Ballot Draft #6567

Frac Iron Guidelines and Requirements

API RECOMMENDED PRACTICE 16FI
FIRST EDITION, XXXX 202X

1 Scope

This document establishes minimum guidelines that set the foundation for ultimately reducing the severity and frequency of failures in frac iron equipment.

This document covers temporarily installed pressure-containing equipment (commonly known as frac iron) used to convey stimulation fluids from the fluid end to the wellhead, inclusive of pump down equipment associated with plug and perforating or ball-drop operations. This document addresses the following equipment:

a) piping or treating lines;

b) connections;

c) hoses;

d) manifolds;

e) pressure relief devices;

2 Normative Reference

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API Specification 7HU2 *Oilfield Hammer Unions, First Edition*

API Specification 6A, *Specification for Wellhead and Tree Equipment*

API Specification 16C, *Choke and Kill Equipment*

API Recommended Practice 585, Pressure Equipment Integrity Incident Investigation, Second Edition

ISO 9712, Non-destructive testing — Qualification and certification of NDT personnel, Fifth Edition

ASME *Boiler and Pressure Vessel Code (BPVC), Section IX: Welding and Brazing Qualifications*

ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products

ASTM E10, Standard Test Method for Brinell Hardness of Metallic Materials

ASTM E18, Metallic materials - Rockwell hardness test

ASTM E112, Standard Test Methods for Determining Average Grain Size

ASTM E110, Standard Test Method for Rockwell and Brinell Hardness of Metallic Materials by Portable Hardness Testers

ASTM E165, Standard Practice for Liquid Penetrant Testing for General Industry

ASTM E709, Standard Guide for Magnetic Particle Testing

ASTM E1188, Standard Practice for Collection and Preservation of Information and Physical Items by a Technical Investigator

ISO 148-1, Metallic materials - Charpy pendulum impact test

ISO 2859-1:1999, Sampling procedures for inspection by attributes, First Edition

ISO 5208, *Industrial valves — Pressure testing of metallic valves*

ISO 6506, parts 1 through 4, *Metallic materials - Brinell hardness test First Edition*

ISO 6508, parts 1 through 3

NACE MR 0175/ISO 15156 2 3, (all parts) *Petroleum and natural gas industries—Materials for use in H_2S containing environments in oil and gas production*

3 Terms, Definitions, and Abbreviations

3.1 Terms and Definitions

For the purposes of this standard, the following terms and definitions apply.

3.1.1
pressure-containing
Wetted component whose failure would result in loss of bore fluid to the environment.

3.1.2
pressure-controlling
Component whose failure would result in loss of pressure control but not a loss of bore fluid to the environment.

3.1.3
pressure-retaining
Non-wetted component whose failure would result in loss of bore fluid to the environment.

3.1.4
repair
Activity involving disassembly, reassembly and testing of frac equipment with or without the replacement of parts other than bodies.

NOTE Repair does not include machining, welding, heat treating, other manufacturing operations or the replacement of bodies.

3.1.5
visible leakage
Leakage of test fluid seen during a pressure test, either through direct observation or with the use of video equipment.

NOTE Leakage may be observed through or past a pressure boundary or at an interface.

3.1.6
wetted
Component in direct contact with bore fluid.

3.2 Abbreviations

For the purposes of this standard, the following abbreviations apply.

CVN charpy v-notch

H2S hydrogen sulfide

HBW hardness Brinell number

LT leak testing

MWP maximum working pressure

MT magnetic particle testing

NDE non-destructive examination

NPT non-productive time

OEC other end connection

OEM original equipment manufacturer

PPE personal protective equipment

PQR procedure qualification record

PT penetrant testing

QTC qualification test coupon

UT ultrasonic testing

WPQ weld procedure qualification

WPS weld procedure specification

4 Restricted Areas

To minimize exposure to onsite personnel, a restricted area (a.k.a. buffer zone, red zone, or exclusion zone) shall be established around pressurized temporary piping and equipment during stimulation operations. The restricted area shall include at a minimum the following.

a) boundaries clearly identified and marked;

b) boundaries, ingress/egress rules (including but not limited to access points and routes) and “Active / Safe” status be communicated to onsite personnel involved with stimulation operations.

c) identification of a Restricted Area Supervisor (or equivalent) responsible for:

   1) determining restricted area “Active” / “Safe” zone designations;

NOTE An "Active" designation includes but is not necessarily limited to prime-up, pressure testing, and pumping/treating operations.

2) communicating the specific hazard analysis for each location/operation/shift with onsite personnel in the pre-shift safety meeting and additional personnel arriving on location during active operations;

3) communicating status of restricted area "Active" / "Safe" zone designations with signals or signs during active operations;

4) authorizing and monitoring entry into the restricted areas;

5) ensuring personnel who are authorized to enter a restricted area have hi-vis identification.

5 Frac Iron Rigup and Use

5.1 Wellsite Pressure Testing

5.1.1 Hydrostatic pressure testing should be completed following the initial rigup or on connections which have been disconnected since the last pressure test, to verify integrity.

5.1.2 Pressure test results should meet one of the following, whichever is lowest:

a) value of 1,000 psi (6895 kPa) above expected maximum treating pressure,

b) 95% of the lowest rated relief device in the system, or

c) maximum working pressure of the lowest rated component.

5.1.3 Pressure test acceptance criteria shall be defined prior to starting the test. A minimum acceptance criteria of pressure drop shall not to exceed 5 % in 5 minutes.

5.1.4 A low-pressure shell test, below 500 psi (3447 kPa), should be performed to visually inspect for leakage to the environment prior to increasing to final test value. Visual inspection of pressurized equipment should be completed.

5.2 Overpressure Events

5.2.1 Overpressure events are defined when a component is exposed to a pressure above its rated maximum working pressure (MWP).

5.2.2 In the case of an overpressure event, the pressure data should be reviewed to determine the risks and potential severity based on the maximum working pressure reached as follows:

a) 0-2.5% over MWP, review and document event for approval prior to continued use;

b) 2.5-10% over MWP, review and complete inspection of all affected components in accordance to documented procedure as referenced in section 6.2;

c) 10+% over MWP, scrap all affected components following Discarding Components (see 6.6).

5.3 H_2S Exposure

5.3.1 Products and materials shall be selected for the intended service. Standard service products shall not be used in sour gas applications or in situations where there is potential for exposure of wetted components to H_2S exceeding the allowable thresholds defined within NACE MR-0175. The sour gas rated products used, shall be designed in accordance with NACE MR-0175 for exposure to H_2S.

5.3.3 In the event of an exposure of standard service iron to H_2S, iron shall either be scrapped or evaluated by competent personnel or metallurgist to determine disposition of the iron. Reuse of any iron that has been exposed to H_2S shall be approved and documented by the owner of the iron.

5.4 Safety

5.4.1 Hammer unions are clearly marked with the size, figure number, pressure rating, and material reference number. Products designed for H_2S service and associated hammer union connections are clearly marked sour gas. Parts of one size and figure number shall not be assembled with parts of another size and figure number.

NOTE: Reference is made to API 7HU1 for further information.

5.4.2 Repairs, loosening, tightening, or striking, shall not be performed on pressurized components or connections. During freezing temperatures, pressurized components and connections, should be inspected for ice plugs or blockages.

5.4.3 Severely worn, eroded, or corroded products shall not be used.

NOTE Contact the manufacturer for more information on how to identify the limits of erosion and corrosion.

5.4.4 Wing union nuts having severely flattened and extruded ears shall be addressed by one of the following:

a) grinding off extruded material; or

b) removing the nut from service.

5.4.5 Treating iron components shall be validated to be fit for use with regards to environmental and job conditions. Minimum ambient temperature for material on hammer unions shall be in accordance with API 7HU2.

5.5 Hammer Union Makeup

5.5.1 Resilient Lip Seal Installation

The resilient lip seal installation shall be in accordance with the following.

a) be inspected for damage;

b) have a uniform thickness and surface throughout;

c) may have a light oil based lubricant applied to ease installation;

d) placed against the opening of the female end connector with the raised seal diameter against the taper;

e) Using a rubber mallet, lightly strike around the face of the seal in a circular direction to insert into the female end connector until it is fully seated.

5.5.2 Assembly of Hammer Unions

5.5.2.1 Threads of the union nut and female end connector shall be free of debris, dirt, deformed threads, or other imperfection that would prevent proper mating.

5.5.2.2 Lugs of the union nut shall not have excessive deformed material that is likely to fly off when struck.

5.5.2.3 A light oil based lubricant should or may be used to external threads of the female end connector.

5.5.2.4 For unions with nut retainer segments, segments shall be present and properly installed with a segment retainer ring.

5.5.2.5 Male and female end connectors shall be aligned. The union nut shall be hand tightened onto the female end connector. NOTE Misalignment may result in connection loosening during pumping, i.e., insufficient torque during make-up.

5.5.2.6 Using at least a 4lb hammer, strike the lugs until the union nut no longer rotates when struck

5.5.2.7 If assembling a union where one component has the ability to swivel, a wrench or other tool to prevent the component from spinning should be used while hammering the assembly together.

5.6 Hub or Clamp Ended Connection Make up

5.6.1 General

5.6.1.1 Products with hub ends shall be correctly matched before mating together.

NOTE Hub ended connections are typically not marked with a size or type.

