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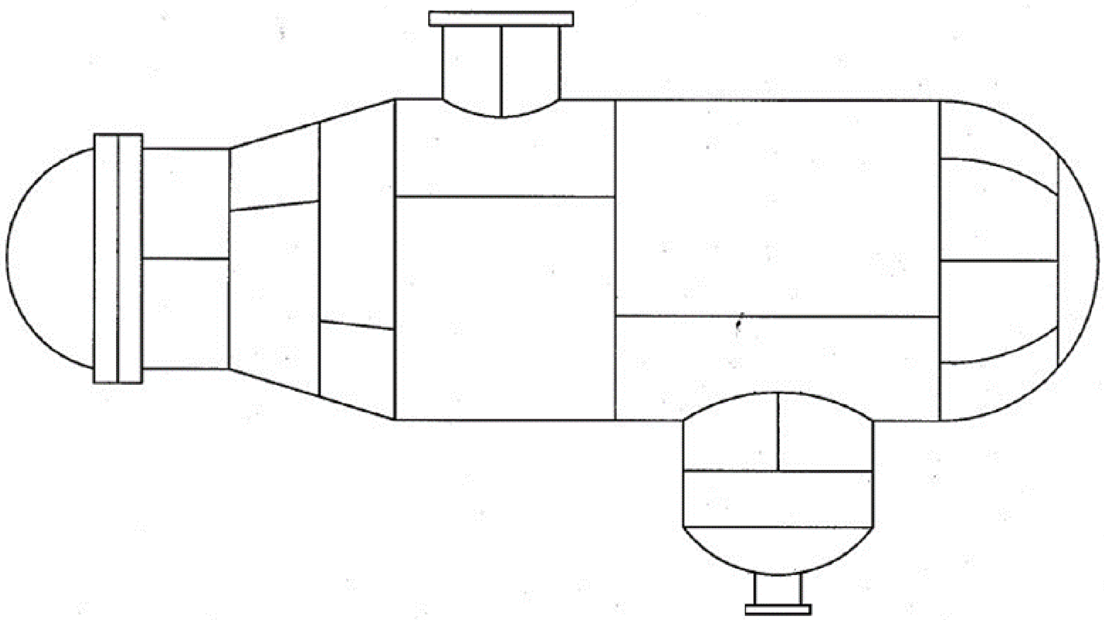
Facilities Instructions, Standards, and Techniques - Volume 2-9

Inspection of Unfired Pressure Vessels



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The Bureau of Reclamation operates and maintains 53 hydroelectric powerplants and many switchyards, pumping plants, dams, canals, and associated facilities that are important to electric power and water delivery systems. This document establishes consistent procedures for the inspection of unfired pressure vessels in accordance with the National Board Inspection Code (ANSI/NB-23) and the ASME Boiler and Pressure Vessel Code.

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Technical Service Center

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Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Codes and Standards

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American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section VIII, Division 2, 2019.

American Society for Nondestructive Testing, ASNT Central Certification Program, ACCP-CP-1 Revision 8, 2012.

National Board Inspection Code (ANSI/NB-23) 2017 Edition.

Occupational Safety and Health Administration (OSHA), Part 1910.169

Reclamation Safety and Health Standards Section 17.12-17.14 (October 2009)

Reclamation Standards and Documents

FAC 01-04	*Review of Operation and Maintenance Program Examination of Associated Facilities (Facilities Other Than High- and Significant-Hazard Potential Dams)*
FAC 01-07	*Review/Examination Program for High and Significant Hazard Dams*
FAC 04-01	*Power Review of Operation and Maintenance (PRO&M) Program*
FAC 04-14	*Power Facilities Technical Documents*
FIST 4-1A	*Maintenance Schedules for Mechanical Equipment*
FIST 4-1B	*Maintenance Schedules for Electrical Equipment*
RCD 03-03	*Request for Deviation from a Reclamation Manual Requirement and Approval or Disapproval of the Request*
RSHS	*Reclamation Safety and Health Standards, Section 17, Hand Tools, Power Tools, Pressure Vessels, Compressors, and Welding*

Reclamation Forms

POM: https://teamssp.bor.doi.net/printanddup/forms/POM%20Forms/Forms/AllItems.aspx

POM-226, FIST Revision Request

POM-300, FIST Variance Form

Acronyms and Abbreviations

ANSI	American National Standards Institute
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
D&S	Directives and Standards
FIST	Facilities Instructions, Standards, and Techniques
FAC	Project Planning and Facility Operations, Maintenance, and Rehabilitation (of the Reclamation Manual)
H_2S	hydrogen sulfide
MAWP	maximum allowable working pressure
NBIC	National Board Inspection Code
NDE	Non-Destructive Examination
OSHA	Occupational Safety and Health Administration
PPE	personal protective equipment
O&M	operations and maintenance
PRO	Power Resources Office
PRO&M	Power Review of Operation and Maintenance
psi	pounds per square inch
POM	Power Operations and Maintenance
RCD	Records Management (of the Reclamation Manual)
Reclamation	Bureau of Reclamation
RM D&S	Reclamation Manual Directive and Standard
RSHS	Reclamation Safety and Health Standards
scfm	standard cubic feet per minute
TSC	Technical Services Center
UT	ultrasonic testing

Symbols

%	percent
°F	Degree Fahrenheit

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1.0 Introduction

The Bureau of Reclamation operates and maintains hydroelectric powerplants, switchyards, pumping plants, water delivery equipment and associated facilities in the 17 western United States. These facilities house complex electrical and mechanical equipment that must be kept operational because they are critical to the electric power and water delivery systems relied on by many. FIST manuals are technical documents that provide criteria and procedures that should be utilized by the offices involved in managing Reclamation facilities and assets.

This document establishes standard technical practices to ensure the safe, reliable, economic, and efficient O&M of Federal facilities by keeping related assets in good condition and ultimately protecting Federal investments. These technical practices provide a sufficient level of detail to ensure consistent application while providing flexibility for the use of innovative techniques and approaches. This document was developed with input from staff in Reclamation's Denver, regional, and area offices.

1.1 Purpose and Scope

This document is intended to promote uniformity in the manner that assets are managed, documented, and coordinated, and may be utilized by transferred facilities and other entities as appropriate. It establishes consistent procedures, minimum standards, and O&M criteria for hydroelectric equipment and systems owned and operated by Reclamation. Other technical documents may provide additional electrical and mechanical maintenance information for the equipment or systems discussed in this document.

O&M requirements are based on industry standards and experience. Maintenance requirements vary based on equipment condition and past performance, and sound engineering practices and maintenance management should be employed for special circumstances. Manufacturer recommendations and instructions should be consulted for additional maintenance that may be required beyond what is stated in this manual.

This volume includes standards, practices, procedures, advice on day-to-day operation, maintenance, and testing of mechanical equipment in Reclamation facilities.

1.2 Reclamation Standard Practices

FIST manuals are designed to provide guidance for maintenance and testing on equipment in Reclamation's facilities. There may be multiple ways to accomplish tasks outlined in this document. Facilities may exercise discretion as to how to accomplish certain tasks based on equipment configurations and available resources.

