U.S. Chemical Safety and Hazard Investigation Board

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January 26, 2023

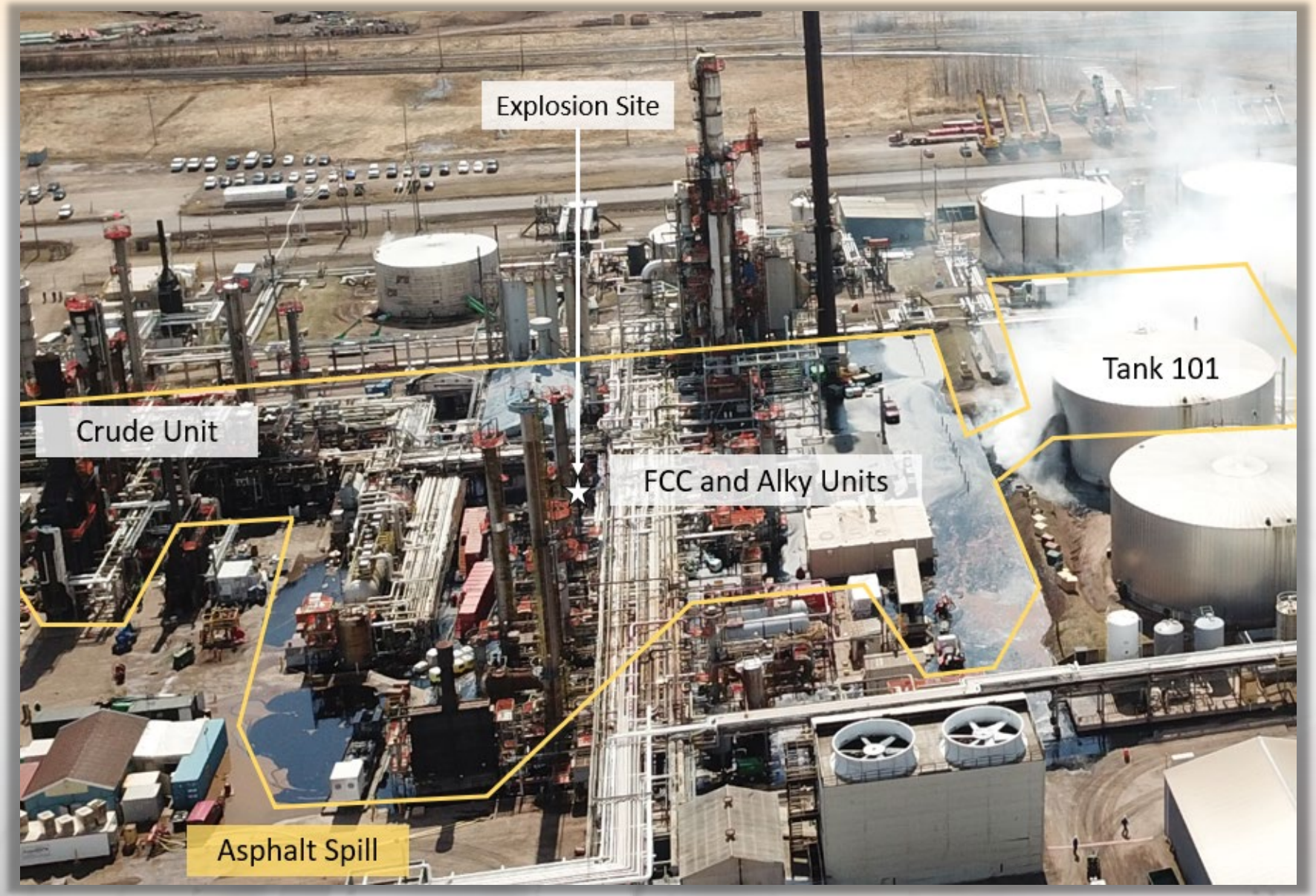
FCC Unit Explosion and Asphalt Fire at Husky Superior Refinery

