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Reballot Draft #6217

Standard for Repair and Remanufacture of Drill-through Equipment

API STANDARD 16AR
SECOND EDITION, XXX 2024

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Standard for Repair and Remanufacture of Drill-through Equipment

1 Scope

This standard specifies requirements for repair and remanufacture of drill-through equipment built under API 16A.

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

This standard is applicable to and establishes requirements for the repair and remanufacture of the following specific equipment:

- a) ram blowout preventers (BOPs);
- b) ram blocks, operators, packers, and top seals;
- c) annular BOPs;
- d) annular packing units;
- e) hydraulic connectors;
- f) drilling spools;
- g) adapters;
- h) loose connections;
- i) clamps;
- j) other end connections (OECs).

Dimensional interchangeability is limited to end and outlet connections. Simplified examples of surface and subsea equipment defined by this standard are shown in Figure 1 and Figure 2.

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

This standard defines various repair/remanufacture specification levels (RSLs) for the equipment identified below as well as the mandatory equipment traceability that is required to prove conformance.

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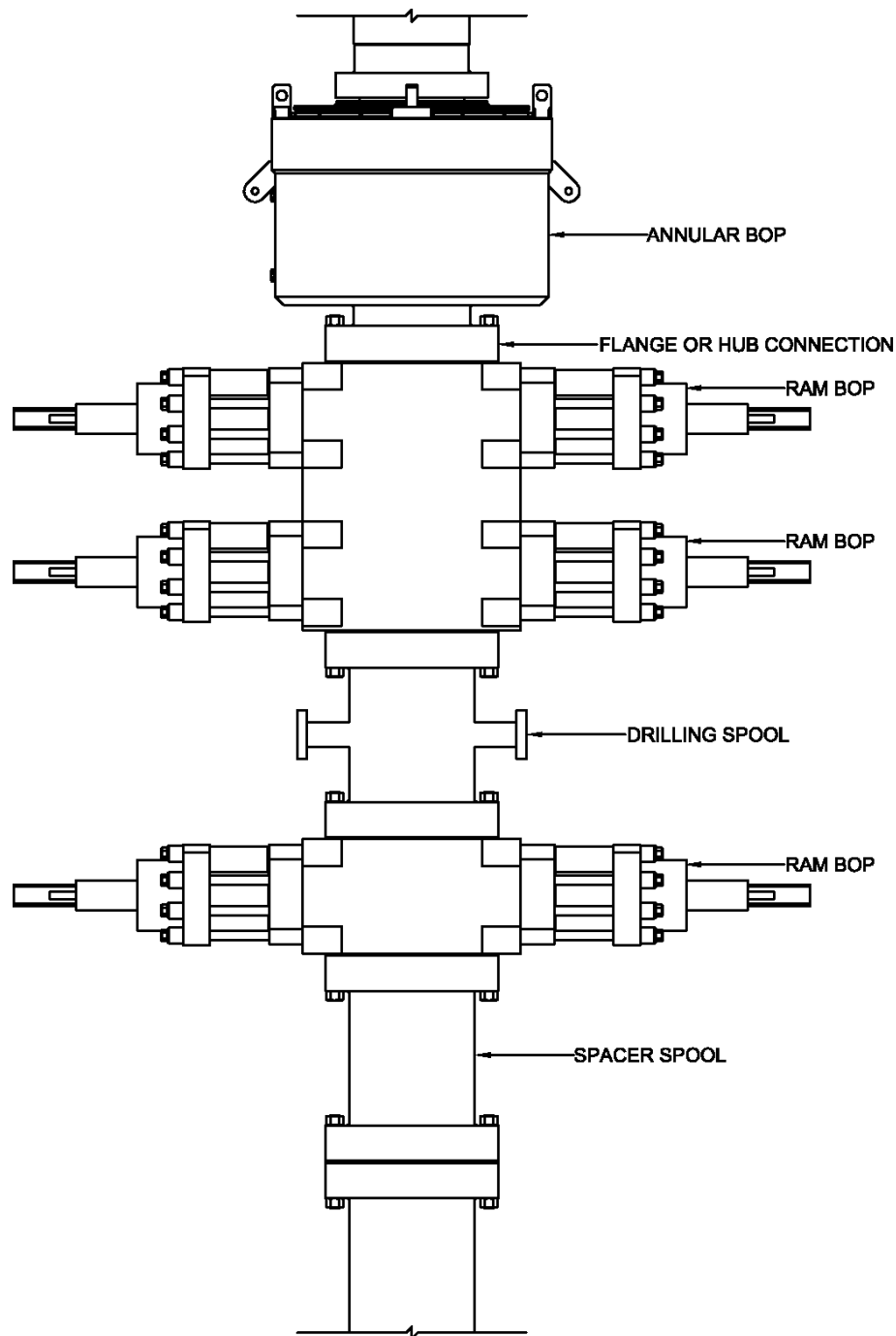


