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API Standard 16FR

Ballot #6714

Repair and Remanufacturing of Marine Drilling Riser Equipment

**API STANDARD 16FR
FIRST EDITION, XXXX**

Ballot Draft

1 Scope

This standard specifies requirements for repair and remanufacturing of the following drilling riser components built under an API 16F or 16R specification:

1. Choke, Kill, and Auxiliary Lines
2. Riser Joints
3. Buoyancy Equipment

Components which did not conform to the requirements of API 16F first edition or newer at the time of manufacture are outside the scope of this document.

This standard also covers the testing, inspection, welding, marking, certification, storing, and shipping of equipment repaired or remanufactured per this standard.

Maintenance activities are not governed by this document, but the documentation of those activities is included in the scope.

Ballot Draft

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API STANDARD 16FR

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 (including any amendments) applies.

API Specification 16F, Specification for Marine Drilling Riser Equipment

API Specification Q1: Specification for Quality Management System Requirements for Organizations Providing Products for the Petroleum and Natural Gas Industry.

ASME Boiler and Pressure Vessel Code (BPVC), Section V: Nondestructive Examination; article: 4 Ultrasonic Examination Methods for Welds

ASME¹ Boiler and Pressure Vessel Code Section IX

ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 - Rules for Construction of Pressure Vessels

ASME Boiler Pressure Vessel Code (2010), Section V, Subsection A, Article 9

ASNT-SNT-TC-1A², Recommended Practice for Personnel Qualification and Certification in Nondestructive Testing

ASTM³ E110, Standard Test Method for Indentation Hardness of Metallic Materials by Portable Hardness Testers

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

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

ASTM E18, Standard Test Methods for Rockwell Hardness of Metallic Materials

ASTM E94, Standard Guide for Radiographic Testing

ASTM E140, Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

ASTM E165, Standard Test Method for Liquid Penetrant Examination

ASTM E384, Standard Test Method for Knoop and Vickers Hardness of Materials

ASTM A388, Ultrasonic Examination of Steel Forgings

¹ American Society of Mechanical Engineers, Two Park Avenue, New York, NY 10016.

² American Society for Nondestructive Testing, PO Box 28518, 1711 Arlingate Lane, Columbus OH 43228.

³ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM E709, Standard Guide for Magnetic Particle Examination

AWS⁴ QC1 Standard for AWS Certification of Welding Inspectors.

AWS D1.1, ASME Boiler & Pressure Vessel Code, Section IX

ISO⁵ 6506-1, Metallic materials, Brinell hardness test, Part 1: Test method

ISO 6507-1, Metallic materials, Vickers hardness test, Part 1: Test method

ISO 6508-1 All parts, Metallic materials, Rockwell hardness test

ISO 9712, International Standard for Nondestructive Testing Personnel Qualification and Certification

CSWIP-WI-6-92⁶, Requirements for the Certification of Visual Welding Inspectors (Level 1), Welding Inspectors (Level 2) and Senior Welding Inspectors (Level 3) (fusion welding) in accordance with BS EN ISO 17637:2011

NACE MR0175⁷/ISO 15156 (all parts), Petroleum and natural gas industries – Materials for use in H₂S – containing environments in oil and gas production

⁴ American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166-6672, www.aws.org.

⁵ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

⁶ TWI Certification Ltd., Granta Park, Great Abington, Cambridge CB21 6AL, United Kingdom, www.cswip.com.

⁷ NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

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

acceptance criteria

Specified requirements of acceptability applied to product or process characteristics.

3.1.2

Auxiliary lines

Conduit [excluding choke and kill (C&K) lines] attached to the outside of the riser main tube (e.g. hydraulic supply line, buoyancy control line, mud boost line).

3.1.3

bolting

See API Specification 16F.

3.1.4

certificate of conformance

COC

Document in which the manufacturer, remanufacturer, or technical authority certifies that the assembly or part is in conformance to the mentioned standard(s), specifications, in accordance with the original- or current product definition (OPD or CPD), on the date of issuance.

3.1.5

certificate of service

COS

Document in which the equipment manufacturer, remanufacturer, or technical authority, certifies that the equipment has been inspected, repaired, and/or successfully tested in conformance with the requirements of the defined workscope and assures that the listed equipment on the certificate is fit for service on the date of issuance.

3.1.6

critical areas

Area(s) of a product, including but not limited to sealing surfaces, stress/strain locations under static load, and/or stress/strain locations under dynamic load, which result in specific limits or controls, as defined by the OPD/CPD, for that product while in service.

3.1.7

critical dimension

Dimension(s) identified by the manufacturer as requiring verification and documentation.

3.1.8

critical cross-section

A section(s) in a part or component identified by technical assessment (i.e., stress calculations or analysis) as a location(s) where mechanical properties are to be evaluated to establish compliance with design and material specification of the OEM/CEM.

3.1.9

current equipment manufacturer

CEM

Design owner or remanufacturer of the traceable current assembled equipment, single equipment unit, or component part responsible for the current product definition.

NOTE The OEM can be the CEM as long as they own the CPD that is active for the equipment.

3.1.10 current product definition

CPD

Complete design verified and validated definition of the requirements for the current assembled product, single equipment unit, or component part needed for its current design, manufacture, use, maintenance and service.

3.1.11

dehydrogenation heat treatment

DHT

Activity carried out to diffuse hydrogen and minimize the risk of hydrogen cold cracking in completed or partially completed weld joints prior to the weld joint cooling to ambient temperature.

3.1.12

end connector

Any integral feature of a body used as a means to join together equipment that contains pressure, permits flow of retained fluid between the joined equipment, and provides a seal at the joint.

NOTE: End connectors include, but are not limited to, internal or external threads, clamp hub, , and studded or through-bolted flange.

3.1.13

equipment owner

Owner of the equipment repaired or remanufactured in conformance with this document.

3.1.14

flange

A protruding rim, with holes to accept bolts and having a sealing mechanism, used to join pressure-containing equipment with dimensions specified in this standard.

3.1.15

heat (noun)

Material originating from a final melt, or for remelted alloys, or the raw material originating from a single remelted ingot.

3.1.16

heat treatment

heat treating

Specified, timed sequence of controlled heating and cooling of materials for the purpose of changing physical or mechanical properties.

3.1.17

indication

Abnormalities found during nondestructive examination.

3.1.18

Inherent indications

Indications that are not associated with a surface rupture (e.g. magnetic permeability variations, nonmetallic stringer).

3.1.19

integral (*adjective*)

Parts made of a single forging/casting or joined by welding process.

3.1.20

Intermediate Stress Relief

ISR

Activity carried out to reduce residual stresses and diffuse hydrogen from completed highly stressed weld joints so that the risk of cracking is minimized upon the weld joint cooling to ambient temperature.

NOTE ISR can be used to reduce the risk of decreasing the base material properties when multiple welding operations are performed on a component. For example, a flange can receive an ISR after the seal groove inlay, then receive the final PWHT after the flange has been circumferentially welded to its mating component.

3.1.21

major repair weld

Weld whose depth is greater than 25% of the original wall thickness or 25.4 mm (1 in.), whichever is less.

3.1.22

manufacturer

OEM or CEM of the product or part.

3.1.23

manufacturing data book

MDB

Composite file of records from a traceable API product which includes records associated with the original API product manufacturing including certification records as required by this standard.

3.1.24

material traceability level

MaTL

The extent of traceability that a part or component has available for a repair or remanufacture.

3.1.25

other end connector

Connector which is not specified in an API specification or standard.

NOTE: This includes API flanges and hubs with non-API gasket preparations and manufacturer's proprietary connections.

3.1.26

original equipment manufacturer

OEM

Design owner or manufacturer of traceable assembled equipment, single equipment unit, or component part.

3.1.27

original product definition

OPD

Complete design verified and validated definition of the requirements for the original assembled product, single equipment unit, or component part needed for its original design, manufacture, use, maintenance, and service.

3.1.28

Part Component

Individual piece used in the assembly of a single unit of equipment.

3.1.29

post-weld heat treatment PWHT

Any heat treatment subsequent to welding, including stress relief.

3.1.30

pressure-containing

Component whose failure to function as intended would cause a release of pressurized fluid to the environment.

3.1.31

pressure-containing weld or pressure-containing weldment

Weld whose absence or failure will reduce or compromise the pressure-containing integrity of the component.

3.1.32

primary-load-carrying component

Component whose failure would compromise the structural integrity of the marine drilling riser system.

NOTE Examples are components that carry all or a major part of the tension in the riser.

3.1.33

procedure qualification record PQR

Record of the welding data used to make the test weldment containing the actual values or ranges of the essential and supplementary essential variables used in preparing the test weldments, including the test results.

3.1.34

product history file PHF

Composite file of records from a traceable API product which includes records associated with the API product repair and remanufacturing, including certification records required by this standard.

3.1.35

rated working pressure

Maximum internal pressure equipment is designed to contain and/or control.

3.1.36

relevant indication

Indication (liquid penetrant or magnetic particle inspection) with a major dimension greater than 1.6 mm (0.062 in).

3.1.37

remanufacture

Process of disassembly, reassembly and testing of marine drilling riser equipment, with or without the replacement of parts, in which machining, welding, heat treatment, or other manufacturing operation is employed.

3.1.38

remanufacturer

OEM or CEM that performs the repair or remanufacturing work.

3.1.39

repair

Process of disassembly, inspection, reassembly and testing of marine drilling riser equipment, with or without the replacement of parts in order to correct failed or worn components.

NOTE Repair does not include machining, welding, heat treating or other manufacturing operations of component parts.

3.1.40

repair weld

Welding performed to correct a nonconformance.

3.1.41

replacement part

replacement component

new, unused, or used part that satisfies the original or current product definition.

3.1.42

serialization

Assignment of a unique code to individual parts and/or pieces of equipment to maintain records.

3.1.43

skim cut

Re-facing of a machined surface within allowable tolerances to remove defects or restore surface finish.

NOTE Examples include API 6A or API 16A ring groove sealing surfaces, other end connection, proprietary sealing surfaces, non-sealing critical dimensions and areas in conformance with the CPD or API Specification.

3.1.44

statement of fact

SOF

Document in which the manufacturer, remanufacturer, or technical authority certifies that the repair or activity performed was made in accordance with the scope defined by the service provider and equipment owner.

3.1.45

technical authority

Competent and technically qualified person or organization with evidence to demonstrate the expertise, skills, and experience regarding design, quality, and manufacturing processes necessary to perform the required verification(s).

3.1.46

welding procedure specification

WPS

Written and qualified procedure for welding, including specific essential, nonessential, and supplementary essential variables for each welding process.

NOTE These variables and their meanings are defined in ASME Boiler & Pressure Vessel Code Section IX, Article II, and Article IV.

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3.2 Abbreviations

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

CE	carbon equivalency
CEM	current equipment manufacturer
COC	certificate of conformance
COS	certificate of service
CPD	current product definition
CRO	corrosion-resistant overlay
DAC	distance amplitude curve
DHT	dehydrogenation heat treatment
FAT	factory acceptance test
HAZ	heat-affected zone
ISR	intermediate stress relief
ITP	inspection test plan
LP	liquid penetrant
MDB	manufacturing data book
MP	magnetic particle
MPI	magnetic particle inspection
MaTL	material traceability level
MTR	material test record
NDE	nondestructive examination
OD	outside diameter
OEM	original equipment manufacturer
OES	optical emission spectroscopy
OPD	original product definition
PHF	product history file

PM	preventive maintenance
PMI	positive material identification
PQR	procedure qualification record
PWHT	post-weld heat treatment
QMS	quality management system
QTC	qualification test coupon
SOF	statement of fact
TPI	third party inspection
UTS	ultimate tensile strength
WPS	welding procedure specification

4 Equipment Owner Records and Reports

The repairer / remanufacturer shall obtain from the equipment owner the following, as available, in support of the workscope:

- a) equipment manufacturing data book (MDB) records;
- b) equipment product history file (PHF) records;
- c) equipment certification records;
- d) documenting requirements for the PHF;
- e) requested material traceability level (MaTL) for the product; and
- f) third party inspection (TPI) requirements.

Based on the equipment traceability the repairer / remanufacturer shall inform the owner what MaTL can be achieved with the agreed workscope.

NOTE Failure to provide PHF documentation can adversely affect the MaTL that can be obtained.

5 General Requirements

5.1 General

Quality control requirements for specific equipment and parts as specified in this shall meet the API 16F edition to which the riser was manufactured, or a more recent edition.

