**PDHonline Course M551 (2 PDH)**

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# An Introduction to Inspection of Boilers and Unfired Pressure Vessels

*Instructor: J. Paul Guyer, P.E., R.A., Fellow ASCE, Fellow AEI*

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**PDH Online | PDH Center**

5272 Meadow Estates Drive
Fairfax, VA 22030-6658
Phone: 703-988-0088
www.PDHonline.com

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# An Introduction to Inspection of Boilers and Unfired Pressure Vessels

*J. Paul Guyer, P.E., R.A.*

## CONTENTS

1. INSPECTION AND TEST FREQUENCIES
2. UNFIRED PRESSURE VESSELS
3. BOILER INSPECTIONS
4. UNFIRED PRESSURE VESSEL INSPECTIONS
5. PRESSURE TESTS
6. OPERATIONAL TESTS
7. REPAIRS AND ALTERATIONS
8. INSPECTION CERTIFICATES AND REPORTS
9. MAXIMUM ALLOWABLE WORKING PRESSURE

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## 1. INSPECTION AND TEST FREQUENCIES

**1.1 BOILERS.** Inspection and test frequencies for boilers are shown in Table 1.

| Item | Internal Inspection | External Insp. & Operational Test | Hydrostatic Test |
|---|---|---|---|
| Boilers – Wet or dry lay-up | At least annually. At resumption of active service. | External at least annually. External and operational at resumption of active service. | Hydrostatic testing in accordance with NBBI, Part 2, paragraph 4.3.1. Test pressure should not exceed 90% of the lowest setting pressure relief device at least annually. |
| Boilers –Heating ASME Section IV | | | |
| Hot Water Heating or Hot Water Supply Boilers | \3\ /3/ At least every three years. After any repair or alteration of pressure parts. \3\ Check firesides on oil fired units annually /3/ | At least annually. After any alteration or modification to boilers, control equipment, or Auxiliaries. | Hydrostatic test in accordance with NBBI, Part 2, paragraph 4.3.1. Test pressure should not exceed 90% of the lowest setting pressure relief device at least annually. Strength test in accordance with NBBI, Part 3, paragraph 4.4.1 after repair or alteration of pressure parts. Additional times at the discretion of the inspector. |
| Steam Heating Boilers | At least annually. After any repair or alteration of pressure parts. | At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries. | Hydrostatic testing in accordance with NBBI, Part 2, paragraph 4.3.1. Test pressure should not exceed 90% of the lowest setting pressure relief device at least annually. Strength test in accordance with NBBI, Part 3, paragraph 4.4.1 after repair or alteration of pressure parts. Additional times at the discretion of the inspector. |
| High Efficiency and Condensing Hot Water Heating Gas Fired Boilers | At least every three years. (See Note 3) | At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries. | Hydrostatic testing in accordance with NBBI, Part 2, paragraph 4.3.1. Test pressure should not exceed 90% of the lowest setting pressure relief device at least annually. |

Figure 1

Inspection and Test Frequencies – Boilers

| | | | |
|---|---|---|---|
| Boilers – Power<br>ASME Section I | | | |
| High Pressure Steam and Water Boilers | At least annually. After any repair or alteration of pressure parts. | At least annually. After any alteration or modification to boilers, control equipment, or auxiliaries. | Hydrostatic testing in accordance with NBBI, Part 2, paragraph 4.3.1. Test pressure should not exceed 90% of the lowest setting pressure relief device at least annually. Strength test at least once every 3 years. Strength test after repair or alteration of pressure parts. Additional times at the discretion of the inspector. |
| Domestic Hot Water Heaters (HLW)<br>ASME Section IV | If \3\ practical /3/: At least every two years. Check oil fired units annually. | At least every two years. Check oil fired units annually. | Discretion of inspector. Note: Glass-lined vessels not to exceed Maximum Allowable Working Pressure (MAWP). |
| Notes:<br>1. All manhole and handhole gaskets must be replaced after application of the strength test unless they are of the non-compressible steel type.<br>2. The inspector should use good judgment when inspecting the firesides and watersides of these type boilers. Boroscopes should be used when possible to avoid damage to the units. If removal of the burner assemblies and watersides is warranted by the inspector the maintenance personnel shall have proper training in the safe removal of components without damaging the unit. Ensure that all required gaskets are on hand before re-assembly of components. | | | |

Figure 1 (continued)

Inspection and Test Frequencies – Boilers

**2. UNFIRED PRESSURE VESSELS.** Inspection and test frequencies for unfired pressure vessels are as shown in Tables 2, 3, or 4, as applicable.

| Item | Internal Inspection | External Insp. & Operational Test | Hydrostatic Test |
|---|---|---|---|
| Pressure Vessels & Heat Exchangers (15 to 250 psig) (100 kPa to 1.7 MPa) MAWP | Every 3 years or more frequently as determined by procedures in the NBBI Code for vessels subject to corrosion. After any repair or alteration of pressure parts. For LPG see Table 3-3. | Every 3 years or more frequently as determined by procedures in the NBBI Code for vessels subject to corrosion. After any repair or alteration of pressure parts. Inspection must include test and calibration of safety valves and pressure and temperature gages. | Strength test in accordance with NBBI, Part 3, paragraph 4.4.1 after repair or alteration of pressure parts. Additional times at the discretion of the inspector. |
| Pressure Vessels & Heat Exchangers (greater than 250 psig) (1.7 MPa) ( MAWP) | Every 3 years or more frequently as determined by procedures in the NBBI Code for vessels subject to corrosion. After any repair or alteration of pressure parts. For LPG see Table 3-3. | Every 3 years or more frequently as determined by procedures in the NBBI Code for vessels subject to corrosion. After any repair or alteration of pressure parts. Inspection must include test and calibration of safety valves and pressure and temperature gages. | Hydrostatic Test every 6 years of service. If inspection shows no sign of corrosion, the test may be deferred until the next inspection, but must be tested at least every 12 years. Hydrostatic testing in accordance with NBBI, Part 2, paragraph 4.3.1. Test pressure should not exceed 90% of the lowest setting pressure relief device. Strength test in accordance with NBBI, Part 3, paragraph 4.4.1 after repair or alteration of pressure parts. Additional times at the discretion of the inspector. |

