Timeline of Key Events



Safety culture - Grangemouth

DAVE HENNIKER

Safety culture - Grangemouth

Lessons were not learned at Texas City refinery

- Need to focus on process safety and develop process safety performance indicators to prevent major accidents
- Corporate Boards have a duty to manage HSE risks to prevent major accidents

Safety culture - Grangemouth

The BP Task Force determined that "cost targets" played a role in the incident

"There was too much emphasis on short term cost reduction reinforced by KPI's in performance contracts, and not enough longer term investment for the future. HSE was unofficially sacrificed to cost reductions, and cost pressures inhibited the staff from asking the right questions; eventually staff stopped asking"

Safety culture – 2002 findings

2002 BP study (Veba):

- Stated its findings were “urgent and far reaching with important implications for the site, including the integrity of the on-going site operations.”
- Warned of “serious concerns about the potential for a major site incident” due to mechanical integrity problems

Safety culture – 2002 findings

- A follow-up study found “the current integrity and reliability issues at TCR are clearly linked to the reduction in maintenance spending over the last decade” (Kearney Report)

- “The prevailing culture at the Texas City refinery was to accept cost reductions without challenge and not to raise concerns when operational integrity was compromised” (Kearney Report)

Safety culture – 2003 findings

- In a refinery maintenance study the ISOM area scored low: “cost cutting measures have intervened with the group’s work to get things right…usually reliability improvements are cut”
- External safety audit found (GHSER) inadequate training, a large number of overdue action items and a concern about “insufficient resources to achieve all commitments”
- “The condition of the infrastructure and assets is poor” (GHSER)

Safety culture – 2004 findings

- Three major incidents and three fatalities at the refinery
- Audits, indicators and losses showed Texas City PSM performance declining

Safety culture – 2004 findings

- BP Group audit found systemic safety problems at 35 business units including Texas City

- Increases in maintenance spending at the refinery were largely reactive in response to equipment failures and incidents such as the UU4 fire

Safety culture – Pre-March 2005 findings

- BP Group Refining executives ordered a 25% reduction "challenge" for the 2005 budget despite recognized mechanical integrity deficiencies at the refinery
- Although the Texas City plant manager objected and partially restored maintenance funds, plant morale was negatively impacted
- 2005 Safety Business plan key risks included mechanical integrity and operator competency, stating "Texas City kills someone in the next 12-18 months"

Safety culture – Pre-March 2005 findings

Telos assessment of Texas City found serious safety culture deficiencies including:

- Serious mechanical integrity hazards led to "an exceptional degree of fear of catastrophic incidents"
- "Production and budget compliance gets … rewarded before anything else" and "pressure for production, time pressure, and understaffing are the major causes of accidents"
- Leadership commitment "is undermined by the lack of resources to address severe hazards"

CSB analysis of safety culture

BP Texas City Managers did not create an effective reporting and learning culture

- Personnel were not encouraged to report safety problems and some feared retaliation for doing so.
- The lessons from incidents and near-misses were often not identified or acted upon.