NOTE An assembly can have more than one certificate of conformance (COC) for its various components that can coexist together to provide certification for the entire assembly. Similarly, an assembly can have more than one current equipment manufacturer (CEM) or original equipment manufacturer (OEM).

5.2 Replacement Components

The repaired component(s) shall meet the design and functional requirements of the original product definition (OPD) or the current product definition (CPD).

For components manufactured to API 16F, replacement components shall conform to the API 16F edition to which the original component was manufactured or more recent edition of API 16F.

If the original component was not manufactured to API 16F, the replacement component shall meet the requirements of API 16F first Edition or a more recent edition, provided the original component meets the following criteria:

- a) The component shall be covered under the scope of API 16F (first edition or newer edition).
- b) The documentation shall validate the original component conformed to API 16F first edition or newer at the time of manufacture.
- c) If the component is a marine drilling riser coupling conforming to API 16R it shall be treated as conforming to API 16F first edition.

Replacement bolting shall conform to the requirements of the latest edition of API 16F regardless of requirements at time of manufacture of the original product.

NOTE Components which did not conform to the requirements of API 16F first edition or newer at the time of manufacture are outside the scope of this document.

5.3 Remanufactured Components

The remanufactured component(s) shall meet the design and functional requirements of the original product definition (OPD) or the current product definition (CPD).

For components manufactured to API 16F, remanufactured components shall conform to the API 16F edition to which the original component was manufactured or more recent edition of API 16F.

If the original component was not manufactured to API 16F, the remanufactured component shall meet the requirements of API 16F first Edition or a more recent edition, provided the original component meets the following criteria:

- a) The component shall be covered under the scope of API 16F (first edition or newer edition).
- b) The documentation shall validate the original component conformed to API 16F first edition or newer at the time of manufacture.
- c) If the component is a marine drilling riser coupling conforming to API 16R it shall be treated as conforming to API 16F first edition.

NOTE Components which did not conform to the requirements of API 16F first edition or newer at the time of manufacture are outside the scope of this document.

5.4 Inspection of Primary Load Path, Class 2, or Class 3 Bolting with Full Traceability Intended for Reuse

5.4.1 Inspection and acceptance criteria shall be in conformance with OEM/CEM written procedures.

5.4.2 Bolting shall be removed from any product assembly, cleaned, and inspected, including:

- a) Visual inspection of internal and external threads for wear, mechanical damage, corrosion, and stretch/yielding;
- b) Visual inspection of bolt hole/mating body threads for wear, mechanical damage, and corrosion;
- c) NDE of the threads and non-threaded areas using one of the following methods:
 - 1) MP
 - 2) LP
 - 3) Phased-Array UT
- d) Dimensional inspection

NOTE 1 See API 16F bolting requirements for details on bolting classes.

NOTE 2 Encoders may be used with Phased-Array UT inspection. See API 16AR Annex L for further information.

5.5 Inspection of Bolting with Loss of Traceability

5.5.1 For utility bolting, inspection shall be in conformance with the OEM/CEM requirements.

5.5.2 For non-utility bolting in which traceability cannot be determined (i.e., with lost traceability) and which is intended to be reused shall be removed from any product assembly, cleaned, and inspected.

NOTE Reuse of bolting where traceability cannot be determined assumes risk which depends on the application, condition, and use history of the bolting. Reuse of bolting should be thoughtfully considered. Loss of traceability carries an inherent risk as important information about material processing and mechanical properties will be unknown.

5.5.3 Bolting which has coating, and the presence of the coating would affect the results of the inspection process, shall have the coating removed in the area intended to perform inspection, as a minimum. The area(s) in which coating was removed shall be touched-up or the bolting recoated in conformance with the OEM/CEM requirements.

NOTE Bolting which does not meet API 20E requirements, or which was not originally manufactured in conformance with API 20E, may still be at risk of hydrogen embrittlement depending on the application and the coating process used (e.g., zinc electroplating). See API TR 21A for information on bolting selection and testing in hydrogen charging environments.

5.5.4 Inspection criteria for bolting in which traceability cannot be determined shall meet the OEM/CEM's requirements. All inspections shall be in conformance with written procedures. Inspection shall include,

- a. Visual Inspection for wear, mechanical damage, and corrosion. Bolt hole threads shall also be inspected for wear and deformation.
- b. Hardness Testing per ASTM E18. A minimum of three (3) hardness punches at 120-degrees apart shall be performed. Hardness testing shall be performed on the bolt ends or nut non-bearing face. Bolting shall be cleaned and prepared for hardness testing.
- c. PMI or OES shall be performed to establish the alloy type.
- d. Dimensional Inspection.
- e. Volumetric NDE inspection which shall include, as a minimum, longitudinal straight-beam UT inspection.
- f. NDE of threaded areas using one of the following methods:
 - 1) MP
 - 2) LP
 - 3) Phased-Array UT
- g. For headed bolts, surface NDE of head-shank junction shall be performed.

NOTE Encoders may be used with Phased-Array UT inspection. See API 16AR Annex L for further information.

5.5.5 Bolting acceptance criteria shall be in conformance with the OEM/CEM's requirements. Additionally, for carbon and low alloy steel bolting, all hardness readings shall be less than or equal to 34.0 HRC.

5.5.6 Bolting which meets the acceptance criteria may be reused in conformance with the OEM/CEM's repair and remanufacture requirements. Bolting inspected and accepted in conformance with this section shall not be considered API 20E or API 20F compliant and shall be noted as such on the COC or COS.

5.5.7 Bolting inspected and accepted in conformance with this section shall be marked with an identification number traceable to the inspection (e.g., COC or COS identification number, work order number, etc.) and have any marking appended with "-LT". The repairer/remanufacturer shall inform the owner of bolting inspected which has a loss of traceability.

5.5.8 Bolting which is inspected and includes a "-LT" as part of the marking shall be inspected per 5.4 or 5.5; however, shall not be considered bolting with full traceability.

5.4 Replacement Parts

Replacement parts shall be documented in conformance with Annex B. Replacement parts shall be traceable by either lot or serial numbers.

Equipment shall be reassembled in accordance with documented specifications of the OEM/CEM.

5.5 Visual Inspection

After final acceptance testing, equipment shall be visually inspected per the OEM/CEM's written inspection criteria. Visual inspection results shall be recorded.

5.6 Documentation

Repair and/or remanufacturing performed on the product shall be documented according to Annexes A and B.

Documentation of traceable repaired and/or remanufactured equipment shall be in accordance with API 16F and Annex A.

6 Quality Control Requirements

6.1 General

Section 6 specifies quality control requirements and shall apply to primary-load-carrying components and/or pressure-containing components within the scope of this specification.

Quality control requirements for non-primary-load-carrying components and/or non-pressure-containing components within the scope of this specification shall be performed and documented in accordance with the manufacturer's written specifications.

6.2 Measuring and Testing Equipment

6.2.1 General

Equipment used to inspect, test, or examine material or other equipment shall be identified, controlled, calibrated, and adjusted at specified intervals in conformance with documented measuring and testing equipment manufacturer instructions or applicable nationally or internationally recognized standards.

6.2.2 Pressure-measuring Devices Type and Accuracy

Test pressure-measuring devices shall be accurate in accordance with API 16F.

Test pressure-measuring devices shall be either pressure gauges or pressure transducers and shall be accurate to at least ± 1.0 % of full-scale range.

If pressure gauges are used in lieu of pressure transducers, they shall be selected such that the test pressure is indicated within 20 % and 80 % of the full-scale value.

Pressure tests shall be documented in a chart (e.g. linear, circular, or digital) in the PHF.

The record shall identify the recording device, calibration due date and shall be dated and signed.

Calibration procedures and intervals shall be in accordance with API 16F.

6.3 Quality Control Personnel Qualifications

6.3.1 Nondestructive Examination (NDE) Personnel

Personnel performing nondestructive examination (NDE) shall be qualified in accordance with the manufacturer's or remanufacturer's documented training program that conforms to the requirements specified in ISO 9712 or ASNT SNT-TC-1A.

6.3.2 Visual and Dimensional Examination Personnel

Personnel performing visual and dimensional examinations, including welders, shall take and pass an annual vision examination in accordance with the remanufacturer's documented procedures.

The remanufacturer's documented procedures shall conform to ISO 9712 or ASNT-SNT-TC-1A.

6.3.3 Welding Inspectors

6.3.3.1 Personnel performing visual inspection of welding operations and completed welds shall be qualified to one of the following:

- a) AWS Senior Certified Welding Inspector (SCWI) in accordance with AWS QC1;
- b) AWS Certified Welding Inspector (CWI) in accordance with AWS QC1;
- c) AWS Certified Associate Welding Inspector (CAWI) in accordance with AWS QC1 and under the supervision of an AWS SCWI or AWS CWI.
- d) CSWIP Certified Visual Welding Inspectors (Level 1);
- e) CSWIP Certified Welding Inspectors (Level 2);
- f) CSWIP Certified Senior Welding Inspectors (Level 3);
- g) Welding inspector certified by the remanufacturer's documented training program.

6.3.3.2 The remanufacturer shall have written procedures:

- a) defining the roles, responsibilities, authority, and accountability of a welding inspector;
- b) defining essential welding variables and equipment monitoring;
- c) defining welding, weld NDE, and post-weld heat treatment (PWHT) audits. Internal audits shall be performed at least annually, covering on-site areas and shifts. Supplier audits shall be performed in accordance with the manufacturer's written procedure for validation of supplier processes.
- d) defining the In-house welding inspector certification program, if used, including training syllabus, instructor qualification requirements, length of certification, and renewal requirements.

6.3.4 Third Party Inspection

If third-party inspection (TPI) is used, the following shall apply:

- a) TPis shall be competent to perform the inspection service and certification related product requirements defined in the inspection scope;
- b) Evidence of the determination of competence of TPI personnel shall be recorded and maintained by the TPI company in accordance with their quality management system (QMS) documented procedures and requirements for competence;

- c) The TPI scope shall be defined in the purchase order by the equipment owner;
- d) The TPI requirements defined in the purchase order shall be included in the inspection test plan (ITP) for the product.

6.3.5 Other Personnel

Personnel performing measurements, inspections, tests or other quality control activities for acceptance shall be qualified and competent in accordance with the remanufacturer's QMS documented procedures and requirements, which meet API Q1 or other internationally recognized QMS standard.

6.4 Quality Control Requirements for Equipment and Parts

6.4.1 General

Manufactured, remanufactured or replacement parts shall be in conformance with the OPD/CPD.

Quality control records and marking for specific equipment and parts shall be in conformance with API 16F.

The original product definition (OPD) or CPD shall include but is not limited to:

- a) validation records;
- b) verification records;
- c) engineering drawings;
- d) quality control requirements;
- e) welding requirements;
- f) operation and maintenance manuals;

6.4.2 Quality Control Instructions

Quality control work shall be controlled by the remanufacturer's documented instructions, which include an ITP or other methodology that provides an auditable tracking document with quantitative and qualitative acceptance criteria.

6.4.3 Nondestructive Examination General

6.4.3.1 Nondestructive Examination (NDE) Instructions

NDE instructions shall be validated and detailed regarding the requirements of this standard and those of applicable nationally or internationally recognized standards specified by the remanufacturer. Surface and volumetric NDE instructions shall be approved by a NDE Level III examiner.

6.4.3.2 NDE Qualification Levels

NDE personnel shall be qualified in accordance with requirements specified in ISO 9712 or ASNT SNT-TC-1A.

6.4.4 Hardness Testing

Hardness testing requirements shall meet the following:

- a) Hardness testing methods shall be in accordance with one of the following: ASTM E10, ASTM E18, ASTM E110, ASTM E384, ISO 6506-1, ISO 6507-1, or ISO 6508-1;
- b) At least one hardness test shall be performed on each part tested, at a location determined by the remanufacturer's specifications;

- c) For pressure-containing and primary-load-path welds shall be hardness tested. At least one hardness test shall be performed in both the weld and in the adjacent unaffected base metal after final heat treatment and machining operations. Hardness values shall meet the requirements of the OEM/CEM written specification. Locations deemed inaccessible by the OEM/CEM for hardness testing shall be identified and recorded.

NOTE this can apply to welds not performed by the remanufacturer if existing welds were post weld heat treated.

- d) The hardness testing used to qualify each part shall be performed after the final heat-treatment cycle in the finished machine condition;
- e) The value of the hardness test shall be stamped on the part adjacent to the test location.

It is permissible for the hardness marking to be covered by other components after assembly;

- f) When NACE MR0175 is required per API 16F, hardness measurements for components shall be in accordance with the limits in NACE MR0175.
- g) Hardness measurement results shall be added to the PHF.