Figure 1—Simplified Example of Surface Drill-through Equipment

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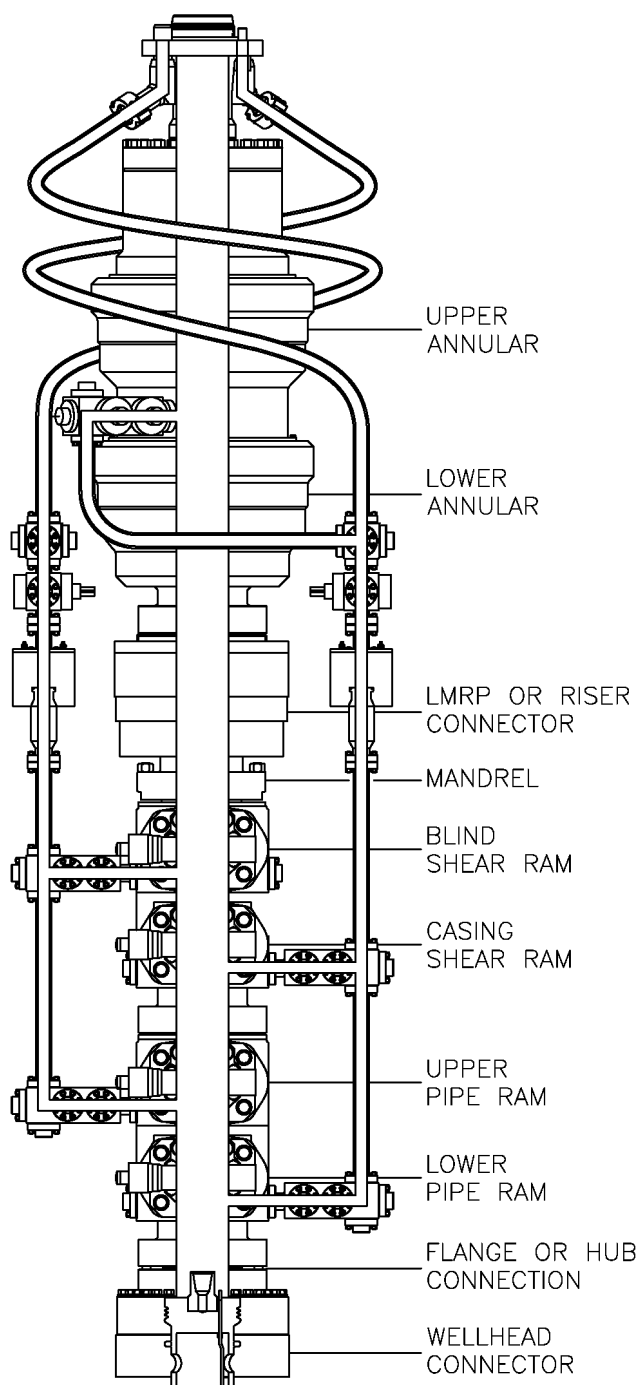


Figure 2—Simplified Example of Subsea Drill-through Equipment

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2 Normative References

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 5DP, *Specification for Drill Pipe*

