OAK RIDGE National Laboratory

Pressure Testing: Fact and Fiction

Mark Lower

May 13, 2024

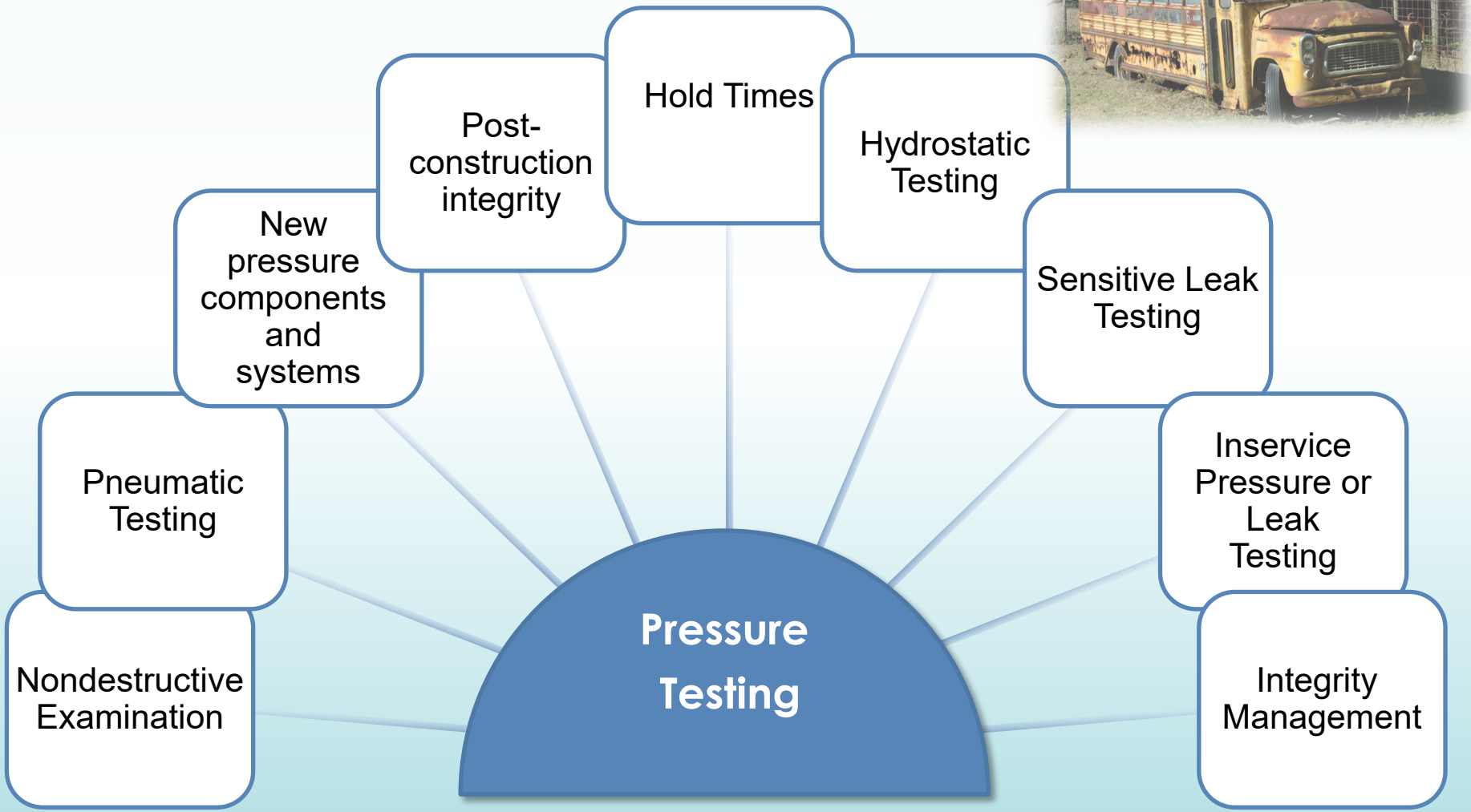
National Board General Meeting

Scottsdale, Arizona

ORNL is managed by UT-Battelle LLC
for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

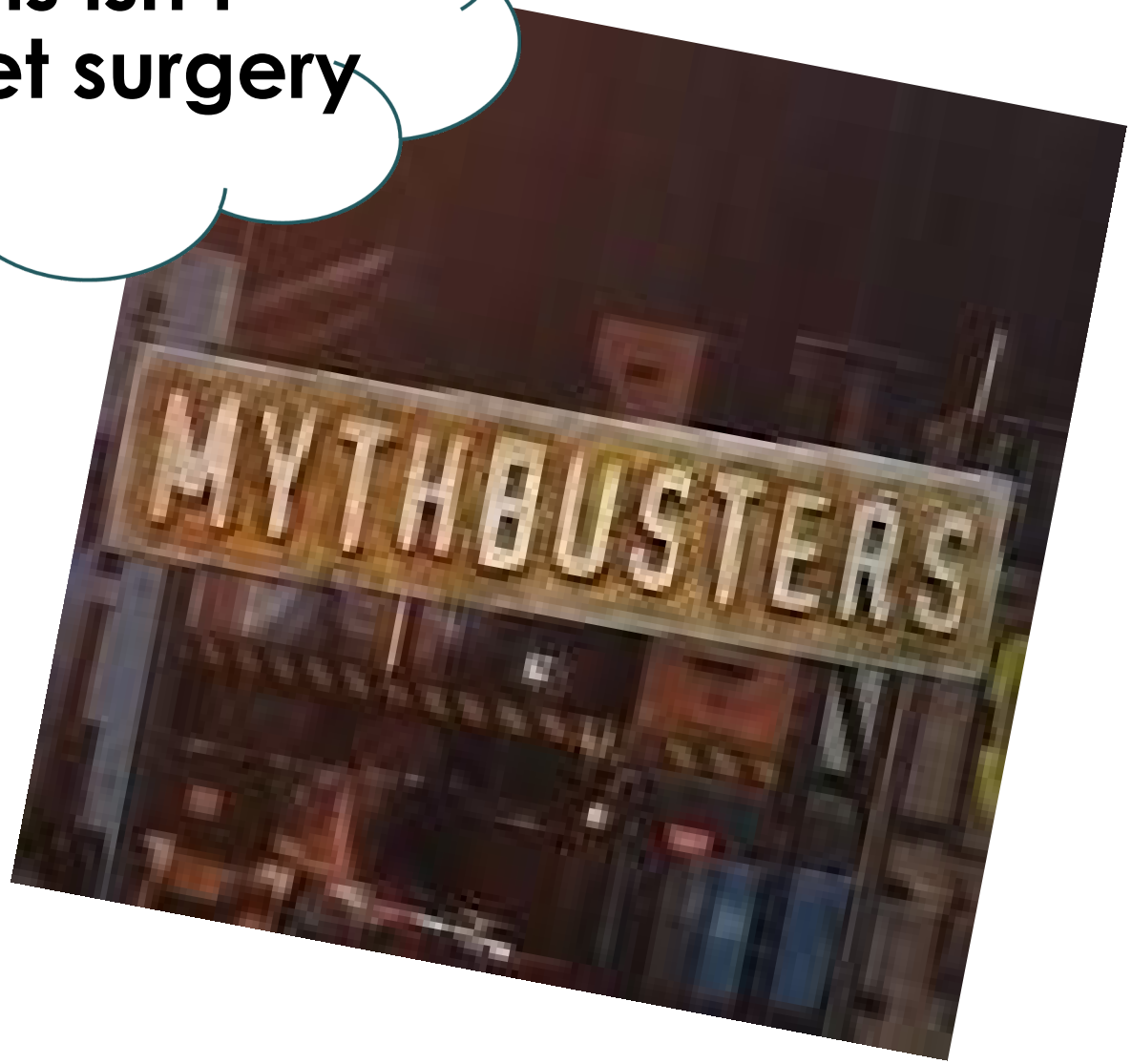
Pressure Testing



Group Participation Exercise

Group Participation Exercise

This isn't rocket surgery



OAK RIDGE National Laboratory

1. Pressure testing is performed (required) for which of the following reasons? (pick all that apply)

a. Verify leak tight integrity of pressure equipment
b. Verify gross structural integrity
c. Verify burst capacity
d. Blunt cracks to increase material toughness
e. Verify pressure retaining capacity of all components of the pressure boundary