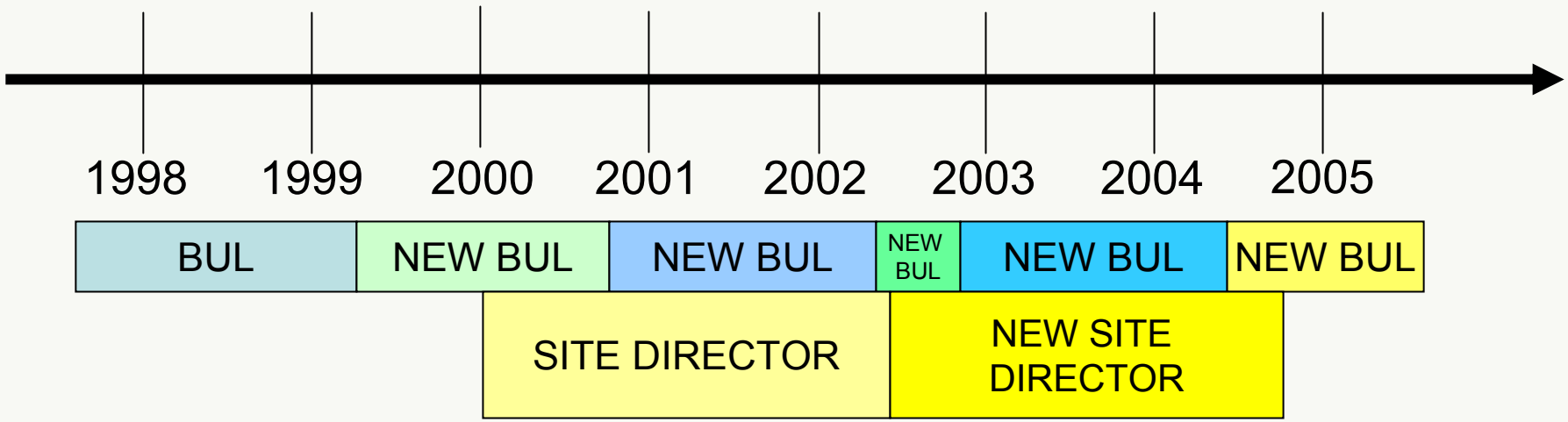
CSB analysis of safety culture

BP Group and Texas City managers did not effectively evaluate the safety implications of major organizational, personnel, or policy changes

- Merger of BP and Amoco led to a lack of focus on process safety
- Texas City site reorganizations reduced organizational stability and the prominence of the PSM function
- Policy changes such as budget cuts and bonus plans revisions eliminating PSM metrics impaired process safety performance

Safety culture analysis

Numerous Leadership Changes at Texas City Site



BUL = Business Unit Leader

CSB analysis of safety culture

BP executives did not effectively control risk of major incidents

- BP primarily paid attention to, measured, and rewarded personal safety
- Reliance on the low personal injury rate at Texas City as a safety indicator failed to provide a true picture of process safety performance
- In response to the reports of safety problems, executives oversimplified the risks and did not address serious hazards

CSB analysis of safety culture

BP Corporate oversight was ineffective

- BP Board of Directors did not effectively monitor and control major accident risk
- BP executives did not effectively responded to reports detailing critical PSM problems

CSB Analysis of Safety Culture

BP Corporate oversight was ineffective (cont.)

- BP executives made spending cuts without assessing the safety impact of those decisions
- Audits and studies showed that spending cuts and production pressures impaired process safety performance in areas such as mechanical integrity and training
- The response to those identified deficiencies was neither timely nor sufficient

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OSHA Process Safety Regulation and Enforcement

OSHA enforcement history at Texas City site

- There were 10 incidents resulting in 10 deaths in prior 20 years; four fatalities since 2001
- These inspections resulted in $270,255 in proposed fines; $77,860 was paid in negotiated settlements
- One planned PSM inspection in 1998

OSHA enforcement history at Texas City

- In 1992, OSHA cited and fined Amoco on the hazardous design of a similar blowdown drum and stack at the Texas City refinery
- In a settlement agreement, OSHA withdrew the citation and the fine when Amoco stated the blowdown conformed to industry safety standards (API 521)
- The refinery continued to use blowdown drums without flares

OSHA PSM enforcement

- The OSHA PSM Standard is designed to prevent catastrophic releases of hazardous chemicals
- PSM regulatory history emphasizes the importance of a specialized inspection for low frequency but high consequence accidents
- PSM enforcement program commits OSHA to conduct planned comprehensive inspections of facilities with an accident history

OSHA PSM Enforcement

- The “primary enforcement model” of the PSM standard is the Program Quality Verification (PQV) inspection, which intended to be
  - “Highly resource intensive” and last from weeks to months
  - Conducted by a “select, well-trained” and experienced team

OSHA PSM Enforcement

- The ten OSHA Regions each are directed to submit five candidate facilities each from eight targeted industry sectors, which included oil refining, with the greatest number of accidents

PQV Inspections 1995 – March 2005
(10-year Cumulative Totals)

	Number of Facilities	Federal Planned	Federal Unplanned	State Planned	State Unplanned
Total for all 8 sectors	**2,816**	**9**	**77**	**48**	**29**
Refining	**203**	**0**	**21**	**6**	**11**

Sources: U.S. Census Bureau, 2002 Economic Census and OSHA Integrated Management Information System (IMIS) inspections within industry

OSHA PSM Standard – Management of Change (MOC)

- OSHA requires MOC reviews for changes to chemicals, technology, equipment, facilities, and procedures
- In contrast, industry safety guidelines additionally recommend that MOC requirements apply to changes to organization, personnel or policy, but OSHA's PSM standard does not
- Failure to review the safety implications of these types of changes was causal to the incident

