A Comparison:

ASME B31.1 Power Piping
versus
ASME B31.3 Process Piping

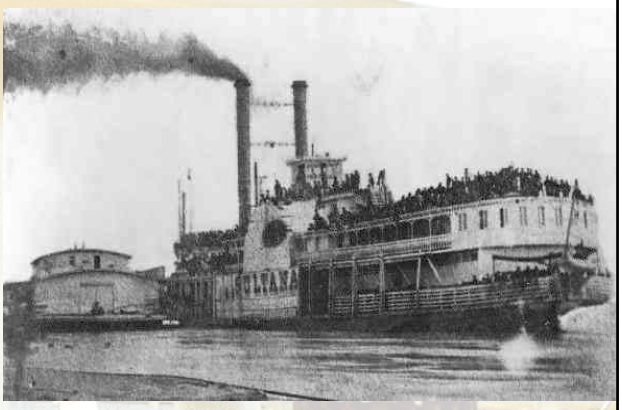
Don Frikken, PE

Topics Discussed

- B31 History
- Scopes
- Organization of the Codes
- Bases for Allowable Stresses
- Piping Component Standards
- Fluid Service Requirements
- Material Requirements
- Pressure Design
- Flexibility Analysis
- Fabrication and Installation
- Inspection, Examination and Testing

B31 History

- In the mid 1800's, boiler explosions were occurring at the rate of one every four days
- On April 27, 1865 the boiler explosion on the Sultana killed 1800 returning civil war soldiers



- From 1898 to 1903, more than 1200 people were killed in the U.S. in 1900 separate boiler explosions. The catastrophic explosion of a fire tube boiler in a factory in Brockton, Massachusetts, in 1905 killed 58 people

B31 History

- ASME formed a committee to address the boiler explosion problem - 1911
- ASME Boiler and Pressure Vessel Code (BPVC) was the first comprehensive standard for the design, construction, inspection, and testing of boilers and pressure vessels - 1915
- American Standards Institute initiated a project to develop a piping code - 1926
- American Tentative Standard code for Pressure Piping – 1935
- Separate sections were split off starting in 1955

B31 Piping Codes

PIPELINE CODES

- B31.4 Liquid Transportation Pipelines
- B31.8 Gas Transportation Pipelines
- B31.11 Slurry Transportation Pipelines

B31 Piping Codes

PIPING CODES

- B31.1 Power Piping
- B31.3 Process Piping
- B31.5 Refrigeration Piping
- B31.9 Building Services Piping

BOTH

- B31.12 Hydrogen Piping and Pipelines

B31 Piping Codes

- Each Code provides a set of requirements for obtaining a safe, reliable and economical installation.
- The designer is cautioned that the Code is not a design handbook; it does not eliminate the need for the designer or for competent engineering judgment.

ASME Piping System Standards

BPE-1 Bioprocessing Equipment

PVHO-1 Pressure Vessels for Human Occupancy

B&PV Code, Section III for Nuclear Power Plants

Other USA Piping System Standards

NFPA 13 – Installation of Sprinkler Systems
NFPA 24 – Installation of Private Mains
NFPA 50 – Bulk Oxygen Systems
NFPA 54 – National Fuel Gas Code
CGA – Handling of Anhydrous Ammonia (K61.1)
Chlorine Institute #6 – Piping Systems for Chlorine

B31.1 and B31.3 Scopes

Rules have been developed considering piping typically found in

ASME B31.1	ASME B31.3
electric power generating stations, industrial and institutional plants, geothermal heating systems and central and district heating and cooling systems. (100.1)	petroleum refineries; chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants; and related processing plants and terminals. (300.1)

B31.1 and B31.3 Scopes

Power piping systems …include but are not limited to

- steam
- water
- oil
- gas
- air

[100.1.2]

This Code applies for all fluids, including:

(1) raw, intermediate, and finished chemicals;
(2) petroleum products;
(3) gas, steam, air, and water;
(4) fluidized solids;
(5) refrigerants; and
(6) cryogenic fluids.

[300.1.1(b)]

Requirements

B31.1 provides requirements for types of piping

- Boiler External
- Blowoff and Blowdown
- Instrument, Control and Sample
- Spray Type Desuperheater
- Pressure Relief
- Flammable or Combustible Liquids
- Flammable Gases and Toxic Fluids
- Piping for Corrosive Fluids
- Temporary
- Steam Trap
- Pump Suction and Discharge
- District Distribution Systems

B31.3 provides requirements for fluid services

- Category D (utility)
- Category M (lethal)
- Elevated Temperature (creep range)
- High Pressure (above about 100 MPa)
- High Purity
- Normal (Process)
- Severe Cyclic Conditions

Organization of the Codes

I Scope and Definitions
II Design
III Materials
IV Dimensional Requirements
V Fabrication, Assembly, and Erection
VI Inspection, Examination and Testing

Organization of the Codes

VII Operation and Maintenance

Appendices covering:

- Nonmetallic Piping and Piping Lined with Nonmetals
- Design of Safety Valve Installations
- Corrosion Control
- Restrained Underground Piping