6.4.5 Critical Dimensions and Critical Areas

Critical dimension requirements shall meet the following;

- a) Critical dimensions, as defined by the OEM or CEM, shall be documented and recorded for each part, and such documentation shall be retained by the OEM or CEM.
- b) Critical dimensions, as defined by the OEM or CEM, shall be within the tolerances specified in the CPD.
- c) Critical areas, as defined by the OEM or CEM, shall be in conformance with the CPD, as defined in Annex A.
- d) The OEM or CEM shall define and document the extent to which dimensions shall be verified and recorded.

6.4.6 Traceability

Traceability requirements shall meet the following:

- a) Parts and material shall be traceable in accordance with the OPD or CPD;
- b) Identification shall be maintained on materials and parts, to facilitate traceability, as required by documented manufacturer requirements;
- c) OEM/CEM documented traceability requirements shall include provisions for maintenance or replacement of identification control records;
- d) Original markings lost before remanufacturing, shall be reestablished by markings that provide traceability that has been reestablished and documented by the remanufacturer.
- e) Welds without sufficient documentation / traceability in the PHF to meet the design specification of the manufacturer shall be removed.

Note: Base metal properties of the weldment can be obtained per Section 8.4.2. Accumulated post weld heat treatment time cannot be established once lost.

When traceability markings are still present and clearly legible, these markings may be reapplied as per OEM/CEM written specifications.

6.4.7 Chemical Analysis

Chemical analysis shall be required for the base metal and filler material of remanufactured primary-load-carrying components or pressure-containing components.

- a) Chemical analysis shall be performed when a material test record (MTR) is not available;
- b) Chemical analysis shall be performed in accordance with the remanufacturers written procedure;
- c) The chemical composition shall be in conformance with the requirements of API 16F.

6.4.8 Visual Examination

Visual examination requirements shall meet the following:

- a) Each part shall be visually examined.
- b) Visual examination of castings and forgings shall be performed in accordance with the OEM/CEM written specification;
- c) Acceptance criteria shall be in accordance with the OEM/CEM written specifications;
- d) Non-well fluid-wetted and non-sealing surfaces shall be examined in accordance with the OEM/CEM written specifications.

6.4.9 Surface NDE

Surface NDE requirements shall meet the following:

- a) For Surface NDE of ferromagnetic materials, accessible surfaces of each finished part shall be inspected after final heat treatment and final machining operations by either magnetic particle (MP) or liquid penetrant (LP) methods;
- b) For Surface NDE of non-ferromagnetic materials, accessible surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by the LP method;
- c) For Surface NDE of overlay cladding, accessible surfaces of each finished part shall be inspected after final PWHT. If the cladding is to remain as-welded and not machined, no additional surface inspection shall be required after subsequent heat treat cycles. If the cladding is to be final machined, then the newly machined surface shall require surface inspection by the LP method.
- d) LP examination shall be in accordance with ASTM E165;
- e) MP examination shall be in accordance with ASTM E709. Prods are not permitted on well fluid-wetted surfaces or sealing surfaces.

6.4.10 Acceptance Criteria for MP and LP

6.4.10.1 General

Inherent indications shall not be considered as relevant indications.

6.4.10.2 Acceptance Criteria for Surfaces Other than Pressure Contact (Metal-to-Metal) Sealing Surfaces

Inherent indications not associated with a surface rupture shall not be considered relevant indications including:

- a) No relevant indications interpreted as a crack;
- b) No relevant indication with a major dimension equal to or greater than 5 mm (0.2 in);
- c) No more than ten relevant indications in continuous 40 cm² (6 in²) area;
- d) Four or more relevant indications in a line separated by less than 1.6 mm (0.062 in) (edge to edge) are unacceptable.

There shall be no relevant indications in the pressure-contact (metal-to-metal) sealing surfaces.

6.4.11 Volumetric NDE of Parts

6.4.11.1 Sampling

Sampling requirements shall meet the following:

- a) For quench-and-tempered remanufactured or replacement products, the volumetric inspection shall be performed after heat treatment for mechanical properties exclusive of stress-relief treatments or re-tempering to reduce hardness;
- b) As far as practical the entire volume of each part shall be volumetrically inspected (radiography or ultrasonic) after heat treatment for mechanical properties and prior to machining operations that limit effective interpretation of the results of the examination.

6.4.11.2 Ultrasonic Examination

Ultrasonic examination requirements shall meet the following:

- a) Remanufactured parts: Ultrasonic examination of remanufactured parts shall be performed in accordance with the flat-bottom-hole procedures in ASTM A388 (except immersion method may be used) and ASTM E428;
- b) Calibration: Distance amplitude curve (DAC) shall be based on 1.6 mm (0.0625 in) flat-bottom hole for metal thicknesses through 38 mm (1.5 in), on 3.2 mm (0.125 in) flat-bottom hole for metal thicknesses from 38 mm (1.5 in) through 150 mm (6 in), and on 6.4 mm (0.25 in) flat-bottom hole for metal thicknesses exceeding 150 mm (6 in).

6.4.11.3 Acceptance Criteria Ultrasonic Examination

The following acceptance criteria for ultrasonic examination shall apply:

- a) no single indications exceeding reference DAC;
- b) no multiple indications exceeding 50 % of reference DAC.

Multiple indications shall be defined as two or more indications (each exceeding 50 % of the reference DAC within 13 mm (0.5 in) of each other in any direction.

6.4.11.4 Radiographic Examination

Radiographic examination of parts shall be performed in accordance with methods specified in 6.5.3.2.

6.4.11.5 Acceptance Criteria Radiographic Examination

The following acceptance criteria for radiographic examination shall apply:

- a) no cracks, laps, or bursts;
- b) no group of indication in a line that have an aggregate length greater than "t" in a length of 12t, where "t" refers to Table 1;
- c) no elongated indications with length greater than specified in Table 1.

Table 1: Inclusion Criteria

Thickness, t		Inclusion Length	
mm	(in.)	mm	(in.)
<19	< 0.76	6.4	0.25
$19 \leq t \leq 57$	$0.76 \leq t \leq 2.25$	$0.33 \times t$	$0.33 \times t$
> 57	> 2.25	19.0	0.75

6.4.12 Coating Inspection

Coating shall be to the OPD/CPD documented requirements.

6.5 Weld NDE

Pressure-containing or load-bearing welds shall be surface NDE and visually inspected.

Weld NDE requirements shall meet the following:

- a) weldments and the entire accessible weld shall be examined in accordance with the methods and acceptance criteria of this standard;
- b) 100% of surfaces prepared for welding shall be visually examined prior to initiating welding;
- c) Examinations shall include a minimum of 13 mm (0.5 in) of adjacent base metal on both sides of the weld;
- d) Weld NDE surface preparation acceptance shall be in accordance with the remanufacturer's written specification;
- e) Welds shall be examined in conformance with remanufacturer's written specification;
- f) Any undercut detected by visual examination shall be evaluated in accordance with the remanufacturer's written specification;
- g) Surface porosity and exposed slag are not permitted on or within 3 mm (0.125 in) of sealing surfaces.
- h) NDE shall be carried out after final PWHT.

6.5.1 Weld NDE - Surface Examination (Other than Visual)

Weld NDE surface examination requirements shall meet the following:

- a) 100% of primary load carrying and pressure-containing repair welds, weld metal overlay welds, and repaired fabrication welds shall be examined by either MP or LP methods after completion of final welding, PWHT and machining operations;
- b) The examination shall include 13 mm (0.5 in) of adjacent base material on both sides of the weld;
- c) The test method and acceptance criteria for Surface NDE shall be in conformance with API 16F

6.5.2 Repair Welds

Repair weld requirements shall meet the following:

- a) Repair welds shall be examined using the same methods and acceptance criteria used in examining the base metal;
- b) The examination shall include 13 mm (0.5 in) of adjacent base material on both sides of the weld;
- c) Surfaces of ground-out areas for repair welds shall be examined prior to welding to ensure defect removal using the acceptance criteria for fabrication welds.
- d) Wrought tubular products shall not be repair welded.

6.5.3 Weld NDE — Volumetric Examination of Weld

6.5.3.1 Sampling

Sampling requirements shall meet the following:

- a) 100% of full-penetration pressure-containing welds and full-penetration welds in the primary load path shall be examined by either radiography or ultrasonic after completion of welding, PWHT, and machining operations.
- b) Repair welds for which the repair is greater than 25 % of the original wall thickness or 25.4 mm (1 inch) (whichever is less) shall be examined by either radiography, ultrasonic or acoustic emission methods after completion of welding and PWHT;
- c) Examinations shall include at least 12.7 mm (0.5 in) of adjacent base metal on all sides of the weld;

6.5.3.2 Radiography Examination

Radiography examination requirements shall meet the following:

- a) Radiographic examinations shall be performed in accordance with ASTM E94, to a minimum equivalent sensitivity of 2% and a 2-2T quality level;
- b) Both X ray and gamma ray radiation sources are acceptable within the inherent thickness range limitation of each source;
- c) Real-time imaging and recording/enhancement methods may be used when the manufacturer or remanufacturer has documented proof that the methods will result in a minimum equivalent sensitivity of 2% and a 2-2T quality level;
- d) Wire-type image quality indicators are acceptable for use in accordance with ASTM E747.

6.5.3.3 Radiography Examination Acceptance Criteria

The following criteria shall not be accepted through radiographic examination:

- a) cracks, zones of incomplete fusion, or zones of incomplete penetration;
- b) any elongated slag inclusion that has a length equal to or greater than specified in Table 2;
- c) any group of slag inclusions in a line having an aggregate length greater than the weld thickness, t , in any total weld length $12t$, except when the distance between successive inclusions exceeds six times the length of the longest inclusion;
- d) any rounded indications in excess of that specified in ASME Boiler and Pressure Vessel Code, Section VIII, Division 1;

Table 2: Weld Inclusion Criteria

Weld thickness t		Inclusion length	
mm	(in)	mm	(in)
< 19	< 0.76	6.4	0.25
$19 \leq t \leq 57$	$0.76 \leq t \leq 2.25$	$0.33 t$	$0.33 t$
> 57	> 2.25	19.0	0.75

6.5.3.4 Ultrasonic Examination

Ultrasonic examinations shall be performed in accordance with procedures specified in ASME Boiler and Pressure Vessel Code, Section V, Article 4.

6.5.3.5 Ultrasonic Examination Acceptance Criteria

Ultrasonic examination acceptance criteria shall be per API Specification 16F.

6.5.3.6 Weld NDE – Hardness Testing

Weld NDE hardness testing requirements shall meet the following:

- a) Accessible pressure-containing welds, primary-load path welds, and major repair welds (including structural welds) shall be hardness tested.
- b) At least one hardness test shall be performed in both the weld and in the adjacent unaffected base metal after completion of heat treatment and machining operations.
- c) The hardness recorded in the procedure qualification record (PQR) shall be the basis for acceptance if the weld is not accessible for hardness testing.
- d) Hardness testing shall be performed in accordance with one of the following:
 - 1) ASTM E18, ASTM E110 (Rockwell) or ISO 6506-1;
 - 2) ASTM E10, ASTM E110 (Brinell) or ISO 6508-1;
- e) The value of the hardness test shall be stamped on the part adjacent to the test location as per 6.3.4. It is permissible for hardness marking to be covered by other components after assembly.

6.5.3.7 Hardness Examination Acceptance Criteria

Hardness values shall meet the requirements of the OPD/CPD.

6.6 Non-Metallic Parts

Inspection of Non-metallic parts shall be in conformance with API 16F.

6.7 Other End Connector

Other end connector shall conform to API 16F. The OEM or CEM product definition requirements shall be met.

6.8 Assembled Equipment

Assembled equipment shall meet the requirements as specified in the Product Specific Sections (Sections 13, 14, and 15).

- a) The quality control requirements shall include pressure tests and hydraulic operating system tests, for each assembled equipment unit in conformance with 13.4. Alternatively, each component in the assembly subject to pressure may be tested individually.;
- b) Serialization shall be recorded on assembled equipment and shall be carried out in accordance with the OEM/CEM written specification;
- c) A report shall be prepared in which all serialized and individual-heat-traceable parts are listed as traceable to the assembly (e.g., assembly part number, serial number);
- d) The hydrostatic proof or shell test pressure shall be determined by the rated working pressure for the equipment and be in conformance with 13.4.