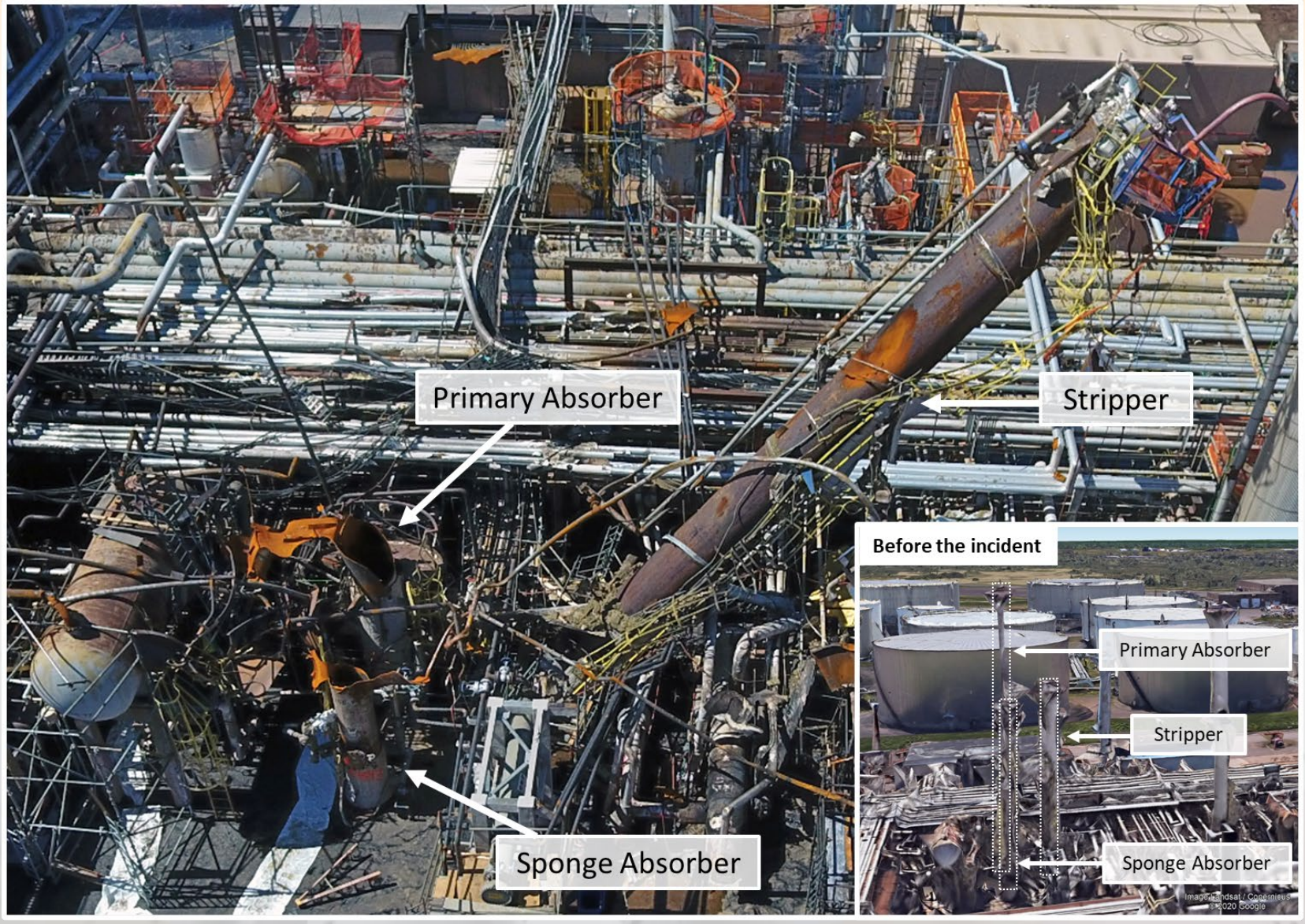
Incident Summary

- April 26, 2018
- Operators were shutting down the fluid catalytic cracking (FCC) unit for a planned turnaround
- Two vessels exploded around 10:00 a.m.
  - Explosion debris struck asphalt storage tank
  - HF near-miss
- Asphalt fire around 12:00 p.m.
  - Evacuation lifted at 6:00 a.m. the next morning