Notes:

1. Test frequencies and inspections may be increased at the discretion of the inspector or owner if the UPV is subjected, by the nature of its service, to an accumulation of deposits or thermal or mechanical stresses that could affect the integrity of the vessel.
2. A hydrostatic pressure test not to exceed 1.5 times the MAWP for BPVC ASME Section VIII Division 1 vessels and 1.25 times the MAWP for BPVC ASME Section VIII Division 2 vessels may be substituted for the internal inspection.
3. If the tube bundle of the heat exchangers is a higher pressure than the shell, both sides of the heat exchanger must be hydrostatically tested.
4. Unfired pressure vessels are to be inspected externally and re-certified anytime they are relocated or moved. It is the activity's responsibility to inform the inspector of the move. For UPVs designed and built to be portable, reinspections are not required after a move as long as the vessel does not leave the base. The inspector will indicate the UPV is "portable" on all appropriate reports. Once a UPV designed to be portable is relocated outside the base, any certified NAVFAC boiler inspector or NAVFAC-approved contract boiler inspector may issue a certificate (9-11014/32) for the length of the deployment period but not exceeding the original certificate's expiration date. A copy of the original inspection report and certificate must accompany the pressure vessel during the deployment/transfer period. The extent of reinspection after the move for pressure vessels designed to be portable consists of an external inspection to check for damage incurred while in transit, a visual examination to determine if the installation is conforming to applicable codes and a visual examination to verify that all code required safety devices are installed. If any of these inspection processes indicates discrepancies with the pressure vessel and/or installation then the full inspection requirements of this UFC apply.
5. Use of ultrasonic thickness (UT) testing in addition to internal inspection is highly encouraged.

Figure 2

Inspection and Test Frequencies - Unfired Pressure Vessels (UPVs)

| Item | Internal Inspection | External Insp. & Operational Test | Hydrostatic Test |
|---|---|---|---|
| MILSPEC Vessels<br><br>See note 1 | Every 3 years of service. Inspection must include test and calibration of safety valves and pressure and temperature gages.<br><br>See Note 1.<br>For MILSPEC Vessels (Pressure Vessels Design, Built and Stamped to \4\ MIL-DTL-22606 /4/) or any non-ASME vessels see Note 3. | Every 3 years of service. Inspection must include test and calibration of safety valves and pressure and temperature gages. | See note 2 |
| \3\ /3/ | \3\ /3/<br>For MILSPEC Vessels (Pressure Vessels Design, Built and Stamped to \4\ MIL-DTL-22606 /4/) or any non-ASME vessels see Note 3. | \3\ /3/ | \3\ /3/ |
| Carbon Dioxide ($CO_2$) Storage Tanks<br><br>See note 4 | Only if the vessel has been depressurized or has been opened to the atmosphere other than for immediate repair or maintenance; or when directed by an authorized boiler inspector. | Every 3 years; or after any repair or alteration of pressure parts; or when directed by an authorized boiler inspector.<br><br>See note 5 | After any repair or alteration of pressure parts; or when directed by an authorized boiler inspector. Caution should be taken in performing hydrostatic testing. It is essential that all water be removed from the vessel before returning it to service. Water will freeze and create blockages. |
| Liquid Petroleum Gas (LPG) Storage Tanks | Every 3 years or more frequently as determined by procedures in the NBBI Code. After any repair or alteration of pressure parts. Use ultrasonic testing instead of visual internal inspection. | Every 3 years or more frequently as determined by procedures in the NBBI Code. After any repair or alteration of pressure parts. Bench test or replace the UL or ASME safety valves every 6 years.<br><br>See note 6 | After any repair or alteration of pressure parts, otherwise at the discretion of the inspector. |

Notes:

1. A visual internal inspection for MILSPEC vessels \3\ /3/ is not required every 3 years provided the vessel (or vessel bank) successfully passes a gas analysis with oil mist plus particulate matter concentration equal to or less than 5 milligrams per cubic meter and dew point equal to or colder than -40 degrees F (-40 degrees C); and an ultrasonic thickness measurement check in accordance with the Paragraph in Chapter 5 entitled, "Ultrasonic Examination Military Specification". The maximum acceptable interval between visual inspections is 12 years.
2. At intervals indicated in *Naval Ship's Technical Manual* S9086-SY-STM-010, Chapter 551, vessels will be required to be tested according to "551-1.14.1". The flask(s) requiring re-certification is to be tested by Ultrasonic (UT) testing or Acoustic Emission (AE) testing. Hydrostatic testing is being eliminated because it does not provide data on flask wall cracking which has been determined to be the

Table 3

Inspection and Test Frequencies - UPVs (Special Cases)

primary failure mode."

3. Activities may elect to prepare and inspect MILSPEC vessels using NAVSEASYSCOM boiler inspectors according to *Naval Ship's Technical Manual* S9086-SY-STM-010, Chapter 551, *Compressed Air Plants and Systems*. However, if either a NAVSEASYSCOM or NAVFAC boiler inspectors are used they will be required to perform internal and external inspections as explained above every 3 years (as opposed to the 6-20 year re-certification intervals allowed in *Naval Ship's Technical Manual* S9086-SY-STM-010, Chapter 551). A pressure vessel that is neither MILSPEC nor ASME code may only be certified when design drawings and engineering calculations from the manufacturer are available to the inspector to positively determine whether the vessel is safe to operate. The inspector may ask for proof of the manufacturer's quality control procedures and tests prior to issuing a certificate\4\ ./4/ \3\ /3/

4. We recommend inspectors familiarize themselves with current versions of Compressed Gas Association (CGA) G-6.1, *Standard for Insulated Carbon Dioxide Systems at Consumer Sites*, and CGA G-6.7, *Safe Handing of Liquid Carbon Dioxide Containers That Have Lost Pressure*.

5. Inspection must include testing of relief valves by an ASME Repair Facility Holding a "VR" stamp or replacement with new ASME stamped valves. Also required is calibration of all pressure and temperature gages. Note: The external inspection should be limited to the visible portions of the system, including the vessel and appurtenances such as pressure relief devices, the piping system, and hose lines. Initial inspections may require adding an isolation valve between the vessel and relief valve. The mandatory isolation valve requirements are listed in the ASME *Boiler and Pressure Vessel Code*, Section VIII, Division I, Appendix M, Paragraph M-5.