a. Leakage is not allowed during the time of the required visual inspection

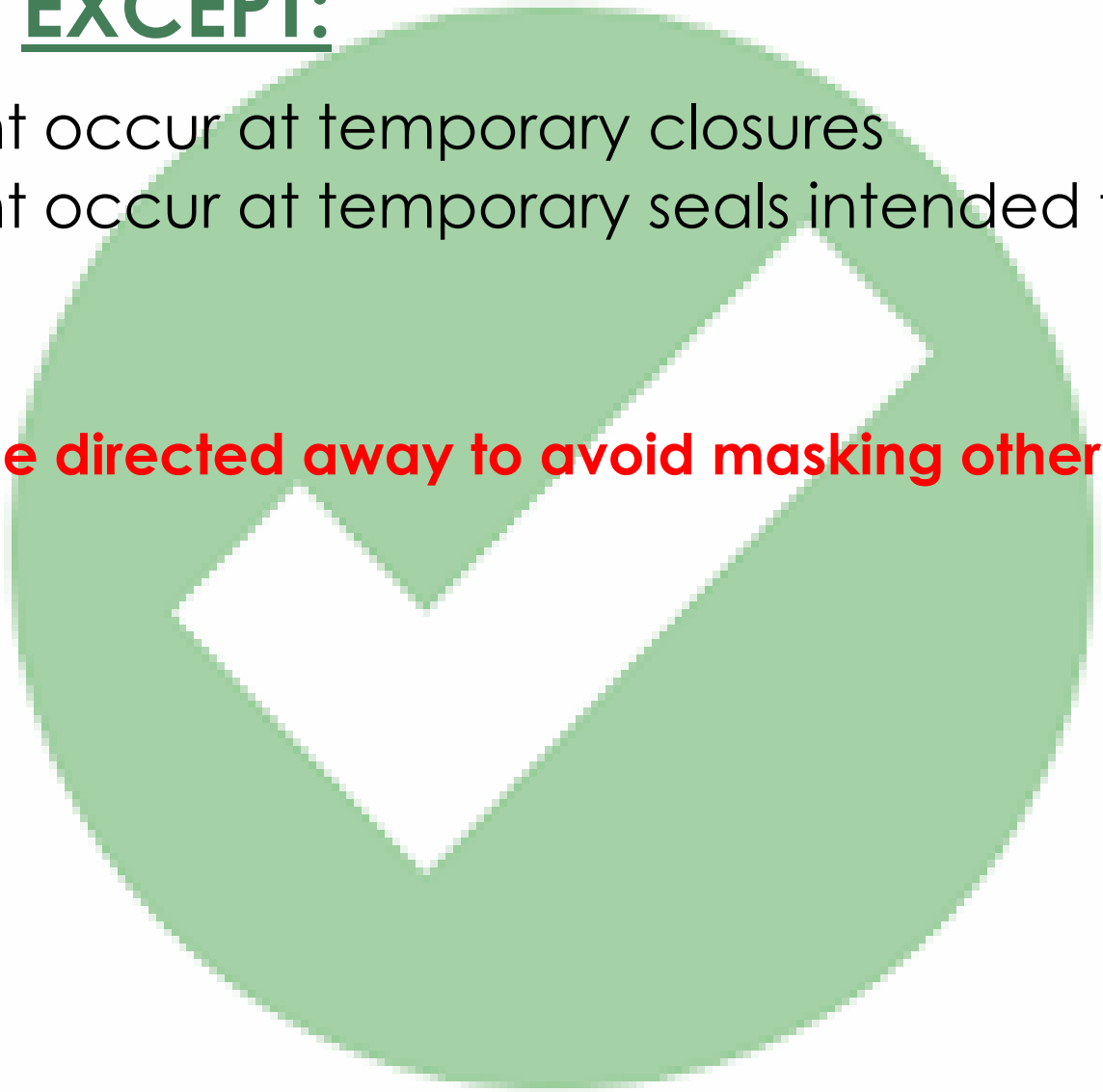
a. Leakage is not allowed during the time of the required visual inspection EXCEPT:

A. Leakage that might occur at temporary closures
B. Leakage that might occur at temporary seals intended for welded connections

NOTE: Leakage must be directed away to avoid masking other joints

a. Leakage is not allowed during the time of the required visual inspection EXCEPT:

A. Leakage that might occur at temporary closures
B. Leakage that might occur at temporary seals intended for welded connections



NOTE: Leakage must be directed away to avoid masking other joints

b. Verify gross structural integrity

- Increased pressure above MAWP/MOP will identify GROSS structural defects

b. Verify gross structural integrity

- Increased pressure above MAWP/MOP will identify GROSS structural defects
- Will NOT identify:
  - Minor fabrication defects
  - Issues associated with fatigue
  - Material toughness problems

b. Verify GROSS structural integrity

- Increased pressure above MAWP/MOP will identify GROSS structural defects
- Will NOT identify:
  - Minor fabrication defects
  - Issues associated with fatigue
  - Material toughness problems

c. Verify burst capacity of component

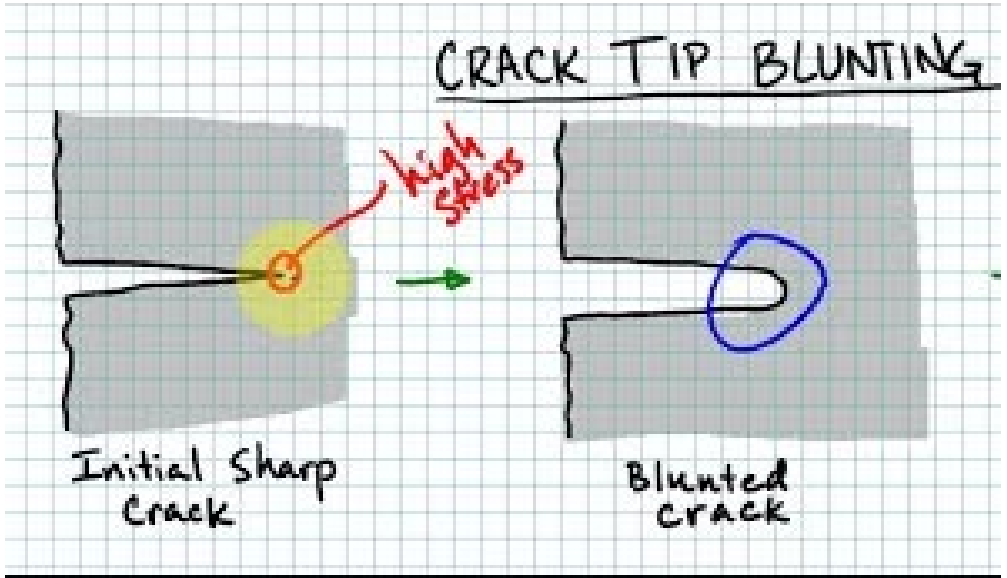
- Proof test or burst testing to establish the maximum working pressure can be used when thickness cannot be determined using design rules in the codes
- Detailed prescriptive requirements using various methods (Bursting, strain measurement, brittle coating, displacement measuring)
- Requirements provided for the following:
  1. Boilers and boiler components: ASME Section I, A-22;
  2. ASME Section IV; HG-500, HC-400, and HLW-500;
  3. Pressure vessels and vessel components: i) ASME Section VIII, Div. 1, UG-101;
  4. Listed Piping components as required by the standard;
  5. Other listed components, that do not have standard established pressure temperature ratings, Unlisted piping components (non-standard fittings) ASME B31.3, 304.7.2 (c), ASME B31.1, 104.7.2 (c)
- **Not used as much due to FEA methods**

c. Verify burst capacity of component

- Proof test or burst testing to establish the maximum working pressure can be used when thickness cannot be determined using design rules in the codes
- Detailed prescriptive requirements using various methods (Bursting, strain measurement, brittle coating, displacement measuring)
- Requirements provided for the following:
  1. Boilers and boiler components: ASME Section I, A-22;
  2. ASME Section IV; HG-500, HC-400, and HLW-500;
  3. Pressure vessels and vessel components: i) ASME Section VIII, Div. 1, UG-101;
  4. Listed Piping components as required by the standard;
  5. Other listed components, that do not have standard established pressure temperature ratings, Unlisted piping components (non-standard fittings) ASME B31.3, 304.7.2 (c), ASME B31.1, 104.7.2 (c)
- **Not used as much due to FEA methods**