- Consequences:
  - 36 injuries (including 11 OSHA recordable injuries); no fatalities
  - 39,000 pounds of flammable hydrocarbon vapor mixture released
  - $550 million property damage

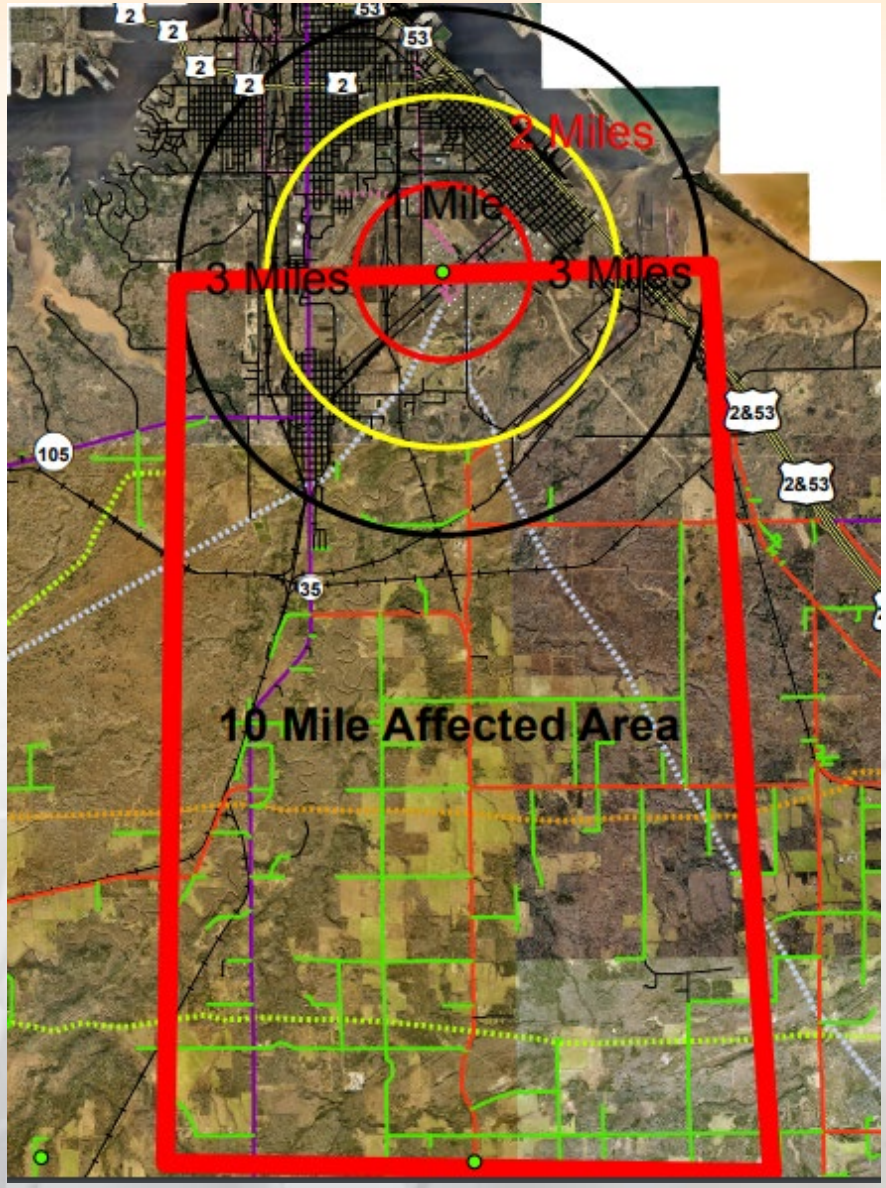
Source: WDIO ABC News


Explosion Site
Tank 101
Crude Unit
FCC and Alky Units
Asphalt Spill


Primary Absorber
Stripper
Sponge Absorber
Before the incident
Primary Absorber
Stripper
Sponge Absorber
Image Landsat / Copernicus
© 2020 Google