6. The minimum required rate of safety valve discharge for aboveground LPG tanks is to be in accordance with the following table:

| Tank Surface Area $ft^2$ ($m^2$) | Flow Rate (CFM) Air $ft^3$/min ($m^3$/sec) | Tank Surface Area $ft^2$ ($m^2$) | Flow Rate (CFM) Air $ft^3$/min ($m^3$/sec) |
|---|---|---|---|
| 20 (1.9) or less | 626 (0.295) | 250 (23.23) | 4960 (2.341) |
| 25 (2.32) | 751 (0.354) | 300 (27.87) | 5760 (2.718) |
| 30 (2.79) | 872 (0.412) | 350 (32.52) | 6540 (3.087) |
| 35 (3.25) | 990 (0.467) | 400 (37.16) | 7300 (3.445) |
| 40 (3.71) | 1100 (0.519) | 450 (41.81) | 8040 (3.794) |
| 45 (4.18) | 1220 (0.576) | 500 (46.45) | 8760 (4.134) |
| 50 (4.65) | 1330 (0.628) | 550 (51.10) | 9470 (4.469) |
| 55 (5.11) | 1430 (0.675) | 600 (55.74) | 10170 (4.800) |
| 60 (5.57) | 1540 (0.727) | 650 (60.39) | 10860 (5.125) |
| 65 (6.04) | 1640 (0.774) | 700 (65.03) | 11550 (5.451) |
| 70 (6.50) | 1750 (0.826) | 750 (69.68) | 12220 (5.767) |
| 75 (6.97) | 1850 (0.873) | 800 (74.32) | 12880 (6.079) |
| 80 (7.43) | 1950 (0.920) | 850 (78.97) | 13540 (6.390) |
| 85 (7.90) | 2050 (0.967) | 900 (83.61) | 14190 (6.697) |
| 90 (8.36) | 2150 (1.015) | 950 (88.26) | 14830 (6.999) |
| 95 (8.83) | 2240 (1.057) | 1000 (92.90) | 15470 (7.301) |
| 100 (9.29) | 2340 (1.104) | 1050 (97.55) | 16100 (7.598) |
| 105 (9.75) | 2440 (1.152) | 1100 (102.19) | 16720 (7.891) |
| 110 (10.22) | 2530 (1.194) | 1150 (106.84) | 17350 (8.188) |
| 115 (10.68) | 2630 (1.241) | 1200 (111.48) | 17960 (8.476) |
| 120 (11.15) | 2720 (1.284) | 1250 (116.13) | 18570 (8.764) |
| 125 (11.61) | 2810 (1.326) | 1300 (120.77) | 19180 (9.052) |
| 130 (12.08) | 2900 (1.369) | 1350 (125.42) | 19780 (9.335) |
| 135 (12.54) | 2990 (1.411) | 1400 (130.06) | 20380 (9.618) |
| 140 (13.01) | 3080 (1.454) | 1450 (134.71) | 20980 (9.901) |

Table 3 (continued)

Inspection and Test Frequencies - UPVs (Special Cases)

| | | | |
|---|---|---|---|
| 145 (13.47) | 3170 (1.496) | 1500 (139.35) | 21570 (10.180) |
| 150 (13.94) | 3260 (1.539) | 1550 (144.00) | 22160 (10.458) |
| 155 (14.40) | 3350 (1.581) | 1600 (148.64) | 22740 (10.732) |
| 160 (14.86) | 3440 (1.623) | 1650 (153.29) | 23320 (11.006) |
| 165 (15.33) | 3530 (1.666) | 1700 (157.94) | 23900 (11.280) |
| 170 (15.79) | 3620 (1.708) | 1750 (162.58) | 24470 (11.549) |
| 175 (16.26) | 3700 (1.746) | 1800 (167.23) | 25050 (11.822) |
| 180 (16.72) | 3790 (1.789) | 1850 (171.87) | 25620 (12.091) |
| 185 (17.19) | 3880 (1.831) | 1900 (176.52) | 26180 (12.356) |
| 190 (17.65) | 3960 (1.869) | 1950 (181.16) | 26750 (12.625) |
| 195 (18.11) | 4050 (1.911) | 2000 (185.81) | 27310 (12.889) |
| 200 (18.58) | 4130 (1.949) | | |

Table 3 (continued)

Inspection and Test Frequencies - UPVs (Special Cases)

| Item | Internal Inspection & Operational Test | External Inspection | Hydrostatic Test |
|---|---|---|---|
| Deaerators | Every 6 years. After any repair or alteration of pressure parts. Inspection must include test and calibration of safety valves and pressure and temperature gages. Inspection must include test and calibration of safety valves and pressure and temperature gages. | Every 3 years. After any repair or alteration of pressure parts. | Tightness test every 6 years. Strength test after repair or alteration of pressure parts. \4\ Strength test in accordance with NBBI, Part 3, paragraph 4.4.1. /4/ Additional times at the discretion of the inspector. |

Notes:

1. In addition to the \4\ /4/ inspection, the operators of the vessel should periodically examine and test the deaerators for proper operation. Improperly operating deaerators result in excessive corrosion and cracking. The key to satisfactory operation is proper water treatment.
2. Scheduling of deaerator inspection at many facilities requires scheduled downtime for many heating and power plants. The activity should prepare to hire a company specializing in deaerator evaluations to determine if the vessel is repairable if cracking or excessive corrosion is found during the visual inspection. Options to lease deaerators prior to the inspection should be considered.

Table 4

Inspection and Test Frequencies – Deaerators

## 3. BOILER INSPECTIONS

**3.1 GUIDANCE.** The activity operating and maintaining the boiler provides all material and labor necessary to prepare the boilers for inspection in accordance with the NBBI Code. The activity assists the inspector as required during the inspections. Exception to this policy occurs when the operation and maintenance of a boiler is under the cognizance of a contractor. In this case, the contractor provides material, labor, and assistance. Inspectors should not compromise on the code's intent, but should exercise restraint when interpreting the fine points of the ASME Code.