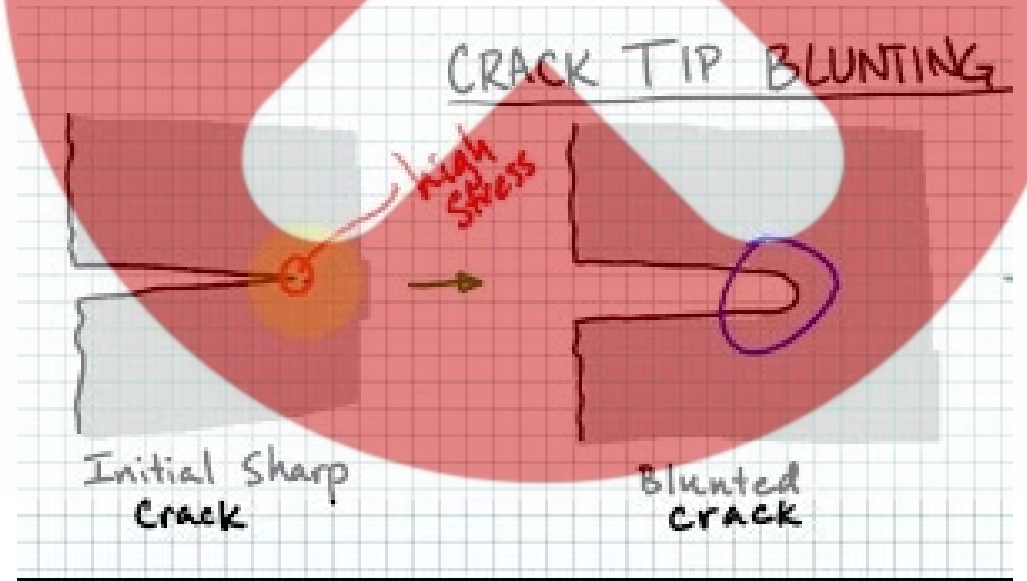
d. Pressure test is not intended to blunt cracks

- crack tip blunting is the phenomenon of small-scale plastic deformation of an initially sharp crack
- Blunting cracks DOES increase material toughness
- Crack tip blunting only occurs when the actual stress is high enough to produce plastic deformation
- Stress state is related to temperature, actual yield strength and strain hardening properties



d. Pressure test is not intended to blunt cracks

- crack tip blunting is the phenomenon of small-scale plastic deformation of an initially sharp crack
- Blunting cracks DOES increase material toughness
- Crack tip blunting only occurs when the actual stress is high enough to produce plastic deformation
- Stress state is related to temperature, actual yield strength and strain hardening properties



e. Verify pressure retaining capacity of all components of the pressure boundary

Just discussed leakage is not acceptable

e. Verify pressure retaining capacity of all components of the pressure boundary

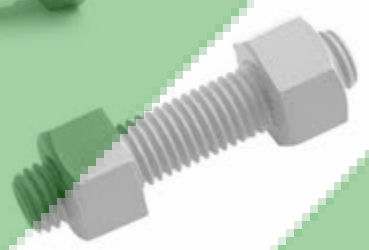
The following are "exempted" from the pressure test:

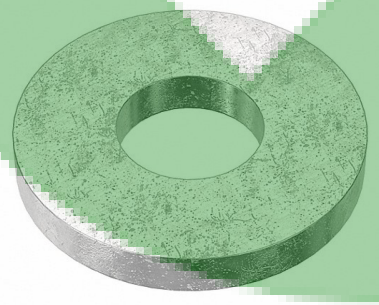
1. Bolts
2. studs
3. nuts
4. washers
5. nonwelded access opening covers
6. gaskets

e. Verify pressure retaining capacity of all components of the pressure boundary

The following are "exempted" from the pressure test:

1. Bolts
2. studs
3. nuts
4. washers
5. nonwelded access opening covers
6. gaskets





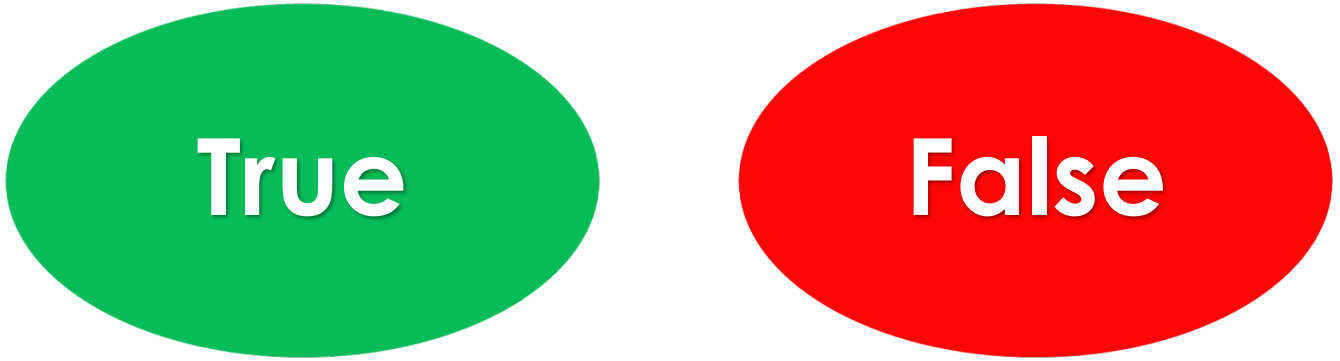
Proof

These conclusions are reinforced by

(1) the minimum hydrostatic and pneumatic test pressures specified in a particular edition of a construction code are not the same, and

(2) the specified minimum hydrostatic and pneumatic test pressures vary in different construction codes and edition

2. Codes and standards allow any type of pressure test at the user's discretion?



2. Codes and standards allow any type of pressure test at the user's discretion?

False

A pneumatic test may be used in lieu of a hydrostatic test only when any of the following conditions exists:

(1) when components, appurtenances, or systems are so designed or supported that they cannot safely be filled with liquid

(2) when components, appurtenances, or systems that are not readily dried are to be used in services

(3) When the equipment or piping contains internal linings that could be damaged by the test medium

2. Codes and standards allow any type of pressure test at the user's discretion?

False

A leak test is only acceptable if agreement is reached between the Manufacturer/manufacturer and Inspector

3. There is no difference in a pressure test performed as a requirement for initial construction and those performed for post-construction integrity management?