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

API Specification 16A, *Specification for Drill-through Equipment*¹

API Specification Q1, *Specification for Quality Management System Requirements for Manufacturing Organizations for the Petroleum and Natural Gas Industry*

ANSI²/ASME B31.1³, *Power Piping*

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

ASME *Boiler and Pressure Vessel Code* (BPVC), Section V: *Nondestructive Examination*; Article: 5 *Ultrasonic Examination Methods for Materials*

ASME *Boiler and Pressure Vessel Code* (BPVC), Section VIII: *Rules for Construction of Pressure Vessels*; Division 1

ASME *Boiler and Pressure Vessel Code* (BPVC), Section VIII: *Rules for Construction of Pressure Vessels*; Division 1; Appendix 4: *Rounded Indication Charts Acceptance Standard for Radiographically Determined Rounded Indications in Welds*

ASME *Boiler and Pressure Vessel Code* (BPVC), Section IX: *Welding, Brazing, and Fusing Qualifications*; Article I: *Welding General Requirements*

ASME *Boiler and Pressure Vessel Code* (BPVC), Section IX: *Welding, Brazing, and Fusing Qualifications*; Article II: *Welding Procedure Qualifications*

ASME *Boiler and Pressure Vessel Code* (BPVC), Section IX: *Welding, Brazing, and Fusing Qualifications*; Article III: *Welding Performance Qualifications*

ASME *Boiler and Pressure Vessel Code* (BPVC), Section IX: *Welding, Brazing, and Fusing Qualifications*; Article IV: *Welding Data*

ASME *Boiler and Pressure Vessel Code* (BPVC), Section IX: *Welding, Brazing, and Fusing Qualifications*; QW-403.26

ASNT-SNT-TC-1A⁴, *Personnel Qualification and Certification in Nondestructive Testing*

¹ A previous edition of API 16A be used as referenced in specific sections of this standard..

² American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.

³ ASME International, 2 Park Avenue, New York, New York 10016-5990, www.asme.org.

⁴ American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, www.asnt.org.

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ASTM A370 ⁵, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A388/A388M, *Standard Practice for Ultrasonic Examination of Steel Forgings*

ASTM A967/A967M, *Standard Specification for Chemical Passivation Treatments of Stainless Steel Parts*

ASTM D395, *Standard Test Methods for Rubber Property—Compression Set*

ASTM D412, *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension*

ASTM D471, *Standard Test Method for Rubber Property—Effect of Liquids*

ASTM D1414, *Standard Test Methods for Rubber O-Rings*

ASTM D1415, *Standard Test Method for Rubber Property—International Hardness*

ASTM D2240, *Test Method for Rubber Property—Durometer Hardness*

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 Examination*

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

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

ASTM E165/E165M, *Standard Practice for Liquid Penetrant Examination for General Industry*

ASTM E384, *Standard Test Method for Microindentation Hardness of Materials*

ASTM E428, *Standard Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing*

ASTM E569/E569M, *Standard Practice for Acoustic Emission Monitoring of Structures During Controlled Stimulation*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

AWS A4.2M ⁶, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*

AWS QC1, *Standard for AWS Certification of Welding Inspectors*

⁵ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

⁶ American Welding Society, 8669 NW 36 Street, #130, Miami, Florida 33166-6672, www.aws.org.

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CSWIP-WI-6-92 ⁷, *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 the requirements of BS EN ISO 17637:2011*

ISO 6506-1 ⁸, *Metallic materials—Brinell hardness test—Part 1: Test method*

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

ISO 6508 (all parts), *Metallic materials—Hardness test—Rockwell test (scales A-B-C-D-E-F-G-H-K)*

ISO 6892, *Metallic materials—Tensile testing at ambient temperature*

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

ISO 18265, *Metallic materials—Conversion of hardness values*

NACE MR0175 ⁹/ISO 15156 (all parts), *Petroleum, petrochemical, and natural gas industries—Materials for use in H₂S-containing environments in oil and gas production*

SAE AMS 2750E ¹⁰, *Pyrometry*

SAE AMS-H-6875B, *Heat Treatment of Steel Raw Materials*

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

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

3.1.1

acceptance criteria

Defined limits placed on characteristics of materials, equipment, processes, or service.