**3.2 EXTERNAL INSPECTION OF BOILERS.** Perform external inspections of boilers in accordance with Part 2, Section 2, Inspection-Detailed Requirements for Inservice Inspection of Pressure-Retaining Items, in the paragraph entitled, "External Inspection" of the National Board Inspection Code. Test safety devices as part of the external inspection. Perform final testing of safety valves of power boilers on the boiler to which the valve will be mounted. The operational tests and observations are considered to be part of the external inspection.

**3.3 INTERNAL INSPECTIONS OF BOILERS.** Perform internal inspections of boilers in accordance with Part 2, Section 2, Inspection-Detailed Requirements for Inservice Inspection of Pressure-Retaining Items, in the paragraph entitled, "Internal Inspection" of the National Board Inspection Code. Boiler inspectors have the authority to order that boiler metal samples and/or ultrasonic tests be taken for their examination to ascertain the actual condition of the pressure parts.

**3.4 BOILERS IN WET OR DRY LAY-UP.** In addition to the external and internal inspections required above, review the lay-up procedures being used to ensure that they conform to all other applicable requirements.

## 4. UNFIRED PRESSURE VESSEL INSPECTIONS

**4.1 GUIDANCE.** The activity operating and maintaining the pressure vessel provides all material and labor necessary to prepare the unfired pressure vessel for inspection in accordance with the NBBI Code. The activity assists the inspector as required during the inspections. Exception to this policy occurs when the operation and maintenance of the pressure vessel is under the cognizance of a contractor. In this case, the contractor provides material, labor, and assistance. Inspections of pressure vessels located on Navy bases in foreign countries must comply with this guidance under the constraints of regulations in effect. Inspectors should not compromise safety issues, but should exercise restraint when interpreting the fine points of the ASME Code.

**4.2 EXTERNAL INSPECTIONS OF UNFIRED PRESSURE VESSELS.** Perform external inspections of unfired pressure vessels in accordance with Part 2, Section 2, Inspection-Detailed Requirements for Inservice Inspection of Pressure-Retaining Items, in the paragraph entitled, “External Inspections” of the National Board Inspection Code.

**4.3 INTERNAL INSPECTIONS OF UNFIRED PRESSURE VESSELS.** Perform internal inspections of unfired pressure vessels in accordance with Part 2, Section 2, Inspection-Detailed Requirements for Inservice Inspection of Pressure-Retaining Items, in the paragraph entitled, “Internal Inspections” of the National Board Inspection Code. Inspectors have the authority to order metal samples and/or ultrasonic tests for their examination to ascertain the actual condition of the vessel.

### 4.4 MILITARY SPECIFICATION (MILSPEC) PRESSURE VESSELS

**4.4.1 INTERNAL AND EXTERNAL INSPECTIONS.** Examine vessels in accordance with the paragraphs in this chapter entitled, “External Inspections of Unfired Pressure Vessels” and “Internal Inspections of Unfired Pressure Vessels” . View internal

surfaces using remote viewing equipment (borescope/fiberscope), if necessary, supplied by the activity or by another acceptable method. Record areas of wear, corrosion, abuse, and/or damage and attach to the inspection report.

**4.4.2 ULTRASONIC EXAMINATION MILITARY SPECIFICATION.** Subject vessels to an ultrasonic thickness measurement check. The activity performs the checks while the inspector observes. Make the checks at the point of tangency between the cylinder and the end heads. Take measurements at 2-inch (50.8 mm) intervals around the circumference of the vessel. Take measurements on a line along the head from the point of tangency, across the end of the head to the far point of tangency; take measurements along a similar line at right angles to the first at the end of the head. Take lines of measurement at each end of the vessel. Arrange the lines so that the vessels low point, where water may collect and corrosion may form, is measured. Take measurements every \2\ three /2/ years. Ultrasonic measurement points for vessel configurations other than spherical or cylindrical must be approved by the inspector. The lines and points of measurement will be identical at each inspection. The activity will maintain measurement records. The vessel will not be derated nor certified if the measured thickness is less than that prescribed by the standard by which it was constructed, for example, ASME Section VIII, Division I, ASME Section VIII, Division 2, or Military Specification MIL-DTL-22606, Flask and End Plugs, Compressed Gas for Air, Oxygen, and Nitrogen (SHIPS).

**4.4.2.1 ULTRASONIC EXAMINATION ASME DIVISION I & DIVISION II VESSELS.** Use of ultrasonic thickness (UT) testing in addition to internal inspection is highly encouraged and should be performed by the inspector.

**4.4.3 VARIATIONS.** Address requests for variations in the inspection and testing procedures for MILSPEC pressure vessels to the NAVFAC Boiler Inspection Certification Board with a copy to the respective (East or West) NAVFAC Senior Boiler Inspector.

**4.5 DEAERATORS.** The purpose of a deaerating heater (deaerator) is to remove non-condensable gases and dissolved oxygen from the feedwater. A properly operating deaerator will have no more than 10 ppb (parts per billion) O2 in the outlet water. Deaerators are subject to thermal cycling and corrosion. Proper operation of deaerators is extremely important because of their critical function in protecting the boiler system from corrosion. Catastrophic failure of deaerators is usually attributable to cracks forming longitudinally and transversely to the heat affected zones of the welds. Deaerators are potentially a great danger because of their location at the top of the heating or power plant. To ensure deaerators provide safe reliable service, they require periodic visual inspections of their internal and external surfaces. If visual inspection reveals cracking, then a company specializing in deaerator inspection must perform an ultrasonic examination of the entire vessel and wet fluorescent magnetic particle examinations of the heat affected zones of the welds, prior to certification, to determine if continued operation of the vessel is safe. Subject repairs to post-weld heat treatment and hydrostatic testing prior to certification.

**4.6 LIQUIFIED PETROLEUM GAS (LPG) TANKS.** Non-mandatory guidelines may be found in the National Board Inspection Code, SUPPLEMENT 7, Page 259, “Inspection of Pressure Vessels in Liquefied Petroleum Gas (LPG) Service.”

**4.6.1 EXTERNAL INSPECTION.** Examine LPG (propane, butane, etc.) tanks in accordance with paragraph S7.4, page 260. Record areas of wear, corrosion, abuse, and/or damage and attach to the inspection report. Check capacity rating on safety relief valve nameplate for proper valve discharge.