True

False

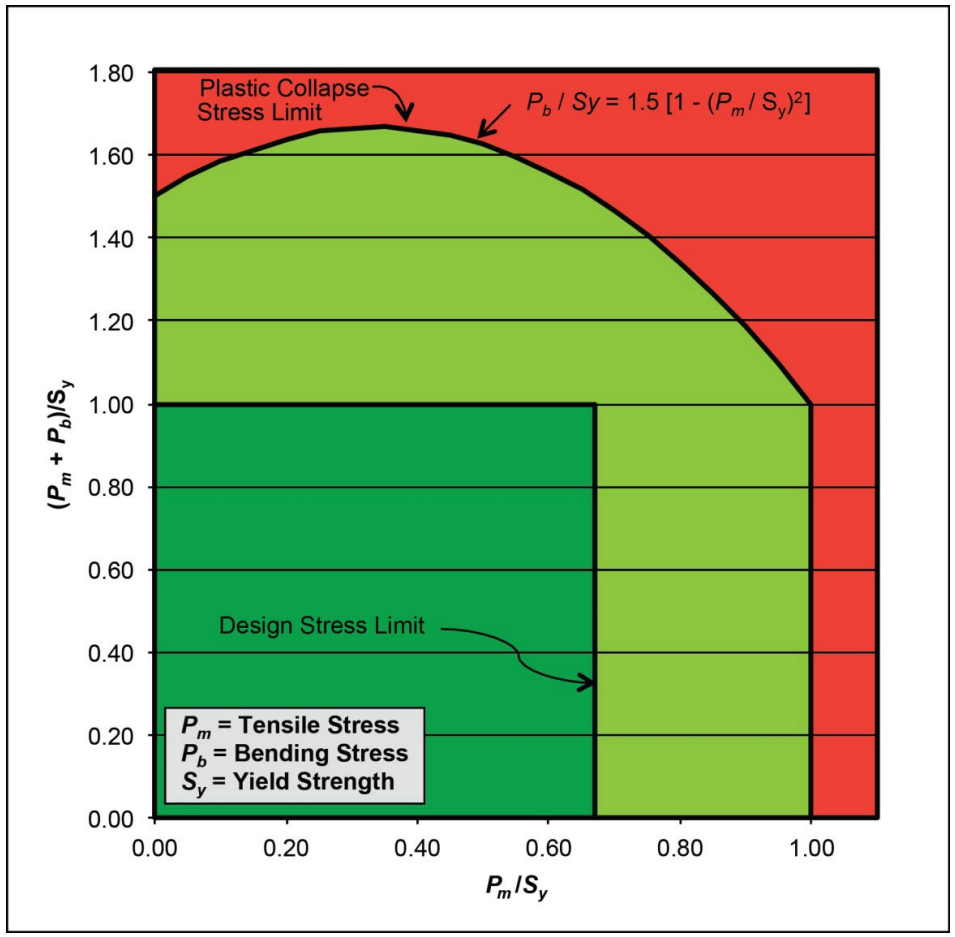
3. There is no difference in a pressure test performed as a requirement for initial construction and those performed for post-construction integrity management?

Kind of True

Post Construction

- The following post-construction standards adopted by many jurisdictions provide guidance regarding pressure tests
  - ✓ National Board Inspection Code (NBIC)
  - ✓ API Standard 510, Pressure Vessel Inspection Code: In-Service Inspection, Rating, Repair, and Alteration
  - ✓ ASME PCC-2, Repair of Pressure Equipment and Piping
- General guidance from ASME PCC-2
  - ✓ Pressure testing of a piping system through equipment is not recommended
  - ✓ In-service test pressures are specified according to the original code of construction
  - ✓ The test pressure should be at least 77% of the piping test pressure
  - ✓ The resulting stress due to pressure shall be limited to 100% SMYS

Pressure tests should not exceed the maximum stress limits of the original code of construction for EACH COMPONENT

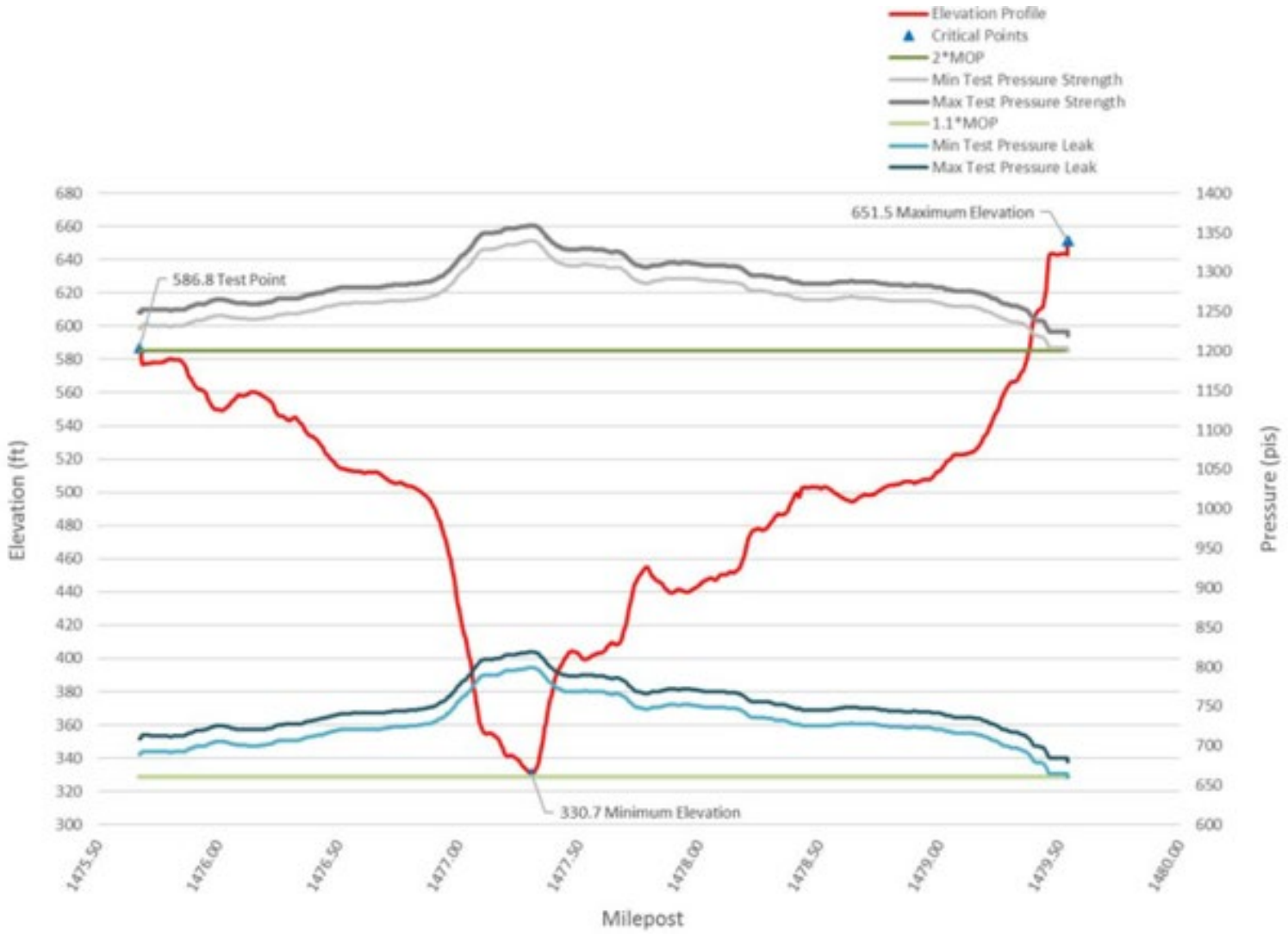


Need to understand:

1. Minimum pressure test value for components
   a) Most PCCs require not less than 1.0 x MAWP
   b) DOT–regulated pipelines not less than 1.5 x MAWP
   c) Does not include pressure tests associated with repairs or alterations
2. Maximum stress limits of the original code of construction (not shown, how to find them??)