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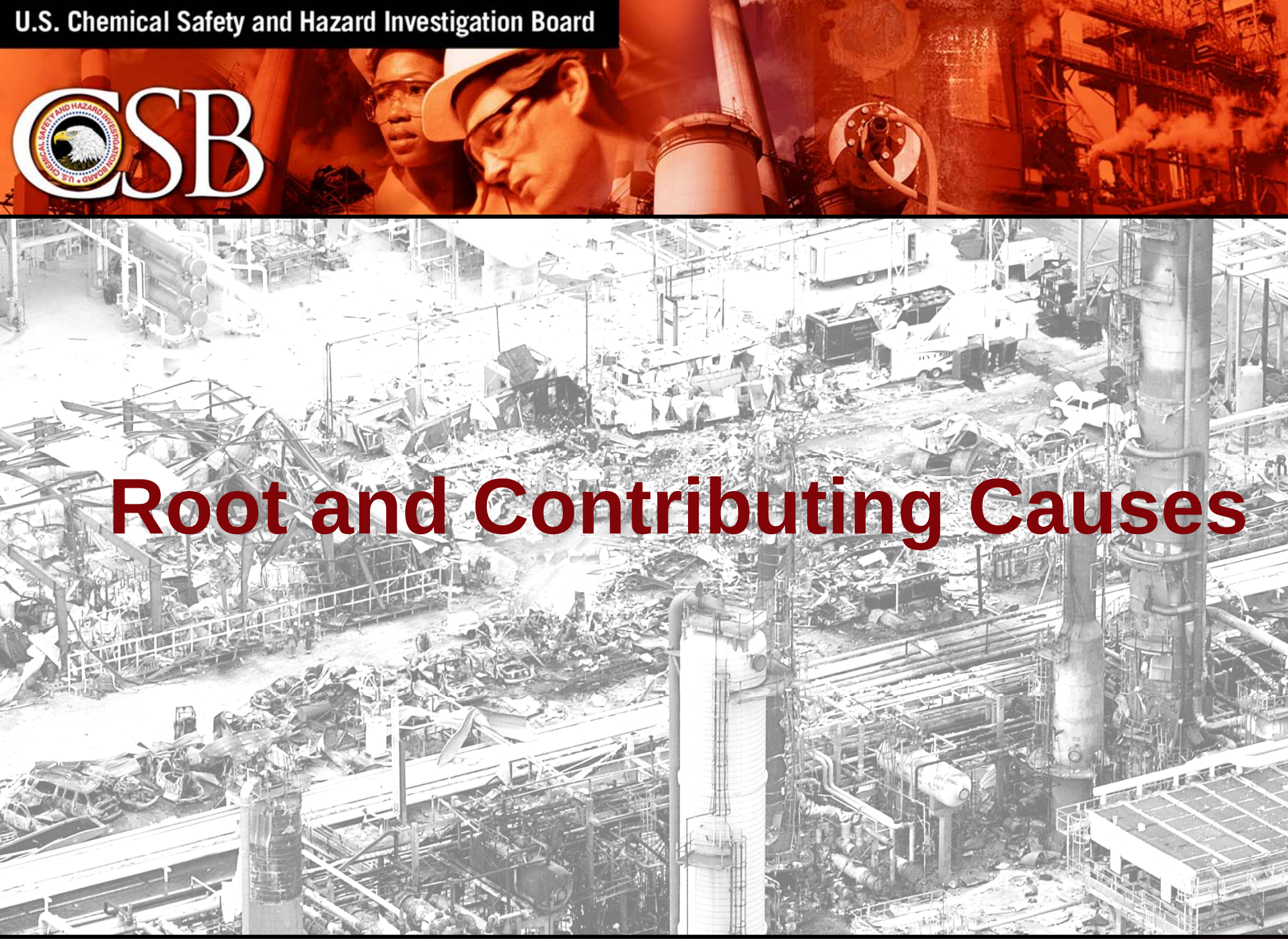

Root and Contributing Causes

Root causes

BP Board did not provide effective oversight of major accident prevention

BP Senior executives:

- Focused, measured and rewarded mostly personal safety performance, but not process safety
- did not provide adequate resources to prevent major accidents
- did not ensure a safety review of organizational, personnel , or policy changes

Root causes

BP Texas City Managers did not:

- create an effective reporting and learning culture
- follow and enforce up-to-date procedures
- incorporate good practice equipment design
- effectively incorporate human factors into their process safety programs

Contributing Causes

Texas City Managers:

- lacked an effective mechanical integrity program
- did not have an effective policy to control vehicle traffic near hazardous process areas
- did not effectively implement their Pre-Startup Safety Review policy to remove nonessential personnel during startup
- policy for siting trailers was not sufficiently protective of trailer occupants