6.9 Quality Control Records

6.9.1 General

The quality control records required by this standard are those documents and records used to substantiate that materials and equipment have been made to this Standard.

6.9.2 NACE Records Requirements

Records required to demonstrate conformance of equipment to NACE MR0175 / ISO 15156 shall be in addition to those described in other clauses of this standard, unless the records required by this standard also satisfy the NACE MR0175 / ISO 15156 requirements.

6.9.3 Records Control

The organization shall maintain a documented procedure to define the controls and responsibilities needed for the initiation, identification, collection, storage, protection, retrieval, retention time, and disposition of records.

Records, including those from outsourced activities, shall be established and controlled to provide evidence of conformity to requirements and of the effective operation of the QMS, per existing internationally recognized quality management standard (API Q1 or ISO 9001).

Records shall be retained for a minimum of 10 years following the date the equipment was received by the service provider, or as required by customer, legal, and other applicable requirement, whichever is longer.

Records required by this standard shall be signed and dated.

Records shall be legible, identifiable, retrievable, and protected from damage, deterioration, or loss.

Records can be hard copies and/or computer-stored as defined in the organization records control system procedure.

6.9.4 Records Maintained by Remanufacturer

6.9.4.1 General

The remanufacturer shall retain documents and records as required in clause 7.2.

In addition, the remanufacturer shall provide PHF records in conformance with Annex B to their equipment owner in either electronic format, hard copy, or both, as specified in the purchase order by the equipment owner.

6.9.4.2 Parts or Components Covered in API 16F

The following records shall be retained for parts or components covered in API 16F:

- a) PQR;
- b) welder performance qualification record;
- c) welding equipment records:
 - 1) calibration tests;
 - 2) certification documentation;
- d) MTRs:
 - 1) chemical analysis;
 - 2) tensile tests qualification test coupon (QTC);
 - 3) impact tests (QTC, as required);
 - 4) hardness tests (QTC);
- e) NDE personnel qualification records;
- f) NDE records:
 - 1) visual/optical NDE records;
 - 2) surface NDE records;
 - 3) full penetration fabrication;
 - 4) weld volumetric NDE records;
 - 5) repair weld NDE records;
- g) Hardness test records;
- h) Welding process records (Weld Map):
 - 1) welder identification;

- 2) welding procedure specification (WPS);
 - 3) filler material heat/lot number;
 - 4) weld location
 - 5) PWHTs and dehydrogenation heat treatments (DHT);
- i) Heat treatment records:
- 1) actual temperature;
 - 2) actual times at temperature;
- j) Hydrostatic pressure test records;
- k) volumetric NDE records;
- l) test records for testing as required by individual equipment sections;
- m) critical dimensions and critical areas as defined by the remanufacturer in the OPD/CPD as applicable.

7 Quality Management System Requirements

7.1 General

The organization shall establish, document, implement, and maintain a QMS, per an existing internationally recognized quality management standard (e.g. API Q1 or ISO 9001). The organization shall continually improve the effectiveness of the QMS through the use of the quality policy, quality objectives, audit results, analysis of data, corrective and preventive actions, and management review.

7.2 Control of Documents

The QMS documentation shall include:

- a) Statements of quality policy and quality objectives;
- b) A quality manual that addresses each requirement of this standard and includes:
 - 1) the scope of the QMS, including justification for exclusions to specific QMS elements;
 - 2) a description of the sequence and interaction between the processes of the QMS;
 - 3) identification of processes that require validation;
 - 4) reference to documented procedures that control the QMS processes;
 - 5) documented procedures established for the QMS;

- 6) documents and records to ensure the effective planning, operation, and control of its processes and compliance with specified requirements;
- 7) a documented procedure for the identification, distribution, and control of documents required by the QMS, including required documents of an origin external to the organization;
- 8) a method for control of procedures, work instructions and forms required by the QMS;
- 9) a documented procedure for inspection and testing to verify that product requirements have been met.

7.3 Training and Awareness

The organization shall:

- a) Provide QMS training to the organization's personnel and contractors who affect the execution of services or provision of service-related products;
- b) Ensure that customer-specified training and/or customer-provided training, if required, is included in the training program;
- c) Maintain personnel records on education, training, skills, experience, and other competencies needed for the function;
- d) Define responsibilities, authorities, and accountabilities of personnel throughout the organization;

7.4 Control of Testing, Measuring, Monitoring Equipment

The remanufacturer shall maintain a documented procedure which defines the required testing, measurement, monitoring, and detection equipment to be controlled and necessary to provide evidence that service or service-related product meets specified requirements.

The procedure shall address equipment traceability, frequency of calibration, calibration method, acceptance criteria, suitable environmental conditions, storage, and handling.

The procedure shall identify required assessments and maintain records when the validity of the previous testing, measuring, monitoring, or detection results are found not to conform to calibration requirements. The organization shall take action on the equipment and service affected.

Testing, measuring, monitoring and detection equipment shall have unique identification.

When the equipment is externally provided, the organization shall verify that the equipment is suitable to provide evidence of conformity of service or service-related product to specified requirements.

7.5 Contract Review

7.5.1 General

The organization shall maintain a documented procedure for the review of contract requirements related to the execution of services or provision of service-related products.

7.5.2 Determination of Requirements

The organization shall determine:

- a) Requirements specified by the customer, including the requirements for service planning, execution, and evaluation;
- b) Requirements not stated by the customer but considered necessary by the organization or industry recognized standards for the execution of service and provision of service-related product;
- c) Documentation requirements pertaining to the certificate of conformance, MDB, PHF, and any other required traceable documents.

Where the customer has provided incomplete, incorrect, or unachievable requirements in the purchase order, the customer shall be informed, and a resolution shall be documented on the purchase order.

7.6 Purchase Control

The organization shall maintain a documented procedure and qualification of outsourced services to ensure that purchased or outsourced services and service-related products conform to specified requirements.

A list of approved suppliers and their approved scope shall be documented and maintained.

Selection of outsourced service suppliers by the remanufacturer shall include the following prior to initiation of the purchase agreement:

- a) Assessment of the supplier at supplier's facility to meet the organization's purchasing requirements; and
- b) Verification that the supplier's QMS conforms to the quality system requirements specified for suppliers by the organization.

7.7 Design and Development

7.7.1 Design and Development Planning

The remanufacturer shall maintain a documented procedure to plan and control the design and development of the product.

The procedure shall identify:

- a) the design and development stages;
- b) the activities required for completion, review, and verification of each stage;
- c) the interfaces between different groups involved in design and development; and
- d) the responsibilities and authorities for the design and development activities.

The remanufacturer shall manage the interfaces between different groups involved in design and development to ensure effective communication and clear assignment of responsibilities.

When design and development are outsourced, the remanufacturer shall ensure the supplier meets the requirements of 7.7.

7.7.2 Design Documentation

Design documentation shall include the methods, assumptions, formulas, and calculations.

7.7.3 Design and Development Inputs

Inputs relating to design of the product shall be determined and records maintained.

These inputs shall include:

- a) customer-specified requirements;
- b) environmental and operational conditions;
- c) methodology, assumptions, and formula documentation;
- d) historical performance and other information derived from previous similar designs;
 - 1) requirements provided from an external source;
 - 2) requirements for products and service-related products, including its functional and technical requirements.

7.7.4 Design Verification

The design and development requirements are to be examined and confirmed to be in conformance with specified requirements of the purchase order and API 16F edition the equipment was manufactured to, or at least to the API 16F 1st edition.

To ensure that the design outputs have satisfied the design input requirements, design verification and a final review shall be conducted and documented as identified within the organization's procedure.

Records of design verification, any necessary actions, and the final review shall be maintained.

7.7.5 Design Validation

Design and development validation shall be performed in accordance with planned arrangements to ensure that the resulting product is capable of meeting the requirements for the specified application or intended use, where known.

Validation shall be completed prior to the delivery or implementation of the product.

The completed design shall be approved after validation. Competent individual(s) other than the person or persons who developed the design shall approve the final design.

Records of the results of validation and necessary actions shall be maintained.

Parts that do not have existing validation records within an assembly covered under the CPD shall require the API 16F validation testing that loads the part in conformance with the design verification calculations.

7.7.6 Control of Design and Development Changes

Design and development changes shall be identified, and records maintained by the remanufacturer. The changes shall be reviewed, verified, validated, and approved before implementation. The review of design and development changes shall include evaluation of the effect of the changes on constituent parts and product already delivered. Records of the results of the review of changes and any necessary actions shall be maintained.

7.8 Control of Nonconforming Product

7.8.1 General

The organization shall ensure that product which does not conform to product requirements is identified and controlled to prevent its unintended use or delivery. A documented procedure shall be established to define the controls and related responsibilities and authorities for dealing with nonconforming product.

When nonconforming product is corrected, it shall be subject to inspection to demonstrate conformity to the requirements.

Nonconformances dispositioned as acceptable shall be approved by a competent person that has the education, training, skills, and experience needed to make the verifications.

Records of inspection and conformance with acceptance criteria shall be maintained.

7.8.2 Field Nonconformity Analysis

The documented procedure for nonconforming product shall include requirements for identifying, documenting and reporting incidents of field nonconformities, identified after delivery, or product failures. The documented procedure shall ensure the analysis of field nonconformities, provided the product or documented evidence supporting the nonconformity is available to facilitate the determination of the cause. The documented procedure shall ensure that action is taken to the effects or potential effects of the non-conformance.

7.9 Field Reporting

7.9.1 The organization performing the repair and remanufacturing shall take on the internal responsibilities of the remanufacturer for failure reporting in conformance to this section.

7.9.2 When the organization performing the repair and remanufacturing is responsible for the CPD, they shall take on the external responsibilities for the failure reporting in conformance to this section.

8 Materials

8.1 General

Section 8 is only applicable to primary-load-carrying and pressure-containing components as defined in API 16F.

Repaired/remanufactured parts shall satisfy the OPD or CPD design requirements for the product repaired and /or remanufactured under this standard.

Metallic materials designed for sour conditions shall meet the design requirements of NACE MR0175 / ISO 15156 as required by the edition of API16F to which the product was manufactured (or later).

8.2 Material Traceability Level

The traceability of the material shall be designated by a MaTL. In the event traceability is lost, this document provides requirements and guidance needed to obtain the proper documentation for meeting the necessary MaTL.

8.3 Metallic Parts

A written material specification shall be required for all metallic repair parts, or metallic parts added during remanufacturing to a component or an assembly.

The remanufacturer shall meet or exceed the material specifications for the product as listed in the OPD or CPD. The OPD or CPD shall contain the following information:

- a) acceptance and/or rejection criteria;
- b) material composition with tolerance;
- c) material qualification;
- d) allowable melting practice(s);
- e) forming practice(s);
- f) heat treatment procedure, including cycle time and temperature with tolerances, heat treating equipment and cooling media;
- g) NDE requirements;
- h) Mechanical property requirements.

NOTE For existing parts remanufactured to MaTL-1 or MaTL-2, it is recognized some of this information may not be available.

8.4 Metallic Material Traceability

8.4.1 General

To start the remanufacturing process, material composition and mechanical properties for the base material should be identified or determined. This may result in different traceability levels. The reasons for current MaTL designation shall be documented by the repairer or remanufacturer and be included as part of any CoC per Appendix D,

When a component has different traceability levels, the lowest MaTL-of the component shall be used to describe it.

When a assembly has components with different traceability levels, the lowest MaTL-of the components shall be used to describe the assembly.

NOTE The minimum required MaTL for a component or assembly is typically set forth by the equipment owner before the beginning of repair or remanufacture.

When a weldment has components with different MaTL levels, the lowest MaTL level of the weldment component shall be used to describe the weldment.

8.4.2 Materials Traceability Levels

The materials traceability levels shall be as listed below:

MaTL-1: For components when traceability has been lost, the component shall be designated as MaTL-1.

MaTL-2: For components when traceability has been lost; however, all properties required in Section 8.5 for MaTL-2 have been re-established, the component shall be designated as MaTL-2.

MaTL-3: For components when traceability has full documentation or properties required by API 16F have been fully established by testing, the component shall be designated as MaTL-3.

8.5 Reestablishing Material Traceability

When material traceability is lost, the following subsections shall be used to re-establish traceability.

8.5.1 Reestablishing Tensile Properties

When tensile properties of a component are unknown, but there is enough traceability to support that other components have been made with the same heat of material, and heat treatment, a component may be used as a sacrificial part to be tensile tested through the critical cross-section in order to obtain and verify the tensile properties of a component. Ensure this sacrificial part meets the properties and all minimum design requirements of the OEM/CEM written material specification. Tensile properties reestablished in this fashion are grounds to maintain the tensile requirements for MaTL-3.