5.6.1.2 The correct size of clamps shall be used to secure the mated hub ends of products.

5.6.1.3 The correct size of bolting or locking devices shall be used and tightened in accordance with OEM recommendation to ensure safe operation of the products.

5.6.2 Seal Installation

5.6.2.1 Sealing surfaces and seal pockets on hub ends shall be cleaned and free from damage or corrosion.

5.6.2.2 Seals, sealing elements, and if necessary spacer rings shall be cleaned and free from damage.

5.6.2.3 Apply grease or proper lubrication to sealing surfaces or pockets, seals and sealing elements.

5.6.2.4 Follow manufacturer's recommendations for seal installation, seal materials for service conditions, sealing orientation, sealing elements, and spacer rings ensuring correct seating of components.

5.6.3 Assembly

5.6.3.1 Ensure mating faces on all hub ends are cleaned and free from damage or corrosion.

5.6.3.2 Apply grease or lubrication to pockets on mating hub ends or follow manufacturer's recommendations.

5.6.3.3 Ensure load bearing surfaces to clamps, locking devices, or threads to bolting are cleaned and free from damage or debris. Lubricate or apply anti-seize as applicable per manufacturer's recommendations.

5.6.3.4 Correctly align hub ends on mating products so that seals, sealing elements, or spacer rings can be properly received into adjoining bores or sealing pockets.

5.6.3.5 Mate products together so that seals, sealing elements, and spacer rings are properly secured and contained.

5.6.3.6 Install clamps or other locking devices around mated hub ends and secure with correct sized studs and nuts or by other means as designed by manufacturer.

5.6.3.7 Tighten studs and nuts of clamped connections so there is relative even spacing of exposed threads of studs sticking out beyond installed nuts. Tighten other locking type devices as recommended by manufacturer.

5.6.3.8 Further tighten nuts on studs using a criss-cross or star-like pattern using the proper tools or equipment or as directed by manufacturer's guidelines.

5.6.3.9 Apply required torque to nuts or other locking devices as defined by manufacturer to fully tighten clamped connections.

5.6.3.10 Jolt clamped connections by striking back end of clamps with rubber mallet or dead blow hammer of at least 4-lb size.

5.6.3.11 Reapply tightening torque to nuts in same criss-cross or star-like pattern as before. Repeat as required until there is no movement felt or seen around clamps, studs, or nuts ensuring clamped connections are completely tightened.

5.7 Swivels

5.7.1 Seven Degrees of Freedom

5.7.1.1 To provide complete freedom of movement, seven swivel rotation points (degrees of freedom) is recommended to be used between any two end points or any restriction to movement, such as the ground or structures. One possible way to achieve seven degrees of freedom is to use two Style 50 swivel joints and one Style 10 swivel joint. Alternatively, flexibles may be used to provide equivalent freedom of movement.

5.7.1.2 When using less than seven degrees of freedom, an engineering assessment should be completed to assess the iron movement to prevent premature failures.

5.7.1.3 Watch for layout conditions that may place the swivels in a bind, preventing free movement. Any such restrictions may eliminate or otherwise hinder and impair the freedom of movement that you have achieved.

5.7.1.4 The included angle formed between pup joints on each side of swivel joints should be 150° or less. This will ensure proper bends are maintained and the flowline is not too straight.

5.7.2 Pump Discharge

5.7.2.1 A fatigue-resistant union connection is recommended for this flowline layout location

5.7.2.2 If winged union treating iron is to be used, one recommended configuration is: Female pump discharge flange → Male x male S10 swivel → S50 swivel → Valve → Pump Joint.

5.7.2.3 If the female sub end of a S10 swivel is connected directly to a male discharge flange, it can be difficult to make-up that union "ring-tight" due to the rotation of the adjacent swivel. The male x male S10 swivel joint will eliminate that rotation during hammering.

5.7.2.4 Reducing the overall length of flowline equipment on the back of the pump truck can reduce the amount of bending and movement of the layout during operation.

5.7.2.5 Brackets used to secure flowline equipment on the back of a frac pump truck should clamp down directly to the outer diameter of the piping. There should be no rubber padding used with clamps.

5.7.3 Pump to Manifold

5.7.3.1 Seven Degrees of Freedom recommendation as stated in 5.7.1 should be followed.

5.7.3.2 Pup joint lengths between the frac pumps and manifold should be kept to less than 6 ft (1.8 m). Avoid using multiple pup joints in series.

5.7.3.3 Pup joints should be positioned and arranged so that there are shallow angles to the ground.

5.7.3.4 Vibrations during operation can cause the flowline layout to bury itself into the ground and once it is buried, movement of the layout is severely restricted.

5.7.3.5 Flat wood blocks or plywood sheets should be placed underneath the flowline layout to prevent burying the flowline.

5.7.3.6 Flowline layout will also have the freedom to slide on top the wood.

5.7.3.7 Blocks should not be used with V-notches since they will restrict movement of iron.

5.7.4 Pump to Ground Line

5.7.4.1 Follow Seven Degrees of Freedom recommendation as stated in 5.7.1.

5.7.4.2 Flowline equipment coming directly from the frac pump should only be connected to the ground mainlines with a swivel joint. Never connect a pup joint, valve or fitting (tees, laterals, elbows) directly to a mainline fitting.

5.7.4.3 Pup joint lengths between the frac pumps and ground mainline should be kept to less than 6 ft (1.8 m). Avoid using multiple pup joints in series. Pup joints should be positioned and arranged so that there are shallow angles to the ground.

5.7.5 Manifold to Wellhead

5.7.5.1 Follow Seven Degrees of Freedom recommendation as stated in 5.7.1.

5.7.5.2 Ensure 3 in. and 4 in. ground manifolds on the ground mainlines connected to the wellhead have swivel joints on either end.

5.7.5.3 Communication lines should be installed between each mainline going to the wellhead, if communication is not being made on the manifold trailer.

5.7.5.4 Keep maximum length of straight joints between swivel bridges to 40 ft (12.2 m), to allow for movement.

5.8 Bleed-off Lines

5.8.1 All bleed lines should be secured to prevent possibility of movement and rotation.

5.8.2 The following anchoring practices should be followed:

a) Minimum of one significant anchor behind the TEE and at least one significant anchor over the bleed or flow line.

b) Installation of additional significant anchors every 10 ft (3 m) with the last one at the end of the line.

5.8.3 Swivel joints should not be used on 2 in. bleed off lines. Elbows, tees and pup joints should be used for bleed off lines. If the use of swivel joints cannot be avoided, the 2 in. flowline should or shall be secured to prevent uncontrolled movement of the layout during pressure release.

5.8.4 Direction changes may be made with the following:

a) cushion/target 90° elbows,

b) hard 90° elbows,

c) standard tees with bull plugs, and

d) standard laterals with bull plugs.

5.8.5 Valves shall not be installed at the end of a bleed line.

5.8.6 Prime-up and bleed off plug valves which are open to atmosphere should not be positioned vertically.

NOTE The open bore can collect precipitation and freeze in cold temperatures creating an ice plug in the valve and potentially disabling the valve functionality.

5.9 Isolation Systems

5.9.1 An isolation system should be installed as close to wellhead as possible. A plug/gate isolation valve or check valve, or both, should be used.

5.9.2 A single isolation valve should be installed between the pump and manifold or ground line.

5.10 Pressure Relief Systems

5.10.1 At a minimum a primary pressure release system able to release pressure at a level below the lowest rated maximum working pressure (MWP) component shall be installed. The following are examples of pressure release systems:

a) mechanical relief valves;

b) nitrogen relief valves;

c) automated relief valves.

5.10.2 A secondary pressure relief system to protect equipment from exceeding the maximum working pressure (MWP) defined by the equipment manufacturer should also be considered. An example is a burst disk, or similar.

5.10.3 Primary pressure relief systems shall be tested following initial rig up and prior to initial system pressure test.

5.10.4 A record of pre-job pressure relief tests should be maintained is recommended throughout the job duration

5.10.5 A discharge line should be connected to the outlet of the pressure relief device to contain potentially high velocity fluid during pre-job test or in case of an over-pressure event. It is recommended to follow bleed-off line recommendations for these discharge lines.

5.10.6 If a relief system is not connected to a discharge line it shall be configured in a way to prevent hazard to personnel or equipment.

5.10.7 The device shall be connected to a fitting on the mainline and supported in a way that resists or withstands the forces exerted on it during the pressure release event. Consideration should be taken with regards to force direction to provide support to prevent tipping or damage to connections.

5.11 Flexible Pipe

5.11.1 Pre-Job Inspection

5.11.1.1 Prior to rig up operation of flexible hose, an inspection of hose throughout the entire length to ensure the protective layer(s) / outer layer(s) are free of damage, tears or punctures shall be performed.

5.11.1.2 If any damage is noticed, line should be removed and further inspection of the underlying layers should be completed before allowing the line back in service. Follow manufacturer's guidelines for allowances and acceptance criteria.

5.11.1.3 Check for signs of damage on the end fittings, terminations, connections and bend stiffener (if any). Record and report any damage and follow its progression.

5.11.1.4 Remove any enclosed debris from the bore of the hose.

5.11.1.5 Inspect inner bore of hose checking for signs of cracks, wear or damage. Follow manufacturer's guidelines for acceptance criteria.