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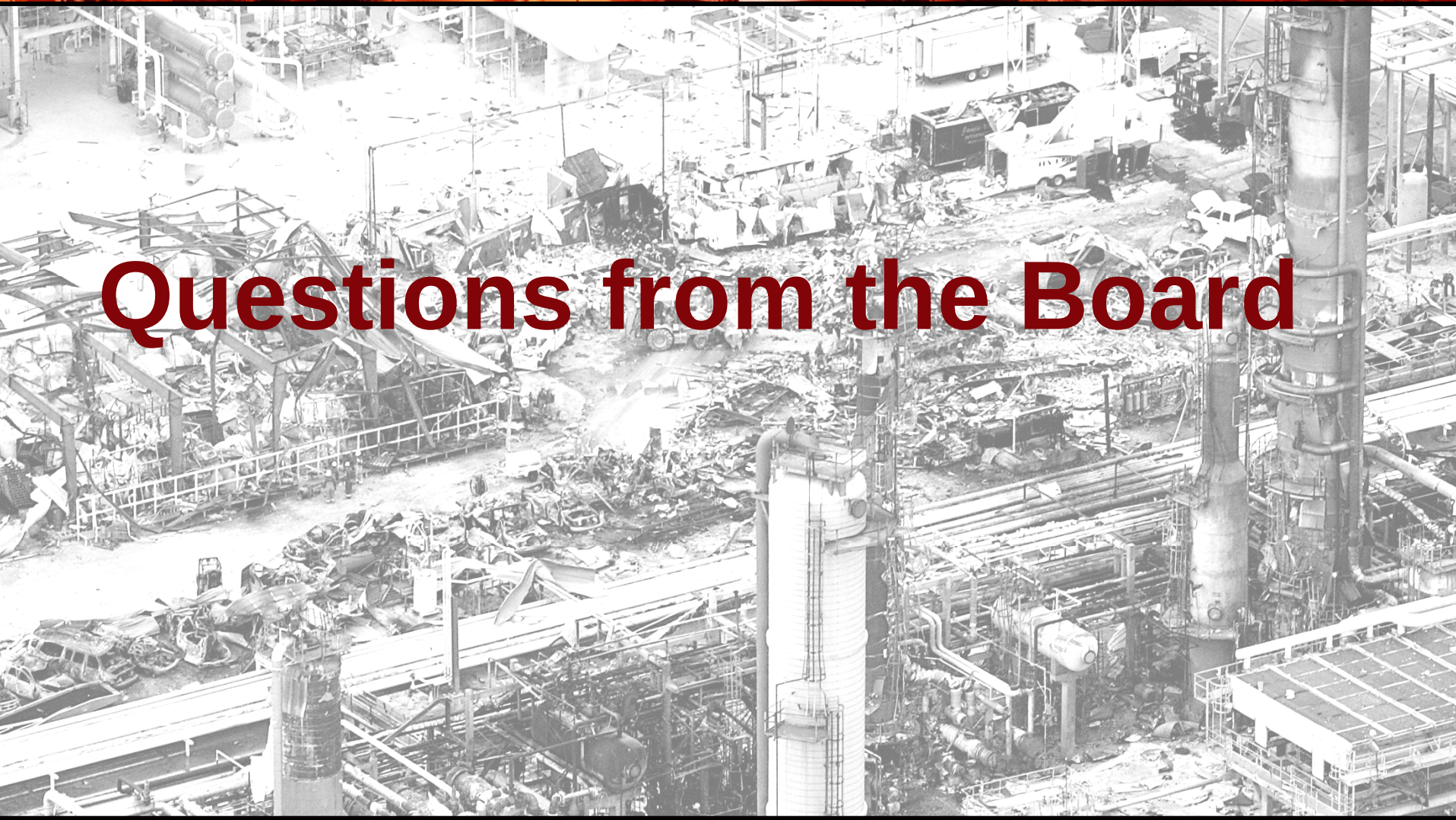
Questions from the Board



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Recommendations

Recommendations

American Petroleum Institute and United Steelworkers Union

- Create two new consensus standards for the refining and petrochemical industries
  - Performance indicators for process safety
  - Fatigue prevention guidelines

Recommendations

OSHA

- Strengthen enforcement of the planned comprehensive PSM inspections

Recommendations

OSHA

- Amend the Process Safety Management Standard to require a Management of Change (MOC) safety review for organizational, personnel and policy changes