**4.6.2 INTERNAL INSPECTION.** These tanks contain a non-corrosive liquid, and have virtually no internal corrosion. Inspect vessels by means of an ultrasonic thickness measurement check.

**4.6.3 HYDROSTATIC TEST.** Perform hydrostatic tests after any repair or alteration of pressure parts (additional times are at the discretion of the inspector). Prior to

performing a hydrostatic test, verify support structure is adequate to support the weight of the hydrostatic liquid. If a hydrostatic test is not possible, request approval for a pneumatic test from the Owner.

**4.6.4 SAFETY RELIEF VALVES.** Fit LPG tanks with ASME \4\ Section VIII, Division I certified, or Underwriters Laboratories UL 132 stamped, spring-loaded safety relief valves. Do not fit safety relief valves for LPG service with lifting devices. Replace or bench test safety relief valves every 6 years of service. This will be done by a company authorized to perform such tests on either ASME or UL safety valves.

## 5. PRESSURE TESTS

**5.1 HYDROSTATIC TESTS.** Make hydrostatic tests in accordance with the paragraphs below and the National Board Inspection Code, Part 2, Section 4, Inspection-Examinations, Test Methods, and Evaluations, the paragraph entitled, "Pressure Testing".

**5.1.1 STRENGTH TEST PRESSURE.** Base strength tests on the maximum allowable working pressure (MAWP) of the boiler or pressure vessel as marked or as recalculated as a result of previous tests. All boilers and unfired pressure vessels covered by ASME Section I or Section VIII, Division 1 subjected to internal pressure will be tested hydrostatically at a pressure of 1-1/2 times the highest safety valve popping pressure or 1-1/2 times the MAWP, whichever is less. Unfired pressure vessels constructed by the standards of ASME Section VIII, Division 2 subjected to internal pressure will be tested hydrostatically at a pressure of 1-1/4 times the highest safety valve popping pressure or 1-1/4 times the MAWP, whichever is less. Exceptions follow:

- Vessels not capable of supporting the weight of liquids (see Chapter 10, MAWP).
- Vessels not readily dried that are to be used in services where traces of the testing liquid cannot be tolerated.
- The test pressure for enameled vessels will be at least equal to, but need not exceed, the maximum allowable working pressure marked on the vessel.
- The test pressure for glass-lined vessels will not exceed the maximum allowable working pressure.
- The test pressure for cast iron vessels will be 2 times the maximum allowable working pressure for maximum allowable working gage pressures greater than 30 psig (206.84 kPa) and 2-1/2 times the maximum allowable working pressure but not to exceed 60 psig (413.69 kPa) (gage pressure) for maximum allowable working gage pressures under 30 psig (206.84 kPa).

- The test gage pressure for vessels and piping in high-pressure air systems (3,000 psig (20684.27 kPa) and over) will not exceed 1-1/2 times the maximum allowable working pressure of the system.

**5.1.1.1 VACUUM VESSELS.** Single-wall vessels designed for a vacuum or partial vacuum only, and chambers of multi-chamber vessels designed for vacuum or partial vacuum only, need not be subjected to a hydrostatic test.

**5.1.1.2 SPECIAL COMBINATION UNITS.** Test special combination units so that each pressure chamber (vessel) receives the required hydrostatic test without pressure in the others.

**5.1.1.3 HYDROSTATIC TESTS WITH FLUIDS OTHER THAN WATER.** Test procedures for fluids other than water must be approved by the Owner.

**5.1.2 TIGHTNESS TEST PRESSURE.** Perform the tightness test pressure at above the normal operating pressure, but not exceeding the lowest safety valve set pressure. Safety valves may be blocked or gagged for this test.

**5.1.3 PRECAUTIONS**

- Direct connection of the boiler to the water system is prohibited, where an approved back-flow prevention device is not installed, to prevent contamination of the potable water system.
- Provide a power-driven or hand pump for application of the test pressure if the boiler feed pump will not deliver the test pressure. The test pump will be provided by the activity or its utilities contractor and operated and inspected to ensure that it is in proper working condition prior to connecting it to the boiler or the vessel.

**5.1.4 POSSIBLE DEFORMATION.** If any indications of probable permanent deformation are observed, cease the test until the weak parts have been properly strengthened. If necessary repairs are not practicable, apply a new test, progressing up to 20 psi (138 kPa)) less than the pressure at which the preceding test ceased. If the test is successful, make the new maximum allowable working pressure two-thirds of the test pressure, and reset or replace the safety valves in accordance with the new maximum allowable working pressure.

**5.1.5 HOLD PRESSURE.** For all boilers, UPVs and heat exchangers, pressure should not drop more than 10 percent within 15 minutes. If the pressure drop exceeds 10 percent, repair leaks and repeat the test. If the pressure drop is within 10 percent and inspection does not reveal leaks in the pressure parts, assume that the leaks are through the isolation valves, manholes, and handholes.

**5.1.6 INSPECTION UNDER PRESSURE.** Inspect all joints and connections for leaks or other defects while the vessel is under pressure. The pressure held during this inspection need not necessarily be equal to the hydrostatic test pressure, but will not be less than two-thirds of the hydrostatic pressure. Where the test pressure exceeds the MAWP of the item, the test pressure must be reduced to the MAWP for close examination by the inspector.

**5.1.7 PERMANENT DEFORMATION.** Where permanent deformation of the unfired pressure vessel shell or heads, or of the boiler shell or drum has occurred, whether as a result of hydrostatic pressure tests or from normal operating pressures, make repairs only after it has first been definitely determined that such repairs are practicable and economical. After approved repairs of this nature have been completed, recalculate the maximum allowable working pressure of the vessel or boiler according to the requirements of the appropriate standards. Prior to returning the vessel or boiler to service, perform a hydrostatic test, based on the recalculated maximum allowable working pressure.

**5.1.8 GASKETS.** Replace manhole and handhole gaskets after performing the hydrostatic strength test unless a non-compressible metal gasket is used.