VII Nonmetallic Piping and Piping Lined with Nonmetals
VIII Piping for Category M Fluid Service
IX High Pressure Piping
X High Purity Piping

Appendices covering:

- Aluminum Alloy Flanges
- Expansion Joints

Bases for Design Stresses

B31.1 – The lowest of

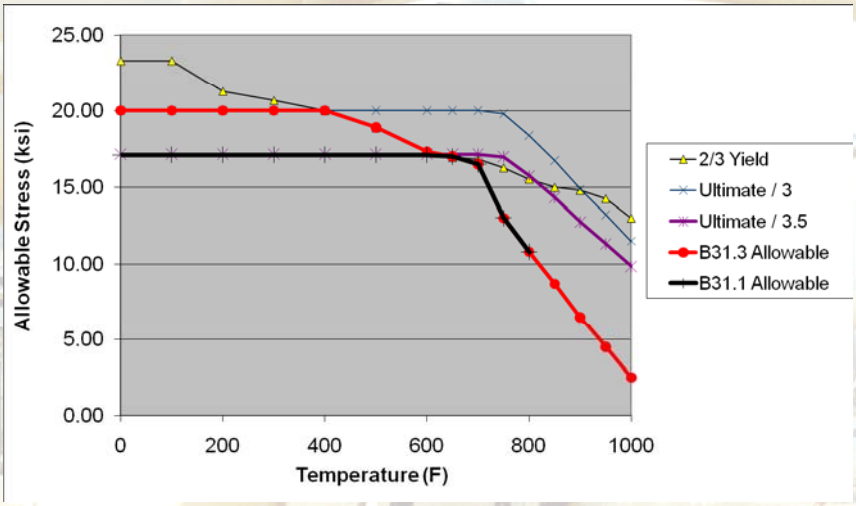
- the specified minimum tensile strength divided by 3.5
- tensile strength at temperature divided by 3.5
- 2/3 of specified minimum yield strength
- 2/3 of yield strength at temperature; except for austenitic stainless steels, 90% of yield strength at temperature
- Creep strength criteria

B31.3 – The lowest of

- the specified minimum tensile strength divided by 3
- tensile strength at temperature divided by 3
- 2/3 of specified minimum yield strength
- 2/3 of yield strength at temperature; except for austenitic stainless steels, 90% of yield strength at temperature
- Creep strength criteria

Bases for Design Stresses

ASTM A106 Grade B Carbon Steel (US Customary Units)



Piping Component Standards

- *Standard Components:* Those listed by standard number in Table 126.1, which lists material specifications (ASTM) as well as component standards
- *Nonstandard Components:* Those not so listed.

- *Listed Components:* Those listed by standard number in Table 326.1 and Appendix A
- *Unlisted Components:* Those not so listed.

Nonstandard/Unlisted Components

Can be used if they:

- "adherence to dimensional standards of ANSI and ASME is strongly recommended when practicable", and
- Meet the pressure design formulas and procedures given in para. 104

[104, 126.2]

Can be used if they:

- "are checked for adequacy of mechanical strength under applicable loadings…", and
- "composition, mechanical properties, method of manufacture, and quality control are comparable to listed components"; and have pressure-temperature ratings that conform with para. 304

[302.2.3, 326.1.2]

Selected Fluid Service Requirements

- Furnace butt welded pipe is not permitted for flammable, combustible or toxic fluids
- Soldered joints may not be used for flammable or toxic fluids

- Furnace butt welded pipe is permitted only for Category D fluid service (utility)
- Soldered joints may be used only for Category D fluid service (utility)

Selected Fluid Service Requirements

- Brazed joints may not be used for flammable or toxic fluids in fire hazard areas
- Threaded joint size limited by temperature and pressure; example max. pressure NPS 3 (DN 80) joint is 400 psi (2750 kPa)
- Pipe thinner than STD WT may not be thr'd

- Brazed joints are permitted for fluids that are flammable, toxic or damaging to human tissue only if safeguarded
- NPS 1-1/2 (DN 40) and smaller tapered joints must be Sch 80 for notch sensitive material in Normal Service

Material Requirements

- ***Listed Material:*** a material that conforms to a specification in Appendix A or to a standard in Table 126.1 – may be used (123.1.1)
- ***Unlisted Material:*** a material that is not so listed – may be used under certain conditions (123.1.2)
- ***Unknown Material:*** may not be used (123.1.3)

- ***Listed Material:*** a material that conforms to a specification in Appendix A or to a standard in Table 326.1 – may be used (323.1.1)
- ***Unlisted Material:*** a material that is not so listed – may be used under certain conditions (323.1.2)
- ***Unknown Material:*** may not be used (323.1.3)

Material Requirements

An unlisted material may be used if (123.1.2)

- It conforms to a published specification covering chemistry, mechanical properties, etc.
- Otherwise meets the requirements of the Code
- Allowable stresses are determined in accordance with Code bases, and
- Qualified for service…at all temperatures

An unlisted material may be used if (323.1.2)

- It conforms to a published specification covering chemistry, mechanical properties, etc.
- Otherwise meets the requirements of the Code
- Allowable stresses are determined in accordance with Code bases, and
- Qualified for service…at all temperatures (323.2.4)