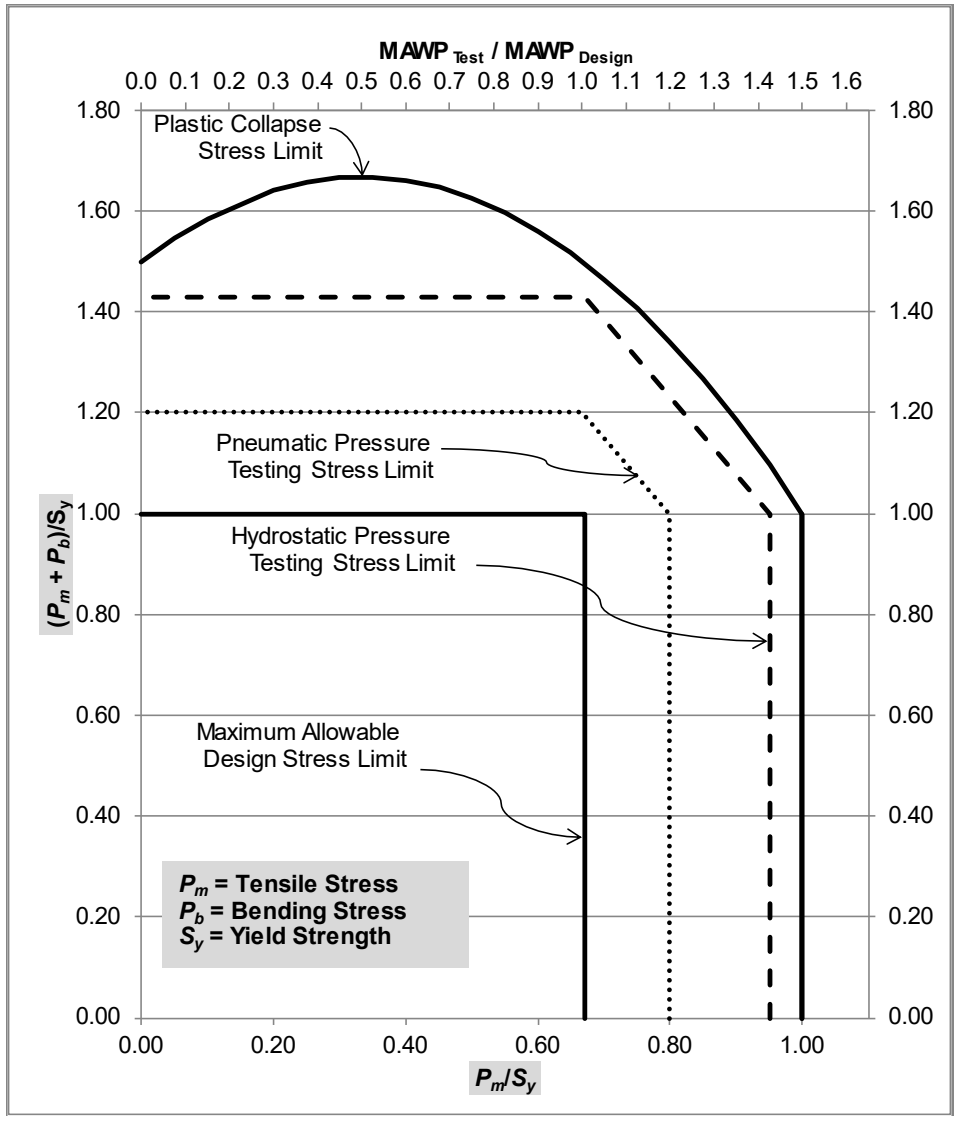
Pipelines and pressure vessels with a test pressure greater than 1.0 SMYS may experience yielding

Elevation changes can have significant impacts



OAK RIDGE National Laboratory

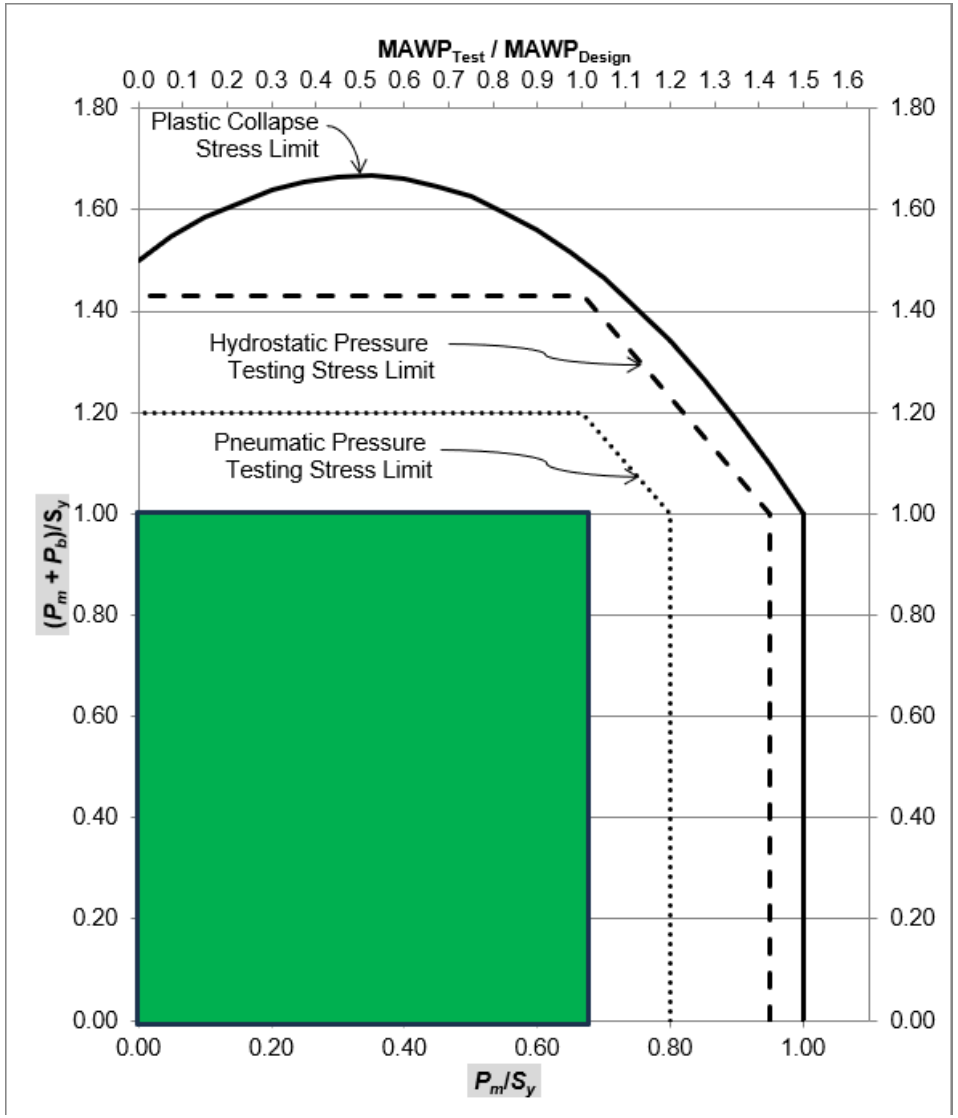
Pressure Test Limit Stresses*



Limit stress for combined tension and bending

*Osage, D. A. and Sowinski, J. C., 2014, *ASME Section VIII—Division 2 Criteria and Commentary*, ASME PTB-1-2014, American Society of Mechanical Engineers, New York, New York.