3.1.2

adapter

Pressure-containing piece of equipment having end connections of different nominal size and/or pressure ratings, used to connect other pieces of equipment of different nominal sizes and/or pressure ratings.

3.1.3

annular blowout preventer annular BOP

Blowout preventer that uses an annular shaped elastomeric sealing element to seal the space between the tubular and the wellbore or an open hole.

⁷ TWI Certification Ltd., Granta Park, Great Abington, Cambridge CB21 6AL, United Kingdom, www.cswip.com.

⁸ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211 Geneva 20, Switzerland, www.iso.org.

⁹ NACE International, 15835 Park Ten Place, Houston, Texas 77084, www.nace.org.

¹⁰ SAE International (formerly the Society of Automotive Engineers), 400 Commonwealth Drive, Warrendale, Pennsylvania 15096-0001, www.sae.org.

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3.1.4

blowout preventer

BOP

Equipment installed at the wellhead to contain wellbore pressure either in the annular space between the casing and the tubulars or in an open hole during drilling, completion, testing, or workover operations.

3.1.5

body

A portion of equipment including end connections, with or without internal parts, designed to contain wellbore pressure.

3.1.6

bolting

Threaded fasteners, tap-end studs, double-ended studs, headed bolts, cap screws, screws, and nuts.

3.1.7

calibration

Comparison to a standard of known accuracy and making any needed adjustment(s).

3.1.8

casting (noun)

Object at or near finished shape obtained by solidification of a molten metal in a mold.

3.1.9

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.

3.1.10

certificate of service

COS

Document in which the equipment manufacturer, remanufacturer or technical authority, certifies that the equipment has been inspected, repaired and 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.

3.1.11

fit for service

FFS

Equipment that has the integrity to operate and function within the boundaries of its OPD or CPD ratings through a technical evaluation.

3.1.12

chemical analysis

Determination of the chemical composition of material.

3.1.13

clamp (noun)

Device with internal angled shoulders used to fasten mating sealing hubs.

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3.1.14

closure bolting

Bolting used to assemble or join wellbore pressure-containing parts including end and outlet connections.

NOTE Examples of closure bolting include flange bolting, bonnet bolting, end connection bolting on BOPs, ram door bolting, and hub clamp bolting.

3.1.15

conformance

Satisfying the specified requirements of the referenced specification, specification section, or document.

3.1.16

corrosion-resistant ring groove

Ring groove lined with a CRA or an austenitic stainless steel to resist metal-loss corrosion

3.1.17

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.

3.1.18

critical dimension

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

3.1.19

current equipment manufacturer

CEM

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

NOTE The original equipment manufacturer (OEM) can be the current equipment manufacturer (CEM) as long as they own the CPD that is active for the equipment.

3.1.20

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.

3.1.21

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.

3.1.22

design status

Status of a product managed under the requirements of this standard, with regard to changes to elements of the original product definition (OPD) as well as improvements to the OPD or obsolescence of the product.

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3.1.23**drilling spool**

Pressure-containing piece of equipment having end connections and outlets used below or between drill-through equipment.

3.1.24**Spacer spool**

Pressure-containing piece of equipment having end connection, used below or between drill-through equipment.

3.1.25**end connection**

Integral male or female thread, clamp hub end connector, flange (studded or through-bolted), or any other means used to join together equipment that contains or controls pressure.

3.1.26**equipment**

Components or assemblies to which this specification is applicable.

3.1.27**equipment owner**

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

3.1.28**fabrication weld**

Weld that joins two or more parts.

3.1.29**ferrite number**

The measure of chrome and nickel equivalent in an austenitic stainless steel material.

3.1.30**fit for service****FFS**

Equipment that has the integrity to operate and function under a specific set of conditions and within the boundaries of its ratings through a technical evaluation.

3.1.31**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.