**5.2 PNEUMATIC TESTS.** Perform a pneumatic test only in extreme cases, when a hydrostatic test is not permissible. Do not perform pneumatic tests without the written approval of the Owner. Include the proposed pneumatic test procedures for each particular test in the request. Pneumatic test procedures for each particular test are in UG-100 for Section VIII Division 1 vessels, and in Article T-4 for Section VIII Division 2 vessels. The pneumatic test pressure will be 1.25 times the MAWP for Division 1 vessels and 1.15 times the MAWP for Division 2 vessels. A pneumatic test may be used in lieu of the hydrostatic test prescribed as follows:

- For vessels that are so designed and/or supported that they cannot safely be filled with water.
- For vessels not readily dried that are to be used in services where traces of the testing liquid cannot be tolerated and the parts of which have, where possible, been previously tested by hydrostatic test pressure.

**5.3 PRESSURE TEST RESULTS**

**5.3.1 YIELDING DURING TEST.** If yielding occurs, and examination shows the vessel is in satisfactory condition, establish the MAWP as 50 percent of the pressure at yielding.

**5.3.2 NO YIELDING DURING TEST.** If yielding does not occur, increase the pressure step by step until the required test pressure has been reached. Then hold the pressure for a sufficient time to permit inspection of the vessel for leaks or signs of failure.

**5.3.3 INSPECTION UNDER PRESSURE.** If permanent deformation occurs, replace or repair the vessel. If permanent deformation occurs in a vessel not constructed to the ASME Boiler and Pressure Vessel Code, drill and discard the vessel.

## 6. OPERATIONAL TESTS

**6.1 GUIDANCE.** Following internal inspection, as part of the external inspection, bring the boiler or unfired pressure vessel up to operating pressure and temperature. Inspect, and cause to function under operating conditions, all automatically and manually operated control devices provided for controlling the operation of the vessel, steam or water pressure, hot water temperature, combustion, and boiler water level. Inspect under operating conditions all associated valves and piping, pressure and temperature indicating devices, metering and recording devices, and all boiler auxiliaries. Boilers firing oil or gas without fully automatic or semiautomatic controls must have an Owner waiver to be certified. All combustion controls attached to the boiler regardless of the fuel being fired must be in good working order or the inspection certificate will be withheld. Inspections and tests of boilers may be made with the main steam or hot water distribution valves closed or open, as necessary, to fire the boiler and operate it under normal operating conditions. Testing the function of automatically or manually controlled devices and apparatus that may interfere with the distribution requirements should be done with the main steam or hot water distribution valves closed, as applicable.

**6.1.1 PURPOSE.** These additional inspections and tests allow the inspector to discover any inefficient or unsafe operation or maintenance of the vessel or of the boiler or its auxiliaries that may be evidenced under operating conditions.

**6.1.2 CONDITIONS TO BE REPORTED.** Report all deficiencies requiring adjustment, repair, or replacement, and all conditions indicating excessive operating and maintenance cost. *Withhold certificates until the deficiencies are corrected*.

**6.2 FIRING EQUIPMENT.** Inspect, for any deficiency that may be evidenced under operating conditions, the operation of all firing equipment including oil burners, gas burners, fuel injectors, fuel igniters, coal stokers, and feeders, burner safety controls

and other such equipment provided to introduce fuel into the boiler furnace and to ignite the fuel. Inspect the flame pattern to ensure that it is consistent with manufacturer specifications. All fuel leaks must be repaired before the certificate is issued.

**6.3 CONTROLS.** Inspect the operation of all controls directly associated with the operation and safety of the boiler for any defects preventing proper operation. These controls include such items as unloading valves, high-pressure cutout devices, high temperature cutout devices, low-pressure cut-in devices, and burner safety controls. Inspect the operation of combustion controls, steam pressure controls, water temperature controls, and feedwater controls. Make sure that the ability of the combustion control and steam pressure control to maintain proper steam pressure (or water temperature in high temperature water installations) and air-fuel ratio is demonstrated throughout the capacity range of the boiler and the load swings encountered in the operation of larger boilers. Ensure that the air-fuel ratio is checked during the inspection using either $CO_2$ or $O_2$ measuring devices and that the results are consistent with manufacturer recommendations or appropriate industry or Owner guidelines. CO and stack temperature will also be checked. Ensure that the boiler is properly tuned for efficient operation and that CO emissions are optimized consistent with manufacturer specifications or appropriate industry or Owner guidelines. Check fully-automatic boiler controls for the proper programming sequence and timing with respect to pre-purge, ignition, pilot proving, flame proving, and post-purge periods. Check the operation of flame failure and combustion air failure devices to ensure that they properly shut off the supply of fuel; this should be done by simulating a flame failure (by manually shutting off the fuel or by other means) and by observing the operation of the controls, solenoid valves, diaphragm operated valves and so forth, which are to operate during a flame failure. The installation of the boiler and controls including the fuel train and the operation of automatic burner management systems must comply with the *National Fire Codes* (NFC), including NFPA 85, *Boiler and Combustible Systems Hazards Code*; and ASME CSD-1 in effect at the time of installation of the boiler. Inspect feedwater controls, and check the ability of the

controls to maintain proper water level throughout the range of capacity with load swings. Check the operation of the low-water fuel cutoff and automatic water feeding devices by draining the float bowl, lowering the boiler water level, and performing the necessary steps to cause these devices to function to ensure that they operate properly.

**6.4 PIPING AND PIPING CONNECTIONS.** While the boiler (or vessel) is operating at full operational pressure, examine all steam and water pipes, including connections to the water columns and all associated piping, for leaks. If any leaks are found, determine whether they are the result of excessive strains due to expansion, contraction, water hammer, or other causes. Look for undue vibration, particularly in piping connections to the boiler and the vessel. Where excessive vibration is found, examine connections and parts for a tendency to crystallize.

**6.5 DEVICES**

**6.5.1 TEMPERATURE INDICATING DEVICES.** Observe all temperature indicating devices for indications of excessive temperatures, particularly during and immediately following the time when high load demands are made on the boiler and the vessel.

**6.5.2 METERING AND RECORDING DEVICES.** While the boiler is operating under normal conditions, observe the operation of all metering and recording devices. When there is evidence that any such device is not functioning properly, it must be adjusted, repaired, or replaced as necessary.