Pressure Test Limit Stresses*

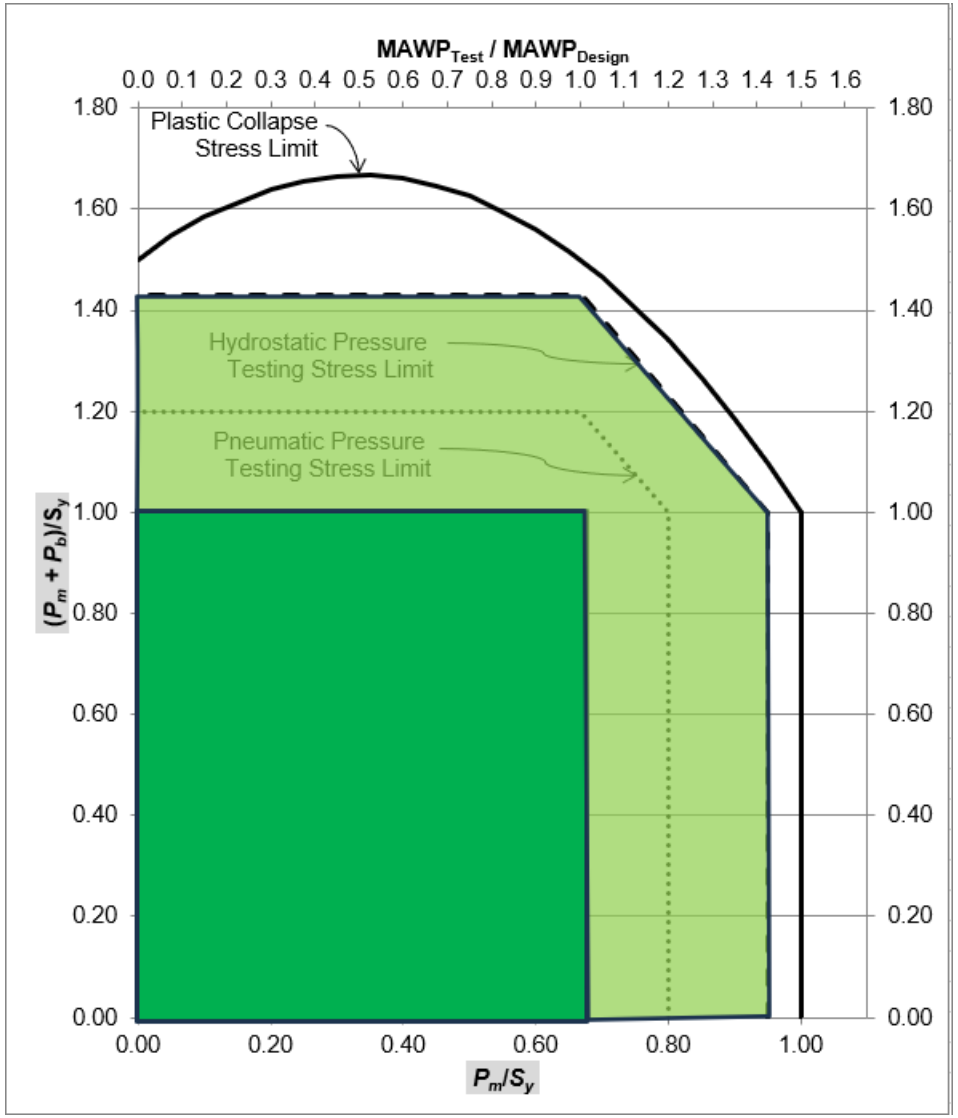


Limit stress for combined tension and bending

a) Maximum Allowable Stress [GREEN]

*Osage, D. A. and Sowinski, J. C., 2014, *ASME Section VIII—Division 2 Criteria and Commentary*, ASME PTB-1-2014, American Society of Mechanical Engineers, New York, New York.

Pressure Test Limit Stresses*



Limit stress for combined tension and bending

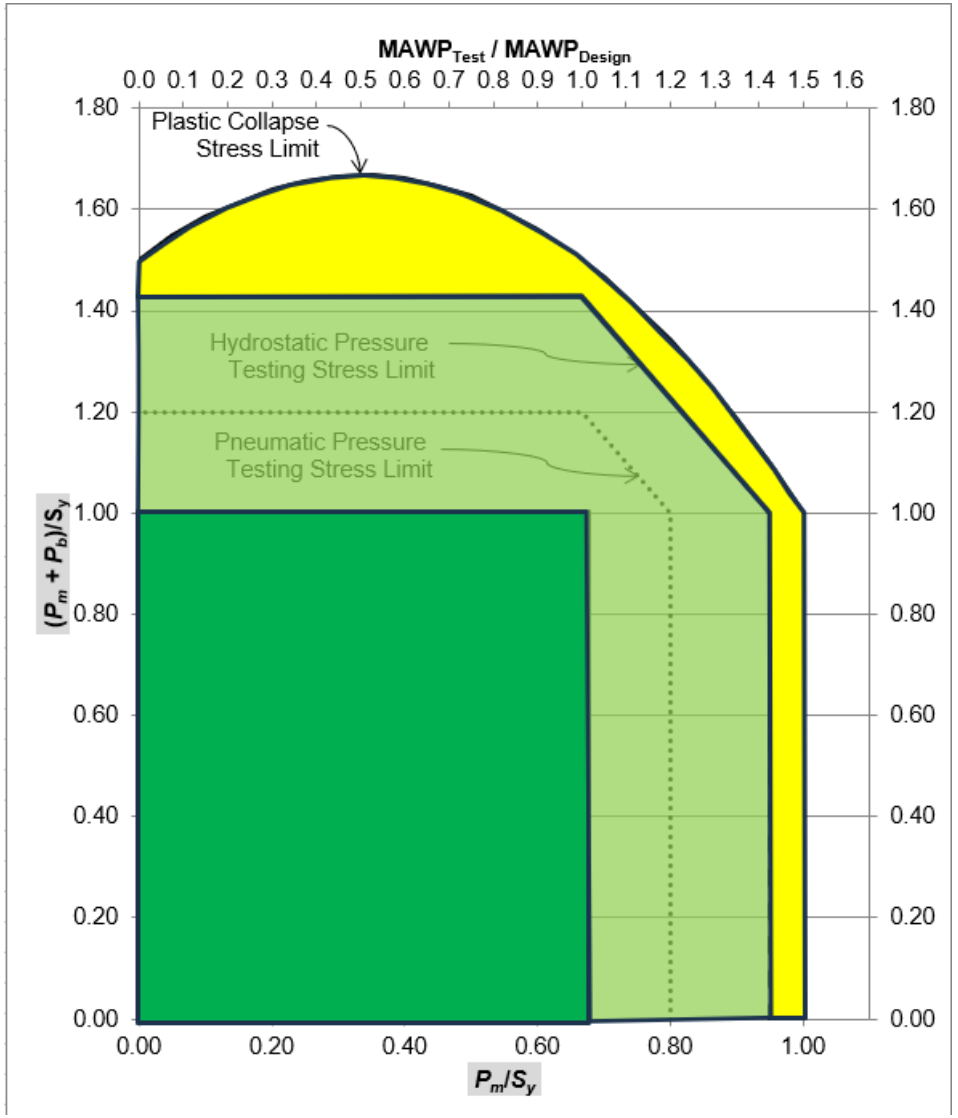
a) Maximum Allowable Stress [GREEN]

b) Allowable "Occasional loading" (pressure test limits) [Light Green]

- Dependent on type of test

*Osage, D. A. and Sowinski, J. C., 2014, *ASME Section VIII—Division 2 Criteria and Commentary*, ASME PTB-1-2014, American Society of Mechanical Engineers, New York, New York.