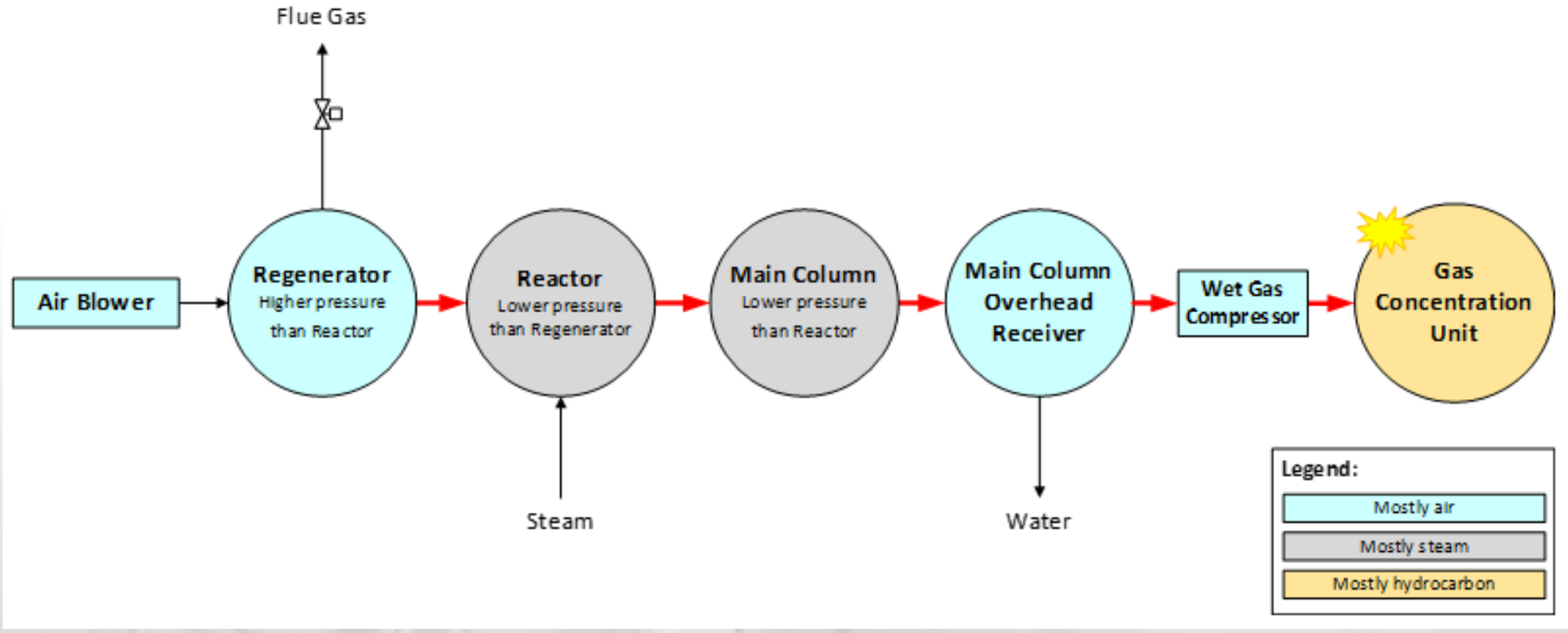

4X4

Source: WDIO ABC News



Source: Douglas County, Wisconsin

Cause


Flue Gas
Air Blower
Regenerator
Higher pressure than Reactor
Reactor
Lower pressure than Regenerator
Main Column
Lower pressure than Reactor
Main Column Overhead Receiver
Wet Gas Compressor
Gas Concentration Unit
Steam
Water
Legend:
Mostly air
Mostly steam
Mostly hydrocarbon