**6.6 VALVES**

**6.6.1 BLOW-DOWN VALVES.** Test the freedom of each blow-down valve and its connections by opening the valve and blowing down the boiler for a few seconds. Determine whether the valve is excessively worn or otherwise defective, and whether

there is evidence of restrictions in the valve or connected piping preventing proper blow-down of the boiler.

**6.6.2 STOP AND CHECK VALVES.** While the boiler (or vessel) is operating, inspect the operating condition of each stop and check valve where possible. Serious defects of externally controlled stop valves may be detected by operating the valve when it is under pressure. Similarly, defects in check valves may be detected by listening to the operation of the valve or by observing any excessive vibration of the valve as it operates under pressure.

**6.6.3 PRESSURE REDUCING VALVES.** While there is pressure on the system, open and then close the by-pass valve, as safety and operating conditions permit, and observe the fluctuation of the pressure gage pointer as an aid in determining possible defects in the operation of the pressure reducing valve or the pressure gage. Look for evidence that may indicate improper condition of the relief or safety valves provided for pressure reducing valves.

**6.6.4 SAFETY AND SAFETY RELIEF VALVES.** Inspect the valves for evidence of leaks and proper operation. Check the popping pressure and blow-down of safety valves by allowing the pressure of the boiler to rise so that the valves lift. Inspect the valve drains and discharge to ensure that they are free from obstructions and installed according to the ASME Code. For multiple valve operations, where an accumulation test cannot be accomplished, check the freedom of the valve to lift using the lifting lever provided the pressure is within 10 percent of the valve set pressure. Similarly, check safety relief valves by using the lifting lever. Proper installation and operation is necessary prior to issuing an inspection certificate.

**6.7 BOILER AUXILIARIES.** While the boiler is operating under normal conditions, observe the operation of all boiler auxiliaries for any defects that may prevent the proper functioning of the boiler or which may indicate a lack of proper maintenance. Discourage the unnecessary use of multiple auxiliaries or the use of a large auxiliary

during a light load period (when a smaller auxiliary could be substituted.) Steam leaks, wastage to atmosphere, and so forth, should be called to the attention of the operating personnel. Particular attention should be given to deaerator venting practice. Venting should be held to the minimum required to preclude oxygen entrainment in the feedwater. When intermittently operating condensate pumps are used, look for any tendency toward the creation of a vacuum when a pump starts. If this happens, the installation of a small continuously operating, float throttled, condensate pump (in parallel with intermittently operating pumps) will ensure a condensate flow at all times. If there are a number of intermittently operating condensate pumps, it may be possible to convert one of them (if of small enough capacity) to continuous throttled operation.

**6.8 BOILER AND FEEDWATER TREATMENT.** Observe the operation of equipment provided for boiler and feedwater treatment, and check the materials and procedures used for boiler and feedwater treatment to ensure adequate protection against scale and corrosion in the boiler, plant, equipment, and distribution system. The internal condition of the boilers, as evidenced from inspections required, the paragraph entitled, “Internal Inspections of Boilers,” is the determining factor regarding the adequacy of materials, and procedures used in boiler and feedwater treatment. Withhold the certificate if an effective boiler water treatment program is not being implemented.

**6.9 FUEL HANDLING PRACTICES.** Check the fuel handling practices and make recommendations toward the elimination of multiple handling, heating of tanks not in use, and the simultaneous use of heaters in a duplex fuel oil pump and heater set where load conditions do not require this procedure. Avoid heating entire tanks. Limit heating within a tank to heating at the suction point only. With respect to residual fuel oil tanks, frequent tank changes (utilizing the full capacity of the tank, from max full to max drawdown, extending to the tank bottom) should be encouraged as a means of precluding sludge buildup.

## 7. REPAIRS AND ALTERATIONS

**7.1 GUIDANCE.** Repairs to the equipment may be necessary before certification. The activity may already be aware of necessary repairs prior to any inspections and tests. Prior to issuing a certificate, all deficiencies that cause an unsafe condition must be corrected. The repairs must be completed in accordance with the applicable code. For pressure parts, repairs must be performed in accordance with the NBBI and ASME Codes. For combustion control safeguards (burner safety controls), the equipment must be repaired to meet the requirements of the NFPA 85 or ASME CSD-1, as applicable. To ensure safe operating conditions, repairs to flame safeguard equipment should only be made by the manufacturer or his authorized representative.

**7.2 CONTRACTOR REPAIRS.** Owner activities may be allowed the option of using Owner welders qualified in accordance with the applicable standards to make repairs and alterations to boilers and unfired pressure vessels, or a contractor holding a NBBI (R) stamp in accordance with Part 3, Section 1, Repairs and Alterations – General and Administrative Requirements of the *National Board Inspection Code*. For welding repairs or alterations, the contractor, or Owner organization furnishing the qualified welder, must complete an Owner documentation equivalent to the National Board Form R-1 and stamping and nameplate attachment is required.

**7.3 SETTING SAFETY AND RELIEF VALVES.** The setting of safety valves of power boilers and relief valves of UPVs within the limits of ASME Section I and VIII are adjustments. Other changes in settings, welding, or machining are repairs. Repairs and adjustments of these valves are not valid unless performed by the manufacturer or a valve repair company. *Repairs by the Owner are prohibited.* The contractor is required to affix a National Board VR nameplate to the repaired valve. Whether the valve is repaired or adjusted; document the breaking of the seal, the setting of the valve, and resealing of the valve. Power boilers and UPVs are not certifiable unless all safety and relief valves are sealed and tagged. Bench testing the valve with no

adjustments may be performed by a non-AMSE shop/Government. It is required that documentation be provided including the valve's nameplate data, pressure at which it opened, date and time of test and the signature of the tester.

**7.4 RECORDS.** ANSI/NB-23, National Board Inspection Code, Part 3, Section 5, Repairs and Alterations – Certification/Documentation and Stamping gives the formats for the various forms: Form R-1 Report of Welded Repair, Form R-2 Report of Alteration, Form R-3 Report of Parts Fabricated by Welding, Form R-4 Report Supplementary Sheet. If the information in these forms is acceptable to the inspector, the repairs or alterations can proceed and be inspected. Upon inspector approval of the work, the activity must make a permanent record of the repairs or alterations.