Reclamation's regions, PRO, and TSC agree that certain practices are required to be consistent across all Reclamation facilities. Mandatory FIST procedures, practices, and schedules that appear in **{Red, bold, and bracketed}** or **[Black, bold, and bracketed]** text are considered Reclamation requirements for the O&M of equipment in power facilities. RM D&S FAC 04-14, *Power Facilities Technical Documents*, describes the responsibilities required by text designations: **{Red, bold, and bracketed}**, **[Black, bold, and bracketed]**, and plain text, within this technical document. Refer to RM D&S FAC 04-14 for more details concerning technical documents.

1.3 Maintenance Tables

Maintenance tables for tasks described in this document are included in FIST 4-1A, *Maintenance Scheduling for Mechanical Equipment*, and FIST 4-1B, *Maintenance Scheduling for Electrical Equipment*.

1.4 Manufacturer Recommendations

The information in this document is based on manufacturers' documentation and historic Reclamation practices. Due to the differences in equipment designs, owner's manuals and manufacturer's recommended maintenance should be consulted when developing job plans. Not following the manufacturer's guidance may void the warranty of new equipment. If there is a discrepancy between the FIST and the manufacturer's recommendations, the job plan must use the more stringent practice unless there is a reason that a less restrictive maintenance practice is warranted. Use of a less restrictive maintenance practice must be approved as outlined in RM D&S FAC 04-14 by either a deviation or a variance. A deviation may be granted in accordance with RCD 03-03 and variances are approved in accordance with FAC 04-14 using POM Form 300.

1.5 FIST Revision Requests

The FIST Revision Request Form (POM-226) is used to request changes to a FIST document. The request will should include a summary of the recommended changes and a basis for the revision or new FIST. Submit FIST revision requests to the PRO Manager. The PRO Manager will keep a list of revision requests for each FIST and include these in the next scheduled revision unless the change is prioritized sooner.

1.6 Mechanical Database

The TSC Mechanical Equipment Group created and maintains a Mechanical Equipment Database. All Reclamation employees have access to the database, which contains test data, operating data, and general information about the following:

- Turbines
- Governors
- Gates and valves

- Pressure vessels
- Penstocks
- Elevators
- Hoists
- Cranes

The database:

- Provides visibility of other Reclamation facilities with similar equipment; i.e., find all Reclamation facilities with Obermeyer Gates.
- Is a critical tool for facility reviewers, i.e., reviewers can obtain printable forms from the database website for each asset being reviewed. The form can be taken to the site and used to compare and update information.
- Tracks equipment testing frequencies and critical data comparison. For example, governor alignment results can be compared to the previous governor alignment results. An increase in operating pressures or opening/closing times can indicate gate repairs are required.
- Provides updated testing and inspection dates for gates, valves, pressure vessels, and penstocks for mechanical inspectors/reviewers to use during Power Reviews (RM D&S FAC 04-01), Associated Facilities Reviews (RM D&S FAC 01-04), and High and Significant Hazard Dam Reviews (RM D&S FAC 01-07).

When tests and alignments, as outlined in FIST 4-1A, *Maintenance Schedules for Mechanical Equipment,* or the database, are completed, facilities or regional personnel should submit the recorded data to the Mechanical Equipment Group (bordromechequipdb@usbr.gov). A service agreement is established with TSC to update the database and keep it accurate. The PRO&M review programs use this database to ensure tests and alignment are up to date and are being tracked.

The link to the Mechanical Equipment Database is: https://mechdb.usbr.gov/MechDB/.

2.0 Unfired Pressure Vessels at Reclamation Facilities

All Reclamation facilities contain unfired pressure vessels, which are pressure vessels where no external heat is applied. Unfired pressure vessels include air receivers, governor air-over-oil tanks, air circuit breakers, and accumulator tanks for hydraulic operating systems.

Many of the pressure vessels at Reclamation facilities are over 40 years old. Because of the effects of corrosion and erosion, these tanks may no longer have their original design strength. Because of changes in operating conditions, they may experience more severe service and wear than was originally anticipated.

Pressure vessels are not generally thought of as a safety hazard to personnel. However, OSHA records indicate that 69 people in the last decade have died as a result of accidents involving both unfired and fired pressure vessels.

The pressure vessel inspection program's main purpose is to ensure that each pressure vessel is safely operated and maintained. Regularly scheduled pressure vessel inspections:

- Improve facility, personnel, and public safety,
- Prevent damage to the environment,
- Improve reliability,
- Reduce O&M costs,
- Minimize unscheduled outages,
- Minimize liability.

Unfired pressure vessels owned by private industry and state agencies are regulated by state law. They are designed, built, and installed according to ASME codes and are subject to meeting the inspection and certification requirements of the NBIC (ANSI/NB-23). They are also required to comply with any specific regulations of the state in which they are located. Unfired pressure vessels owned by the Federal Government are not subject to state laws.

RSHS govern Reclamation's pressure vessels and require that Reclamation facilities design, construct, install, inspect, and maintain boilers and unfired pressure vessels according to:

- The current ASME Boiler and Pressure Vessel Code,
- The current NBIC (ANSI/NB 23),
- The current codes and regulations of the state (in which they are installed).

This FIST manual provides inspection and testing guidelines for unfired pressure vessels that meet or exceed the requirements of the above-mentioned codes.

A number of unfired pressure vessels in service at hydroelectric facilities require inspection and certification. Some examples are:

- Oil tanks for governors.
- Air receiver tanks.
- Air circuit breakers.
- Accumulator tanks for hydraulic operating systems.

Most of the pressure vessels in Reclamation service were designed and constructed according to one of the following two pressure vessel design codes:

- The ASME Code or Section VIII of the ASME *Boiler and Pressure Vessel Code*.
- The API Standard 620, *Design and Construction of Large, Welded, Low-pressure Storage Tanks*, which provides rules for lower pressure vessels not covered by the ASME Code. This standard has been discontinued but remains active.

In addition, some vessels designed and constructed between 1934 and 1956 may have used the rules in the API-ASME Code for Unfired Pressure Vessels for Petroleum Liquids and Gases. This code was discontinued in 1956. Pressure vessels that were not fabricated according to the above-mentioned codes and standards need to be evaluated during the inspection process to determine whether the factor of safety is adequate.

Examples of typical unfired pressure vessels at Reclamation facilities are shown below (Photographs 1, 2 and 3).

Photograph 1. Governor Oil Tank

Photograph 2. Air compressor and receiver tank.

Photograph 3. Air receiver tank.

3.0 Causes of Deterioration in Pressure Vessels

There are a variety of conditions that cause deterioration in pressure vessels. Common conditions are listed and described below:

3.1 Corrosion

Corrosion is one of the most prevalent conditions found in pressure vessels. The following types of corrosion are commonly found:

3.1.1 Pitting

Shallow, isolated, scattered pitting over a small area that does not substantially weaken the vessel. It could, however, eventually cause leakage.

3.1.2 Line corrosion

This is a condition where pits are connected, or nearly connected, to each other in a narrow band or line. Line corrosion frequently occurs in the area of intersection of the support skirt and the bottom of the vessel and at the liquid-vapor interface.

3.1.3 General corrosion

This is corrosion that covers a considerable area of the vessel. When this occurs, consider the safe working pressure of the vessel that is directly related to the remaining material thickness.

3.1.4 Grooving

This type of corrosion is a form of metal deterioration caused by localized corrosion. It may be accelerated by stress concentration. Grooving may be found adjacent to riveted lap joints or welds and on flanged surfaces, particularly the flanges of unstayed heads.