Material Requirements

- Materials for BEP must be ASME B&PV Code materials
- Use at temperatures above maximum in the stress tables is generally not permitted
- No rules for use at temperatures below -20ºF (-29ºC)

- Use at temperatures above maximum in the stress tables is generally permitted
- Extensive rules for use at temperatures below -20ºF (-29ºC)

Cast Iron Fluid Service Limits

Gray Iron	Generally limited to 250 psi (1725 KPa) saturated steam service	May not be used in flammable service above 150 psi (1035 kPa) May not be used in other services above 400 psi (2760 kPa)
Malleable Iron	Limited to 350 psi (2415 kPa) and 450ºF (230ºC)	Limited to -20ºF to 650ºF (-29ºC to 343ºC)
Ductile Iron	Generally limited to temperature of 450ºF (232ºC) and B16.42 ratings	Generally limited to temperature range of -20ºF to 650ºF (-29ºC to 343ºC) and B16.42 ratings

Pressure Design

The rules for pressure design are essentially the same in B31.1 and B31.3, but they are not identical.

Design Pressure & Temperature

allowance for pressure and temperature variation: The Codes allow the design pressure to be set below the most severe coincident pressure and temperature for the following variations:

- Can exceed allowable by 20% for no more than 1 hr/event and no more than 80 hr/year
- Can exceed allowable by 15% for no more than 8 hr/event and nor more than 800 hr/year
- Can exceed allowable by 33% for no more than 10 hr/event and no more than 100 hr/year
- Can exceed allowable by 20% for no more than 50 hr/event and nor more than 500 hr/year

Flexibility Analysis

Acceptance Criteria for Sustained Loads

Dead Loads Live Loads	$S_L \le S_h[W]$	$S_L \le S_h[W]$
Wind Earthquake Water Hammer	$S_L \le 1.2S_h$ or $S_L \le 1.15S_h$	$S_L \le 1.33S_h(E_c)$, or $S_L \le 0.90S_{yt}X(E_c)$

Flexibility Analysis

Acceptance Criteria for Displacement Loads

$$S_E \le S_A = f\,[1.25(S_c + S_h) - S_L]$$

- Max. value of **f** is 1.0
- Use single Stress Intensification Factor
- Provides SIF's for buttwelds, tapered transitions & reducers

- Max. value of **f** is 1.2
- Use in-plane and out-of-plane Stress Intensification Factors

Fabrication

- Welder & brazer qualification and bending & forming requirements are very similar but not identical
- Preheating and post weld heat treatment requirements are different, for example
  - B31.1 requires preheating to 200ºF (95ºC) or post weld heat treatment for carbon steel with thickness less than or equal to 3/4 in. (19.0 mm)
  - B31.3 requires neither preheating nor post weld heat treatment for the same thickness range

Installation

- Bolts must be threaded trough the nut
- Threaded joints that are intended to be seal welded *should* be made up without any thread compound.
- Bolts may be one thread short of a full nut
- Threaded joints that are intended to be seal welded *shall* be made up without any thread compound.

Inspection and Examination

- Authorized inspector required for boiler external piping, ASME B&PV Code, Section I
- Does not include the concept of random with progressive examination… either 100% or none
- Owner's Inspector is required to verify examination and testing was done correctly
- Does include the concept of random with progressive examination, e.g. 5% random RT

Examination

Examination required by Table 136.4:

Over 750°F (400°C)	Visual plus For NPS ≤ 2 (DN ≤ 50), MP/LP For NPS > 2 (DN > 50), 100% radiography
Over 1025 psig (70 bar) and 350 to 750°F (175 to 400°C)	Visual plus For wall thickness ≥ ¾" (19 mm), 100% radiography
All Others	Visual only

Examination

Examination required by para. 341:

Category D (utility)	Visual Only
Normal (Process)	Visual plus 5% radiography
Category M (lethal)	Visual plus 20% radiography
Elevated Temperature (creep range)	Visual plus 5% radiography 100% LP/MP of fillet welds
High Pressure (above about 100 MPa)	Visual plus 100% RT

Leak Testing

- BEP requires hydrotest in accordance with ASME B&PV Code, Section I
- Non BEP requires hydrotest or, at the owner's option, pneumatic, sensitive leak or initial service leak testing
- Insulated systems may be tested by fluid loss over time method
- Category D Fluid Service may be initial service leak tested
- All other fluid services require hydrostatic or pneumatic testing
- Category M Fluid Service requires a sensitive leak test in addition to the hydrostatic or pneumatic test

Leak Testing

- Hydrostatic test is at 1.5 times design pressure
- Pneumatic test is at 1.2 to 1.5 times design pressure
- Hydrostatic test pressure must be held a minimum of 10 minutes, and then may be reduced to design pressure for leak examination period

- Hydrostatic test is at 1.5 times design pressure corrected for temperature
- Pneumatic test is at 1.1 to 1.33 times design pressure
- Hydrostatic test pressure must be held a minimum of 10 minutes, and may not be reduced for leak examination period