Alternatively; if a sacrificial part cannot be used, an MaTL-2 for the component may be obtained via hardness testing. The ultimate tensile strength (UTS) of non-austenitic steels (including ferritic and martensitic stainless) may be reestablished by hardness testing as described herein, and the approximation to tensile strength shall be in accordance with ASTM A370. If the material specification the component was originally manufactured to is available, and the specification establishes a hardness range intended for the tensile properties such as yield and tensile strength, and the hardness of the component is within that range, then the yield strength based shall be considered to be the same as the minimum on the specification, regardless of approximated actual UTS.

To reestablish the tensile properties via hardness testing for MaTL-2 of other materials not described in the previous paragraph, the hardness test shall be as specified here in, however, the original material specification to which the part was produced, and which describes minimum tensile properties and gives a hardness range is required to be available. In this case, if the material hardness is within hardness range, then the yield and tensile strength shall be considered as the minimum on the material specification.

Hardness testing shall be performed in accordance with ASTM E10, ASTM E110, ISO 6506-1, ASTM E18, or ISO 6508-1.

When hardness conversion is needed, it shall be done in accordance with ASTM E140.

An MaTL-2 for a component may be obtained by testing a QTC of the same alloy composition and similar heat treatment. The QTC shall be heat treated to be within +/- 2 HRC of the actual component's hardness. The size of the QTC and specimen location and orientation shall be in accordance with latest requirements of API 16F. The acceptance criteria shall be established by using the minimum requirements of the original design. If the original design is not available, then new requirements may be established by stress calculations or FEA.

8.5.2 Reestablishing Chemical Composition

When a component has full traceability to an MTR with chemical composition or to a Mill Certificate, the component shall be identified as meeting composition requirements for MaTL-3.

In the absence of traceability to chemical composition. To obtain MaTL-3 for the component, composition shall be reestablished to the original material specification and original design requirements (Such as NACE MR0175) via testing by Optical Emission Spectroscopy (OES).

NOTE Since this is a product analysis, permissible variations may be established in accordance with industry standards such as ASTM A788.

When composition is unknown, and the original material specification requirements are unknown, an MaTL-2 may be obtained by performing positive material identification (PMI), provided the component will not undergo any welding processes as described in section 9.

MaTL-2 of components to be welded shall be established by product check analysis. The analysis shall be performed by OES for carbon and low alloy steels, and PMI is acceptable for other materials provided PMI is capable of properly identifying the alloy for use in combination with weld procedure specification. The chemical composition of the alloys shall meet applicable design requirements such as limits in NACE MR0175.

The chemical composition obtained by OES for carbon and low alloy steels shall include all alloying elements, carbon, and all elements needed to determine carbon equivalency (CE) per the following formula.

$$CE = C\% + Mn\%/6 + (Cr\%+Mo\%+V\%)/5 + (Ni\%+Cu\%)/15$$

8.5.3 Reestablishing Impact Values

When impact properties are required by the edition of API16F (to which the product was manufactured or later) for a particular component, and there is traceability to the MTR, then the component shall be identified as meeting the impact properties of MaTL-3.

When impact properties of a component are unknown, but there is enough traceability to support that other components have been made with the same heat of material, and heat treatment, a component may be used as a sacrificial part to be impact tested through the critical cross-section in order to obtain and verify the impact properties of a component. Ensure this sacrificial part meets API 16F (as described in section 8.1) and all minimum design requirements. Impact properties reestablished in this fashion are grounds to maintain the impact requirements for MaTL-3.

Impact testing, or traceability to impact values for austenitic stainless steel is not required; thus, for components made with these materials MaTL-3 shall be maintained regardless of available documentation.

NOTE "MaTL-2 cannot be established if impact testing is required but the test documentation is not available. This will result in a MaTL-1. Reestablishing the properties per this section or replacing the component can achieve an MaTL-3."

8.5.4 Reestablishing Hardness Values

If hardness testing was required by API 16F in conformance with design output at the time the component was produced, hardness values shall be reestablished in accordance with ASTM E10, ASTM E110, ISO 6506-1, ASTM E18, or ISO 6508-1."The acceptance criteria shall be as required by the OPD. If design parameters are unknown, calculations or FEA may be used to propose a new hardness range for the component. Hardness values established this way shall be identified as meeting the hardness requirements for MaTL-3.

If a component has undergone a surface heat treatment process, or a hard-facing overlay process which does not allow for hardness testing of the unaffected base metal, then the component shall be identified as meeting MaTL-1 unless the base metal properties can be verified in the documentation.

8.5.5 Reestablishing Product Form (Cast vs. Wrought)

When the product is not known to be a casting or a wrought, and this is part of the acceptance criteria or necessary to establish proper welding procedures, the material shall be metallographically inspected to determine whether it has a wrought structure or a cast structure. The metallography may be performed at a lab or in-situ depending on accessibility of the component. Wrought products shall be free from dendritic structures on the base metal.

NOTE If a component is known to have been previously welded or weld repaired, it is important to perform metallography on more than one location to avoid confusing the cast structure from a weld with the base metal structure.

If product form is in conformance with API 16F and the original design specifications shall be considered to be MaTL-3. If product form is in compliance with API 16F but not in compliance with the original design requirements shall be considered to be MaTL-2, provided no welding is required, or product form is not essential to establishing adequate weld procedures.

8.6 Tubular Components

8.6.1 Base Metal Repair of Tubular Components

Weld repair of wrought tubular components shall be prohibited. The repair of tubular components shall be performed by replacing the damaged area with a new section of material which meets or exceeds the original design requirements, and the joining of the component's new section shall be performed with an appropriate and qualified weld procedure specification as described in Section 9.

8.7 Non-Metallic Components

Non-metallic component shall conform to API 16F.

9 GENERAL WELDING REQUIREMENTS

9.1 Primary-load-carrying and Pressure-containing Weldments

9.1.1 Codes and standards

All welding procedures, welders and welding operators shall be qualified in accordance with ASME BPVC, Section IX or other recognized industry standards when approved by the purchaser. NACE MR0175/ISO 15156 requirements shall be applicable to weldments and weld procedure qualifications intended for sour service environment. All welding procedures shall be qualified to meet the design requirements. Additional welding requirements or codes and standard may apply as agreed upon by the purchaser and the remanufacturer. Other sections of this standard may have additional requirements based on the CPD and/or CEM.

Weld procedure qualification and welding practices should be supplemented with requirements necessary for the prevention of hydrogen delayed cracking of welds for alloys with high hardenability e.g., low alloy steels.

9.1.2 Mechanical property requirements/PWHT time

When PWHT is required, test coupons which include weld material shall be post-weld heat treated with the nominal temperature at minimum and maximum cumulative time at temperature to be used in production. Mechanical property and other testing required by this specification, governing welding code, and design requirements shall be completed at minimum and maximum PWHT times allowed by WPS.

NOTE Maximum PWHT time allowed may be up to 25% additional time from what is recorded on the PQR as permitted by ASME BPVC Section IX.

9.1.3 Butter Welds

Butter welds, as defined in ASME BPVC, Section IX, shall be approved by CEM. Butter weld joints and joining welds shall require procedure qualification records (PQRs) for the buttering weld process and for the joining weld process. A welding procedure specification (WPS) shall be required for the entire completed weldment joint.

9.1.4 CVN impact toughness

When design requirements specify impact testing, the WPS shall be qualified with impact testing at or below the minimum temperature specified. Notch toughness shall be taken in the weld metal (WM) heat-affected zone (HAZ), and base metal (BM). In case of WPSs with no PWHT, BM impact testing is not required. For procedure qualification tests joining dissimilar materials, HAZ and BM shall be tested for both base metals.

9.2 Structural Welding Procedure and Welder Performance

Structural weld procedures and welder/operator performance shall be qualified in accordance with AWS D1.1, ASME BPVC Section IX, or other recognized industry structural welding specification.

Welding procedures shall be qualified to meet the design requirements. When impact and/or hardness testing is required by design, the specimens shall be taken from the welded coupon in accordance with the requirements of section **Error! Reference source not found.**

9.3 Noncritical Welding

Welding of noncritical components shall be in accordance with manufacturer's written procedures/specifications or manufacturer-approved written procedures/specifications. Noncritical welding shall not be allowed on the following: sour service applications, pressure-containing, hoisting equipment, primary-load carrying members, and/or lifting devices.

9.4 Documentation

The WPSs, PQRs and supporting data, viz., weld test history, base metal MTRs, consumable certificates, PWHT charts and lab test reports etc., shall be maintained as records in accordance with the quality control record requirements from section 6.5.

9.5 Consumable storage and handling

The remanufacturer shall have a written procedure for storage, handling, and control of welding consumables. Materials of low-hydrogen type shall be stored and used as recommended by the consumable manufacturer to retain their original low-hydrogen properties. Any reconditioning of fluxes and SMAW electrodes shall be carried out in accordance with the manufacturer's recommended practice.

9.6 Preheating

Preheating of assemblies or parts, when required, shall be performed in accordance with the remanufacturer written procedures (e.g. requirements for ensuring suitable/capable preheat/interpass temperature control that includes heating methods, distance-set-off, for torch heating, neutral flame, etc.).

9.7 Dehydrogenation Heat Treatment (DHT)

Any heat treatment performed prior to final PWHT, such as DHT or intermediate stress relief (ISR), shall be included as part of the welding procedure qualification if performed within 175 °F (79 °C) of the nominal final PWHT temperature. Remanufacturer shall have written procedures for DHT.

When welds (excluding overlay) made on low alloy steels with the SMAW, SAW, or FCAW processes are allowed to cool below the minimum preheat temperature, prior to PWHT, they shall be subjected to a DHT immediately after completion of welding. The weldment shall be held between 450 °F (232 °C) and, 700 °F (370 °C) for 2 hours minimum prior to slow cooling under insulation or in still air.

DHT is not required provided the electrode/flux used is classified by the filler metal manufacturer with a diffusible-hydrogen designator of H4 (e.g., E7018-H4).

9.8 Post-Weld Heat Treatment (PWHT)

9.8.1 PWHT procedure and documentation

PWHT shall be in accordance with the manufacturer's/remanufacturer's written procedures. The written procedures approved by the remanufacturer shall include:

- a) Method of temperature control (including ramp rates) and control of cooling rate to ambient temperature. The procedure shall include control methodology for fans, winds, or other environmental conditions that can affect the cooling rate.

- b) Location of controlling and monitoring thermocouples. A sketch shall be included in the routing or traveler to depict the location of the part thermocouples.
- c) Identification of part loading supporting equipment (racks or baskets) and a sketch showing the location of parts in the furnace's qualified heating zone.
- d) Area to receive the source of heating for local heat treatments, the type and amount of insulation and the methods to control the heating gradient outside of the local heating area.
- e) Method and control of ISRs performed as an intermediate heat treat to allow further processing of the part prior to the final PWHT, such as a Larsen-Miller Parameter (LMP), in order to estimate the effect of ISR on the material when performing an ISR.
- f) All PWHT cycles shall be recorded on a furnace chart or digital file.

9.8.2 Furnace PWHT

Furnace PWHT shall be performed using heat-treating equipment qualified to API 16A.

9.8.3 Local PWHT

Local PWHT shall be carried out in accordance to a written procedure consisting of heating a band around the weld at a temperature within the range specified in the qualified WPS. The minimum width of the controlled band adjacent to the weld, on the face of the greatest weld width, shall be the thickness of the weld or 2 in. (50 mm), whichever is less. Gas heated infrared heaters may be used. Open flame PWHT is not permitted.

A sketch of local PWHT heater size and location, and location of the thermocouples shall be provided in the PHF.

WPS's and/or additional associated procedures shall specify the following if PWHT or ISR is required:

- a) A procedure for attaching thermocouples to the weldment.
- b) Holding temperature range.
- c) Holding time.
- d) Heating method.
- e) Insulation.
- f) Temperature control devices.
- g) Recording equipment.
- h) Maximum heating rate.
- i) Maximum cooling rate.
- j) Temperature gradients.

9.8.4 PWHT temperature limits

PWHT temperatures shall not exceed the manufacturer's stated minimum specified tempering temperature. WPS PWHT median temperature shall be at least 14 °C (25 °F) below the minimum specified or actual tempering temperature of the raw forging.

9.9 Repair Welds

9.9.1 Scope of repair welding

Welding shall be considered as a repair if performed after PWHT, or if no PWHT is required, after final NDE of the weldment. In-process weld repair prior to PWHT (if applicable) is not considered weld repair.