5.11.1.6 Follow manufacturer recommendations for annual or semi-annual pressure tests, manufacturers inspection, and regular flushing / routine visual inspection post-job

5.11.2 Handling and Lifting

5.11.2.1 Follow manufacturer's guidelines and instructions for safe and proper lifting of flexible hoses.

5.11.2.2 Flexible lines require forklift and/or crane lifting operations, i.e. certified equipment and trained personnel. Use of tandem cranes during lifting operations is acceptable.

NOTE Pallets, wooden boxes, lifting support, and specialized lifting devices may be required.

5.11.2.3 Use suitable equipment to perform safe lifting and maneuvering operations.

5.11.2.4 Use recommended harnesses, clamps, strapping, or other devices as recommended or allowed by manufacturer to ensure safe handling, lifting, and maneuvering of flexible hose during both installation and removal operations.

5.11.2.5 At no time should wire rope or chains be allowed to come into contact with either the end fittings or the flexible pipe.

5.11.2.6 Ensure flexible hose is properly supported and restrained during lifting, maneuvering, and installation operations so that unsafe conditions are minimized.

5.11.2.7 Ensure lifting and maneuvering of flexible hose does not result in bending of hose failing to meet manufacturer's minimum bend radius requirements.

5.11.2.8 Do not lift flexibles from a single point near the middle of the line.

5.11.2.9 Ensure flexible line OEM approves non-standard lift procedures before rigging up flexible lines

5.11.3 Installation and Removal

5.11.3.1 When working with flexible lines, do not be in the line of fire if unsecured hose falls or bent hose straightens to prevent serious injury.

5.11.3.2 Install hose so that end connections are properly secured and tightened.

5.11.3.3 Install hose so that bend in flexible hose is greater than manufacturer's required minimum bend radius.

5.11.3.4 Inspect end connections to ensure they do not have any damage that would affect structural integrity or sealing.

5.11.3.5 Ensure connections seals are properly installed.

5.11.3.6 Ensure installation of flexible hose does not create high bending loads to end connections. If necessary, add supports or restraints to hose to reduce binding applied to end connections.

5.11.3.7 Watch for layout conditions that may cause outer surfaces or hose cover to come into contact with sharp edges or rub on objects. If necessary, reposition flexible hose from interferences or place protective barrier at identified locations to prevent damage during operation.

5.11.3.8 If flexible hose is installed so that a portion of the hose is resting on the ground, place a flat board underneath hose as a protective barrier from external damage due to effects of vibration.

5.11.3.9 If possible, install flexible hose so that fluids are prevented from sitting idle or becoming concentrated on low spots within the hose.

5.11.3.10 When removing a flexible, use a forklift or crane to support the weight of the flexible line while the first end connection is loosened. Once the first end of the flexible line is disconnected repeat this process for the other end.

NOTE Removing large bore flexibles can require controlled release of bending force with use of secondary restraints that can be slowly loosened.

5.11.4 Operations

5.11.4.1 Follow manufacturer's recommendations by not exceeding pressure and flowrate limitations.

5.11.4.2 Never attempt to handle, lift, maneuver, or restrain any portion of the flexible hose while under pressure.

5.11.4.3 Follow manufacturer's guidelines for safe operation by using flexible hose within defined product ratings.

5.11.4.4 Do not use hose in applications where parameters that are not compatible with its design or construction.

5.11.4.5 Do not allow chemicals and acids to become stationary or sit idle inside hose for extended periods.

5.11.4.6 Be certain to thoroughly flush flexible hose with clean fluids after use and especially after treatments using chemicals or acids.

5.11.4.7 Protect end connections from damage from handling and from corrosion when flexibles are not connected.

5.12 API Flange Makeup

5.12.1 General

5.12.1.1 The size, grade, and number of studs used to makeup flanged ends shall be in accordance with API 6A or API 16C.

NOTE Conformance with API 20E and 20F is not required.

5.12.1.2 Flanges modified from API 6A, e.g., double drilled, shall not be used.

5.12.2 Initial Flange Makeup

5.12.2.1 Clean mating flange faces.

5.12.2.2 Inspect mating faces of flanges for damage.

5.12.2.3 Clean ring grooves and inspect for damage.

5.12.2.4 Ring gaskets should be visually inspected and lubricated using mineral-base oil (20W or higher), synthetic motor oil (5W or higher), or a general-purpose grease (without metallic additives) suitable for high pressure metal-to-metal application. Lubricant should only be applied as thin film.

5.12.2.5 Bolt holes on flanges shall be aligned to allow for passage of studs through holes.

5.12.2.6 Prior to installation, stud threads and the bearing faces of nuts should be well lubricated with thread grease (Note: For example API RP 5A3/ISO 13678) or high quality anti-seize lubricant. When making up closure bolting on flanges torque values should be determined by using appropriate friction factors.

NOTE: Friction factors differ based on lubricants, or closure bolting coating/ plating systems.

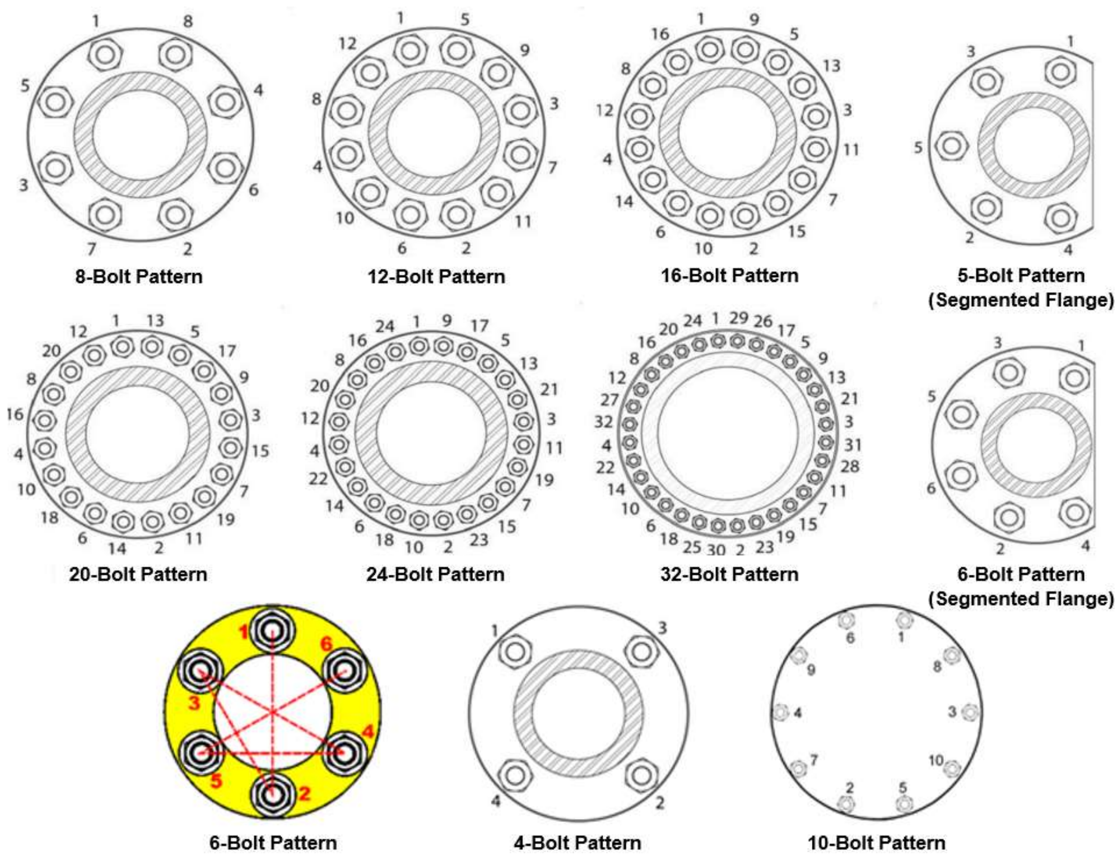
5.12.2.7 Nuts shall be tightened by hand until nuts on both sides, if applicable, ~~until nuts~~ are in contact with both flanges and nuts have equal thread engagement.

5.12.3 Application of Torque

5.12.3.1 Ring gaskets shall be secured and contained between mated flange faces.

5.12.3.2 Connections ~~is~~ shall not be tightened while subject to pressure.

5.12.3.3 Flange bolting shall be tightened gradually, repeatedly working around the bolt pattern in a "crisscross" or "star" pattern until final preload has been confirm at all fasteners. As an alternative, multi-head tools may be used per the manufacturer's procedures. See Figure 1:



[a] Face-to-face contact is not necessary for Type 6BX flanges to hold static pressure. For some small 6BX flanges, applying torque until face-to-face contact is achieved can result in over-stressing the bolting and/or damaging the flange. For larger Type 6BX flanges, face-to-face contact can be achieved without damaging the bolting or flange, and can result in a connection with improved resilience to the cyclic loading encountered during frac operations. If recommended bolt stresses are exceeded in order to achieve face-to-face contact, controls should be implemented to ensure that bolts will not be damaged.

[b] After tightening is complete, studs shall protrude beyond faces of nuts by a minimum distance of one thread pitch.

Figure 1 – Flange Bolting Patterns [a,b]

5.13 Vibration

5.13.1 General

Pumping vibration is a common root cause to of fatigue failures on, such as washout or rupture of pressure-containing components, in treating iron. There are a significant number of contributors to vibration and fatigue failure. Some common root causes or contributing factors are addressed in 5.13.2 through 5.13.5.