3.1.32**forging (noun)**

Shaped metal part formed by the forging method.

3.1.33**full-penetration weld**

Weld that extends throughout the complete wall section of the parts joined.

3.1.34

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heat**heat lot**

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

3.1.35**heat-affected zone****HAZ**

Portion of the base metal that has not been melted, but whose mechanical properties or microstructure has been altered by the heat of welding or cutting.

3.1.36**heat-treatment lot**

Same parts or same size of raw material of a single heat, heat treated together as a single austenitizing, quenching, tempering, and / or stress-relieving charge.

3.1.37**heat treatment****heat treating**

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

3.1.38**heat treatment load**

For batch furnaces: material placed on loading or carry devices and moved as a batch through one heat treat cycle. For continuous furnaces: group of pieces of material with the same nominal size that is moved sequentially through the heat treatment process using the same process parameters.

3.1.39**hot-work (verb)**

Deform metal plastically at a temperature above the recrystallization temperature.

3.1.40**hub**

Protruding rim with an external angled shoulder and a sealing mechanism used to join pressure-containing equipment.

3.1.41**hydraulic connector**

Hydraulically actuated drill-through equipment that locks and seals on end connections.

3.1.42**indication**

Evidence of cracks, pits, or other abnormalities found during nondestructive examination (NDE).

3.1.43**integral (adjective)**

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

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3.1.44

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 Intermediate stress relief (ISR) may 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 may receive an ISR after the seal groove inlay, then receive the final PWHT after the flange has been circumferentially welded to its mating component.

3.1.45

leakage

Visible passage of pressurized fluid from the inside to the outside of the pressure-containment area of the equipment being tested.

3.1.46

loose connection

Flange (studded or open-face), hub connection, or OEC used to join together equipment, but not integral to the equipment.

3.1.47

maintenance

Upkeep of well control equipment that is performed in accordance with the equipment owner's preventive maintenance program and the manufacturer's guidelines.

NOTE These procedures may include but are not limited to: inspections, cleaning, polishing, function testing, pressure testing, NDE, and change out of sealing parts and those parts defined in the PM program to be changed either periodically or on a cycle basis.

3.1.48

major repair weld

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

3.1.49

manufacturer

OEM or CEM of the product or part.

3.1.50

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.

3.1.51

original equipment manufacturer

OEM

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

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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.

3.1.53

other end connection

OEC

Connection that 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.

3.1.54

part

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

3.1.55

performance requirement level

PR

Designation determined by the extent of testing successfully performed in accordance with minimum performance criteria identified by API 16A.

3.1.56

postweld heat treatment

PWHT

Controlled heat treatment subsequent to welding, including stress relief to obtain desired material properties.

3.1.57

pressure-containing part or member

Pressure-containing member or part exposed to wellbore fluids whose failure to function as intended would result in a release of wellbore fluid to the environment.

NOTE 1 Examples include bodies, bonnets, connecting rods, and replaceable seats within a pressure-containing member or part.

NOTE 2 In this document, the use of the word component and member are interchangeable.

3.1.58

pressure-containing weld

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

3.1.59

pressure-controlling bolting

Bolting used to assemble or join pressure-controlling part(s).

NOTE Examples: bolting on ram, hydraulic operator cylinder bolting, hydraulic cylinder piston bolting, seat or seal retainer bolting, shear ram blade bolting.

3.1.60

pressure-controlling part

Parts intended to control or regulate the movement of wellbore fluids.

NOTE 1 Examples include packing elements, rams, and replaceable seats within a pressure-containing member or part.

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NOTE 2 In this document, the use of the word component and member are interchangeable.

3.1.61

pressure-retaining bolting

Bolting used to assemble or join pressure-retaining parts whose failure would result in a release in wellbore fluid to the environment.

NOTE Examples: studs and nuts on top of housing hydraulic connector and clamp bolts.

3.1.62

pressure-retaining part or member

Part not exposed to wellbore fluids whose failure to function as intended will result in a release of wellbore fluid to the environment.