Repair of base metal/base metal buildup by welding shall be considered a weld repair.

9.9.2 Riser Main Tube

Wrought tubular products shall not have base metal weld repair/buildup performed.

9.9.3 Repair welding documentation

All repair welds to pressure-containing members, where failure would result in release of wellbore fluid to the environment, and to primary-load-carrying members shall be mapped. At minimum, this map shall include the details required by Section **Error! Reference source not found.**, plus the following:

- a) Part Sketch denoting new weld/repair Area
- b) Number PWHT hours per weld used for this remanufacturing cycle, if applicable
- c) Accumulation of all PWHT hours per weld, if applicable
- d) Number PWHT hours for base material, if applicable

9.9.4 PWHT of Weld Repairs

The original WPS(s) shall have sufficient PWHT time qualified for the total cumulative time at temperature, including the additional PWHT time applied after repair welding. The PWHT temperature of the weld repair shall not exceed the PWHT temperature range of original WPS(s).

When WPS previously used for existing welds has insufficient PWHT time qualified for the repair to be performed, new PQR(s) is required to qualify previously used WPS(s) for enough cumulative time to permit a repair. The new PQR/WPS may be a standalone document and from a different company than previously used WPS if all essential variables of previously used WPS are identical with additional PWHT time at temperature.

Alternatively, all weld metal and HAZs (at least 1/8 inch additional material from weld toe) shall be removed prior to weld repair provided there is documented PQR or simulated PWHT evidence that base metal properties will meet minimum mechanical property requirements. This assessment of base metal properties shall account for all cumulative time at temperature the component has been subject to prior to the current repair.

For welds originally processed with local PWHT, the previous PWHT history does not need to be evaluated if the weld metal, HAZ, and base metal subjected to local PWHT are removed prior to weld repair. Manufacturer shall determine the amount of base metal subjected to local PWHT and requiring removal

10 Marking Requirements

10.1 General

Equipment that is repaired or remanufactured shall be marked. The repair or remanufacture marking requirements are in addition to and shall not replace original marking requirements of API 16F.

Location of marking for metallic equipment which is repaired or remanufactured shall be in accordance with API 16F.

The following marking shall be added to the equipment:

- a) "RMFR" for remanufacture or "RPR" for repair;
- b) remanufacturer's name or mark;
- c) date of repair or remanufacture (month and year) e.g. March 2016 is coded as 0316.

Repaired parts do not require "RPR" marking.

Original markings lost before remanufacturing, shall be reestablished by markings that provide a level of traceability that has been verified by the remanufacturer.

Product changes as result of repair or remanufacture that reduce original API 16F ratings shall be noted on the repair / remanufacturing name plate and the original name plate shall be removed.

10.2 Metallic Components Marking

Required marking on metallic components shall be performed by using dot, vibration, round "V" stamping, cast, or laser engraving.

10.3 Specific Codification Requirements of Equipment

In addition, the remanufacturer's part number shall be marked on the component.

11 Storing and Shipping

Equipment shall be stored and shipped in accordance with API 16F.

12 Certification

12.1 General

Certificate records shall be added to the equipment PHF to support the traceability of the product through equipment life.

NOTE Certificates are product status reports on the conformance to specifications at time of issue and do not infer duration of validity.

12.2 Certificate of Conformance

On completion of the repair or remanufacturing of marine drilling riser equipment under this standard, a COC shall be issued unless otherwise specified by the equipment owner. For equipment or components that does not fully conform to this document, 16FR shall not be stated on the COC.

If repairs completed only include replacement of parts that have their own COC, the only COC's required for conformance of the assembly / system are the COC's of the replacement components. In this case, the replaced parts shall be in conformance with the CPD.

Minimum requirements for the COC shall be used to certify repairs and remanufacturing under this standard. The minimum requirements for the COC are listed in Annex C.

12.3 Statement of Fact

Inspections and repairs performed on a part or system made in accordance with the reduced / limited scope defined by the owner shall be documented by a statement of fact (SOF).

SOF's issued under this standard shall follow the requirement of Annex D.

NOTE This record does not fulfil the requirements of a COC or other documents verifying product design.

12.4 Certificate of Service

On completion of marine drilling riser equipment inspections, testing and/or repair performed in conformance with this standard under the limitations of the defined workscope, a COS shall be issued.

COS's issued under this standard shall follow the requirements of Annex E.

NOTE The COS confirms the equipment is Fit For Service (FFS).

13 Choke, Kill, and Auxiliary Lines

13.1 General

This section provides requirements specific for repair and remanufacture of Choke, Kill and Auxiliary lines.

13.2 Performing repair and remanufacturing

13.2.1 Skim cutting

Tolerances after skim cutting shall conform to the CPD.

The corrosion resistant thickness remaining after finish machining operation shall be verified to be in conformance with the minimum thickness requirements. The minimum thickness requirements shall be specified by the CEM.

Note: Suitable corrosion resistance requires sufficient thickness.

13.2.2 Remanufacture by Welding

Welding shall be performed in accordance with Section 9, General Welding Requirements.

13.2.2.1 Boost Lines and Choke and Kill Lines

Remanufacture by welding of pins and boxes shall be performed per a qualified weld procedure per Section 9.

Remanufacture by welding of corrosion-resistant overlay (CRO) shall meet the requirements of Section 9. The CRO shall be repaired either with PWHT or shall be welded with a WPS qualified for repair with no PWHT. For build up using CRO, the WPS shall be qualified to meet the design criteria.

Remanufacture by welding of hard-facing overlay shall meet the requirements of Section 9.

Remanufacture of thermal spray and fused components (such as riser pins) may be performed by removing the thermal spray and replacing with qualified overlay welding procedure. Remanufacture by reapplication of thermal spraying and fusion shall be prohibited.

Remanufacture by welding of tubular components shall not be permitted. To repair damaged tube, a pup piece shall be used. Length shall be made up by adding a pup piece, the length between the two weld joints shall be as defined by written OEM specification, or at a minimum of 3 ODs long.

When remanufacturing by welding the joint between pin and tube, or box and tube, if pin/box remains welded to the tube; weld metal repairs shall be performed in accordance with the requirements of Section 9. If pin/box is removed, the weld metal and corresponding HAZs shall be removed. The PWHT cumulative soak time shall not exceed the maximum qualified for the WPS(s) including base metal under the local PWHT soak band. After removing the HAZ, the length shall be made up by using one of the methods described below:

- a) Replacing the original pin/box with a modified pin/box having an integral extension in the area to be welded (e.g. longer weld neck).
- b) Addition of a pup piece to the tubular component shall have a length between the two weld joints as defined by written OEM specification, or a minimum of 3 ODs long.

13.2.2.2 Hydraulic Lines

Welding shall be in accordance with the requirements of the general welding section (Section 9). Additional requirements and exceptions are specified herein.

Weld procedure qualification of Austenitic stainless steel components shall be exempt from impact testing requirements.

Weld procedure qualification of ferritic-austenitic stainless steels shall be inspected for ferrite content by ASTM E562 point count method. The microstructure of weld HAZs and ferritic-austenitic weld metal (when ferritic-austenitic weld metal is used) shall have between 30 % and 70 % ferrite.

Remanufacture by welding of hydraulic pins or hydraulic boxes shall be performed with a qualified weld procedure per Section 9.

Backing/purging gas should be used to prevent weld related oxide scales and heat tint.

Remanufacture by welding of Ferritic-Austenitic hydraulic tubular components shall not be permitted, remanufacture by welding in accordance with requirements of Section 9 is permitted for 300 series stainless steel. In order to repair damaged tube, a pup piece shall be used. Length between the two weld joints shall be as defined by written OEM specification, or at least 3 ODs long. If a weld joint needs to be cut out, the corresponding HAZ shall also be removed as defined in Section 9.

When remanufacturing by welding the joint between pin and tube, or box and tube, if pin/box remains welded to the tube; weld metal repairs shall be performed in accordance with the requirements of Section 9. If pin/box is removed, the weld metal and corresponding HAZs shall be removed. After removing the HAZ, length shall be made up by one of the described methods:

- a) Replacing the original pin/box with a modified pin/box having an integral extension in the area to be welded (e.g. longer weld neck).
- b) Addition of a pup piece to the tubular component shall include adding a pup piece, the length between the two weld joints shall be as defined by written OEM specification, or a minimum of 3 ODs long.

13.2.3 Hydraulic Line Straightening

Stainless steel hydraulic tube may be remanufactured by straightening, and the work shall be carried out in accordance with a written procedure.

The following shall be strictly prohibited:

- a) Straightening Ferritic-Austenitic Stainless Steels with the use of external heat sources.
- b) Stress relieving after straightening of Ferritic-Austenitic Stainless Steels by use of external heat sources.
- c) Straightening of sections with creases, gouges or where bending is directly on a weld or its associated HAZ.

13.3 Factory Acceptance Testing

13.3.1 Hydrostatic Testing

13.3.1.1 General

Repaired equipment shall be subjected to a leak test of 1.0 times rated working pressure.

NOTE If only buffing or honing is performed, and the tolerances remain within OPD/CPD specified wear limits and quality control requirements; this is not considered a repair.

Remanufactured equipment shall be subjected to a hydrostatic test of 1.5 times rated working pressure.

Replacement pins and boxes not welded into the line assembly (e.g. threaded) shall be hydrostatic tested to 1.5 times rated working pressure, unless documentation of previous hydrostatic testing of the replacement part exists.

Replacement pins or boxes not welded into the line assembly, and which has already been hydrotested to 1.5 times rated working pressure, the assembled line shall be hydrotested to 1.0 times rated working pressure.

13.3.1.2 Low Pressure Test

Pressure of 1.4 MPa to 2.1 MPa (200 psi to 300 psi) shall be applied and held for not less than 10 minutes after stabilization. This test shall be performed before any higher pressure has been applied.

The results of this test shall be documented.

NOTE It is not necessary to bleed this pressure off before preceding to the high pressure test described below.

13.3.1.3 High Pressure Test

Pressure as defined by 13.4.1.1 shall be applied for not less than 10 minutes after stabilization.

The allowable test pressure tolerance above test pressure shall be no more than 5% of test pressure or 3.45 MPa (+500 psi), whichever is less.

The results of this test shall be documented.

14 Riser Joints

14.1 General

Riser Joint main tube and coupling shall be classified as load-sharing or non-load-sharing.

Choke, kill and auxiliary lines shall be repaired and remanufactured per Section 13.

Buoyancy equipment shall be repaired and remanufactured per Section 15.

Equipment shall be reassembled in accordance with documented specifications of the remanufacturer.

14.2 Repair and Remanufacture

14.2.1 Remanufacture by Welding

Welding shall be in accordance with the requirements of the general welding section (Section 9 of this document). Additional requirements and exceptions are specified herein.

14.2.1.1 Riser Coupling

Remanufacture by welding of Corrosion resistant overlay (CRO) shall meet the requirements of general welding section (Section 9 of this document). The CRO procedure may include PWHT or may be welded without PWHT if the weld and its associated HAZ are outside the base material. For build up using CRO, the WPS shall be qualified to meet the design criteria.

Base metal repair sealing areas may be performed by weld buildup in accordance with qualified weld procedures that meet Section 9.

14.2.1.2 Riser Pipe

To repair base metal damage, a pup piece shall be used. The pup piece shall meet base material requirements of the design per API 16F. The weld metal and corresponding HAZs shall be removed. The PWHT cumulative soak time shall not exceed the maximum qualified for the WPS(s) including base metal under the local PWHT soak band. After removing the HAZ, the length shall be made up by using one of the methods described as follows:

- a) When adding a pup piece, the length between the two weld joints shall be as defined by written OEM specification, or at least 3 ODs in length.
- b) If the pup piece is seamed pipe/tubular, then the pup piece seams shall not be aligned with the original riser pipe seams. The minimum angle between longitudinal seam welds shall be 45 degrees.

14.2.1.3 Repair of Coupling to Pipe Joints

When coupling remains welded to the pipe; weld metal repairs shall be performed in accordance with the requirements of the general welding section (Section 9).

When coupling is removed, the weld metal and corresponding HAZs shall be removed. The PWHT cumulative soak time shall not exceed the maximum qualified for the WPS(s) including base metal under the local PWHT soak band. After removing the HAZ, the length shall be made up by using one of the methods described as follows:

- a) Replacing the original coupling with a modified coupling having an integral extension in the area to be welded (e.g. longer weld neck).
- b) Addition of pup piece to a tubular component. When adding a pup piece, the length between the two weld joints shall be as defined by written OEM specification, or at minimum of 3 ODs long. If the pup piece is seamed pipe/tubular, then the pup piece seams shall not be aligned with the seams of the original pipe/tubular component. The minimum misalignment angle between longitudinal seam welds shall be 45 degrees.