Safety Issues

1. Transient Operation Safeguards
2. Process Knowledge
3. Process Safety Management Systems
4. Industry Knowledge and Guidance
5. Brittle Fracture During Extreme Events
6. Emergency Preparedness

Safety Issue #1: Transient Operation Safeguards

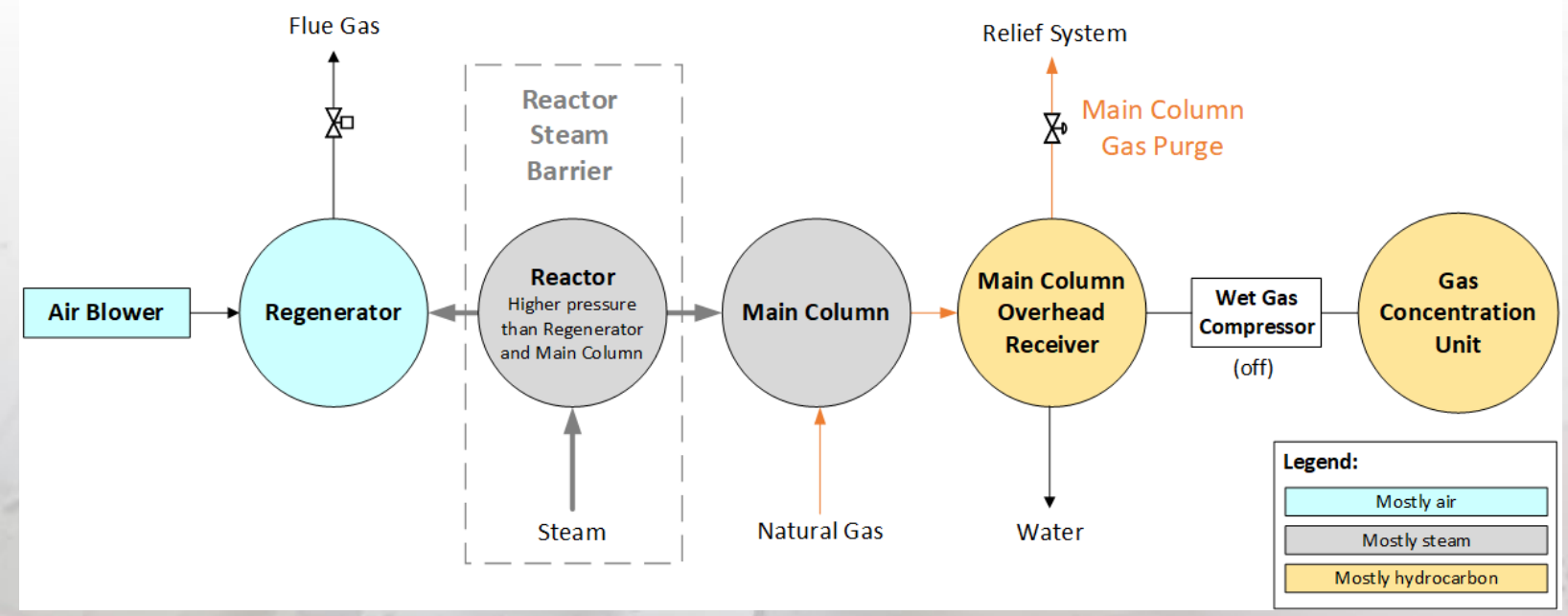
Transient Operation:
The operating mode when the process is in transition and is not in its normal operations mode.