5.13.2 Pump type

Pumps with fewer plungers generate pressure pulses spaced further apart, leading to lower frequency and higher amplitude vibrations.

5.13.3 Fluid velocity

See 5.14.

5.13.4 Iron freedom of movement

5.13.4.1 Maintaining flexibility in treating iron rigup is critical

5.13.4.2 Including proper swivels and/or flexible lines to allow for movement will help to absorb vibration energy. Refer to Section Rig Up – Swivels and Rig Up - Flexible Lines

5.13.4.3 A common constraining element is iron sinking into the ground during operation. To reduce likelihood of sinking, support iron using a broad base stand. Commonly used solutions are wood blocks, mats, or other suitable materials.

5.13.4.4 Constrained iron must be properly aligned to ensure there is not a bind in the connections leading to additional fatigue forces This can be verified through alignment measurements of constraining points or through required make-up torque during connection of iron. The connection should freely join together by hand and require minimal rotation by hammer. Refer to the section titled Hammer Union Makeup.

5.13.5 Cavitation

5.13.5.1 Pump cavitation can lead to increased amplitude of pressure pulses from the pump and increased vibration in the iron

5.13.5.2 All pumps should be properly primed and re-primed if positive suction pressure is lost prior to any pumping operation.

5.14 Velocity

5.14.1 During pumping operations, consideration should be given to reducing the amount of erosion in piping and components to minimize the risk to personnel and the environment. Flow velocity of proppant laden fluid should not exceed 45 ft/sec (13.7 m/sec) through flow iron or associated metal components during continuous service. Fluid velocity below 3 feet/second (1 m/sec) could result in the deposition of sand or other solid particles creating flow restriction or plugging. Flow velocities through liquid lines can be found using Equation (1) from API 14E.

$$V_1 = \frac{0.012\, Q_1}{d_1^2} \qquad (1)$$

where

V_1 is the average liquid flow velocity, in ft/sec (m/sec);

Q_1 is the liquid flow rate, in bbl/day;

d_1 is the pipe inside diameter, in in. (mm)

5.14.2 Flow velocity through flexible pipes shall follow manufacturer's recommendations.

6 In-service Integrity Management

6.1 Certification Inspection Intervals

6.1.1 Inspection intervals and the scope of inspection will vary greatly based on the service type the equipment is subject to. Frequency of inspections should take into account the following conditions.

a) Severity of service:

1) sand volume;

2) exposure to chemicals;

3) fluid velocity for erosion wear.

b) Established corrosion rate trends.

c) Amount of corrosion allowance remaining.

d) Available historical data.

e) Regulatory requirements.

6.1.2 Visual inspection shall be done on a component whenever the connection on that component is broken at either end. This includes during initial job rig-up and if there is any component replacement throughout the course of the job.

6.1.3 Inspection should be completed at a pre-defined interval based on determination from previous inspections. If information is not available to make a defined decision, Table 1 may be used for recommended baseline inspection intervals.

Table 1 – Inspection Intervals

Equipment Type	Recommended Inspection Interval
Check valves, plug valves, chokes, and other pressure containing valves	90 Days
All standard equipment connected from the pumping unit to the frac manifold	180 Days
All standard equipment connected to the frac manifold but not in line with a pump, all other equipment	365 Days

6.1.4 Inspections intervals listed in Table 1 may be extended or reduced by the owner/user of equipment when substantiated by historical data and analysis collected and interpreted using existing accepted industry practices such as a risk-based inspection (see API 580) or an existing standard.

6.2 Certification Inspection Processes

6.2.1 General

6.2.1.1 The inspection process shall be in accordance with a documented process. The documented process shall include all required examinations and tests. The NDE inspection type and level should be determined based on component type and risk profile.

6.2.1.2 Typical NDE methods for inspections are outlined in Table 2 for the items specified.

Table 2 – NDE Methods for Inspection

Type of NDE	Area of Inspection
Visual examination	Threads, sealing surfaces, surfaces exposed to fluid flow
UT digital thickness	Wall thickness based on manufacturer's specifications or established minimum thickness calculations from industry recognized standards
MT	Threads, sealing surfaces , solid bodies, joints
PT	Threads, sealing surfaces , solid bodies, joints (for non-magnetic materials)

6.2.1.3 NDE procedures should follow acceptable national standards.

6.2.1.4 Personnel performing MT and PT shall be qualified in accordance with the manufacturer's documented training program that shall be based on one of the following:

a) ISO 9712;

b) ASNT -SNT-TC-1A;

c) a national or international standard that is equivalent to ISO 9712 or ASNT SNT-TC-1A.

6.2.1.5 NDE procedures shall be approved by a level III examiner qualified in accordance with ASNT SNT-TC-1A or ISO 9712.

6.2.2 Equipment

6.2.2.1 Equipment used for inspection shall be capable of completing inspection to the tolerance requirements stated by the OEM and/or any governing specifications and standards as applicable.

6.2.2.2 Items requiring calibration shall be current within the appropriate calibration cycle and calibration standards utilized shall be traceable to a national or international standard such as NIST.

6.2.3 Visual Examination

Visual examination shall be performed to identify obvious damage and defects such as cracks, bending, excessive erosion, excessive corrosion, and other visually identifiable defects that could be detrimental to the continued use of the component.

6.2.4 Ultrasonic Digital Thickness Measurement

6.2.4.1 Ultrasonic digital thickness measurement is utilized to determine the remaining material of a component for comparison to acceptable wear and corrosion limits.

6.2.4.2 Minimum wall thickness shall be in accordance with the OEM recommendations whenever available.

6.2.4.3 When OEM information is not available, minimum wall thickness shall be defined by the owner / operator and shall be in accordance with ~~sound~~ recognized and generally accepted good engineering practices.

6.2.5 Magnetic Particle Examination

6.2.5.1 Magnetic particle testing, where required, shall be performed to identify surface and near surface defects such as cracks, seams, laps and laminations.

6.2.5.2 Magnetic particle testing may only be used on ferromagnetic / magnetizable items. For crack and other flaw detection on non-ferrous materials liquid penetrant as an approved alternative may be performed.

6.2.6 Hydrostatic Pressure Testing

6.2.6.1 All components shall be pressure tested to manufacturer's maximum rated working pressure.

6.2.6.2 The equipment shall show no visible leakage while subjected to test pressure

6.2.6.3 Monitored pressure shall not vary from the test pressure at the start of the test by more than 5 % or 500 psi (3447 kPa), whichever is less, during the entire hold period. The initial test pressure shall not be greater than 5 % or 500 psi (3447 kPa), whichever is less, above the specified test pressure. During the entire hold period, the monitored pressure shall not drop below the specified pressure.

6.2.6.4 The pressure test hold period shall be at least 3 minutes.

6.3 Data Collection and Storage

6.3.1 Data collected during inspections shall be recorded by the inspector to ensure accurate reporting and consistency in data points for future inspections. Data collected should include, but is not limited to the following data points.

a) Date of inspection.

b) Inspector name.

c) Inspection specification – user or OEM defined.

d) Equipment inspected:

   1) description of component;

   2) serial number;

   3) working pressure.

e) Location of inspection points.

f) Results of inspection.

1) numerical values (if applicable);

2) pressure test chart (if applicable);

3) pass/fail.

6.3.2 Once data is collected it should be analyzed against known values to determine whether the equipment is safe to continue to use in service.

6.3.3 Records of inspection including data listed in 6.1 shall be maintained for a minimum of 10 years after inspection.

6.4 Repairs Requirements

6.4.1 When components are found to have failed an inspection, they may be repaired to return them to serviceable condition. The original assembly, defined as the serialized part, may be repaired for however long it is serviceable.

6.4.2 During repair, the pressure containing serialized body and assembly must be maintained together (i.e. swivel). For multi-body assemblies, such as swivels and screw together check valves, the bodies in one assembly shall be maintained together during repair.

NOTE Plugs, seats, and other consumables are not bodies.

6.4.3 Parts determined to be damaged beyond use shall be replaced by parts from OEM manufacturer or alternative manufacturer that has been approved by the customer.

6.4.4 Repairs shall be completed in accordance with OEM or customer-approved repair procedures.

6.4.5 Repairs involving the replacement of parts shall be done by trained and qualified employees.

6.4.6 Repairs shall be validated through appropriate testing methods based on the repair completed.

After repairs are completed, hydrostatic testing at max working pressure shall be performed on the equipment in accordance with 6.2.6.

6.5 Marking Requirements

6.5.1 Upon completion of component inspection certification and prior to return to service, an identifier shall be attached to the component indicating the serial number and required date of the next inspection.

NOTE The identifier can be a colored band, RFID, or other.

6.5.2 At time of inspection and identification of new inspection, previous inspection identification shall be removed or updated to properly identify current inspection. OEM marking shall not be removed.

6.5.3 Inspection expiration date may be based on the ‘in-service’ date of the component rather than the date of the previous inspection so long as the in-service date is within 12 months of the previous inspection data date when stored in a controlled environment.

6.6 Discarding Damaged Components

When pressure containing components have been damaged beyond repair, or are no longer serviceable, the serialized component shall be rendered useless by removing capability to be pressure-containing and disposed of to prevent further usage.

7 Failure Investigation and Analysis

7.1 General

7.1.1 Equipment failure is rarely the result of a single isolated event. Determining and mitigating the factor(s), or root cause, that contributed to the failure can be aided by the application of consistent and thorough investigation techniques.