3.1.5 Galvanic corrosion

Two dissimilar metals in contact with each other and with an electrolyte (e.g., a film of water containing dissolved oxygen, nitrogen, and carbon dioxide) constitute an electrolyte cell, and the electric current flowing through the circuit may cause rapid corrosion of the less noble metal (i.e., the one having the greater electrode potential). This corrosion mechanism is most active when there are large differences between the electrode potentials of the two metals Galvanic corrosion may also exist with relatively minor changes of alloy composition (i.e., between a weld metal and the base metal). Neutral (e.g., an oxide coating on aluminum) or protective coatings may inhibit galvanic corrosion, but in most instances the metals or alloys must be selected on the basis of intrinsic resistance to corrosion. In pressure vessels, the effects of galvanic corrosion are most noticeable at rivets, welds, and flanged and bolted connections.

3.2 Fatigue

Stress reversals (such as cyclic loading) in parts of equipment are common, particularly at points of high secondary stress. If stresses are high and reversals frequent, failure of parts may occur because of fatigue. Fatigue failures in pressure vessels may also result from cyclic temperature and pressure changes. Locations where metals having different thermal coefficients of expansion are joined by welding may be susceptible to thermal fatigue.

3.3 Creep

Material creep occurs when equipment is subjected to any combination of increased temperatures, fluctuating temperatures, increased internal pressure, applied external stresses, inherent or manufactured (e.g., welding) internal stresses, and chemical interactions. A larger magnitude of the combination of changes yields an increased rate of creep. Creep distortion may result in failure, particularly at points of stress concentration. If excessive temperatures are encountered, crystalline structure and composition changes in metals may also take place that may permanently weaken equipment, thereby increasing the rate of creep. Because the rate of creep depends on time, temperature, and stress, the actual or estimated levels of those quantities should be used in any evaluations.

3.4 Temperature

At sub-freezing temperatures, water and some chemicals handled in pressure vessels may freeze and cause failure. Carbon and low-alloy steels may be susceptible to brittle failure at ambient temperatures. A number of failures have been attributed to brittle fracture of steels that were exposed to temperatures below their transition temperature and which were exposed to pressures greater than 20% of the hydrostatic test pressure. Most brittle fractures have occurred on the first application of a particular stress level (i.e., the first hydrostatic test or overload).

Temper embrittlement is a loss of ductility and notch toughness caused by post-weld heat treatment or high temperature service above 700°F. Special attention should be given to low-alloy steels because they are prone to temper embrittlement.

3.5 Hydrogen embrittlement

Hydrogen embrittlement is a loss of strength or ductility in steels caused by atomic hydrogen dissolved in the steel. It is a low temperature phenomenon, seldom encountered above 200°F, and most often occurs as a result of hydrogen evolved from aqueous corrosion reactions. It can vary in appearance and can occur in differing environments, thus giving rise to the various terms by which it is known, including sulfide stress cracking, wet H_2S cracking, hydrogen stress cracking, blistering, blister cracking, hydrogen-induced cracking, and stress-oriented hydrogen-induced cracking. Weld underbead cracking (also known as delayed cracking and cold cracking) is also a form of hydrogen embrittlement; however, in this case, the hydrogen comes from the welding operation rather than from a corrosion reaction.

Some forms of hydrogen embrittlement (e.g., sulfide stress cracking, stress-oriented hydrogen-induced cracking, weld underbead cracking) require an applied stress or residual stress for cracking to occur; others forms occur in the absence of applied or residual stress, where the internal pressure from the recombined hydrogen gas is sufficient to cause the damage (blistering, hydrogen-induced cracking).

Susceptibility to sulfide stress cracking and similar forms of hydrogen embrittlement depends on the strength of the steel. Higher strength steels are more susceptible. The strength level at which susceptibility arises depends on the severity of the environment that the steel is exposed to. Hydrogen sulfide, hydrogen cyanide, and arsenic, in aqueous solutions, all greatly increase the severity of the environment regarding hydrogen embrittlement by increasing the amount of hydrogen that is absorbed by the steel during the corrosion reaction. In hydrogen sulfide environments, cracking can generally be avoided by using steels with a hardness of Rockwell C-22 or below.

Similarly, weld underbead cracking is caused by hydrogen dissolved in a hard, high-strength, weld-heat affected zone. Practicing low hydrogen welding to minimize dissolved hydrogen or using high preheat or post-weld heat treatment to reduce heat affected zone hardness will reduce the likelihood of weld underbead cracking in a susceptible steel.

Hydrogen embrittlement is reversible as long as no physical damage, e.g., cracking, has occurred in the steel. If the atomic hydrogen is removed from the steel before any damage occurs, for example by heating for a short time in the absence of hydrogen to between 300 and 400°F, normal mechanical properties will be restored.

Cracking that can occur in vessels operating in aqueous H_2S service (i.e., wet H_2S cracking) will not always be readily apparent on visual inspection. Other methods, such as magnetic particle (including wet fluorescent) or liquid penetrant, may be required to reveal the cracks.

Welding procedures, repair methods, and inspection procedures must include careful consideration of potential failure in corrosive environments, including failure from the various forms of hydrogen embrittlement.

3.6 Stress corrosion cracking

Stress corrosion cracking is cracking of a metal caused by the combined action of stress and a corrosive environment. Stress corrosion cracking only occurs with specific combinations of metal and environment. The stress required may be either applied or residual. Examples of stress corrosion cracking include chloride stress corrosion cracking of stainless steels in hot, aqueous chloride solutions and ammonia stress corrosion cracking of brass in ammonia solutions (season cracking).

Corrosion alone is not a good indicator of the likelihood of a particular environment to cause stress corrosion cracking in a particular metal. Solutions that are highly corrosive to a material almost never promote stress corrosion cracking.

The principal variables affecting stress corrosion cracking are tensile stress, service temperature, solution chemistry, duration of exposure, and metal properties. Sufficiently modifying any one of these parameters can reduce or eliminate the possibility of stress corrosion cracking occurring in service.

4.0 Inspection of Unfired Pressure Vessels

Certified and inspected pressure vessels are critical to ensure a safe work environment. Smaller pressure vessels that operate at lower pressures generally pose lower risks to personnel when charged. Therefore, pressure vessels of less than 5 cubic feet (37 gallons) in volume and with a MAWP of 150 psi or less are exempt from the certification and non-destructive testing inspection requirements within this section. These pressure vessels should still be visually inspected and maintained to ensure vessel integrity.

4.1 Frequency of Inspections

4.1.1 Inspection and Certification (New and Alterations/Repaired)

Within Reclamation facilities, alterations or repairs to pressure vessels are uncommon. If a pressure vessel fails an inspection due to wall thinning, the entire receiver should be replaced.

Unfired pressure vessels must be inspected and tested before being placed in service and after any alteration or major repair. **{Test and visually inspect the internals and externals of a new or altered vessel prior to commissioning. The next inspection must be performed within 2 years.}** The interval of subsequent inspections must not exceed 5 years (providing deterioration is shown to be low and at a predictable rate). Where deterioration is shown to be rapid in any part of a vessel, the inspection and testing interval will be determined according to the NBIC or 2 years, whichever is shorter. Perform hydrostatic or state acceptable tests when recommended by the qualified person performing the inspection.