NOTE Examples include closure bolts and clamps.

3.1.63

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.

3.1.64

product history file

PHF

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

3.1.65

ram blowout preventer

ram BOP

Blowout preventer that uses metal blocks assembled with elastomer seals to seal off pressure on a wellbore with or without tubulars in the bore.

3.1.66

rated working pressure

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

3.1.67

record (noun)

Document or dataset created and maintained that provides objective evidence of activities performed, results achieved, or statements made.

3.1.68

relevant indication

Any indication [liquid penetrant (LP) or magnetic particle (MP) examination] with a major dimension greater than 1.6 mm (0.062 in.).

NOTE Inherent indications not associated with a surface rupture are considered nonrelevant indications.

3.1.69

remanufacture

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

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3.1.70**remanufacture specification level****RSL**

Level identifying conformance to specified traceability and quality requirements for a part or assembly.

3.1.71**remanufacturer**

Organization that performs the repair and remanufacture work.

3.1.72**repair**

Process of disassembly, inspection, reassembly, and testing of drill-through 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.

3.1.73**repair weld**

Welding performed to correct a nonconformance.

3.1.74**serialization**

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

3.1.75**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, OEC, proprietary sealing surfaces, non-sealing critical dimensions and areas in conformance with the CPD or API Specification.

3.1.76**stabilized**

Pressure testing in a state in which the initial pressure-decline rate has decreased to within the remanufacturer's specified rate.

NOTE Pressure decline can be caused by such things as changes in temperature, setting of elastomer seals, or compression of air trapped in the equipment being tested.

3.1.77**statement of fact****SOF**

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

3.1.78**stress relief**

Controlled heating of material to a predetermined temperature for the purpose of reducing any residual stresses.

3.1.79

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technical authority

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

3.1.80**trepan (verb)**

Produce a hole through a part by boring a narrow band or groove around the circumference of the hole and removing the solid central core of material.

3.1.81**utility bolting**

Bolting that is required to mount equipment and accessories to the drill-through equipment that is not closure bolting, pressure retaining, or pressure controlling.

NOTE Examples: bolting on lifting eye, pad eye (nonwelded), wear bushing, name plate, clamps for tubing, guards.

3.1.82**variable-bore ram****VBR**

Closing and sealing component in a ram BOP that is capable of sealing on a range of tubular sizes.

3.1.83**visual examination**

Examination of parts and equipment for visible defects in material and workmanship.

3.1.84**volumetric nondestructive examination**

Examination for internal material defects by radiography, acoustic emission (AE), or ultrasonic testing (UT).

3.1.85**weld (verb)**

Act of fusing materials, with or without the addition of filler materials.

3.1.86**weld groove (weld prep)**

Area between two metals to be joined that has been prepared to receive weld filler metal, also known as "weld prep".

3.1.87**welding**

Application of any one of a group of welding processes, which applies heat energy sufficient to melt and join one or more pieces of metal through localized fusion and coalescence.

3.1.88**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 BPVC Section IX, Article II and Article IV.

3.1.89**weldment**

Portion or area of a component on which welding has been performed.

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NOTE A weldment includes the weld metal, the heat-affected zone (HAZ), and the base metal unaffected by the heat of welding.

3.1.90

yield strength

YS

Stress level, measured at room temperature, at which material plastically deforms and will not return to its original dimensions when the stress is released.

NOTE The term is expressed in Newtons per square millimeter (pounds per square inch) of loaded area.

NOTE Yield strength (YS) specified in this standard is considered to be the 0.2 % yield offset strength in accordance with ISO 6892 or ASTM A370.