14.2.1.4 Dressing of Weld cap and Root

Grinding/Dressing shall as minimum satisfy the OPD or CPD design requirements for the product.

14.3 Inspection – Post-remanufacturing

14.3.1 Final Assembly Inspection

Gap setting for external lines shall be verified in according with OPD/CPD.

Distance from the riser connector face to the end of the external lines (external line pin stick out) shall be verified to an OPD/CPD procedure.

Inspection procedure shall be in accordance with OEM/CEM procedures.

14.3.2 Drift Test

Drift testing of the riser shall not be required unless specified by the equipment owner.

15 Buoyancy Equipment

15.1 General

"Repair and remanufacturing activities performed on riser buoyancy equipment shall conform to the requirements of this standard."

15.2 Inspection – Pre-repair

Buoyancy modules shall be completely dry on the exterior prior to pre-repair inspection or measurements and prior to repair activities. Inspection shall document the following:

- a) Module Serial Number
- b) Inspected while installed or while removed
- c) Location of inspection (rig, yard, OEM, etc.)
- d) Module pre-repair weight
- e) Repair Category

15.3 Classification of Repair

15.3.1 Category 1 – Cosmetic Repair

A Category 1 buoyancy module repair is defined by damage to the exterior skin, with no damage to the underlying buoyant material.

Materials for Category 1 Repair:

- a) Skin system - The repair skin system shall be one or more layers of suitable formable fabric which restores the outer impact protection of the underlying buoyant material.
- b) Laminating Resin - The laminating resin system shall saturate the skin system fabric and adhere to the

underlying buoyant material so as to minimize the risk of delamination post repair in accordance with qualification requirements in Section 15.4

- c) Paint - Damage to identification marking shall be repaired to show original identification details. Depth break identification coloring shall be restored to original manufacturing specifications.

15.3.2 Category 2 – Medium Sized Repair

A Category 2 buoyancy module repair is defined by damage to the exterior skin, and underlying buoyancy material with a damage depth of no more than 10mm and a surface area no more than 0.10m².

Materials for Category 2 Repair:

- a) Repair materials typically included in a Category 2 module repair are as per Category 1 with the following additions.
- b) Filler Material - Buoyant repair filler material shall bond to the underlying buoyancy material in accordance with qualification requirements in Section 15.4.

15.3.3 Category 3 – Large Sized Repair

A Category 3 buoyancy module repair is defined by damage to the exterior skin, and underlying buoyancy material of a larger volume than a Category 2, without damage to the structural integrity of the buoyancy module. Category 3 repairs typically require the inclusion of hollow spherical fillers in the repair material matrix.

Materials for Category 3 Repair:

- a) Repair materials typically included in a Category 3 module repair are as per Category 2 with the following additions.
- b) Hollow Spherical Fillers - Hollow spherical fillers shall have a hydrostatic rating suitable for the intended depth in accordance with Section 15.4.

15.3.4 Category 4 – Large Module Crack Repair

A Category 4 buoyancy module repair is defined by damage to the exterior skin, with damage to the structural integrity of the buoyancy module. This may include the reattachment of separated pieces no larger than a running length of 500mm. Category 4 repairs typically requires the inclusion of structural support members in the repair material matrix or parent material.

Materials for Category 4 Repair:

- a) Repair materials typically included in a Category 4 module repair are as per Category 3 with the following additions.
- b) Structural support members - Structural support members shall allow for tensile and shear load transfer between the parent material and the members in accordance with Section 15.4.
- c) Bonding Agent - The bonding agent shall provide the bond between the parent material and the structural members for facilitating load transfer between the two components and maintaining a shear and tensile strength in accordance to Section 15.4.

15.3.5 Category 5 – Module Cracked in Half Repair

A Category 5 buoyancy module repair is defined by damage to the exterior skin, and underlying buoyancy material and such that the buoyancy is in multiple large pieces greater than the discrete piece size defined in Category 4.

Materials for Category Repair:

Repair materials typically included in a Category 5 module repair are as per Category 4.

15.4 Composite Repair Material Structure Qualification

15.4.1 General

The combination of the materials used for the given category of repair shall be confirmed to meet the requirements of sections 15.4.1.1 through 15.4.4. The repair facility shall perform tests or produce records of prior tests that confirm the repair material is qualified for rated service depth.

A minimum of two composite repair material matrix samples for each test (crush strength and buoyancy loss) shall be tested. The material test samples shall not have been subjected to prior pressure testing.

Repair facilities shall refer to 16F for hydrostatic test procedures and for composite repair material structure qualification .

In instances where repair materials cannot be imported or sourced in a region where the repair is taking place, any substitute local materials shall meet all the prequalified material property requirements. Material property equivalence shall be demonstrated through material data sheets. Data sheets for the originally qualified material and for the substitute material shall be provided to the equipment owner in the final documentation of the repair.

15.4.1.1 Repair Material Test Samples

Repair material tests samples shall be constructed of all components to be included in the final repair. Composite material test samples shall have a minimum dimension at least 5 times the dimension of the largest macrosphere included in the repair.

Repair material test samples for buoyancy loss shall be at a minimum, large enough to accurately measure buoyancy loss at service depth. Material testing shall meet the relevant sections in API 16F for testing requirement.

If no macrospheres are included in the repair material the test sample size for hydrostatic crush testing shall be, at a minimum, 25 cubic centimeters.

15.4.1.2 Repair Material Adhesion Test Samples

15.4.1.2.1 Test Sample inclusive of bonding agent:

The adhesion test sample shall be comprised of 2 discrete parts of OEM buoyancy material rated to the maximum depth for which the repair is being qualified and a bonding agent. The 2 parts shall be adhesively bonded together. The test sample shall be of appropriate geometry and size to allow for qualification of the bonding agent between the two parts as identified in 15.4.3.

If structural support members are to be included in the repair than qualification test samples shall include support members.

15.4.1.2.2 Test sample exclusive of bonding agent:

The adhesion test sample shall be comprised of 2 parts: one parent material blank which has been fabricated from an OEM buoyancy material, rated to the maximum depth for which the repair is being qualified, and one composite repair material molded to the parent blank without additional bonding agent. The test sample shall be of appropriate geometry and size to allow for qualification of the adhesion between the two parts as identified in 15.4.3.

If structural support members are to be included in the repair than qualification test samples shall include support members.

If no OEM buoyancy material is available, a parent material blank may be fabricated comprised of a compatible composite syntactic foam material. Compatibility between OEM buoyancy material and parent material blanks for qualification testing shall be proven.

Note: A qualification program on a material matrix coupon for Category 5 will qualify the constituent lower category systems.

15.4.2 Water Absorption

Acceptance criteria shall be based on the results of a 24-hour test with the last 20 hours of data extrapolated over a 12-month period.

The total buoyancy loss of the repair material shall not exceed.

- a) 4% for composite buoyancy repair material rated to a depth of 6000ft or shallower,
- b) 5% for composite buoyancy repair material rated to a depth greater than 6000ft.

Qualification testing of repair material shall follow the procedure given in API 16F for the buoyancy modules. The test pressure shall correspond to the maximum service depth rating of the repair material. The test duration shall be 24 hours.

Acceptance criteria shall be based on the results of the 24-hour tests with the last 20 hours of data extrapolated over a 12-month period.

Compression of material at service depth shall not cause more than 1.50% loss of net volume.

15.4.3 Material Bonding

Acceptance criteria shall be based on the results of a 1-hour continuous test at the service depth.

Adhesion between the OEM parent material blank and the added OEM material or composite repair material shall be maintained after completion of the hydrostatic test. No significant cracking, separation, or deformation between the bonding interface shall be accepted.

Following a passing hydrostatic test at service depth, a flexural test shall be performed on the repair material adhesion test sample with the bending load centered at the location of the bond. The test shall be executed till test sample failure.

If failure of the test sample occurs in the parent OEM material, then the bond test shall be deemed adequate.

If failure of the test sample occurs at the bonding location, the failure load value shall be included in final qualification documentation.

15.4.4 Hydrostatic Crush Pressure

Crush strength shall be at least 1.25 times the hydrostatic pressure at service depth.

15.4.5 Flammability Rating

The repair material shall meet the following requirements from UL94 for material classed HBF (horizontal burning foamed) as per API 16F.

15.5 Inspection – Post-repair

15.5.1 Dimensional Inspection

The surface finish of the repair shall be inspected and shown to be free of significant defects that would affect the overall general shape and critical dimensions discussed below.

Overall general shape of the repaired module shall conform to original alignment. Repaired modules shall conform to OEM specified critical dimension tolerances. If no OEM specified critical dimension tolerances are available, the repaired module critical dimensions shall be compared to an equivalent module that has not been repaired. The critical dimensions to verify are as follows:

- a) choke, kill, and auxiliary line recesses and alignment
- b) mux line recesses
- c) flex Pads
- d) module OD
- e) length
- f) strap recesses (if present)
- g) bolting locations, through hole and reinforced area (if present)
- h) additional geometric features (such as auxiliary fairing equipment grooves or VIV suppression designs, if present)

Discrepancies between these dimensions shall be reported.

15.5.2 Weight and Uplift Calculation

The remanufacturer or repair facility shall provide the uplift for the repaired module.

Where OEM original module data is available net lift for a module shall be calculated using the measured weight of the module post repair, the water weight of the attachment hardware, the original module volume at approximately atmospheric pressure, and the density of seawater with a specific gravity of 1.025. The repair facility shall document the details of the calculation method and data used for the net lift calculations.

If original manufacturer issued module documentation is unavailable (original module volume) an uplift test in fresh water and at ambient pressure shall be performed on the module.

The repaired uplift and deviation for the original lift can be calculated from the formula below assuming the volume of the repaired part remains the same.

Repaired Uplift = Original Mass from MDR + Original Uplift from MDR – Repaired Mass

Deviation from Original Uplift = Original Uplift/Repaired Uplift x 100%

Example of using the formula is shown below.

Example

Original Mass of Buoyancy Element = 1046 kg (from Databook)

Original Uplift of Buoyancy Element = 1615 kg (from Databook)

Repaired Buoyancy element Mass = 1110 kg (measured)

Repaired Uplift of Element = 1046+1615-1110 = 1551kg

Deviation from Original Uplift = 1551/1615 x 100% = 96%

Original Mass of Buoyancy Element = 2306 lb (from Databook)

Original Uplift of Buoyancy Element = 3561 lb (from Databook)

Repaired Buoyancy element Mass = 2447 lb (measured)

Repaired Uplift of Element = 2306+3561-2447 = 3420lb

Deviation from Original Uplift = 3420/3561 x 100% = 96

15.6 Documentation – Post-repair

An inspection data sheet, containing the following information as a minimum, shall be prepared for each repaired module.

- a) Level of repair
- b) Original module weight from original documentation (if available)
- c) Original module volume from original documentation (if available)
- d) Original module uplift from original documentation (if available)
- e) Serial number and date of repair.
- f) Service depth rating.

- g) Measured dry weight before repair.
- h) Measured dry weight post repair
- i) Post repair calculated submerged weight in seawater (SG= 1.025)
- j) Critical dimensions listed in Section 15.5.1

In addition to the above module specific information the repair material qualification data and material data sheets if required shall be provided to the equipment owner.

Results and documentation for testing if performed on buoyancy equipment post-repair or post-remanufacture shall be provided to the equipment owner.

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Annex A (Normative)

Manufacturing Data Book Requirements

The identified document contents for the construction of the MDB shall be provided and recorded in order to provide the minimum traceability requirements for remanufacturing of marine drilling riser equipment.

Manufacturing Data Book (MDB)

<u>Document Contents</u>	<u>Delivered to equipment owner</u>	<u>Maintained by Manufacturer</u>
Date of manufacturing / assembly	√	√
Purchase order number/sales order number	√	√
Date of Factory Acceptance Testing (FAT)	√	√
Part and Serial Numbers of equipment and location (including elastomers)	√	√
Assembly drawings	√	√
Manufacturer's Certificate of Conformance (COC)– include listing of the specifications to which equipment is certified.	√	√
Design Verification Documentation		√
3 rd Party Review Certificate	As Required on Purchase Order	√
3 rd Party Approval Certificate	As Required on Purchase Order	√
Material Test Records (including the following):		
a) Chemical Analysis	√	√
b) Tensile tests	√	√
c) Impact tests	√	√
d) Hardness tests	√	√
e) NDE Reports	√	√
f) Heat Treatment	√	√

Manufacturing Data Book (MDB) continued.

