CSB Presentation

CSB Investigation of the Tesoro Anacortes Refinery Heat Exchanger Rupture and Fire

Anacortes, Washington

January 30, 2014
INVESTIGATION REPORT

CATASTROPHIC RUPTURE OF HEAT EXCHANGER
(SEVEN FATALITIES)

TESORO ANACORTES REFINERY
ANACORTES, WASHINGTON
APRIL 2, 2010

KEY ISSUES

- INHERENTLY SAFER DESIGN
- TESORO PROCESS SAFETY CULTURE
- CONTROL OF NONROUTINE WORK
- MECHANICAL INTEGRITY INDUSTRY STANDARD DEFICIENCIES
- REGULATORY OVERSIGHT OF PETROLEUM REFINERIES

REPORT 2010-08-1-WA
JANUARY 2014
Tesoro Anacortes Refinery Investigation

Speakers:

Dan Tillema – Lead Investigator
Don Holmstrom – Director – Western Regional Office
Tesoro Investigation Presentation Proceedings

- Video Animation of April 2, 2010 Incident
- Key Investigation Findings
  - Technical Findings
  - Organizational Findings
  - Regulatory Findings
- Proposed Recommendations
- Public Comment Period
Video Animation of Incident
Technical Findings
NHT Heat Exchangers

- Exchanger A
- Exchanger B
- Exchanger C
- Exchanger D
- Exchanger E
- Exchanger F

- Furnace: Temperature = 625°F
- Reactor: Temperature = 270°F
- Impurities removed from naphtha

- Combined Naphtha and Hydrogen Feed

- Temperature = 130°F
- Pressure = 640 psig

- Temperature = 550°F
- Pressure = 630 psig

- Temperature = 630°F - 710°F
- Pressure = 590 psig
Construction Details of the Failed “E” and Exemplar “B” Exchangers

Diagram showing the construction details of the failed exchangers. The diagram illustrates the flow of hot and cooled reactor effluent through different sections of the exchangers, highlighting areas with non-post weld heat treated longitudinal and circumferential welds.
Magnified sample of steel containing HTHA
Locations of HTHA in B and E Heat Exchangers

E (failed) heat exchanger

- HTHA identified near welds
- (Carbon Steel clad with 1/8" Stainless Steel)

B (exemplar) heat exchanger

- HTHA identified near welds
- 48" long, 0.3" deep crack connected to ID
- 30" internal crack
- (Carbon Steel clad with 1/8" Stainless Steel)
Tesoro Did Not Identify the Potential for HTHA Damage
Industry’s HTHA Resource: API RP 941

- API RP 941 used by refiners worldwide for management of HTHA
- A graph within the standard, the Nelson Curves, is used to predict HTHA
- Location of Nelson curves is based upon industry experience
B/E Heat Exchanger Shell Design Process Conditions Were Below Nelson Curve

Carbon steel Nelson curve

NHT B/E exchanger shell inlet and outlet process design conditions used to determine HTHA susceptibility
No Temperature Measurement Between Exchangers
Estimated operating range of the stainless steel clad portion of the carbon steel NHT B/E heat exchangers.

Carbon steel Nelson curve

Tesorö’s Design Inlet Temperature

CAN 1 (Carbon Steel) CAN 2 (Carbon Steel) CAN 3 (Carbon Steel) CAN 4 (Carbon Steel clad with 1/8" Stainless Steel)
HTHA Occurred Below the Carbon Steel Nelson Curve

Estimated operating range at region of hottest HTHA in the B/E exchangers

Carbon steel Nelson curve

(Carbon Steel clad with 1/8" Stainless Steel)
HTHA Occurred Below the Carbon Steel Nelson Curve

Estimated operating range at region of coldest HTHA in the E exchanger

Carbon steel Nelson curve

(Carbon Steel)

(Carbon Steel clad with 1/8" Stainless Steel)
The current carbon steel Nelson curve is not reliable
Tesoro Organizational Deficiencies
Tesoro Accepted and Normalized Exchanger Leaks

- NHT heat exchangers typically leaked during startup
  - Attempts to fix leaks were unsuccessful
  - Operation techniques developed to minimize leak time
  - Steam lances often used to disperse flammable vapors
Tesoro Failed to Control Exchanger Startup Hazards