Examples:
Startup, shutdown, standby, emergency, procedure-based operations

Safety Issue #1: Transient Operation Safeguards

During the FCC unit shutdown, the refinery's transient operation safeguards were either not implemented or not effective:

- Refinery did not implement a reactor steam barrier
- Refinery did not implement a main column gas purge
- Refinery only relied on slide valves for protection



Safety Issue #2: Process Knowledge

Refinery's FCC technology knowledge was not sufficient to safely shut down the FCC unit:

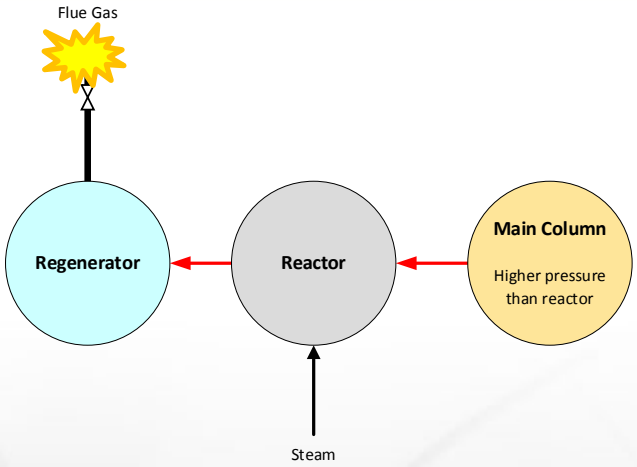
- Refinery's FCC expertise mainly in-house, with minimal engagement with other refineries
- Shutdown procedure had not been technically evaluated for at least 25 years prior to the incident
- Outside expert evaluations were limited to assessing the FCC unit's normal operation
- FCC shutdown procedure contradicted licensor guidance

Safety Issue #3: Process Safety Management Systems

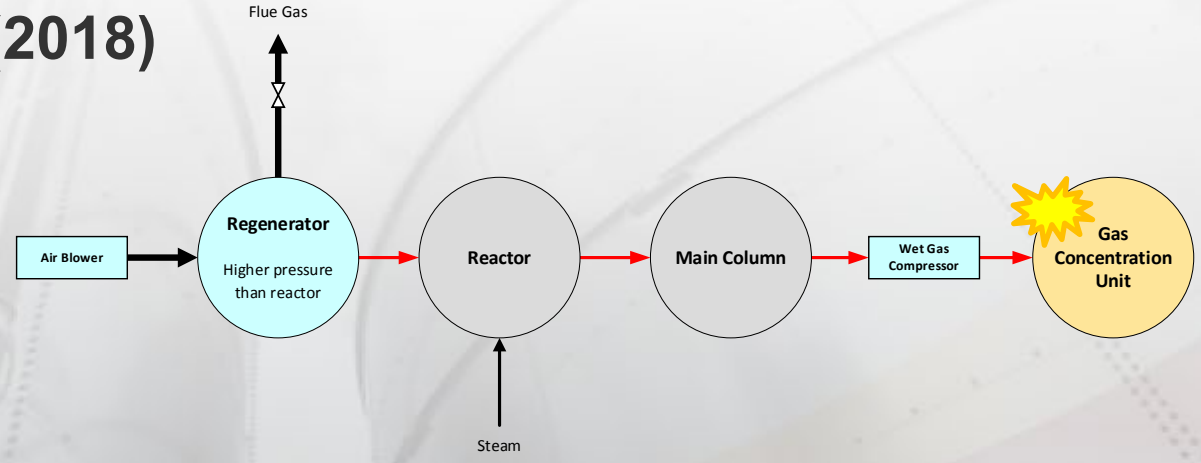
- **Process safety information (PSI)**
  - Licensor's operating manual not incorporated into PSI
- **Operating procedures**
  - Procedures did not have clear instructions, safe operating limits, consequences of deviation
  - Refinery did not identify that venting changes to FCC unit shutdown procedure increased risk of oxygen accumulation inside equipment
- **Process hazard analysis (PHA)**
  - PHA method did not identify some transient operation hazards
- **Operator training**
  - Training program did not prepare operators to safely shut down the FCC unit
  - No hands-on training opportunities (e.g. simulators)

Safety Issue #4: Industry Knowledge and Guidance

- Torrance (2015)



- Superior (2018)



