PHMSA Pipeline Safety Research and Development Forum

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Challenges In the Assessment of Low Temperature Equipment

1. New vs Existing Facilities/Equipment
2. Design Basis vs Upset Conditions or Excursion
3. Minimum Design Metal Temperature
4. Material Properties
5. Insulation & Heat Transfer

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New vs Existing Facilities/Equipment

New Fabrication
- API 620
- API 625
- ASCE 7
- ASME BPVC
- ASME B31.3

Existing Equipment
- API 510
- API 570
- API 653
- API 579-1/ASME FFS-1
- ASME PCC-1
- ASME PCC-2

Post Construction Codes

As stated in paragraph 1.1.1 of API 579-1/ASME FFS-1 2016; “The ASME and API new construction codes and standards for pressurized equipment provide rules for the design, fabrication, inspection and testing of new pressure vessels, piping systems, and storage tanks. These codes typically do not provide rules to evaluate equipment that degrades while in-service and deficiencies caused by degradation or from original fabrication that may be found during subsequent inspections. API 51 … alt … ge tar …

“API 510, API 570, API 653, and NB-23 Codes/Standards for the inspection, repair, alteration, and rerating of in-service pressure vessels, piping systems, and storage tanks do address the fact that equipment degrades while in service.”

New vs Existing Facilities/Equipment

Current 49 CFR 193.2013

- API 620 11th Edition
- ASCE 7-2005
- ASME BPVC Sect. VIII Div. 1 2007
- NFPA 59A (2001)
- NFPA 59A (2006)

Current Editions

- API 620 12th Edition
  Addendum 1 – 2014, 2 – 2018
- ASCE 7-2016
- ASME BPVC Sect. VIII Div. 1 2019
- NFPA 59A 2019

PHMSA FAQ – July 25, 2017

D1. What wind speed should be used in LNG facility equipment design calculations?

Wind forces are addressed in 49 CFR § 193.2067, which requires that LNG facilities be designed to withstand the direct effect of wind forces without loss of structural or functional integrity. Structural engineering design is typically performed using 3-second gust wind speeds in miles-per-hour (mph).

For shop fabricated containers of LNG or other hazardous fluids with a capacity of not more than 70,000 gallons, the wind forces at the location of the specific facility must be based on applicable wind load data in ASCE/SEI 7-05.

PHMSA FAQ – July 25, 2017

D5. As an operator of a LNG Facility, our pressure vessels will be designed and fabricated to the current American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code (BPVC). This differs from the requirements of 49 C.F.R. Part 193. How can I ensure our pressure vessels comply with Part 193?

To comply with the requirements of 49 C.F.R. Part 193, each applicant for a LNG facility designed after March 10, 2004, must do one of the following:

- Ensure compliance with NFPA 59A-2001, Paragraph 3.4.2, using the 1992 ASME BPVC; or,
- Submit an application for a special permit in accordance with 49 C.F.R. § 190.341; or, Demonstrate an equivalent level of safety as described in NFPA 59A-2001, Section 1.2.

Major Design Margin Changes in Codes and Method Change in Standards

Consideration should be given to specifying the latest edition of relevant codes and standards instead of a specific edition:

- Code fabricators are prohibited as stamp holders to manufacturing to past editions. They MUST utilize the latest edition to account for:
  - Advances in analysis approaches
  - Corrections should they be necessary
  - Latest information such as wind speed increases, lowest 1-day mean temperatures, seismic data, etc. which may not be accounted for in older/out of date editions.

Major Design Margin Changes in Codes and Method Change in Standards

Codes – Design Margin Changes

- ASME BPVC VIII-1 1999 Edition
  - Margin from 4:1 to 3.5:1
  - Revised allowable stresses
- ASME BPVC VIII-2 2007 Edition
  - Margin from 3:1 to 2.4:1

Standard

- ASCE 7-2010
  - Wind speeds based on Load Resistant Factor Design (LRFD)
  - Loading from higher tabulated wind speeds applied differently

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Design Basis vs Upset Conditions or Excursion

Normal to High Temperature

- Design based on material strength at expected temperature
- Temperature typically process induced
- Offsets or margins between operating and design conditions are generally adequate with normal operation controls

Low Temperature

- Material strength typically not reduced at lower temperatures
- Brittle Fracture major concern
- Offsets or margins between operating and designs conditions are more complicated to address upsets that have the potential for auto-refrigeration and brittle fracture (ARBF)

Examples of Transient Process Excursions

King[1] presented 9 examples of excursions causing a critical exposure temperature (CET) below the minimum allowable temperature (MAT) based on the design basis of the specific equipment:

1. Pressure Vessel, Loss of Pressure ARBF
2. Chilling Train Vessels, Loss of Gas Compression or Flaring Event

   Sometimes Referred to as "Cold Spin"
3. Distillation Tower and Peripherals, Upset Conditions
4. Bimetallic (Overhead & Bottoms) Loss of Vapor Flow
5. Presence of Nitrogen Gas in Equipment, Lowing the Partial Pressure for the Hydrocarbon Process Gas
6. Compressor Suction Drums, "Settling Out" Pressure after Compressor Stops
7. Compress Discharge Drums, Rapid Pressure Increase after Compressor Starts
8. Loss of Heat Input, from Failure of Other Equipment
9. Overflow/Transport of Liquid, Multiple Chain-of-Event Failures

[1]King, R.E., "Auto-Refrigeration/Brittle Fracture Analysis of Existing Olefins Plants – Translation of Lessons Learned to Other Processes", Journal of Hazardous Materials 142, 2007, pp 608-617

9 Examples of Transient Process Excursions

1. Pressure Vessel, Loss of Pressure ARBF

   Material Selection
2. Chilling Train Vessels, Loss of Gas Compression or Flaring Event

   Material Selection and/or Protective Interlocks
3. Distillation Tower and Peripherals, Upset Conditions

   Operator Training, Controls, and Interlocks
4. Bimetallic (Overhead & Bottoms) Loss of Vapor Flow

   Vessel Internals, Controls, and Interlocks
5. Presence of Nitrogen Gas in Equipment, Lowing the Partial Pressure for the Hydrocarbon Process Gas

   Operator Training, Better Understanding of Potential

9 Examples of Transient Process Excursions

6. Compressor Suction Drums, “Settling Out” Pressure after Compressor Stops

   Operator Training, Controls, and Interlocks

7. Compress Discharge Drums, Rapid Pressure Increase after Compressor Starts

   Operator Training, Controls, and Interlocks

8. Loss of Heat Input, from Failure of Other Equipment

   Operator Training, Controls, and Interlocks

9. Overflow/Transport of Liquid, Multiple Chain-of-Event Failures

   Operator Training, Controls, and Interlocks

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Design Codes Approaches to Minimum Temperature

- ASME Boiler & Pressure Vessel and Piping codes have established MAT's based on the type and grade of material, additional reductions are allowed after considering the ratio of allowable to required stress.
- API 650 and 620, provide tabulations of materials permissible temperatures for various materials by similar groups.
- Both ASME and API require impact testing for use below established minimums.

Post Construction Codes Approaches to Minimum Temperature

API 579-1/ASME FFS-1 follows suit with ASME but does allow some additional assessment methods.

> Reports from multiple sources have been made stating that recently manufactured piping, fitting, and flanges, have reduced toughness and do not satisfy the expected impact energy values for their assigned material group. This issue and a proposed approach was described in "Developing A Fitness For Service Approach For Reduced Toughness Carbon Steel Piping, Fittings & Flanges"[2]

[2] Subramanian, K., Ayewah, D., King, R., and Norris, J., "Developing a Fitness For Service Approach for Reduced Toughness Carbon Steel Piping, Flanges & Fittings", Inspectioneering Journal, Volume 24, Issue 3, 2018, pp 13-17

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Sources for Low Temperature Properties

- ASME BPVC Section II Part D list thermal-physical properties;
  - Thermal Expansion
  - Thermal Conductivity
  - Thermal Diffusivity
  - Moduli of Elasticity
- With the exception of Moduli of Elasticity, values for these properties are not provided for temperatures below 70°F (20°C).
- ASME B31.3 and B31.1, however, do provide values for Thermal Expansion as well as the Modulus of Elasticity does to -325°F (-200°C).

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Sources for Low Temperature Properties

- In addition to the missing conductivity and diffusivity data for materials of construction, low temperature data can be difficult to obtain for standard insulating materials as well.
- Consideration for the effects of radiant vs conductive heat transfer must be considered.

Challenges In the Assessment of Low Temperature Equipment

1. New vs Existing Facilities/Equipment
   Require the use of Latest Editions of Codes & Standards
2. Design Basis vs Upset Conditions or Excursion
   Design Basis & Assessment to Consider All Excursion Scenarios
3. Minimum Design Metal Temperature
   Consideration of Stress Ratio for Assessments of API Design Equipment
4. Material Properties
   Development of Inclusion Material Properties for Low Temperatures
5. Insulation & Heat Transfer
   Development of Inclusion Material Properties and Radiant Temperature Design Approach

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0	20-February-2020	For general presentation use	J Norris

Thank You!