Recommendations

Center for Chemical Process Safety

- Issue guidelines for the safe management of major organizational, personnel, and policy changes

Recommendations

BP Board of Directors

- Appoint an additional non-executive member of the Board of Directors with expertise in refining operations and process safety
- Ensure and monitor
  - an incident investigation program at all of your refineries
  - the use of leading and lagging indicators at all of your refineries

Recommendations

BP Texas City

- Evaluate all process units to ensure critical process equipment is designed safely
  - Multiple level indicators, automatic controls, clear indication of material balance on process control systems
- Ensure all instrumentation and process equipment necessary for safe operation is maintained and tested

Recommendations

BP Texas City and United Steelworkers

- Work together to establish a joint program that allows for reporting and learning from incidents, near misses, process upsets, and hazardous conditions without fear of retaliation

Recommendations

BP Texas City

- Improve training with face-to-face instruction and simulation technology
- Require additional board operator staffing during times of startup, shutdown, and abnormal conditions
- Ensure that all procedures are updated and reflect actual process conditions
- Require knowledgeable supervisors or other technically trained personnel be present during hazardous operation phases, such as unit startup

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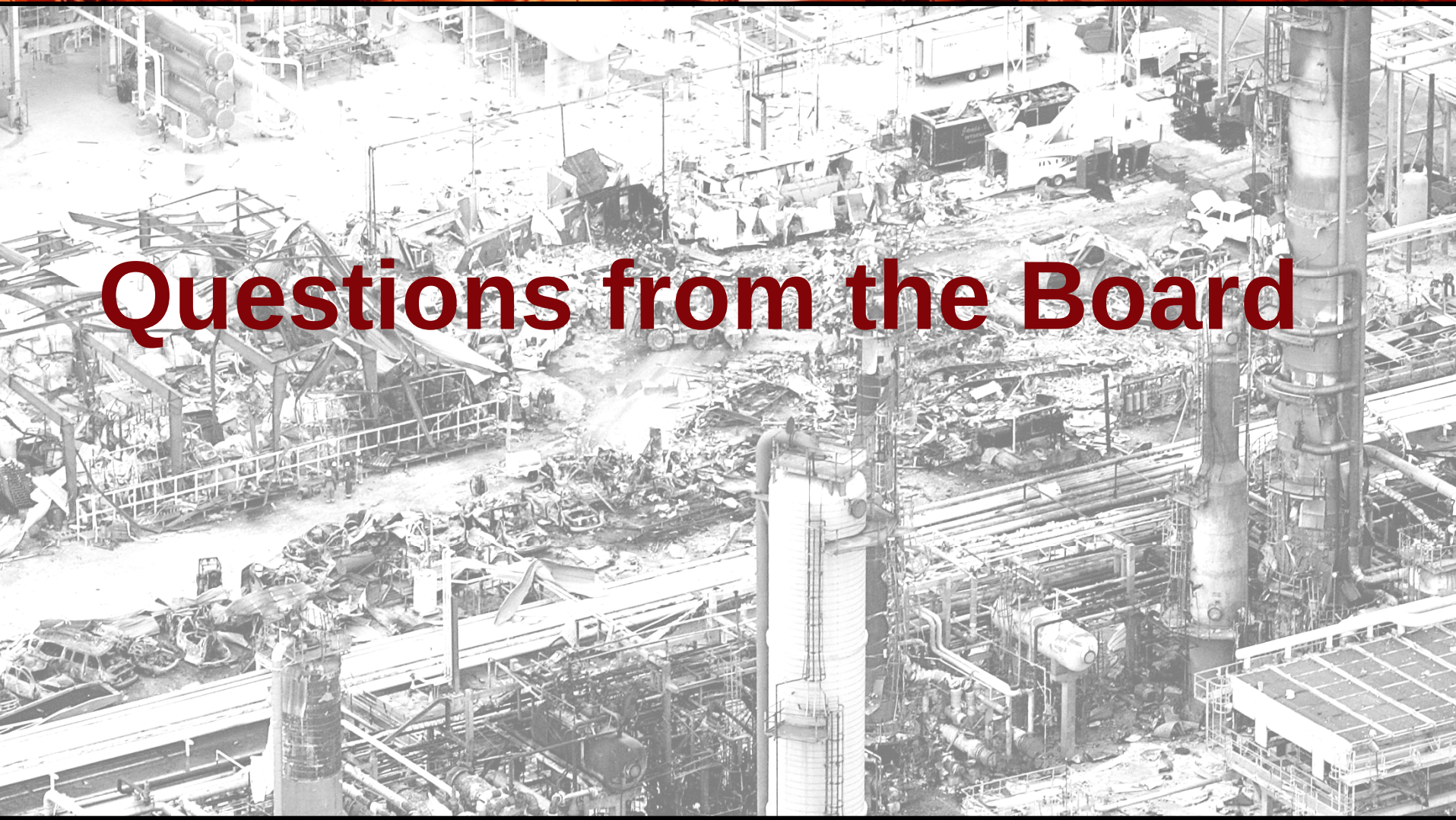
Questions from the Board