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3.2 Acronyms and Abbreviations

AE	acoustic emission
AWS	American Welding Society/Specification Filler Number
BOP	blowout preventer
CE	carbon equivalent
CEM	current equipment manufacturer
COC	certificate of conformance
COS	certificate of service
CPD	current product definition
CRA	corrosion-resistant alloy
CSWIP	certification scheme for welding and inspection personnel
DAC	distance amplitude curve
DHC	delayed hydrogen cracking
DHT	dehydrogenation heat treatment
DPI	dye penetrant inspection
EP	equivalent P-number
ER	equivalent round
FAT	factory acceptance test
FCAW	flux-cored arc welding
Fe	iron
FN	ferrite number
HAZ	heat-affected zone
HBW	hardness Brinell
ID	inside diameter
ITP	inspection test plan
LP	liquid penetrant
MDB	manufacturing data book
MP	magnetic particle
MPI	magnetic particle inspection

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MT	magnetic test
MTR	material test record
NDE	nondestructive examination
OD	outside diameter
OEC	other end connection
OEM	original equipment manufacturer
OPD	original product definition
PAUT	phased array ultrasonic testing
PHF	product history file
PMI	positive material identification
PQR	procedure qualification record
PR	performance requirement
PT	penetrant test
PWHT	postweld heat treatment
QMS	quality management system
Q&T	quenched and tempered
QTC	qualification test coupon
RSL	remanufacture specification level
SAW	submerged-arc welding
SDH	side drilled hole
SMAW	shielded metal arc welding
SOF	statement of fact
SSC	sulfide stress cracking
SST	stainless steel
TCG	time corrected gain
TPI	third-party inspection
UNS	unified numbering system
UT	ultrasonic testing
UTS	ultimate tensile strength
VBR	variable-bore ram

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WPS welding procedure specification

YS yield strength

4 Quality Control Requirements

4.1 General

Equipment repaired and remanufactured to this standard shall meet the quality control requirements specified by this section.

4.2 Measuring and Testing Equipment

4.2.1 General

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

4.2.2 Pressure-measuring Devices

4.2.2.1 Type and Accuracy

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

Test pressure-measuring devices shall be either pressure gauges or pressure transducers and shall be accurate to at least ± 0.5 % 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 (linear or circular) in the product history file (PHF).

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

4.2.2.2 Calibration Procedure

Pressure-measuring devices shall be periodically recalibrated with a master pressure-measuring device or a deadweight tester to at least three equidistant points of full scale (excluding zero and full scale as required points of calibration).

4.2.2.3 Calibration Intervals

Intervals shall be established for calibrations based on repeatability and degree of usage.

Calibration intervals shall be a maximum of 3 months until recorded calibration history can be established by the manufacturer/remanufacturer and new intervals established demonstrating the ability to retain accuracy after a period of time and after repeated use.

The increased calibration intervals shall not exceed 1 year.

NOTE The date of the last test may be noted on the front of the gauge.

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4.3 Quality Control Personnel Qualifications

4.3.1 NDE Personnel

Personnel performing 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.

4.3.2 Visual and Dimensional Examination Personnel

Welding inspectors, NDE inspectors and dimensional inspectors, shall take and pass an annual vision examination in accordance with the remanufacturer's documented procedures that conforms to the applicable requirements of ISO 9712 or ASNT SNT-TC-1A.

4.3.3 Welding Inspectors

4.3.3.1 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 conformance with the provisions of AWS QC1;
- b) AWS Certified Welding Inspector (CWI) in conformance with the provisions of AWS QC1;
- c) AWS Certified Associate Welding Inspector (CAWI) in conformance with the provisions of 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 manufacturer's or remanufacturer's documented training program.

4.3.3.2 The manufacturer or remanufacturer shall have written procedures:

- a) defining the in-house welding inspector certification program including training syllabus, instructor qualification requirements, length of certification, and renewal requirements;
- b) defining the roles, responsibilities, authority, and accountability of a welding inspector;
- c) defining essential welding variables and equipment monitoring;
- d) defining welding, weld NDE, and postweld 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 or remanufacturer's written procedure for validation of supplier processes.

4.3.4 Third-party Inspection

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

- a) Third-party inspectors shall be competent based on the education, training, skills, and experience needed to perform the inspection service and certification related product requirements defined in the inspection scope.

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- 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 clearly 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.

4.3.5 Equipment Certification

Equipment certification shall be approved by a technical authority.