## 8. INSPECTION CERTIFICATES AND REPORTS

**8.1 PROCEDURES FOR SUBMITTING REPORTS AND FORMS.** The following reports and forms are for use in the inspection and testing of boilers and unfired pressure vessels.

**8.1.1 INSPECTION REPORTS - BOILERS AND UNFIRED PRESSURE VESSELS.** The applicable report is to be completed by the inspector to record the condition of the boiler or unfired pressure vessel, the tests performed, and the issuance of the certificate.

**8.1.2 INSPECTION CERTIFICATE FOR BOILERS - UNFIRED PRESSURE VESSELS;** A current and valid certificate, or commercial equivalent for contract inspection, must be posted on, or near, the equipment, by the certifying inspector under a clear protective covering. / Operation of the equipment without the certificate is not authorized. The certificate will be issued under the following conditions:

- No Deficiencies: The inspector will complete and sign after the test inspection.
- Deficiencies Not Affecting Operating Safety: May be issued, but correction must be recorded on the Inspection Report.
- Deficiencies Affecting Operating Safety: Withheld until corrected and re-inspected. The Owner must be notified in writing listing the specific deficiencies.
- Pressure Reduction: Issued for the reduced working pressure. Oral notification, confirmed in writing, must be made by the inspector to the Owner.
- Unserviceable: No certificate may be issued. The inspector must notify the Owner in writing of the deficiencies.

## 9. MAXIMUM ALLOWABLE WORKING PRESSURE

**9.1 GUIDANCE.** The Maximum Allowable Working Pressure (MAWP) will be determined as described in the National Board Inspection Code. The following paragraphs provide further guidance on MAWP. Defects or damage discovered during the inspection must be repaired. If, in the judgment of the inspector, a steam or hot water boiler or vessel is unsafe for operation at the pressure previously approved, reduce the pressure, make proper repair, or condemn the boiler or vessel.

**9.2 STANDARD BOILERS.** Including expansion drums on high temperature water installations. The maximum allowable working pressure of a boiler built in accordance with the ASME BPVC Code must not, in any case, exceed the pressure indicated by the manufacturer's identification stamped or cast upon the boiler or upon a plate secured to it. Specific requirements governing the maximum allowable working pressure on the following standard boilers must be followed.

**9.2.1 STANDARD WATERTUBE BOILERS.** The maximum allowable working gage pressure on a standard watertube boiler, the tubes of which are secured to cast iron or malleable iron headers, or which have cast iron mud drums, must not exceed 1103.16 kPa (160 psig).

**9.2.2 STANDARD CAST IRON STEAM BOILERS.** The maximum allowable working gage pressure for a standard cast iron steam boiler must not exceed 15 psig (103.42 kPa). Standard cast iron hot water boilers operating at temperatures not to exceed 250 degrees F (121.1 degrees C) may be operated at gage pressures up to 160 psig (1103.61 kPa).

**9.3 NONSTANDARD BOILERS**

**9.3.1 NONSTANDARD RIVETED BOILERS.** The maximum allowable working pressure on the shell of a nonstandard riveted heating boiler must be determined in

accordance with the Code, except that in no case can the maximum allowable working gage pressure of a steam heating boiler exceed 103.42 kPa (15 psig,) or a hot water boiler exceed 160 psig (1103.16 kPa) at a temperature not exceeding 250 degrees F (121.1 degrees C).

**9.3.2 NONSTANDARD WELDED BOILERS.** The maximum allowable working gage pressure of a nonstandard steel or wrought iron heating boiler of welded construction must not exceed 15 psig (103.42 kPa) for steam. For other than steam service, calculate the maximum allowable working pressure in accordance with the Code.

**9.3.3 NONSTANDARD CAST IRON BOILERS.** The maximum allowable working gage pressure of a nonstandard boiler composed principally of cast iron must not exceed 15 psig (103.42 kPa) for steam service, or 30 psig (206.84 kPa) for hot water service. The maximum allowable working gage pressure of a nonstandard boiler having cast iron shell or heads and steel or wrought iron tubes must not exceed 15 psig (103.42 kPa) for steam service or 30 psig (206.84 kPa) for hot water service.

**9.4 CALCULATIONS OF MAXIMUM ALLOWABLE WORKING PRESSURE.** When inspection indicates that the thickness of the plate or the strength of any joint is less than that on which the current maximum allowable working pressure is based, or when it is impracticable to apply the required hydrostatic test, calculate a new maximum allowable working pressure in accordance with the rules of the Code. The following factors of safety must be used and increased by the inspector if the condition \4\ /4/of the boiler demands it:

- The lowest factor of safety permissible on existing installations is be 4.5 except for horizontal return tubular boilers having continuous longitudinal lap seams more than 12 feet (3.7 m) in length where the factor of safety is 8, and when this latter type of boiler is removed from its existing setting, it must not be reinstalled for gage pressures in excess of 15 psig (103.42 kPa).

- Reinstalled or secondhand boilers have a minimum factor of safety of 6 when the longitudinal seams are of lap riveted construction, and a minimum factor of safety of 5 when the longitudinal seams are of butt and double strap construction.

- The maximum allowable working pressure for a vessel in operation must be computed with the appropriate formulas in the Code, using dimensions actually determined by the inspection for the thickness and twice the estimated corrosion allowance before the next inspection, and making suitable allowance for the other loadings enumerated in the Code to be considered in the design of a vessel. The maximum allowable working pressure of vessels designed and built with one or more openings, for which the closures are auxiliary equipment not part of the pressure vessels, must be determined only after due consideration of the auxiliary equipment to be used as closures. The minimum factor of safety must not be less than 4 and must be increased by the inspector if the condition and safety of the vessel demand it. The condition of the vessel and the particular service to which it is subject are the determining factors.

**9.5 FACTOR OF SAFETY.** The factor of safety is "built in" to the ASME Code formulas of Section I. For reference, the original formula is:

EQUATION: $P = (TS \times t \times E) / (R \times FS)$

where:

P = pressure in psi
TS = tensile strength, psi
t = thickness, inches
E = efficiency of the longitudinal seam
R = inside radius, inches
FS = factor of safety