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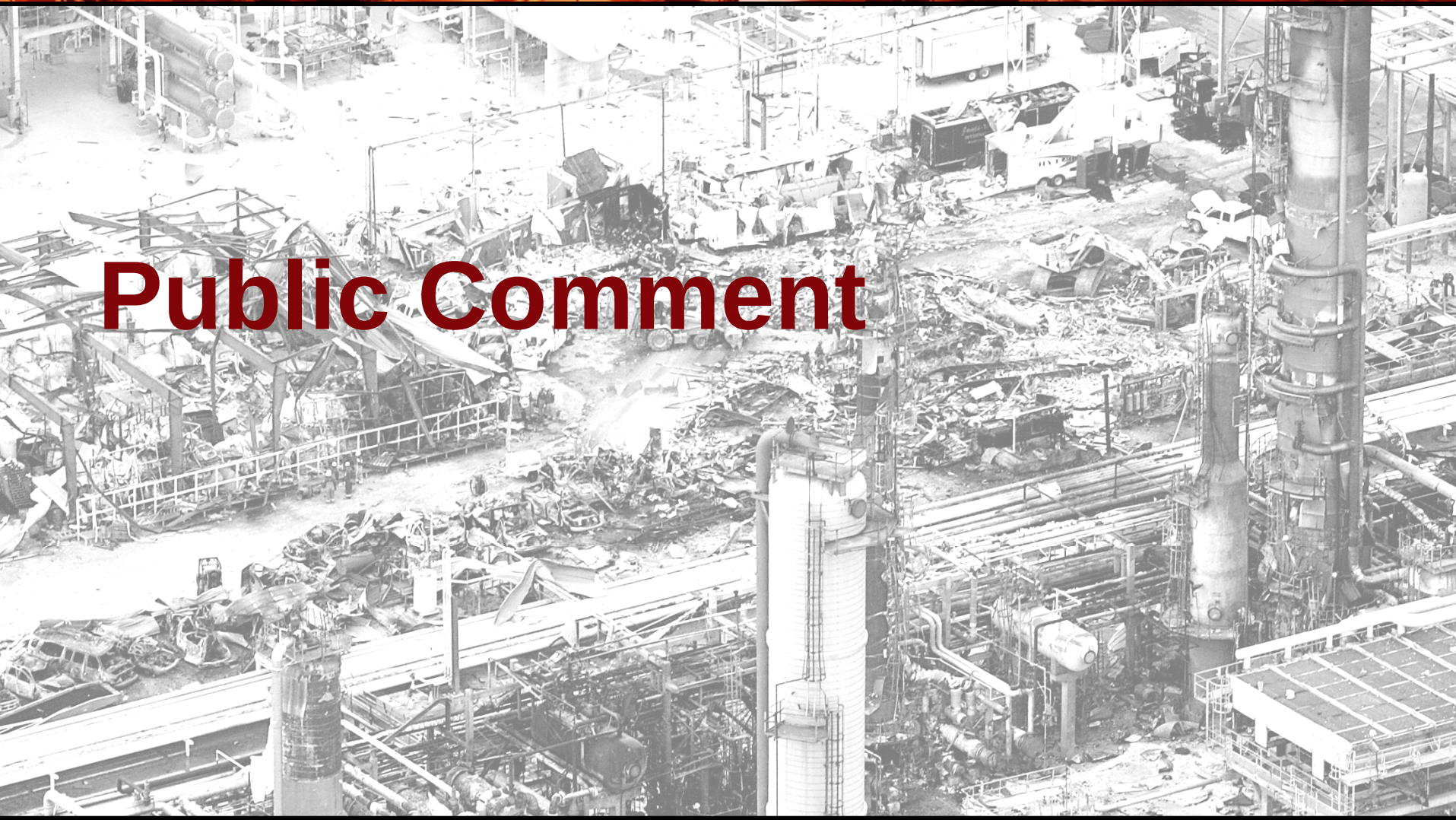

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Board Discussion

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