Pressure Test Limit Stresses*



Limit stress for combined tension and bending

a) Maximum Allowable Stress [GREEN]

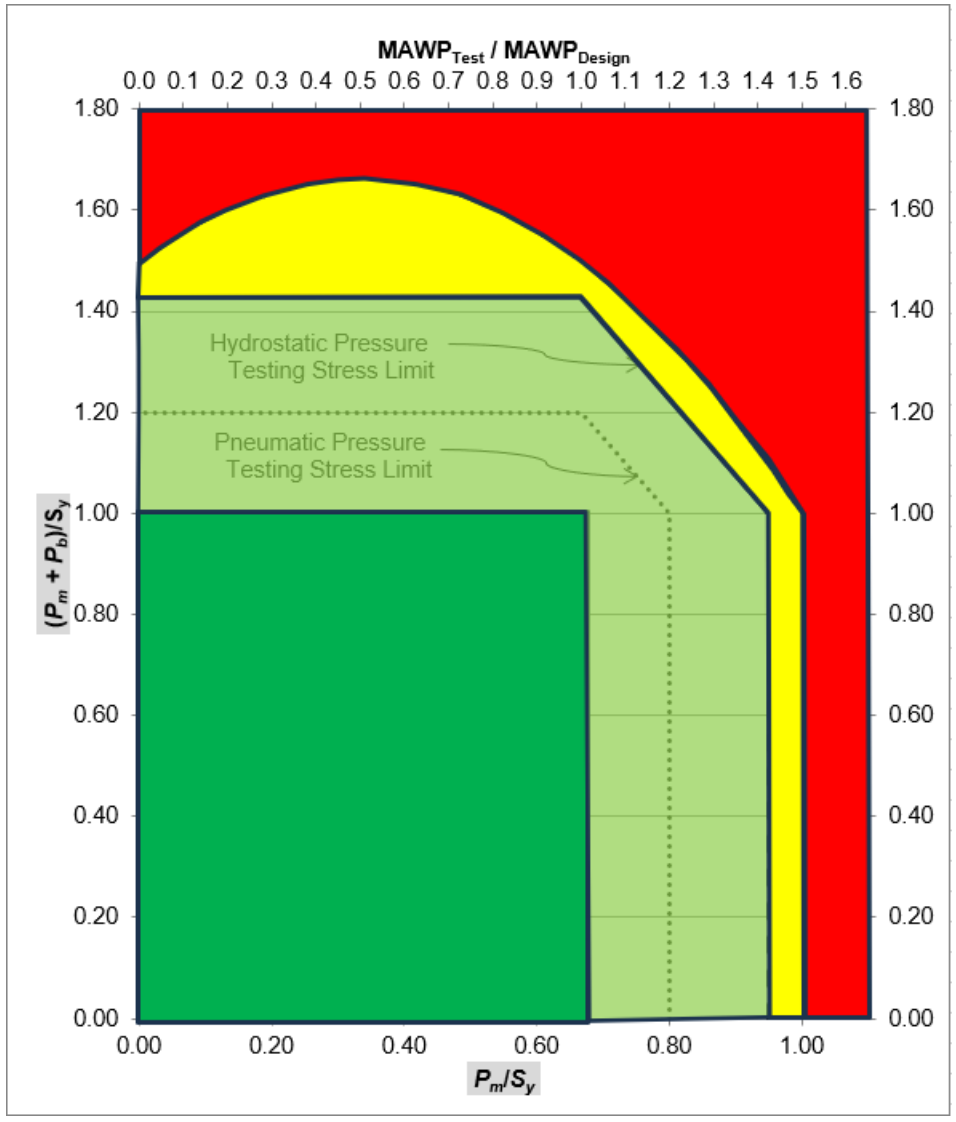
b) Allowable "Occasional loading" (pressure test limits) [Light Green]

- Dependent on type of test

c) Exceeds pressure test limits allowed by code [Yellow]

*Osage, D. A. and Sowinski, J. C., 2014, *ASME Section VIII—Division 2 Criteria and Commentary*, ASME PTB-1-2014, American Society of Mechanical Engineers, New York, New York.

Pressure Test Limit Stresses*



Limit stress for combined tension and bending

a) Maximum Allowable Stress [GREEN]

b) Allowable "Occasional loading" (pressure test limits) [Light Green]

- Dependent on type of test

c) Exceeds pressure test limits allowed by code [Yellow]

d) Potential for plastic collapse (yielding) [Red]

Any intermediate value between the minimum test pressure and maximum stress may be used.

Pressure components with a test pressure greater than 1.0 SMYS may experience yielding

*Osage, D. A. and Sowinski, J. C., 2014, *ASME Section VIII—Division 2 Criteria and Commentary*, ASME PTB-1-2014, American Society of Mechanical Engineers, New York, New York.

Spike Hydrostatic Test (SHT)*

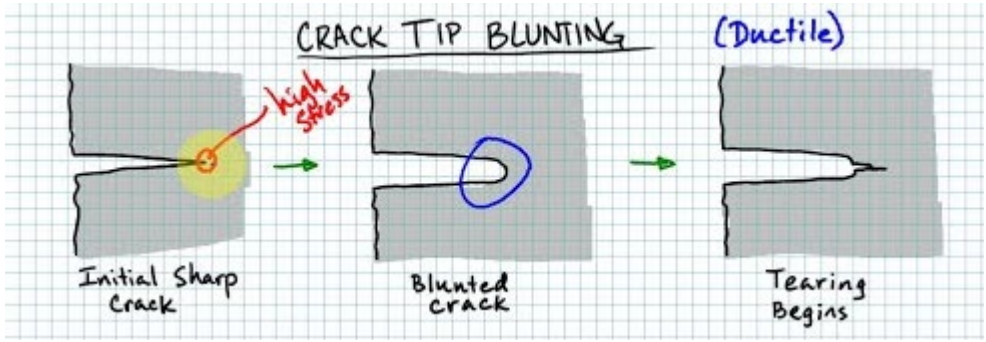
- Simply requiring the new construction minimum test pressure does not necessarily result in the best assessment of pressure equipment integrity
- Concept to retesting/validating integrity of pipelines for demonstrating fitness for service (i.e. the higher the test pressure, the more effective as a demonstration of fitness for service).
- SHT significantly exceeds test pressure to operating pressure ratio and hold time much shorter
- Test pressures result in hoop stress between 100% to 110% SMYS.
- Based on the relationship between the stress and size of defect

*Baker, M., *Spike Hydrostatic Test Evaluation*, Kiefner @ Associates, Inc., 2004

Pressure Reversals*

In some instances, components can be brought to a specified pressure such that a failure occurs. On retest after repairs are completed, the component can fail at a lower pressure. This is called **"pressure reversal."**

- Initiated with the existence of an outer surface flaw (rather than internal)



- Prevalent in ERW pipe seams
- Typically shows as a bulge or local distortion

*Swinson, et al,. Pressure Reversal Tests and Findings: A Hydrotest Background Report To the Office of Pipeline Safety, Technical Task Directive WN-1, Oak Ridge National Laboratory, 1997

Pressure Reversals*

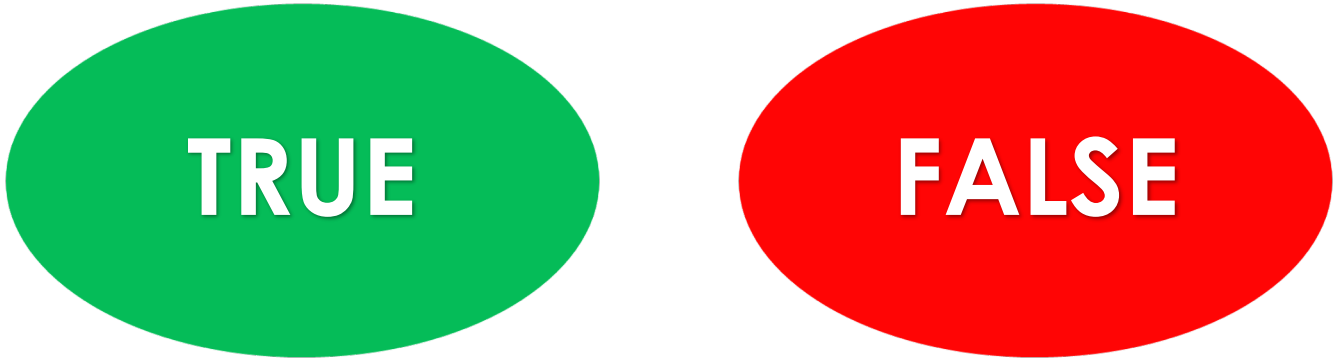
In some instances, components can be brought to a specified pressure such that a failure occurs. On retest after repairs are completed, the component can fail at a lower pressure. This is called **"pressure reversal."**