- Tesoro relied on additional staffing for heat exchanger startup, and:
  - Did not assess risks associated with the additional personnel
  - Did not conduct MOC to consider risks of organizational changes

- PHAs, NHT unit procedure reviews, and organizational MOOCs did not identify increased risk to workers
Tesoro’s PHAs Failed to Reduce Consequences of Incident

PHA cited unidentifiable administrative controls to reduce personnel hazards during startup
Tesoro’s PHAs Failed to Prevent Incident

Damage Mechanism Hazard Reviews used inaccurate data
Estimated operating range of the stainless steel clad portion of the carbon steel NHT B/E heat exchangers.
Industry Codes and Standards Deficiencies
API 941 – Industry’s HTHA Resource

- Contains no minimum requirements to prevent HTHA
- Does not require inherently safer design where feasible
- Does not require verification of operating conditions
- API 941 relies on voluntary submittals
  - Difficult to verify quality of submissions
  - Not all incidents are reported (Tesoro did not report failure to API)
API 941 – Industry’s HTHA Resource

HTHA has been found to have occurred below the carbon steel Nelson curve in at least 8 other refinery incidents.
CSB Proposes New Location for Carbon Steel Nelson Curve

Operating ranges of the hottest (purple) and coldest (green) regions where HTHA was identified in the heat exchangers

CSB to recommend this new location of the carbon steel Nelson curve
Regulatory System Deficiencies
Washington’s PSM Program

- Washington regulatory regime:
  - relies on a framework that is primarily activity-based without a risk reduction target;
  - does not effectively involve the workforce in hazard analysis and prevention of major accidents; and
  - does not employ a sufficient number of staff members with the technical expertise needed to provide sufficient oversight of petroleum refineries.
Safety Case Regulatory Regime

- Independent, Competent, Well-Funded Regulator
- Duty Holder Safety Responsibility
- Continuous Risk Reduction to ALARP
- Regulatory Assessment, Verification, and Intervention
- Adaptability and Continuous Improvement
-Process Safety Indicators that Drive Performance
-Active Workforce Participation
EPA Risk Management Program

Inherently Safer Design is essential for ensuring chemical process safety is achieved.

EPA has the authority to require facilities to use inherently safer design where feasible, but currently does not do so.
Delivery of Proposed Recommendations
Proposed Recommendations

To the U.S. Environmental Protection Agency:

Revise the Chemical Accident Prevention Provisions under 40 CFR Part 68 to require the documented use of inherently safer systems analysis and the hierarchy of controls to the greatest extent feasible in establishing safeguards for identified process hazards. Until this revision is in effect, develop guidance and enforce the use of inherently safer systems analysis and the hierarchy of controls to the greatest extent feasible in establishing safeguards for identified process hazards through the Clean Air Act’s General Duty Clause.
Proposed Recommendations

To the Washington State Legislature, Governor of Washington:

Develop and implement a step-by-step plan to supplement the existing process safety management regulatory framework with the more rigorous safety management principles of the “safety case” for petroleum refineries in the state of Washington.
Proposed Recommendations

To the Washington State Division of Occupational Safety and Health – Labor and Industries:

Perform verifications at all Washington petroleum refineries to ensure prevention of equipment failure because of HTHA and that effective programs are in place to manage hazardous nonroutine work. In addition, provide oversight of the process safety culture program at the Tesoro Anacortes Refinery.
Proposed Recommendations

To the American Petroleum Institute

Revise API RP 941 and API RP 581 to prohibit the use of carbon steel equipment in HTHA-susceptible service and require verification of actual operating conditions. Make additional revisions to API RP 941 to establish minimum requirements to prevent HTHA failures and to require the use of inherently safer design.
Proposed Recommendations

To the Tesoro Refining & Marketing Company LLC:

Participate with API in the API RP 941 revisions to establish minimum requirements to prevent HTHA failures and to require the use of inherently safer design. Following the API RP 941 revisions, develop and implement a plan to meet the new API RP 941 requirements. Improve process safety management programs for damage mechanism hazards to require the hierarchy of controls and the use of inherently safer design.
Proposed Recommendations

To the Tesoro Anacortes Refinery:

Implement a process safety culture program that will assess and continually improve any identified process safety culture issues at the Tesoro Anacortes Refinery.
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