4.1.2 Inspection and Certification (All Receiver Tanks and Pressure Vessels)

Inspection and Certification (All Receiver Tanks and Pressure Vessels) **{Inspect in accordance with the National Board Inspection Code, Reclamation Safety and Health Standards, and this FIST volume.}** The inspection must be performed by a qualified inspector as outlined in the National Board Inspection Code or in accordance within this document.

4.2 Inspector Qualifications

Inspections must be performed by qualified personnel who meet Federal or State certification requirements, or who satisfy the NBIC Owner-User Inspector education and experience requirements, issued by the National Board of Boiler and Pressure Vessel Inspectors.

Reclamation employees who perform the inspections must also be an operator trained and certified to perform ultrasonic thickness examinations and must have one of the following education, experience, training, and certification:

- A degree in engineering from an accredited school plus 1 year of experience in design, construction, repair, or inspection of pressure vessels, or

- An associate degree in mechanical technology plus 2 years of experience in design, construction, repair, or inspection of pressure vessels, or
- A high school education or the equivalent plus 3 years of experience in design, construction, repair, or inspection of pressure vessels.

4.3 Inspection Procedure

This inspection may be external, internal, or both and use a variety of non-destructive examination techniques. The inspection may be performed with the vessel in service or depressurized but should provide the necessary information that allows an adequate assessment of the pressure vessel.

4.3.1 Pre-Inspection Activities

[Ensure operator training and certification for ultrasonic examination within Reclamation facilities meets the minimum requirements set by the ACCP Level II.] Refer to the most recent revision of ASNT Central Certification Program Document, ACCP-CP-1, for information regarding ACCP Level II ultrasonic testing certification. Candidates must complete a 120-hour training requirement before testing for ACCP Level II certification. Training hours may be comprised of theory courses and practical training, though no more than 50% shall consist of practical training.

As of March 2018, ACCP Level II certification documentation is at: https://asntcertification.org/Recertification/ACCP_Level_II.aspx.

[Review the known history of the pressure vessel and assess the current condition using the following criteria:]

1) Date of last inspection.
2) Current jurisdictional inspection certificate.
3) ASME Code Symbol stamping or mark of code of construction (Photograph 4).
4) National Board and/or jurisdiction registration number.
5) Operating conditions and normal contents of the vessel (discuss any unique hazards with the owner or user).
6) Previous inspection report, operating/maintenance logs and test records, and any outstanding recommendations from the previous inspection.
7) The type of connections used during fabrication of the vessel to determine the proper joint efficiency to be used during stress analysis of the pressure vessel.
8) Serial number and materials of construction.
9) Records of wall thickness surveys, especially on vessels where corrosion is a consideration.
10) If required to perform inspection, remove plugs/covers and clean external/internal surfaces of vessel sufficiently.

Photograph 4. ASME Code symbol.

4.3.2 Inspection

[Have a certified inspector perform and document a thorough inspection of pressure vessels. The inspection must include an examination of safety relief devices, vessel wall thickness measurements, vessel equipment, welded connections, and a stress analysis.]

Perform the following steps to thoroughly evaluate the condition of each pressure vessel:

1) Inspect the pressure relief valves and other safety devices per Section 5.0 below to ensure the vessel has adequate protection and is operating within its specified pressure range.
2) Perform ultrasonic measurement techniques to determine the shell and head wall thicknesses for each pressure vessel. Other types of non-destructive examinations should be performed, as required, for any suspect areas identified during the external or internal examination. Document this information for retention for the life of the pressure vessel.
3) Perform a thorough external examination of the pressure vessel and associated equipment, including verification of the welded connections to determine the proper joint efficiency to employ during the stress analysis.
4) Perform a stress analysis based on actual wall thickness data acquired during the ultrasonic thickness survey and the proper joint efficiencies based on the type of construction used during fabrication of the pressure vessel. Compare these results with the original design requirements of the applicable code to ensure that the proper safety factors are being met.
5) Perform an internal examination of the pressure vessel using a borescope or direct visual inspection methods if the pressure vessel has:
   a) significant wall loss, or
   b) poor stress analysis results, or
   c) external evidence of a manufacturer defect, damage, or significant corrosion.

4.3.3 External Inspection

The external inspection provides information regarding the overall condition of the pressure vessel.

[Inspect the exterior of the pressure vessel, including the coatings, evidence of leakage, structural attachments, vessel connections, vessel surfaces, and welded or riveted joints.]

Perform the following steps to evaluate the external condition of each pressure vessel:

1) *Coatings, insulation, or other coverings.* In some instances, it may be necessary to remove portions of coverings, such as corrosion resistant coating or insulation, to investigate their condition and/or the condition of the metal. If the external coverings appear in good condition and there is no reason to suspect any unsafe condition behind them, it is not necessary to remove them for inspection of the vessel.
2) *Evidence of leakage.* Thoroughly investigate any leakage of gas, vapor, or liquid suspected to originate from behind insulation coverings or supports, or evidence of past leakage by removing any covering necessary until the source is determined.
3) *Structural attachments.* Inspect pressure vessel attachments of legs, skirts, or other supports. Check these attachments for distortion or cracks at welds. Check the pressure vessel structural mountings for adequate allowance for expansion and contraction (Photograph 5). Slotted bolt holes or unobstructed saddle mountings may provide adequate allowance.

Photograph 5. Pressure vessel mounting supports.

4) *Vessel connections.* Examine manholes, reinforcing plates, nozzles, and weep holes for defects such as cracks, deformations, and leakage. Check bolts and nuts for corrosion or defects. Weep holes in reinforcing plates should remain open to provide visual evidence of leakage and to prevent pressure buildup between the vessel and the reinforcing plate. Examine accessible flange faces, when necessary, for distortion and condition of gasket seating surfaces (Photograph 6).

Photograph 6. Manhole connection.

5) *Surface inspection.* Examine the surfaces of the vessel for damage such as cracks, dents, gouges, bulges, blisters, or other evidence of deterioration. Give particular attention to the skirt, the support attachment and knuckle section of the head. Dents in a vessel are deformations caused by contact with a blunt object in such a way that the thickness of the metal is not materially impaired. In some cases, a dent can be repaired by mechanically pushing out the indentation. If material distortion is suspected or observed, check the overall dimensions of the vessel to determine the extent and seriousness of the distortion. Cuts or gouges can cause high stress concentrations and decrease the wall thickness. Depending on the extent of the defect, it may be necessary to repair the area by welding or patching. Blend grinding may be a useful method of eliminating some minor types of cuts or gouges.

6) *Welded joints*. Examine welded joints and the adjacent heat-affected zones for cracks or other defects. If suspect areas are found, magnetic particle and liquid penetrant examination is a useful means of determining if cracks or defects exist.

   It is important to determine the weld configuration of the pressure vessel in order to use the proper joint efficiency when performing stress calculations. The ASME Boiler and Pressure Vessel Code specifies six types of weld joints.

   Type 1: Double-welded butt joints. The quality of weld is the same inside and outside the vessel with double-welded butt joints. Backing strips, if used, are removed after welding. After the weld is made on one side, the other side of the joint is cleaned and re-welded.
   Type 2: Single-welded butt joints with backing strips that remain in place after welding.
   Type 3: Single-welded butt joints without backing strips.
   Type 4: Double full-fillet lap joints.
   Type 5: Single full-fillet lap joints with plug welds.
   Type 6: Single full-fillet lap joints without plug welds.

All six weld types are shown in Figure 1 including the typical welding symbol for each.