- Most reported pressure reversals are on the order of less than 10%
  - Some reported values on the order of 30% with one reported at 62%

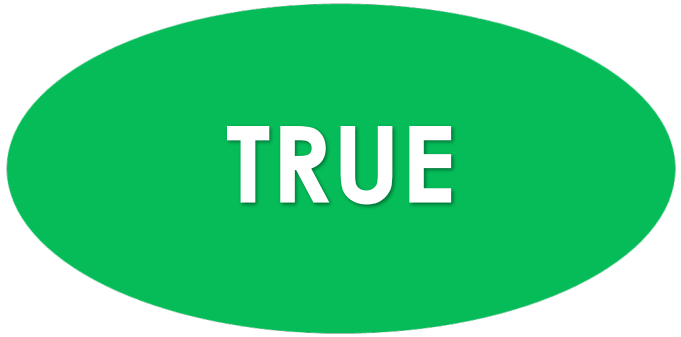
There are better integrity management methods to determine fitness for service than pressure testing

*Swinson, et al,. Pressure Reversal Tests and Findings: A Hydrotest Background Report To the Office of Pipeline Safety, Technical Task Directive WN-1, Oak Ridge National Laboratory, 1997

4. Hydrostatic, pneumatic, and sensitive leak tests are all a form of leak test?



4. Hydrostatic, pneumatic, and sensitive leak tests are all a form of leak test?

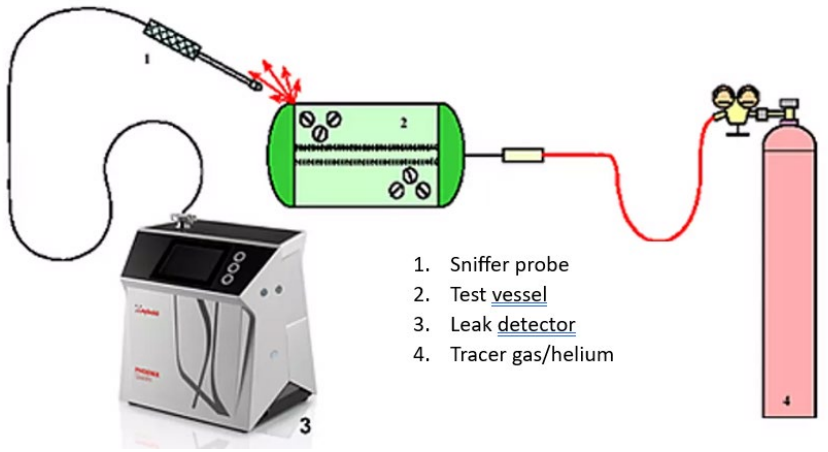


EVERYTHING LEAKS!

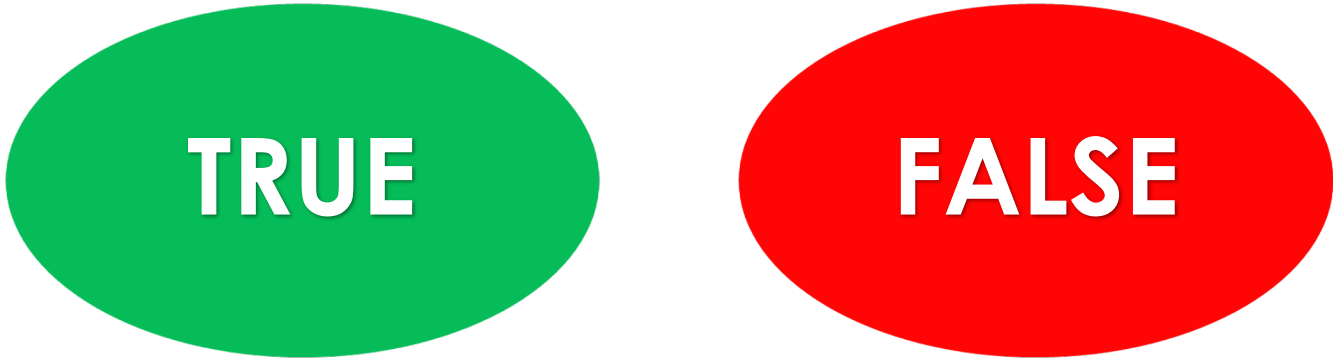
Bubble testing, pneumatic, and hydrostatic testing are given as examples of leak testing in ASME PCC-2

Leak Testing

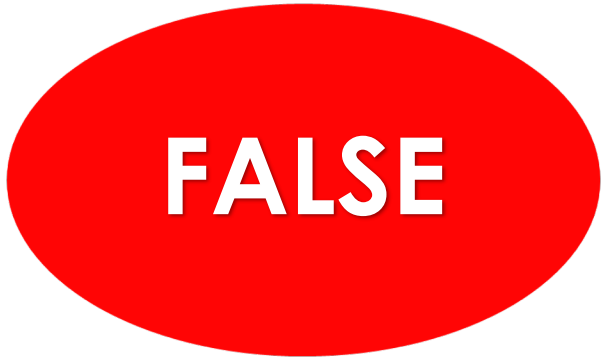
- ✓ Florescent dyes can increase sensitivity
- ✓ Adjust sensitivity via hold times (i.e. air penetrates faster than water)
- ✓ Longer hold times for thicker materials
- ✓ Leak rates are a function of:
  - ❑ Pressure differential
  - ❑ Materials (grain structure, density, product form)
  - ❑ Media/fluid properties viscosity, surface tension
  - ❑ material thickness (i.e. length of leak path)
  - ❑ Surface finish
  - ❑ Temperature
- ✓ Sensitive leak tests can be performed at lower pressures with inert gas to mitigate hazards. May be requested for highly toxic or highly flammable materials



5. Pressure testing is not hazardous if codes and standards requirements and guidance are followed?



5. Pressure testing is not hazardous if codes and standards requirements and guidance are followed?



Most of the hazards are associated with the sudden release of the stored energy in the system. As the system contains joints, valves, gauges, and other components, the failure of the pressure-containing boundary can result in a significant hazard.

Hazard Considerations

- System volume
- Leak vs. Break
- Proximity to:
  - Infrastructure
  - People
- Test temperature

Hydrostatic vs Pneumatic Pressure Test

Hydrostatic

- Incompressible fluids
- Stored energy comes from strain energy of the pressure boundary

Pneumatic

- Compressible gasses
- Stored energy from
  - strain energy of the pressure boundary
  - Release of the compressed gas

ASME BPV VIII Considerations

Multiple issues…

Test pressure limits	Safety	Test Closures	Repairs	Harmonization
• Establish upper limits on the test pressure and ranges on the test and inspection pressures to ensure vessels are not over pressurized • Visual inspection is performed at or below MAWP, not the test pressure	• Precautions to prevent pressure buildup due to thermal expansion and to stand away from vessels during pressurization to guard against stored energy in compressible fluids	• Shall be rated for test pressure • Shall not show evidence of wear or fatigue • Shall be restrained in the event of a blow-out • Threaded plugs shall have required thread engagement	• Depressurization is required prior to repair any leaks and after completion of the pressure test before further operations are performed on the vessel	• Should Division 1 and Division 2 have the same pressure test requirements?

Pressure test hold times?

The End

Hydrostatic Test Failures (a.k.a. Assume the worst)