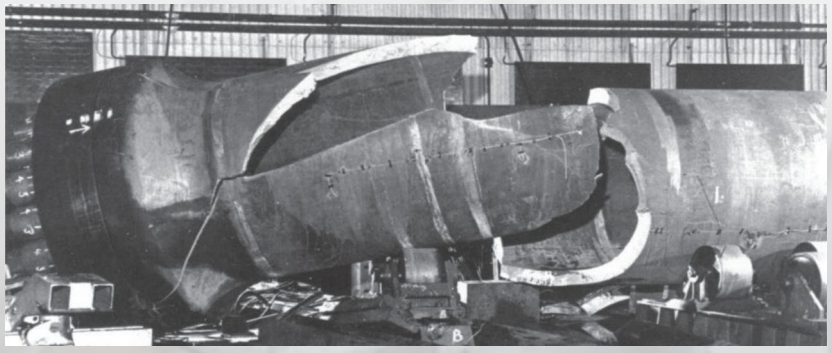
Safety Issue #4: Industry Knowledge and Guidance

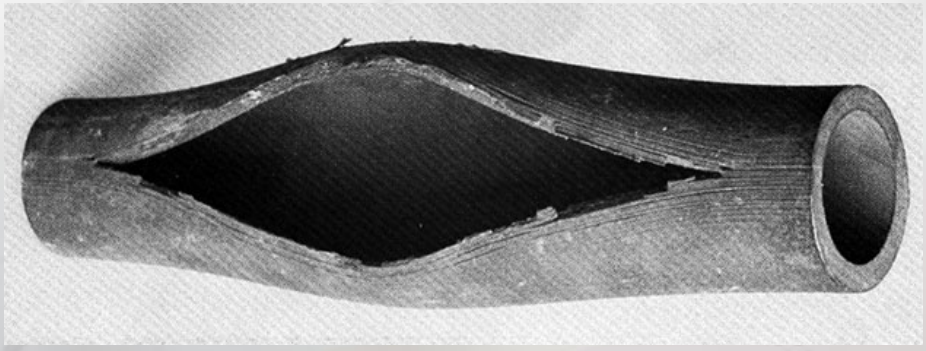
- Husky Superior Refinery knew about the Torrance incident, but workers did not recognize that inadvertent flow in the reverse direction was also possible
- Similar knowledge gaps may exist at other U.S. refineries
- Many different FCC unit designs exist through multiple technology licensors
- Currently, there is no industry publication that establishes common basic process safety expectations for all FCC units

Safety Issue #5: Brittle Fracture During Extreme Events

- The primary and sponge absorber failed by brittle fracture (like breaking glass)
- Newer grades of steels more likely to fail by ductile fracture (fish mouth)
- A-212 and A-201 grade steels no longer recommended

Examples of brittle fracture (left) and ductile fracture (right) – *Not from this investigation*





Source: The Royal Society Publishing (left), Babcock & Wilcox (right)

Safety Issue #6: Emergency Preparedness

- Asphalt storage tank was punctured on its side (not typically considered during design)
- Hot asphalt was stored above its flash point and ignitable when it spilled
- Likely ignition source: pyrophoric material smoldering inside tank when exposed to oxygen

Source: CSB (left), Duluth News Tribune (right)

Key Recommendations

- **Cenovus Energy:**
  - Numerous recommendations for Superior Refinery FCC unit rebuild and future operation
  - Develop an FCC PHA guidance document for use at all Cenovus-operated refineries
  - Develop and implement a technology-specific knowledge-sharing network program across all Cenovus-operated refineries, which at a minimum includes an FCC technology peer network

- **U.S. Occupational Safety and Health Administration (OSHA):**

Develop guidance for performing process hazard analysis on operating procedures to address transient operation hazards.

Key Recommendations (cont.)

- **Environmental Protection Agency (EPA):**

Develop a program that prioritizes and emphasizes inspections of FCC units in refineries that operate HF alkylation units. As part of this program, verify FCC unit safeguards that prevent explosions during transient operation.

- **American Petroleum Institute (API):**

Develop a publicly available technical publication for the safe operation of fluid catalytic cracking (FCC) units. The document should be applicable to both new and existing units.

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