7.1.2 The investigation techniques outlined in API 585 should be used in part or whole to supplement existing failure investigation processes employed by a user/operator.

7.1.3 Varying levels of investigation may be required based on the consequences of the failure (from NPT to injury of a person). The user/operator of the equipment shall have a documented procedure for determining the level of investigation required, based on the consequences of failure.

7.1.4 For incidents which can be reasonably expected to be the subject of litigation, additional information regarding custodianship of physical evidence may need to be tracked. Refer to ASTM E1188 for recommended practices regarding tracking of custody transfer information.

7.1.5 If relevant to the failure, electrical systems or sensors used in equipment scoped into this section of the document, such as in pressure-relief circuits, are also considered to be within the scope of this section of the document.

7.2 Safety

7.2.1 Pressure

7.2.1.1 The site procedure regarding lock-out/tag-out should be followed during rework activities.

7.2.1.2 The failure of pressured equipment often results in a loss of pressure integrity of the failed component and depressurization of adjacent pressure-containing bodies. Powering down well service pumps may be all that is required to place the system in a state that is safe for maintenance activities. However, it is critical that prior to approaching or disconnecting a failed component, the presence of pressure-trapping volumes be understood. Pressured fluids can be trapped in piping between valves or between pressure-controlling elements in an individual valve.

7.2.1.3 Internal pressure shall be vented prior to breaking the end connections or removing a cap or plug from any previously pressured component.

7.2.2 Chemical

Proper containment and/or PPE, considering the retained fluids prior to failure, shall be in place prior to approaching or disconnecting a failed component.

7.2.3 Physical / Mechanical

7.2.3.1 The failed component may be located in a tight space, heavy or awkward to lift, and may have sharp edges at fractured surfaces.

7.2.3.2 The manufacturer's documentation should be referenced for any special installation, removal, or handling instructions.

7.3 Failure Investigation

7.3.1 General

The failure investigation method should be in accordance with the procedures outlined in API 585, or the user/operator's written failure investigation procedure.

Note: For purposes of this document, temporary pipework and manifolds are not considered movable structures or mobile equipment, as defined in API 585. These components are within the scope of this section of this document

7.3.2 Investigation Level

The user/operator of the equipment should have a documented procedure for determining the level of failure investigation required. The level of investigation may vary for each failure incident.

The failure investigation shall at a minimum include the following:

a) the component that failed;

b) the cause(s) of failure;

c) mitigation measures employed.

7.3.3 Data Collection

The user/operator may require the collection of more than just the failed component and failure cause. In this case, the following information should be included in the data collection portion of the failure investigation, if available and relevant to the failure:

a) part number, serial number, and heat code of failed component(s);

b) digital images of the failed component(s) in the installed condition (capture adjacent equipment, layout of adjacent attached piping, and include any support structures);

c) amount and type of fluids and solids pumped through the failed component;

d) pressure and flowrate of pumped fluids prior to failure (and location of transducer or gauge generating the data);

e) pump service history;

f) transducer data log for any condition monitoring in lines upstream or downstream of the failed component, if applicable;

g) calibration data for transducers or monitoring equipment;

h) pressure transducer data log immediately upstream or downstream of tree upper master valve;

i) remote actuation data, if applicable, for any valves upstream or downstream of the failed component;

j) failures of any adjacent or upstream or downstream equipment prior to the failure initiating the investigation;

k) out-of-the-ordinary operations prior to the failure (i.e. shutdown during acid pumping);

l) previous service and/or inspection history for the failed component;

m) previous usage history of the failed component;

n) interview of on-site personnel regarding deviations in rig-up procedure or testing, oddities in component appearance or function during rig-up or testing, visible line movement during pumping operations, etc.

Note: See API 585, Annex D, and ISO 14224, Section 9.5, for additional guidance.

7.3.4 Evidence Documentation and Preservation

7.3.4.1 The user/operator, lead investigator, or the user/operator’s written investigation procedure shall specify the data and physical evidence to be collected,

7.3.4.2 The operator/user shall document and preserve physical evidence resulting from a failure investigation.

7.3.4.3 Digital images of the failed component (in place) shall be documented prior to disconnecting the failed component from adjacent equipment.

7.3.4.4 Separated pieces of the failed component should be gathered and preserved.

7.3.4.5 Separated pieces shall not be reassembled.

7.3.4.6 The minimum number of connections shall be broken to completely disconnect the failed component.

7.3.4.7 Further disassembly of the failed component should be performed by persons identified by the user/operator as primary investigator(s) or designee(s) of the primary investigator(s).

7.3.4.8 Findings on newly exposed surfaces, ports, or bores at the broken connections should be added to the data collected in 7.3.3.

7.3.4.9 The failed component shall be clearly marked or tagged to prevent its reuse.

7.3.4.10 The failed component shall be stored to prevent further damage or exposure to adverse environmental conditions.

7.3.4.11 Where possible, bare metals surfaces, especially any fracture planes, shall be protected from the environment.

7.3.5 Failure Investigation Analysis

7.3.5.1 A failure investigation should commence after the data and physical evidence is collected.

7.4 Reporting

7.4.1 The output of a detailed failure investigation as defined by the user/operator, should be a report that contains the following information at a minimum:

a) author;

b) user/operator;

c) incident date and time;

d) incident location;

e) equipment involved (including part; serial numbers and/or heat code; if available);

f) description of event;

g) consequence of failure;

h) investigation findings (i.e. cause(s));

i) recommendations based on findings.

NOTE Recommendations based on findings during the failure investigation can include further testing activities required to determine causation, updates to process or procedural controls or activities, enhanced process monitoring, additional preventative maintenance requirements, and design or layout modifications.

8 Manufacturing

8.1 Materials

8.1.1 Material Specifications

Metallic and nonmetallic pressure-containing, pressure-retaining and wetted pressure-controlling parts shall require a material specification.

8.1.2 Metallic Requirements

The manufacturer's specification for metallic pressure-containing, pressure-retaining and wetted pressure-controlling parts shall contain the following, including acceptance/rejection criteria:

a) mechanical property requirements;

b) material qualification;

c) heat-treatment procedure;

d) NDE requirements;

e) allowable melting practices;

f) forming practice(s), including hot working, cold working, minimum reduction ratio;

g) heat treating equipment calibration requirements.

8.1.3 Nonmetallic Requirements

8.1.3.1 The manufacturer's specification for nonmetallic pressure-containing or wetted pressure-controlling materials shall define the following:

a) generic base polymer(s) (see ASTM D1418);

b) physical property requirements

c) material qualification

d) storage and age-control requirements

8.1.3.2 Secondary seals (if present) shall meet the same materials requirements as primary seals.

8.1.4 Pressure-containing and Pressure-retaining Metallic Components

8.1.4.1 Applicability

Pressure-containing and pressure-retaining metallic materials shall be fabricated from standard or nonstandard materials as defined in this section.

8.1.4.2 Standard and Nonstandard Metallic Materials

8.1.4.2.1 Standard materials categorized by component and pressure rating are shown in Table 3 and Table 4 with minimum properties, at room temperature, for those materials. Where a pressure-containing or pressure-retaining component does not fit within a particular category, materials shall be selected per the body, body closure, fitting, swivel, integral end connection group of materials. Nonstandard materials are those with minimum properties, at room temperature, which deviate from Table 3 and shall have a material designation 'NS'.

Table 3 – Minimum Material Properties for Standard Materials

Material Designation	**0.2% Offset Yield Strength (min.)** psi (MPa)	**Tensile Strength (min.)** psi (MPa)	**Elongation in 2 in. (50 mm) (min.)** %	**Reduction in Area (min.)** %
45K	45,000 (310)	70,000 (483)	19	32
60K	60,000 (414)	85,000 (586)	18	35
75K	75,000 (517)	95,000 (655)	17	35
95K	95,000 (655)	120,000 (827)	15	35
110K	110,000 (758)	125,000 (862)	15	35

Table 4 – Metallic Materials in Standard and Sour Service Applications

Working Pressure				
6000 psi (41.4 MPa)	7500 psi (51.7 MPa)	10000 psi (69.0 MPa)	15000 psi (103 MPa)	20000 psi (138 MPa)
Body, Body Closure, Swivel, Integral End Connection				
45K, 60K, 75K, 95K, NS[a]	60K, 75K, 95K, NS	75K, 95K, NS		
Pup Joint Pipe[b]				
75K, 95K, 110K, NS				
Hammer Union Nut, Hammer Union Retainer Segments, Hammer Union End Connection				
Per API 7HU2[c]				
Loose Connector				
45K, 60K, 75K, 95K, NS	60K, 75K, 95K, NS	75K, 95K, NS		
Closure Bolting				
A193 GR B7[d], A320 GR L7, A320 GR L43, A453 GR 660D, CRA[e]				

[a] "NS" indicates nonstandard materials as specified herein
[b] Pipe only, ends governed by "End Connection" designation
[c] Non API 7HU2 defined hammer union connections to be per Integral End Connection or Loose Connector
[d] Up to bolt diameters of 2.5in
[e] Per API 6A

8.1.4.2.2 Nonstandard materials shall have a specified minimum yield strength greater than or equal to the lowest standard specified minimum yield strength permitted for that application.

8.1.4.2.3 Non-standard pressure-containing and pressure-retaining materials not in Table 3 shall be produced from carbon or low-alloy steels that have a minimum elongation (2 in) of 14% and a minimum reduction of area of 25%.