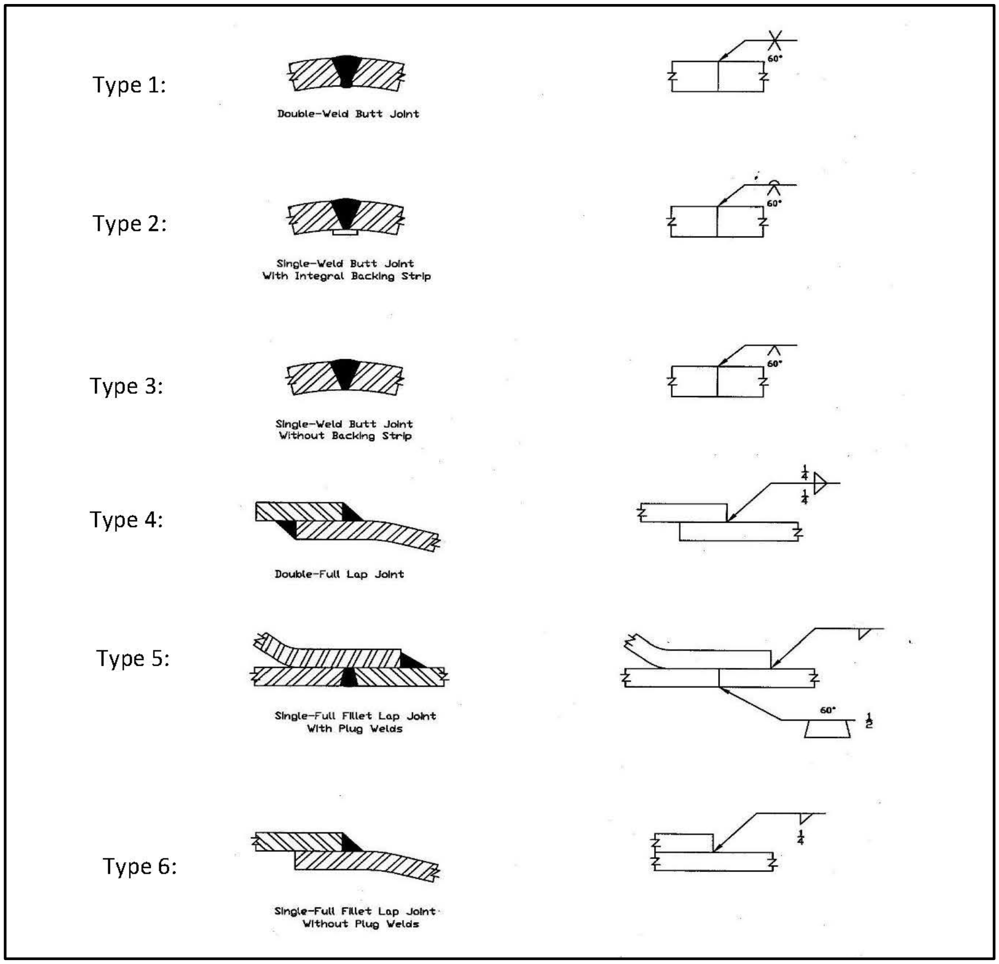

Figure 1. Weld configurations.

For joint efficiencies of welded joints subject to tension, the values depend on the type of weld and the testing processes. The strongest joints are double-welded butt joints (Type 1). Joint efficiencies for the butt joints and other welded connections are shown in Table 1. The configuration for the joint types shown in Table 1 correlate to the joint type in Figure 1.

Joint Type	Full Radiograph	Spot Radiograph	No Radiograph
1	1.00	0.85	0.70
2	0.90	0.80	0.65
3	-	-	0.60
4	-	-	0.55
5	-	-	0.50
6	-	-	0.45

Table 1. Efficiencies of welded joints in shells.

7) *Riveted Vessels.* On riveted vessels, examine rivet head, butt strap, plate, and caulked edge conditions. If rivet shank corrosion is suspected, hammer testing for soundness or spot radiography at an angle to the shank axis may be suitable.

4.3.4 Thickness Survey

[Perform an ultrasonic thickness survey of the pressure vessel shell and dished heads, must be completed by a certified inspector.] Document the test results on the pressure vessel's certification report. The ultrasonic testing equipment should be properly calibrated and have a waveform display with peak-to-peak measurement mode capability and an accuracy of 0.010 inches per inch. The wall thickness data for each subsequent inspection should be used for comparisons to determine if any wall thinning may be taking place and compromising the factor of safety for the pressure vessel.

4.3.5 Stress Analysis

[Using ultrasonic thickness measurements, perform a stress analysis and calculate the factor of safety of the pressure vessels using the ultrasonic thickness measurements for the shell and dished heads.] Use the correct joint efficiencies based on the original fabrication of the pressure vessels.

Pressure vessels designed and fabricated according to the ASME Code typically have safety factors greater than 2.5.

Pressure vessels with calculated factors of safety between 2 and 2.5 should be monitored closely, and any necessary repairs should be made to prevent the factor of safety from becoming lower than 2. It is recommended that any pressure vessel with a factor of safety lower than 2 be replaced.

4.3.6 Internal Inspection

[Inspect the interior of the pressure vessel if the ultrasonic wall thickness data indicates significant loss of material, including an examination of the vessel connections, vessel closures, vessel internals, and corrosion severity.]

Use a borescope or direct visual inspection to perform the following steps to evaluate the internal condition of each pressure vessel:

1) *Vessel connections*. Inspect threaded connections to ensure that adequate threads are engaged. All openings leading to any external fittings or controls should be examined as thoroughly as possible to ensure they are free from obstructions.
2) *Vessel closures*. Check any special closures for adequacy and wear. This includes closures on autoclaves, normally termed 'quick actuating' (quick opening) closures, which are used frequently in the operation of a pressure vessel. Also check for cracks at areas of high stress concentration.
3) *Vessel internals*. Where pressure vessels are equipped with removable internals, these internals need not be completely removed, provided evidence exists that deterioration in regions rendered inaccessible by the internals is not occurring to an extent that might constitute a hazard or to an extent beyond that found in more readily accessible parts of the vessel.
4) *Corrosion*. Note any existing type of corrosion (pitted or uniform), its location, and any obvious conditions on the pressure vessel certification sheet. Data collected for vessels in similar service will aid in locating and analyzing corrosion in the vessel being inspected. The liquid level lines, the bottom, and the shell area adjacent to and opposite inlet nozzles are often locations of most severe corrosion. Welded seams and nozzles and areas adjacent to welds are often subjected to accelerated corrosion.

4.4 Non-Destructive Examination

Non-destructive examination methods of assessing the condition of pressure vessels include magnetic particle examination, liquid penetrant examination, ultrasonic examination, radiography, eddy current examination, visual examination, metallographic examination, and acoustic emission. The most important and useful technique is ultrasonic testing to determine actual wall thickness for the shell and dished heads of the pressure vessels. The inspector should determine the type and amount of non-destructive examination. Experienced and qualified individuals should perform these examinations.

Generally, some type of surface preparation is required prior to non-destructive examination. Personnel performing the examination and tests must have proper training and certification.

4.5 Pressure Testing

Pressure testing is not normally part of a periodic pressure vessel inspection. A pressure test may be required when the inspection discloses unusual, hard-to-evaluate forms of deterioration that may affect the safety factor of the pressure vessel or if any alterations or repairs have been made to the vessel wall.