<u>Document Contents</u>	<u>Delivered to equipment owner</u>	<u>Maintained by Manufacturer</u>
Material Specification Number	√	√
WPS/PQR 3 rd party customer Review Records	As required on purchase order	√
NDE Records:		
a) Surface NDE Records	√	√
b) Volumetric NDE	√	√
c) Repair Weld NDE records	√	√
d) Final Hardness records	√	√
Inspector Qualification Records	As required on purchase order	√
Welding Process Records:		
a) Welder ID	√	√
b) Filler Metal classification, Heat and/or batch number	√	√
c) Flux type and lot number	√	√
d) WPS number(s)	√	√
e) PWHT charts	√	√
f) Total remaining PWHT time per weld	√	√
g) Weld map	√	√
h) Weld inspection records	√	√
i) Sketch of local PWHT heater size location and thermocouples location.	√	√
Welder Qualification Records	As required on purchase order	√
Test Report(s), Pressure Testing and Final Acceptance Testing		
a) Hydrostatic Pressure test records	√	√
b) Final Acceptance Testing reports	√	√
Dimensions (as defined by OEM / CEM)		√.
Critical Areas (as defined by OEM / CEM)		√
Documentation required as defined in API 16F is retained by the OEM / CEM for required retention period.		√

Annex B (Normative)

Product History File Requirements

This annex provides the minimum requirements for the Product History File for equipment covered by the scope of API Standard 16FR.

Traceability shall be provided by the remanufacturer in the PHF for the parts repaired, remanufactured, or replaced. The product history file shall include the following information at a minimum:

Product History File (PHF) Repair Only

<u>Document Contents</u>	<u>Delivered to equipment owner</u>	<u>Maintained by Remanufacturer</u>
Manufacturing Data Book	For replacement parts or assemblies	√
Part and Serial Numbers of equipment and location (including elastomers as applicable)	√	√
Design Verification Report	Available for review at the OEM or CEM	√
Third Party or Class Society Inspection Reports	√	√
Test Report(s), Pressure Testing and Final Acceptance Testing		
a) Volumetric NDE Records / radiographic UT Records	√	√
b) Hydrostatic pressure test records	√ Limited scope and pressure test only	√
c) Critical dimensions and critical areas (as defined by OEM or CEM)	√ Limited scope and basic dimensions only (height, weight, etc....)	√
Final Acceptance Testing reports	√	√
COC	√	√
a) Includes the standard to which equipment is certified.	Conformance to Annex C.	
Serial Numbers of equipment and location	√	√
Parts traceability records	√	√

Product History File (PHF) Repair and Remanufacturing

<u>Document Contents</u>	<u>Delivered to equipment owner</u>	<u>Maintained by Remanufacturer</u>
PMI Test	√	√
Material Specification Number	√	√
Welding Process Records (if applicable)		
Weld Data Sheet which includes: <ul style="list-style-type: none"> • Welder ID • Filler Metal • Welding consumable records • Heat and/or batch number • WPS # • Weld map • Weld inspection records • PWHT records • Sketch of local PWHT heater size location and thermocouples location. 	√	√
Documentation as defined in API 16FR retained by the OEM / CEM for required length of time		√
NDE Records	√	√
Hardness records	√	√
Heat Treatment Records (if applicable)	√	√
Bolting traceability records as per API 16F	√	√
COS a) includes the standard to which equipment is certified to	√	√
SOF which includes: <ul style="list-style-type: none"> • Description of the work done • Pressure tests records • Disassembly records • Origin & serial numbers of parts replaced 	√	√
COS which includes: <ul style="list-style-type: none"> • Description of the work done • Pressure tests records • Disassembly records • Origin and serial numbers of parts replaced. 	√	√

Annex C (Normative)

Minimum Requirements for Certificate of Conformance

C.1 General

This annex provides the minimum requirements for the COC for equipment covered by the scope of API Standard 16FR. An example COC is included at the end of this annex. Format changes are allowed.

C.2 Certificate Requirements

C.2.1 Company Information

The COC shall contain the following API Standard 16 FR service provider information:

- a) — Company name;
- b) — Company address;
- c) — Company telephone number;

C.2.2 Certification Authentication

The API Standard 16 FR service provider shall provide a unique certificate number for each certificate issued.

C.2.3 Certificate Issue Date

The COC shall contain the date when it is issued.

C.2.4 Customer Information

The COC shall contain the name of the customer and the relevant purchase order Number.

C.2.5 Assurance

The certificate shall contain a statement that confirms that all listed equipment has been repaired or remanufactured in conformance with this standard.

The certificate shall contain a statement or list that confirms which API 16F revision has been used on the respective part or assembly.

The certificate shall identify the owner of the product definition (OEM or CEM) that has been used for the repair or remanufacture.

C.2.6 Ratings

The ratings on the certificate shall include but are not limited to:

- a) — rated working pressure;
- b) — rated temperature of metallic components;
- c) — design temperature of nonmetallic components;
- d) — environmental limits, in accordance with NACE MR0 175/ISO 15156, based on the rated working pressure and maximum temperature rating of metallic components.
- e) Tension rating
 - 1) Indicate if the assembly is load-sharing or non-load-sharing

NOTE: Riser running and retrieval load ratings can differ from riser tension rating during operation.

C.2.7 List of Equipment

The certificate shall list the equipment being certified. The list shall contain, at a minimum:

- a) Part number of assembly or component with revision number;
- b) Quantity: The quantity of each assembly or component;
- c) Description: a description of the component or assembly;
- d) A unique number traceable to an item through a serial or batch number;
- e) MaTL designation of the component or assembly;
- f) API 16F revision used to define material requirements for the assembly or component.

C.2.8 Reasons for current MaTL designation

The certificate shall contain a statement or list that confirms the MaTL of the component and reason for the MaTL designation.

C.2.9 Company Endorsement

The certificate shall be endorsed by a company's authorized representative, including, at minimum, the name, signature, title, and date of the signature.

Example

Company Logo

Company Name
Company Address
Company Telephone Number

QR Code or
Bar Code

CERTIFICATE OF CONFORMANCE

Certificate No. :

Customer :

Customer Reference No.:

Date of Remanufacture:

Customer Purchase Order:

Work Order No.:

A. Assurance:

This certificate confirms that the marine drilling riser equipment remanufactured per the above purchase order and as listed below have been repaired and/or remanufactured in conformance with:

- API Standard 16FR, Standard for Repair and Remanufacturing of Marine Drilling Riser Equipment, First Edition.

B. Additional Endorsements:

In addition, the following additional standard(s) have been used in support of the repair and remanufacture of the equipment listed on this certificate:

- API Specification 16F, "Specification for Marine Drilling Riser Equipment," 2nd Edition

C. The certification is related to the following ratings:

Rated Working Pressure:	
Rated Temperature of metallic components:	
Design temperature of nonmetallic components:	
Environmental limits, in conformance with NACE MR0 175/ISO 15156, based on the rated working pressure and maximum temperature rating of metallic components.	
Material traceability level (MaTL):	
Other limitation:	

D. List of inspected equipment:

Item	Assembly or Part No.	Qty.	Description	Serial Number(s)	MaTL No.	PR No.	API spec & rev no.
1							
2							
3							

E. Reasons for current MaTL determination:

Item	Assembly or Part No.	Description	Serial Number(s)	MaTL No.	Reason for MaTL Determination
1					
2					
3					

Signature

Signature

Name:
Title:

Name:
Title:

Company disclaimer or Quality disclaimer (if needed).

Annex D (Normative)

Minimum Requirements for Statement of Fact

D.1 General

This annex provides the minimum requirements for the SOF for equipment covered by the scope of API Standard 16FR. Format changes are allowed.

D.2 Statement Requirements

D.2.1 Company Information

The SOF shall contain the following API Standard 16 FR service provider information:

- a) Company name;
- b) Company address;
- c) Company telephone number;

D.2.2 Statement Issue Date

The Statement Of Fact shall contain the date when it is issued.

D.2.3 Customer Information

The SOF shall contain the name of the customer and the relevant purchase order Number.

D.2.4 Assurance

The SOF shall indicate that the equipment service provision is in conformance with the agreed upon scope by service provider and owner.

D.2.5 Work Performed

The SOF shall accurately describe what inspection, repair and testing activities were performed on the equipment as well as the results of those activities.

D.2.6 List of Equipment

The SOF shall list the equipment being serviced. The list shall contain, at a minimum:

- a) Part number of assembly or component with revision number;
- b) Quantity: The quantity of each assembly or part number;
- c) Description: a description of the part or assembly;
- d) A number traceable to an item such as a serial or batch number if originally provided;

D.2.7 Company Endorsement

The SOF shall be endorsed by a company's authorized representative, including, at minimum, the name, signature, title, and date of the signature.

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Annex E (Normative)

Minimum Requirements for Certificate of Service

E.1 General

This annex provides the minimum requirements for the COS for equipment covered by the scope of API Standard 16FR. Format changes are allowed.

E.2 Certificate Requirements

E.2.1 Company Information

The COS shall contain the following API Standard 16 FR service provider information:

- a) Company name;
- b) Company address;
- c) Company telephone number;

E.2.2 Certification Authentication

The API Standard 16 FR service provider shall provide a unique certificate number for each certificate issued.

E.2.3 Certificate Issue Date

The COS shall contain the date when it is issued.

E.2.4 Customer Information

The COS shall contain the name of the customer and the relevant purchase order Number.

E.2.5 Assurance

The COS shall contain a statement that confirms that all listed equipment has been repaired/remanufactured in conformance with the requirements of the defined workscope from the OEM or CEM.

NOTE The defined workscope does not need to include all requirements of API 16FR.

The COS shall list the company procedure(s) number(s) and revision(s) used for the service provision.

The COS shall state that the defined workscope assures that the listed equipment on the certificate is fit for service (FFS).

The FFS declaration can recommend a next inspection date.

E.2.6 Ratings

The rating on the certificate shall include but are not limited to:

- a) rated working pressure;
- b) rated temperature of metallic components;
- c) design temperature of nonmetallic components;
- d) environmental limits, in conformance with NACE MR0 175/ISO 15156, based on the rated working pressure and maximum temperature rating of metallic components.
- e) Tension rating
 - o Indicate if the assembly is load-sharing or non-load-sharing

NOTE Riser running and retrieval load ratings can differ from riser tension rating during operation.

E2.7 Work Performed

The certificate shall summarize what inspection, repair, remanufactured and testing activities were performed on the equipment.

E.2.8 List of Equipment

The certificate shall list the equipment being certified. The list shall contain, at a minimum:

- a) Part number of assembly or component with revision number;
- b) Quantity: The quantity of each assembly or part number;
- c) Description: a description of the part or assembly;
- d) A number traceable to an item such as a serial or batch number if originally provided;

E.2.9 Company Endorsement

The certificate shall be endorsed by a company's authorized representative, including, at minimum, the name, signature, title, and date of the signature.

Bibliography

- [1] API Bulletin 6AF, Capabilities of API flanges under combinations of load
- [2] API Specification Q2: Specification for Quality Management System Requirements for Service Supply Organizations for the Petroleum, Petrochemical and Natural Gas Industry
- [3] ASME Boiler and Pressure Vessel Code Section VIII, Division 2, Pressure Vessel — Alternate Rules, Appendix 4, Design Based on Stress Analysis
- [4] ASME Boiler and Pressure Vessel Code Section VIII, Division 2, Pressure Vessel — Alternate Rules, Appendix 6, Experimental Stress Analysis
- [5] ASTM A193, Specification for Alloy Steel and Stainless Steel Bolting Materials for High Temperature Service
- [6] ASTM A320, Specification for Alloy Steel Bolting Materials for Low Temperature Service
- [7] ASTM A453, Specification for Bolting Materials, High Temperature, 50 to 120 ksi Yield Strength, with Expansion Coefficients Comparable to Austenitic Steels
- [8] ASTM E747, Standard Practice for Design, Manufacture, and Material Grouping Classification of Wire Image
- [9] ASTM D1418, *Standard Practice for Rubber and Rubber Lattices — Nomenclature*
- [10] ISO 13665, *Seamless and welded steel tubes for pressure purposes — Magnetic particle inspection of the tube body for the detection of surface imperfection*