8.1.4.2.4 Components used in sour service applications shall not use carbon or low-alloy steel materials with specified minimum yield strength greater than 85 ksi. Materials and components intended for sour service shall be in conformance with NACE MR0175/ISO 15156.

8.1.4.2.5 API 6B and 6BX flange end connections shall use materials in conformance with API SPEC 6A.

8.1.4.3 Material Qualification Testing

8.1.4.3.1 For material heat-treated in a continuous furnace, the QTC shall consist of a sacrificial production part or a prolongation removed from a production part.

8.1.4.3.2 For material heat treated in batch loads, the test sample may be a sacrificial part, separately cast or forged QTC or a prolongation.

8.1.4.3.3 When a separately cast or forged QTC is used, the size of the QTC shall be determined using the Equivalent Round (ER) method in API 6A. For forgings, the reduction ratio of the QTC shall be equal to or less than the parts it qualifies.

8.1.4.3.4 A QTC shall qualify only material and parts produced which are of the same heat and have undergone the same mechanical work and specified heat treatment.

8.1.4.3.5 Components that are heat treated using a mixture of continuous and batch furnace applications (i.e. austenitize via continuous furnace and temper via batch furnace) a sacrificial part or prolongation is required for each batch or lot.

8.1.4.3.6 For tubular parts, bar stock and other raw material of uniform cross-section, the prolongation shall have the same cross-section as that of the raw material.

8.1.4.3.7 For complex shapes or varying cross-sections, a prolongation shall meet or exceed the minimum equivalent-round (ER) required for a separate QTC.

8.1.4.3.8 See API 6A for QTC sizing based on ER methods.

8.1.4.4 Tensile Testing

8.1.4.4.1 Minimum tensile properties specified by Table 3 are required for metallic pressure-containing and pressure-retaining equipment.

8.1.4.4.2 Tensile specimens shall be removed from a QTC in accordance with API 6A.

8.1.4.4.3 A minimum of one tensile test shall be performed and shall meet the strength and elongation requirements of Table 3.

8.1.4.5 Impact Testing

8.1.4.5.1 Equipment with a temperature rating of -20°F (-29°C) or colder shall be made from material that has been impacted tested in accordance with this section.

8.1.4.5.2 Impact test requirements for hammer union connections (sub ends, nuts, and retainer segments) shall be in accordance with API 7HU2. Hammer union connections which are integral to another body falling under the scope of this document shall meet the minimum requirements of this document or API 7HU2 as specified by the manufacturer.

8.1.4.5.3 If impact properties are required for a material to be qualified for service, the required tests shall be performed on specimens from a qualification test coupon (QTC) as follows.

a) The QTC shall qualify only material and parts produced using the same heat treat procedure and receiving the same amount of mechanical work.

b) The Charpy V-Notch (CVN) impact requirements using a standard 10 mm x 10 mm specimen shall meet or exceed the values in Table 5.

c) Non-standard specimen sizes are permitted, provided they meet the subsize specimen geometry of Table 6. The minimum acceptable CVN impact value is the 10 mm x 10 mm specimen value in Table 5 multiplied by the appropriate adjustment factor of Table 6.

d) Test method shall comply with the CVN technique of ASTM A370 or ISO 148-1.

e) A minimum of three impact specimens shall be tested to qualify a heat of material.

f) No single impact value shall be below 2/3 of the required average.

g) Wrought bar and tubular products shall meet the longitudinal CVN requirements.

h) Other forged products, where specified, shall meet the transverse or longitudinal CVN requirements.

Table 5 – CVN Impact Values, 10mm x 10mm Specimen

Temperature Rating[a]	Minimum Average Impact Value ft-lb (J)	
	Transverse Direction	Longitudinal Direction
≤ -20 °F (-29 °C)	15 (20)	20 (27)

[a] Test temperature shall be less than or equal to temperature rating of the material.

Table 6 – Adjustment Factors, Subsize CVN Specimens

Specimen Dimensions	Adjustment Factor	Transverse ft-lb (J)	Longitudinal ft-lb (J)
10 mm x 10 mm	1	15 (20)	20 (27)
10 mm x 7.5 mm	0.833	12.5 (16.7)	16.7 (22.5)
10 mm x 6.7 mm	0.78	11.7 (15.6)	15.6 (21.1)
10 mm x 5.0 mm	0.667	10 (13.3)	13.3 (18)
10 mm x 3.3 mm	0.44	6.6 (8.8)	8.8 (11.9)
10 mm x 2.5 mm	0.333	5 (6.7)	6.7 (9)

8.1.4.5.4 Bolting larger than 2.50 in. nominal diameter shall have impact tests performed. Nuts do not require impact testing.

8.1.4.6 Hardness Testing

8.1.4.6.1 Pressure-containing and pressure-retaining components produced from carbon or low-alloy steels shall have at least one hardness test performed on the QTC after final heat treatment.

8.1.4.6.2 For non-standard materials used in pressure-containing or pressure-retaining applications, hardness shall be in accordance with the manufacturer's requirements.

8.1.4.6.3 For standard materials, the hardness, after final heat treatment shall be in accordance with Table 7.

Table 7 – Hardness Measurement

Material Designation	Minimum Brinell Hardness	Maximum Brinell Hardness
45K	HBW 140	HBW 237
60K	HBW 174	HBW 237
75K	HBW 197	HBW 237
95K	HBW 248	HBW 341
NS	Manufacturer's requirements	Manufacturer's requirements

8.1.4.6.4 Materials intended for sour service shall meet the hardness requirements of NACE MR0175/ISO 15156. Pressure-containing, sour service components constructed of steel shall not exceed a hardness of 22 HRC.

8.1.5 Processing

8.1.5.1 Castings

Castings shall not be used for pressure-containing or pressure-retaining components.

8.1.5.2 Melting Practices for Wrought Materials

8.1.5.2.1 Wrought steels used in pressure-containing and pressure-retaining applications shall be vacuum degassed, fully killed.

8.1.5.2.2 Wrought steel shall have grain Size 5 or finer per ASTM E112.

8.1.5.2.3 Additional melting practices for carbon or low-alloy steels, stainless steels or CRA materials shall be in accordance with the manufacturer’s requirements.

8.1.5.3 Forging Practices

8.1.5.3.1 Forgings shall be cold or hot formed using practices that produce wrought structure throughout.

8.1.5.3.2 The minimum forging reduction ratio shall be 3:1.

8.1.6 Heat Treating

8.1.6.1 Heat-treating of material, parts, and qualification test coupons (QTC) shall be performed with production type heat-treating equipment qualified in accordance with API 6A, SAE AMS 2750, SAE AMS H6875, or ASTM A991, or a recognized industry heat-treating standard..

8.1.6.2 Production type heat-treating equipment shall be considered equipment that is routinely used to process production parts having an equivalent round (ER) equal to or greater than the ER of the subject QTC.

8.1.7 Chemical Composition

8.1.7.1 The manufacturer shall specify the chemical composition and composition tolerances of the material.

8.1.7.2 Material composition shall be determined on a heat basis (or a remelt ingot basis for remelt grade materials) in accordance with a nationally or internationally recognized standard.

8.1.7.3 Carbon and low-alloy steels used in pressure-containing or pressure-retaining applications shall have phosphorus and sulphur concentrations below 0.025 % (mass fraction).

8.1.8 Wetted Pressure-Controlling Metallic Components

Metallic wetted pressure-controlling components shall be produced in accordance with the manufacturer's specification and shall include (where applicable) the information in 8.1.2.

8.1.9 Nonmetallic Pressure-Containing and Wetted Pressure-Controlling Components

8.1.9.1 Nonmetallic components intended for pressure-containing or wetted pressure-controlling service shall be produced in accordance with the manufacturer's specification in 8.1.3.

8.1.9.2 Results for qualification tensile testing shall be determined with specimens per a recognized industry standard or on a cross section of molded parts.

8.1.9.3 Qualification approval shall be based on the median of all specimens meeting the specified mechanical requirements of the applicable material specification.

8.1.9.4 Changes in the process or material of qualified components shall be reviewed by the manufacturer who shall then determine if re-qualification is required.

8.1.9.5 Each batch/lot of components shall be identified by a control number.

8.1.9.6 The batch/lot control number shall be maintained throughout all manufacturing operations.

8.1.9.7 Batch records shall be maintained by the supplier for a minimum of five (5) years.

8.2 Welding

8.2.1 Pressure-containing Welds

8.2.1.1 General

8.2.1.1.1 Pressure-containing welds shall be made by qualified welders in accordance with the manufacturer’s documented welding procedure specification (WPS).

8.2.1.1.2 The WPS shall be written and qualified in accordance with ASME BPVC, Section IX.

8.2.1.1.3 The WPS shall describe essential and supplementary essential variables.

8.2.1.2 Weld Procedure Qualification

8.2.1.2.1 The procedure qualification record (PQR) shall include essential and supplementary essential variables used for welding the PQR specimens and the results of PQR tests.

8.2.1.2.2 Weld metal mechanical properties, as demonstrated by the PQR, shall meet or exceed the mechanical properties specified for the design of the part.

8.2.1.2.3 Welder performance qualification (WPQ) shall be in accordance with ASME BPVC, Section IX.

8.2.1.2.4 The WPS, PQR, and WPQ shall be documented in accordance with ASME BPVC, Section IX and maintained as records.

8.2.1.2.5 Base metals not listed in P-number groupings in ASME BPVC Section IX shall be qualified by the manufacturer.

8.2.1.2.6 The manufacturer may use P-number groupings for materials listed in P-number groupings in ASME BPVC Section IX.