[Perform a hydrostatic pressure test to 1.5 times the MAWP if any repair, alteration, unusual deterioration, or significant material loss (corrosion or erosion) has affected the pressure vessel. Recertify and/or re-stamp the pressure vessel following the hydrostatic pressure test.]

Uprating of a pressure vessel can be completed if it is operationally necessary and the stress calculation, using the most recent ultrasonic test of wall thickness data, is acceptable at the new MAWP. Many governor oil tanks have MAWP ratings which are very close to their normal operating pressure, which can cause their pressure relief valves to relieve inadvertently. Uprating the MAWP of these tanks by an additional 50 psi to allow for a higher-rated relief valve is a common practice in Reclamation.

[Uprate the MAWP of a pressure vessel by ensuring the stress calculation is acceptable at the new MAWP and by performing a hydrostatic pressure test to 1.5 times the new MAWP. Recertify and/or re-stamp the pressure vessel following the hydrostatic pressure test.]

Hydrostatic testing is the only acceptable method of pressure testing Reclamation pressure vessels. Other methods of pressure vessel pressure testing are prohibited (such as pneumatic testing by using air compressors to build up the pressure inside a pressure vessel) because using a compressible gas introduces the potential for an explosion.

In the event that test pressure must exceed the set pressure of system relief devices, each device must be prepared as recommended by the valve manufacturer. Metal temperature during a pressure test should not be less than 60°F unless the owner provides information on the toughness characteristics of the vessel material that indicates the acceptability of a lower test temperature. The metal temperature should not exceed 120°F unless the owner specifies the requirement for a higher test temperature.

Perform a thorough inspection of the vessel and its associated connections and components while under pressure. Hold the test pressure for a period of 15 minutes. If the pressure drop exceeds more than 10%, repair leaks and repeat the test. If the pressure drop is less than 10% and an inspection does not reveal leaks in the pressurized parts, it may be assumed that the leaks are through the isolation valves, manholes and/or handholes.

Personnel performing hydrostatic tests must always consider all components to be included in a testing clearance, piping to be disconnected and isolated, exterior and interior visual examination, and test medium used. The below hydrostatic test procedure can be used as a basis for hydrostatic testing within Reclamation facilities.

4.5.1 Hydrostatic Test Procedures

Prior to performing hydrostatic testing for re-rating a tank or pressure vessel for a higher maximum allowable working pressure, a professional engineer should perform calculations to ensure the safety factors are adequate for the new MAWP and for the hydrostatic test pressure (1.5 times the MAWP).

4.5.1.1 Equipment Required

Certain devices are necessary to perform a thorough internal inspection of receivers without manways or access openings. Make sure all pipe, fittings, and valves are properly rated for the hydrostatic test pressure. The following equipment is typically used:

1) Inspection cameras or borescopes.

2) Fittings for blanking off all openings to the receiver, with allowances for the filling, venting and test gauge.
3) A hand pressure pump capable of generating 150% of the maximum allowable working pressure.
4) A calibrated test pressure gauge with a full scale of at least 1.25 times the maximum test pressure.
5) Test medium.
    a) Oil should be used for testing governor actuator tanks. The oil should be of the same type as in the governor operating system.
    b) Water can be used for testing air receivers.

4.5.1.2 Procedure

1) Place a clearance on the system being tested.
2) Lift the safety and completely drain the receiver tank.
3) Disconnect all piping.
4) Examine the interior of the receiver tank for deposits, rust, stress cracks, scaling, pitting and corrosion. If the tank does not have a manway, a borescope camera may be used to perform the interior inspection through the openings that are available.
5) Clean and make repairs as necessary.
6) Plug all openings, but make sure to allow openings for filling, draining, and venting.
    a) A vent must be provided to allow for the removal of ALL air from inside the vessel to be tested, for safety reasons.
7) Pump pressure up to 150% of the MAWP of the vessel to be tested. Hold this pressure for 15 minutes. If the pressure drop exceeds more than 10%, repair leaks and repeat the test. If the pressure drop is less than 10% and an inspection does not reveal leaks in the pressurized parts, it may be assumed that the leaks are through the isolation valves, manholes and/or handholes.
8) Reduce the pressure to 2/3 of the test pressure or to the MAWP of the vessel being tested.
    a) Inspect all weld seams for leaks by lightly tapping all joints with a small ball peen hammer.
    b) Inspect all seams again for leaks or any evidence of leaks.
9) Pump pressure up to 150% of the MAWP of the vessel to be tested. Hold this pressure for 5 minutes.
    a) Inspect all seams again for leaks or any evidence of leaks.
10) Drain and open the vessel being tested. Examine the internals of the receiver for cracks or other signs of failure. If the tank does not have a manway, use a borescope camera to perform the internal inspection.
11) Test the set pressure of the safeties or poppet relief valves.
    a) Safeties or poppet relief valves with a set pressure up to 70 psi should operate within 2 psi of that pressure.
    b) Safeties or poppet relief valves with a set pressure above 70 psi should operate within 3 psi of that pressure.
    c) Safeties or poppet relief valves with a set pressure up to 250 psi should reset within + or – 10% of that pressure.

d) Safeties or poppet relief valves with a set pressure above 250 psi should reset within + or – 5% of that pressure.
e) Check the system to make sure that safeties or poppet relief valves are located on the compressor side of any isolation valves and on the receivers.
f) Restore the system to an operating state and test for leaks in the piping.
g) Remove clearance.

Contact the TSC Mechanical Equipment Group, 86-68410, with concerns or questions regarding hydrostatic test procedures for pressure vessels, particularly with precautions which should be taken before and during testing.

4.6 Maintenance of Unfired Pressure Vessels

In many air receiver tanks, condensation tends to accumulate at the bottom of the vessel. This moisture, if not drained, can lead to an increased corrosion rate.

[Open receiver drain valve and blow down until water is removed from tank. Check for leaks.]

5.0 Inspection of Safety Devices

The most important appurtenances on any pressurized system are the safety devices provided for over-pressure protection of that system. These are devices such as safety valves, safety relief valves, pilot valves, and rupture disks or other non-reclosing devices that are used to reduce an over-pressure condition.

These devices are not designed or intended to control the pressure in the system during normal operation. Instead, they are intended to function when normal operating controls fail, or when abnormal system conditions occur.

Periodic inspection and maintenance of these important safety devices is critical to ensure their continued functioning and to provide assurance that they will be available when called on to operate.

Inspectors are cautioned that the operation of these safety devices involves the discharge of high-pressure fluid or gas. Extreme caution should be used when working around these devices because of hazards to personnel. During testing, suitable hearing protection should be utilized because of extremely high noise levels that can damage hearing.

Pressure relief valves are meticulously sized by the manufacturer, based on both the specifications of the pressure vessel and the compressor. Replacement relief valves must have similar specifications to the original, including thread diameter size, a pressure relief setting that is equal to or below the MAWP of the vessel, and an equal to or greater flow SCFM rating.

A pressure relief valve is required in every compressed air system ahead of the first point that could conceivably act as an air flow restriction. This includes shutoff valves, check valves, and in-line filters because of the risk that they could become obstructed. A relief valve should also be installed on receiver tanks, and there should be no restrictions between the tank and the valve. If there are no restrictions in the discharge line between the compressor and the receiver tank, the relief valve mounted on the receiver tank is sufficient to protect the system.