8.2.2 Repair Welding

8.2.2.1 Repair welding of pressure-containing components is not permitted

8.2.2.2 Local repair to pressure-containing component sealing surfaces may be performed where a WPS and accompanying PQR have been completed and demonstrate that the repair weld does not compromise the structural integrity of the component.

8.2.2.3 Repair welding of pressure-retaining components is not permitted.

8.2.3 Overlay Welding and Hardfacing

Weld overlay and hardfacing shall be performed according to the manufacturer's specification.

8.3 Design Documentation

8.3.1 General

8.3.1.1 Documentation of designs shall include

a) methods,

b) assumptions,

c) calculations, and

d) design requirements

8.3.1.2 Design requirements shall include criteria for

a) size,

b) test pressures

c) operating pressures

d) temperature rating

e) material requirements

f) environmental requirements, and

g) other pertinent requirements on which the design is based.

8.3.1.3 Design documentation media shall be clear, legible, reproducible, and retrievable.

8.3.1.4 Design documentation shall be retained for 5 years after the last unit of that model, size, and rated working pressure is manufactured.

8.3.1.5 Design documentation shall be reviewed and verified by a qualified individual other than the individual who created the document.

8.3.2 Design Validation

8.3.2.1 Manufacturers shall document their design validation procedures and the results of design validation.

8.3.2.2 Validation testing of components that use redundant seals shall be performed with the secondary seal defeated or removed to permit in-test leak detection of the primary sealing element.

8.4 Factory Acceptance Testing

8.4.1 General

8.4.1.1 Measurement, Monitoring and Recording Equipment

8.4.1.1.1 Pressure measuring devices shall be periodically calibrated to ensure accurate pressure readings.

8.4.1.1.2 Calibration intervals shall be established based on repeatability and degree of usage. Calibration intervals may be lengthened or shortened based on recorded calibration history.

8.4.1.1.3 Calibration intervals for pressure-measuring devices shall be a maximum of 3 months until recorded calibration history can be established by the manufacturer. Extension of intervals shall be limited to 3-month increments, with a maximum calibration interval not to exceed 1 year.

8.4.1.1.4 If a pressure chart recorder is not calibrated to meet the accuracy requirements above, it shall be used in parallel with a calibrated pressure gauge, and the pressure indicated by the calibrated gauge at the start and end of the hold period shall be written on the chart.

8.4.1.2 Test Sequence

8.4.1.2.1 The hydrostatic shell test shall be the first pressure test performed.

8.4.1.2.2 Hydrostatic pressure tests and functional tests shall be performed prior to any gas testing, if applicable. The sequence of gas testing may be varied by the manufacturer.

8.4.1.2.3 When required, drift testing of valves, shall be performed after pressure and functional testing has been completed.

8.4.1.3 Leak Detection

8.4.1.3.1 Fluid released during pressure build-up or pressure bleed-down shall not be considered leakage.

8.4.1.3.2 Visible leakage shall be observed directly, such as through a window, or by video equipment.

8.4.1.3.3 When video equipment is used in place of direct observation, resolution and brightness shall be sufficient to determine whether leakage occurs.

8.4.2 Hydrostatic Testing

8.4.2.1 General

8.4.2.1.1 The test fluid shall be water or water with additives.

8.4.2.1.2 hold periods shall not start until the test article and the pressure measuring/recording equipment has been isolated from the pressure source;

8.4.2.1.3 pressure testing shall be conducted prior to the addition of body-filler grease; lubrication may be applied during assembly.

8.4.2.2 Hydrostatic Test Acceptance Criteria

The following acceptance criteria apply to shell tests, seat tests, and conditional hydrostatic body tests.

a) the equipment shall show no visible leakage while subjected to test pressure;

b) monitored pressure shall not vary from the test pressure at the start of the test by more than 5% or 500 psi, whichever is less, for the duration of the hold period;

c) the initial test pressure shall not be greater than 5% above the specified test pressure;

d) during the entire hold period, the monitored pressure shall not drop below the specified pressure;

e) for metal seating check valves, the maximum allowable through-bore leakage in hydrostatic seat testing shall be in accordance with ISO 5208, Rate E.

8.4.2.3 Test Method

8.4.2.3.1 If a shell test is specified, each piece of equipment shall be hydrostatically shell tested prior to shipment from the manufacturer's facility.

8.4.2.3.2 The hydrostatic shell test shall be the first pressure test performed.

8.4.2.3.3 Valves and chokes shall be in the fully or partially open position during the hydrostatic shell test

8.4.2.3.4 Shell test pressure shall not be applied as a differential pressure across closure mechanisms of valves or chokes.

8.4.2.3.5 After testing, the pressure in the test article shall be reduced to 0 psig

8.4.2.3.6 Valves shall have their wetted pressure-controlling component(s) pressure tested at the rated working pressure of the assembly for a duration according to the manufacturers written specification

8.4.2.3.7 Bi-directional valves shall have their wetted pressure-controlling component pressure tested at the assemblies rated working pressure from both directions for a duration according to the manufacturers written specification.

8.4.2.4 Hold Period

8.4.2.4.1 The duration of the shell test pressure hold shall be specified by the manufacturer.

8.4.2.4.2 Other pressure holds, such as seat or plug pressure tests, shall be held for a duration defined in the manufacturer's test procedure.

8.4.2.4.3 The pressure hold period shall not start until the test pressure has been reached or exceeded.

8.4.2.5 Test Pressure

8.4.2.5.1 Standard Equipment

The hydrostatic shell test pressure requirement shall be at least 1.5 times the rated working pressure.

8.4.2.5.2 Special Considerations

8.4.2.5.2.1 For equipment with end connectors or outlet connectors having different rated working pressures, the lowest working pressure rating shall be used to determine the hydrostatic shell test pressure (except for crossover connectors and chokes).

8.4.2.5.2.2 For a crossover connector the following apply:

a) the test pressure shall be based on the rated working pressure for the upper connector;

b) test pressure shall be applied inside and above the restricted-area pack-off of the lower connector;

c) the lower connector shall be tested below the restricted-area pack-off with test pressure based on its rated working pressure.

8.4.2.5.2.3 For a choke having an inlet connector with a higher rated working pressure than the outlet connector, two hydrostatic shell tests shall be performed as follows:

a) the body portion from the inlet connector to the body-to-bean seal point of the replaceable seat or flow bean shall be tested at the shell test pressure for the inlet connector;

b) the remainder of the body, downstream from the seal point, shall be tested at the shell test pressure for the outlet connector;

c) temporary seat seals and/or a blank seat may be used to facilitate testing.

8.4.2.5.2.4 Each bore of multiple-bore equipment shall be tested individually.

8.4.3 Exempted Equipment

The following equipment is exempted from hydrostatic pressure testing:

a) loose connectors (blind flanges, blind unions, blind hubs, non-integral OECs);

b) gaskets and other loose seals;

c) replacement/refurbishment wetted pressure-controlling components such as

   1) plugs for plug valves,

   2) gates and seats for gate valves, and

   3) choke trim.

8.5 Equipment Marking

8.5.1 General

8.5.1.1 Metallic components shall be marked in a low stress area on the exterior surface. The nominal size for equipment shall be marked with US Customary (USC) units.

8.5.1.2 Non-metallic seals shall be marked or tagged.

8.5.1.3 Markings should be visible after all machining, priming, and painting.

8.5.1.4 Hammer union components shall be marked in accordance with API 7HU2.

8.5.1.5 Loose 6B and 6BX flanges and clamp hub end connectors are to be marked in accordance with API 6A. Flanges included as parts of other equipment are to be marked per manufacturer's written specification.

8.5.1.6 Components which are sour service capable shall be clearly marked to indicate they are sour service compatible.

8.5.2 Marking Method

8.5.2.1 Permanent marking methods shall be used to identify metallic parts. Permissible methods include forging and casting markings into bodies, low-stress marking methods (i.e. dot, vibration, or rounded V stamping). Sharp V-stamping is prohibited unless the part is subsequently normalized.

8.5.2.2 Permanent marking methods are preferred for non-metallic seals, but where not possible, seals may be tagged. Molded-in lettering and electro-etching are suitable permanent marking methods for non-metallic seals.

8.5.2.3 Assemblies may be marked with stainless steel banding. The marking method on the band shall meet 8.5.1.1, with the exception that high-stress stamping methods are permitted and does not require subsequent stress relief.

8.5.3 Additional Marking Requirements

8.5.3.1 Markings for metallic components shall be visible after all mechanical processing, heat treating, priming, and painting.

8.5.3.2 Pressure-containing, pressure-retaining and wetted pressure-controlling metallic components shall be uniquely marked such that the component can be tied back to its mechanical, heat treat and FAT records.

8.5.3.3 Valve assemblies may have a nameplate affixed to the valve with the following information clearly marked:

a) nominal size of the assembly per the assembly description;

b) model number and/or end connection sizes;

c) temperature rating;

d) rated working pressure;

e) serial number unique to that assembly which allows for direct link to material and test records.

8.6 Storage and Shipping

8.6.1 Corrosion Prevention

8.6.1.1 Prior to shipment, carbon and low alloy steel parts shall have exposed metallic surfaces protected with a corrosion preventative or be stored indoors in a climate-controlled warehouse.

8.6.1.2 Corrosion prevention for other metal alloy systems such as stainless steel shall be in accordance with the manufacturer's requirements.

8.6.2 Sealing Surface Protection

Exposed sealing surfaces shall be protected from mechanical damage during storage and shipping.

8.6.3 End Connector Protection

End connectors shall be protected from mechanical damage during storage and shipping.

8.6.4 Loose Non-metallic Materials

The manufacturer's requirements for non-metallic seals not assembled into equipment shall include the following minimum provisions:

a) indoor storage in an air-tight bag or container;

b) maximum temperature not to exceed 52°C (125°F)

c) protected from direct natural light;

d) stored unstressed;

e) stored away from contact with liquids;

f) protected from ozone and radiographic damage.

8.6.5 Pre-shipment Checks and Additional Shipping Requirements

8.6.5.1 Preparation for Shipment

Prior to packaging for shipment, components/assemblies shall be visually examined to verify the following:

a) exposed bare metallic surfaces are protected from corrosion;

b) components/assemblies are completely drained of test fluids;

c) metal burrs are removed;

d) the component/assembly is correctly marked;

e) the component/assembly is free from handling damage or other visual surface defects.

8.6.5.2 Packaging Requirements

8.6.5.2.1 The shipper to ensure that packaging and packaging materials chosen are appropriate for the items that are being shipped.

8.6.5.2.2 Pallets and crates shall be of quality that no safety issue is raised, i.e. no rotten wood and no split or broken boards.

8.6.5.2.3 Crates and pallets shall have sufficient clearance between the floor and bottom of the crate or pallet to allow for fork trucks and/or swing lifts to properly handle the loads.

8.6.5.2.4 Shipments shall be packaged to withstand the usual hazards of transportation.

8.6.5.2.5 Products with lifting eye holes shall be positioned for ease of accessibility by overhead lifting devices.

8.6.5.2.6 Packing slips shall be included with the shipment and affixed to the container in a visible location.

8.6.5.2.7 The packing list shall be attached such that, barring tampering, it remains intact until it reaches its destination.

8.7 Records Requirements

8.7.1 General

8.7.1.1 Purpose

The quality control records required by this Standard are necessary to substantiate that all materials and products made to meet this Standard do conform to the specified requirements.

8.7.1.2 Sour Service Part Records Requirements

The manufacturer shall maintain records to substantiate conformance of sour service components to NACE MR0175/ISO 15156.

8.7.1.3 Records Control

8.7.1.3.1 Quality control records shall be legible, identifiable, retrievable, and protected from damage, deterioration or loss.

8.7.1.3.2 Quality control records shall be retained by the manufacturer for a minimum of five years following the date of manufacture as marked on the parts associated with the records.

8.7.1.3.3 Quality control records shall identify the inspector and the date of inspection.

8.7.2 Quality Control Records

8.7.2.1 Metallic Part Records

The following records shall be retained by the manufacturer and reference the applicable heat-treat lot identification. “Heat-treat lot” shall be defined as in API 6A.

a) Material test records as follows:

    1) tensile test;

    2) impact test;

    3) hardness test;

    4) chemical analysis.

b) NDE personnel qualification records (if applicable).

c) Heat-treatment temperature, time at temperature, and quench practice.

d) Surface NDE records referencing unique part identification numbers (if applicable).

e) Part hardness test record (if applicable) as follows:

    1) actual hardness;

    2) hardness scale.

f) Records that dimensional inspection was performed.

8.7.2.2 Nonmetallic Sealing Material Records

8.7.2.2.1 The seal supplier shall certify that materials and end products meet the specifications as required.

8.7.2.2.2 Certification shall include the following:

a) manufacturer's part number;

b) specification number;

c) compound number;

d) batch number;

e) cure/mold date;

f) shelf-life expiration date.

NOTE Shelf-life expiration date specifies the date at which the part is not used for new installations.

8.8 Quality Control

8.8.1 Quality Management System

The manufacturer shall have a quality management system in conformance with API Q1 or ISO 9001.

8.8.2 Measuring and Testing Equipment

Equipment used to inspect, test, or examine material or other parts shall be identified, controlled, calibrated, and adjusted at specified intervals in accordance with documented instructions, and consistent with nationally or internationally recognized standards specified by the manufacturer.

8.8.3 Quality Control Personnel Qualifications

8.8.3.1 Non-Destructive Examination Personnel

Personnel performing NDE shall be qualified in accordance with the manufacturer's documented training program that is based on the requirements specified in ISO 9712 or ASNT SNT-TC-1A.

8.8.3.2 Other Personnel Examination

Other personnel performing measurements, inspections or tests for acceptance shall be qualified in accordance with the manufacturer's documented procedures and requirements.

8.8.4 Quality Control Requirements

8.8.4.1 General

8.8.4.1.1 Quality control work shall be controlled by the manufacturer's documented instructions, which include appropriate methodology and quantitative or qualitative acceptance criteria.

8.8.4.1.2 NDE procedures shall be detailed regarding the requirements of this document and those of all applicable nationally or internationally recognized standards specified by the manufacturer. All NDE procedures shall be approved by a Level III examiner qualified in accordance with ASNT SNT-TC-1A or ISO 9712.

8.8.4.2 Hardness Testing

8.8.4.2.1 Scope

All pressure-containing metallic parts shall be hardness tested.

8.8.4.2.2 Test Method

8.8.4.2.2.1 Hardness testing shall be performed with Brinell or Rockwell methods in accordance with procedures specified in ASTM E110, ISO 6506, parts 1 through 4, ASTM E10 (Brinell), ISO 6508, parts 1 through 3, or ASTM E18 (Rockwell).

8.8.4.2.2.2 ISO 18265 or ASTM E140 shall be used for the conversion of hardness readings for materials within the scope of their application.

8.8.4.2.2.3 Tests shall be performed at a location determined by the manufacturer's specifications and following the last heat-treatment cycle (including all stress-relieving heat-treatment cycles) and all exterior machining at the test location.

8.8.4.2.3 Acceptance Criteria

8.8.4.2.3.1 Parts shall meet the hardness requirements given in Table 7.

8.8.4.2.3.2 Parts below the minimum hardness levels are acceptable if the measured value satisfies the following requirement: the average tensile strength, as determined from the tensile tests results, shall be used with the QTC hardness measurements in order to determine the minimum acceptable hardness value. This is applicable for production parts fabricated from the same heat. The minimum acceptable Brinell hardness value for any part shall be determined by Equation (2):

$$H_{\mathrm{BWc,\,min.}} = \frac{R_{\mathrm{m,\,min.}}}{\overline{R}_{\mathrm{m,\,QTC}}}\left(\overline{H}_{\mathrm{BW,QTC}}\right) \qquad H_{BWc,min.} = \frac{R_{m,min}}{R_{m,QTC}}\left(H_{\mathrm{BW,QTC}}\right) \qquad (2)$$

where

$H_{\mathrm{BWc,\,min.}}$ is the minimum acceptable Brinell hardness according to the HBW method for the part after the final heat-treatment cycle (including stress-relieving cycles);

$R_{\mathrm{m,\,min.}}$ is the minimum acceptable ultimate tensile strength for the applicable material designation;

$\overline{R}_{\mathrm{m,\,QTC}}$

is the average ultimate tensile strength determined from the QTC tensile tests;

$\overline{H}_{\mathrm{BW,QTC}}$

is the average of the Brinell hardness values according to the HBW method observed among all tests performed on the QTC.

8.8.4.3 Dimensional Inspection

8.8.4.3.1 Dimensional inspection shall be performed on parts.

8.8.4.3.2 Sampling shall be in accordance with ISO 2859-1:1999, level II, 1.5 AQL. Threads on all parts in the sample shall be verified to standard dimensions and tolerances by any suitable method. Critical dimensions on all parts in the sample shall be verified.

8.8.4.3.3 Threads shall be in accordance with applicable industry specification.

8.8.4.4 Surface NDE

8.8.4.4.1 When purchaser or manufacturer specifies NDE on parts covered under this standard, all accessible surfaces of each finished pressure-containing part within the scope of this standard shall be examined by liquid-penetrant or magnetic-particle methods after final heat-treatment and final machining operations.

8.8.4.4.2 Examinations shall be done in accordance with procedures specified in ASTM E709 (MT) or ASTM E165 (PT).

8.8.4.4.3 Prods shall not be used on wetted surfaces or sealing surfaces.

NOTE Prods are hand-held electrodes used for local magnetization for surface NDE.

8.8.4.4.4 If any indications are believed to be non-relevant on the basis that they are not associated with a surface rupture (i.e. magnetic permeability variations, non-metallic stringers), they shall be examined by liquid-penetrant surface NDE methods to confirm their non-relevancy.

8.8.4.4.5 The acceptance criteria set forth in API 6A apply.

8.8.4.5 Traceability

8.8.4.5.1 Pressure-containing parts and pressure-retaining parts shall have traceability to the chemistry, mechanical testing, heat and heat-treatment performed and factory acceptance testing (if applicable) on the parts.

8.8.4.5.2 Identification shall be maintained on materials and parts to facilitate traceability, as required by documented manufacturer requirements.

8.8.4.5.3 Manufacturer-documented traceability requirements shall include provisions for maintenance or replacement of identification marks and identification control records.

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