An isolation valve installed between a pressure vessel and relief valve, referred to as a block valve, can be useful when changing relief valves without depressurizing the pressure vessel. However, when not actively changing the relief valve, these block valves shall be opened, and the handle locked or removed to ensure a clear path to the relief valve.

The set pressure of the relief valve must be no higher than the MAWP marked on the pressure vessel.

NOTE: Pressure regulators restrict air flow to regulate pressure. They are not acceptable for protection against excessive system pressure because they do not vent air.

5.1 Safety Device Data

[Evaluate the data of each safety device, including an inspection of each device's nameplate markings for capacity and relief set pressure and the vessel's MAWP.]

Perform the following steps to evaluate the data of each safety device:

1) Compare the nameplate marking or stamping of the device to the stamping on the pressure vessel. The set pressure must be no higher than the MAWP marked on the pressure vessel.
2) If multiple devices are provided, ensure the difference between set pressures does not exceed that permitted by the original code of construction.
3) Verify the nameplate capacity and, if possible, compare it to the system capacity requirements.
4) Check seal identification and ensure it matches nameplates or other identification on the valve or device. If it does not match, repair, or reset the nameplate.

5.2 Inspection of Safety Device Condition

[Inspect the condition of safety devices, including a check for leaks, proper sealing, tight bolting, clean surfaces, rust, damage, and drain clogs.]

Perform the following steps to evaluate the condition of each safety device:

1) Check for evidence that the valve or device is leaking or not sealing properly.
2) Check that seals are intact and show no evidence of tampering.
3) Check that connecting bolting is tight and all bolts are present.
4) Examine the valve for deposits or mineral buildup.
5) Check for evidence of rust or corrosion.
6) Check for damaged or misapplied parts.
7) Ensure that visible drain holes are not clogged with debris or deposits.

5.3 Inspection of Safety Device Installation

Safety devices are required on all pressurized systems. Each installed safety device must be inspected.

Perform the following steps to evaluate the installation of each safety device:

1) Inspect inlet piping and ensure that it meets the requirements of the original code of construction. Check that the inlet pipe size is not smaller than the device inlet size.
2) Inspect discharge piping and ensure that it meets the original code of construction. Check that the discharge pipe size is not smaller than the device outlet size.
3) Check that the valve drain piping is open.
4) Check drainage of discharge piping.
5) Check that the discharge piping is not binding on the valve body, as binding can lead to distortion of the valve body and leakage or malfunction.

6) Check the adequacy and condition of pipe supports. Discharge piping support should be independent of the device itself.
7) Check for possible hazards to personnel from the valve discharge or discharge pipe.
8) Check that there are no intervening valves (such as a block valve) between the pressure source and the valve inlet or between the valve outlet and the point of discharge. Block valves may be permitted in some pressure vessel service under certain controlled conditions when shutting down the vessel to repair a damaged or leaking valve would be difficult. Block valve use should be carefully controlled by written procedures, and the block valves should have provisions to be locked in an open position when not being used.

5.4 Operational Inspection of Safety Devices

Pressure relief valves should be periodically tested to ensure that they are free to operate and will operate according to the requirements of the original code of construction (Photograph 7).

Photograph 7. Pressure relief valve.

[Check for freedom-of-operation if seat leakage is found on a pressure relief valve or if the owner has a concern about the valve being stuck.]

Performing this test may prove that the valve is free to operate and may clear the seating surfaces, allowing the valve to seal. This test is done by activating the test lever (or plunger) and can be accomplished without removing the relief valve. Wear the appropriate PPE and take the necessary operational precautions when performing this test. This test should be performed at a pressure equal to or greater than 75% of the relief valve's set pressure, or damage may occur to the relief valve internals. For example, a relief valve stamped for 200 psi should be checked for freedom-of-operation between 150 psi and 200 psi. This test does not provide any information regarding the set pressure.

{Take the pressure vessel out of service if its pressure relief valve is found to have excessive seat leakage, is stuck closed, or is unable to relieve at the proper pressure.}

Return the affected pressure vessel to service once the condition is corrected (unless special provisions, such as providing additional relief valve capacity by a separate valve, have been made to operate on a temporary basis).

The buildup of corrosion or contaminates on the seat of the relief valve can sometimes cause a pressure relief valve to become inadvertently locked closed after a prolonged period of non-operation.

{Replace all pressure relief valves with new certified units or existing operationally tested pressure relief valves.}

In order to minimize operational downtime, it is recommended that each facility have a second set of identical relief valves available for each pressure vessel. Operational testing of the removed relief valve can be conducted at the facility's leisure. The relief valve can be swapped with its matching valve during the next replacement cycle.

An operational test requires that the relief valve be placed in a test stand that is capable of producing air pressure above the set pressure of the relief valve. The relief valve must relieve at a pressure no higher than 10% over its set pressure. For example, a relief valve stamped for 200 psi should relieve between 200 psi and 220 psi. Performing this test verifies that the relief valve will open and operate as intended and flow greater than the compressor volumetric rate to prevent the system from exceeding the MAWP of the pressure vessel by more than 10%. The setting for a relief valve can only be changed by a qualified organization accredited by the National Board of Boiler and Pressure Vessel Inspectors. Having a spare set of new or pre-tested valves ready for this maintenance is a good and common practice.

5.5 Inspection of Rupture Disks

Rupture disks or other non-reclosing devices may be used as sole relieving devices or in combination with safety relief valves to protect pressure vessels.

Perform the following steps when a rupture disk is used on a pressure vessel.

1) Check the rupture disk nameplate information, including stamped burst pressure and coincident temperature, to ensure it is compatible with the vessel and/or safety relief valve. Some rupture disks, when installed incorrectly, may not burst until well above the stamped pressure.
2) Check markings indicating direction of flow to ensure they are correct.
3) Check that the space between a rupture disk and a safety relief valve is supplied with a pressure gauge, try cock, or telltale indicator to indicate signs of leakage through the rupture disk. Replace leaking rupture disks.

4) Ensure the valve design type is not influenced by back pressure from leakage through the valve if a rupture disk is used on a valve outlet. For non-toxic and non-hazardous gas or fluids, vent or drain the space between the valve and the ruptured disk to prevent the accumulation of pressure.
5) Review the installation to ensure that the combination rules of the code of construction have been applied for rupture disks installed on the valve inlet.

5.6 Inspection of Pressure and Temperature Switches

Pressure and temperature switches may be used as alarms in a pressure vessel to protect operating equipment. Refer to manufacturer's documentation for information on how to adjust set points. Reference facility work orders for appropriate set points.

[Check that pressure switches cut in and out at proper pressures. Check setting of temperature switches.]

[Check pressure and temperature switch calibration and set points.]

6.0 Inspection of Piping Systems

Piping systems are designed for a variety of service conditions. Give particular attention to piping systems that are subject to corrosion, erosion, and fatigue and those that operate at high temperatures (Photograph 8).

All pipe material and fittings should be properly rated for the maximum service conditions to which they are subjected. Review the operating history to determine if there have been any changes in service conditions outside the original design. If operating conditions have changed, review records to ensure piping system components are satisfactory.

Perform the following steps to inspect piping and valves connected to pressure vessels:

1) Inspect for corrosion, cracking, erosion, leakage, and improper support or vibration.
2) Verify that piping is appropriate for service conditions, is properly aligned, and has provisions for thermal expansion if necessary.
3) Repack and reseat or replace valves as required.
4) Clean and repaint piping or replace as required.

Photograph 8. Piping connections.

6.1 Piping Defects

6.1.1 Corrosion

Corrosion occurs in the presence of free oxygen and dissolved salts. If corrosion is found in a pressure vessel, the associated piping systems should be considered suspect. Corrosion can deteriorate large areas of metal surfaces or it can be localized in the form of pitting or galvanic corrosion. For the purpose of estimating the effect of severe corrosion over large areas, the thickness of the remaining sound metal should be determined by the use of ultrasonic equipment or by drilling. The estimated thicknesses of the remaining sound metal can then be used to estimate the safe working pressure.

6.1.2 Cracks

Cracks may result from design and operating conditions that cause continual flexing. Flexing can be caused by thermal or mechanical fluctuations and can lead to metal fatigue. Cracking under these conditions may be accelerated by corrosion. Cracking may also result from fatigue at imperfections existing in material at the time of piping system fabrication. Cracks resulting from fabrication defects will normally occur first in corrosive environments in areas subject to high stress. Areas prone to cracking because of the above conditions should be examined periodically.

6.1.3 Erosion

Erosion may occur as a result of the abrasive action of a liquid or vapor. Solid particles in suspension or liquids entrained in vapor contribute to erosion. Erosion generally occurs in areas where flow is restricted or where flow direction is changed. Areas prone to erosion because of the above conditions should be examined periodically.

6.1.4 Leakage

Thoroughly investigate any leaks and initiate corrective action. A pressure test may be required to obtain information regarding the extent of a defect or detrimental condition.

6.1.5 Improper Support

Visual inspection should include a check for evidence of improper support. Observe the alignment of connections between anchored equipment to determine if any change in position of the equipment (e.g., from settling) has placed an undue strain on the piping or its connection. Inadequate support or the lack of provision for expansion may cause broken attachment welds, cracks, or leakage at fittings. Missing, damaged, or loose insulation may indicate vibration or pipe movements resulting from improper support. Investigate any signs of leakage to determine the cause and correct the condition.

6.1.6 Service Conditions

Prior to replacing piping subject to any of the above defects, check piping to ensure suitability for service in its particular application. All pipe material and fittings should be properly rated for the maximum service conditions under normal operating conditions.

6.2 Inspection of Pressure Gauges

Every pressure vessel should be equipped with a pressure gauge. These gauges often require operational checks and calibration to ensure their functionality and accuracy (Photograph 9).

[Check operation of pressure gauges.]

Look for a loose or stuck pointer. Compare pressure indicated with other gauges on the same system, if possible. If there is any doubt about the accuracy of a gauge, replace it with a new calibrated gauge or remove and check calibration with a standard test gauge or a dead weight tester. If the pressure gauge is not mounted on the vessel itself, check that it is installed in such a manner that it correctly indicates the actual pressure in the vessel.

[Remove gauge and calibrate. Repair or replace as required.]

Photograph 9. Pressure gauge.

7.0 Data Management

[Ensure that a copy of the inspector's approval or certification report is posted on or near the unfired pressure vessel.]

[Maintain the data below for the life each pressure vessel.] This data should include the following information:

1) An ASME Manufacturer's Data Report or, if the vessel is not ASME Code stamped, other equivalent specifications.
2) A pressure vessel data report (first internal inspection). The data report should include the following information:
   a) Manufacturer's Serial Number,
   b) Owner-User's Identification Number,
   c) Pressure vessel dimensional data (width, height, diameter, etc.),
   d) Material of construction,
   e) Original wall thickness data for pressure vessel and dished heads,
   f) Original code of construction including NDE method, and
   g) Safety factor computed from original code of construction.
3) Complete pressure relieving device information, including safety or safety relief valve spring data or rupture disk data, and the date of the latest inspection.
4) Progressive data including, but not limited to, the following:
   a) The date of installation and the date of any significant change in service conditions (pressure, temperature, character of contents, or rate of corrosion).
   b) Drawings showing sufficient details to permit calculation of the service rating of all components on pressure vessels used in process operations subject to corrosive conditions. Detailed data with sketches, where necessary, may serve this purpose when drawings are not available.
   c) The location and thickness of monitor samples and other critical inspection locations, including locations and results of metal thickness surveys.
   d) The limiting metal temperature and its location on the vessel when this is a factor in determining the minimum allowable thickness.
   e) The computed required metal thicknesses and the maximum allowable working pressure for the design temperature and pressure relieving device opening pressure, static head, and other loadings.
   f) Stress calculations performed to determine if the factor of safety complies with the safety factor specified in the original code of construction.
   g) The scheduled date of the next inspection.

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Bureau of Reclamation

RECLAMATION
Managing Water in the West

RECLAMATION MANUAL TRANSMITTAL SHEET

Effective Date: **08/01/2022** Release No. **022 (FIST)**

Ensure all employees needing this information are provided a copy of this release.

Reclamation Manual Release Number and Subject

FIST 2-9, Inspection of Unfired Pressure Vessels

Summary of Changes

The following is a summary of changes in FIST 2-9:
• Maintenance Tables: Consolidated requirements from different FIST manuals • Removed maintenance tables for insertion to FIST 4-1A upon publishing • Revised formatting for consistency
• Section 3.0: Moved from end of document (previously section 7), minor editorial changes
• Section 4.0: Formatting changes; Added exemptions from certification and inspection to PVs less than 37 gallons and 150 PSI
• Section 4.1: Minor clarification to description and instruction. Former instruction converted to Red Bold Bracket requirement.
• Section 4.2 – 4.3: Minor clarification to descriptions and instructions. Former instruction converted to Black Bold Bracket requirement.
• Section 4.5: Minor clarification to description and instruction. Former instruction converted to Black Bold Bracket requirement. Instructions for hydrostatic pressure test added and revised for clarity.
• Section 4.6: Added Black Bold Bracket requirement to blow down condensation from receivers (weekly).
• Section 5.0: Minor clarification to descriptions.
• Section 5.1 & 5.2: Minor clarification to descriptions and instructions. Former instruction converted to Black Bold Bracket requirement.
• Section 5.3: Minor clarification to descriptions and instructions.
• Section 5.4: Minor clarification to descriptions and instructions. Former instruction converted to Black Bold Bracket and Red Bold Bracket requirements. • Section 5.5: Minor clarification to descriptions and instructions.
• Section 5.6: Added Section 4.6 covering Pressure & Temperature Switches.
• Section 6.0: Minor clarification to descriptions and instructions.
• Section 6.1: Added piping service conditions paragraph at end of section.
• Section 6.2: Minor clarification to descriptions and instructions. Former instruction converted to Black Bold Bracket requirement.
• Section 7.0: Minor clarification to descriptions and instructions. Former instruction converted to Black Bold Bracket requirement.
• Expanded and clarified information on equipment and how to perform maintenance tasks
• Incorporated comment revisions from formal review

NOTE: This Reclamation Manual release applies to all Reclamation employees. When an exclusive bargaining unit exists, changes to this release may be subject to the provisions of collective bargaining agreements.

Filing instructions

Remove Sheets	Insert Sheets
FIST 2-9 pp 1-36	**FIST 2-9 pp 1-40**

All Reclamation Manual releases are available at http://www.usbr.gov/recman/

Filed by: **Katherine J. Wheeler** Date: **08/03/2022**