4.3.6 Other Personnel

Personnel performing measurements, inspections, tests, or other quality control activities for acceptance shall be qualified and competent in accordance with the manufacturer's QMS documented procedures and requirements.

The technical authority shall provide evidence of applicable education, knowledge, skills, and experience to be qualified to perform verification of specified design, quality, and/or manufacturing requirements.

4.4 Quality Control Requirements for Equipment and Parts

4.4.1 General

Pressure-containing and pressure-controlling parts exposed to wellbore fluid shall be in conformance with the requirements of NACE MR0175/ISO 15156 (all parts).

Equipment and parts that are to be repaired and remanufactured under this standard shall be reviewed and confirmed to meet the requirements in this standard.

The remanufacturer shall provide the records for the PHF related to the contracted workscope, conforming to the requirements of Annex C.

The MDB, if available, should be the first entry in the PHF, providing traceability for repair and remanufacturing of pressure control equipment.

The MDB shall be provided for newly manufactured parts or assemblies.

4.4.2 Material Requirements

Material used for parts or members shall meet or exceed the requirements of the edition of API 16A under which it was manufactured.

4.4.3 Quality Control Instructions

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

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4.4.4 Nondestructive Examination

4.4.4.1 NDE Instructions

NDE instructions shall be detailed regarding the requirements of this standard and those of all applicable nationally or internationally recognized standards specified by the manufacturer or remanufacturer. NDE instructions shall be approved by a NDE Level 3 examiner.

4.4.4.2 NDE Qualification Levels

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

Personnel performing UT shall be qualified and certified to UT level 2 or 3 and PAUT level 2 or 3 by a 3rd party certification scheme based on ISO 9712 or ASNT SNT-TC-1A.

An NDT Level 3 in the ultrasonic method shall develop the application technique and prepare and approve the testing procedure.

Only Level 2 or 3 certified personnel shall calibrate equipment and interpret the test results.

The ultrasonic testing personnel shall perform examinations in accordance with qualified and approved procedures.

The service provider or client has the right to require personnel to demonstrate their capabilities to perform to the requirements of the qualified procedure.

4.4.4.3 NDE Reporting

NDE records shall be added to the PHF.

NDE records shall contain the following information:

- a) place and date of examination;
- b) contract requirements e.g. order no., specifications, special agreements etc.;
- c) name of the NDE company carrying out the testing;
- d) name of the NDE inspector, including certification level;
- e) applicable NDE standard;
- f) NDE procedure and acceptance criteria for each method used;
- g) test equipment used;
- h) UT calibration data [including reference reflector(s), indication amplitude(s), and distance reading(s)];
- i) validation object if used;
- j) description, dimensions and location of examined areas and, if any, detected recordable indications / defects, using sketch, photograph, written description or other means;

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- k) surface conditions;
- l) temperature of the object;
- m) material type;
- n) examination results with reference to acceptance level;
- o) non-accessable examination areas;

NOTE Describe the limitations for each volumetric method used.

- p) signatures (ordinary signatures or electronic signatures) of personnel responsible for the testing.

NOTE Other information related to the specific method may be listed under each method.

4.4.5 New NDE Technologies

Application of new NDE technologies and acceptance criteria shall be verified and validated in conformance with the OPD or CPD.

Acceptance criteria for any new NDE techniques shall be as effective as the technique it is replacing.

4.4.6 Phased Array Ultrasonic Testing For Bolts And Shafts

Phased Array Ultrasonic Testing (PAUT) for bolts and shafts shall conform to Annex L.

4.4.7 Acceptance Status

The acceptance status of equipment, parts, and materials shall be indicated either on the equipment, parts, or materials or in the records traceable to the equipment, parts, or materials.

4.5 Quality Control Requirements for Specific Equipment and Parts

4.5.1 General

Unless specified differently in this standard, quality control requirements for specific equipment and parts under this standard shall be in conformance with the edition of API 16A under which it was manufactured.

Newly manufactured or replacement parts shall be in conformance the quality control requirements of API 16A under which it was qualified, including design verification and validation.

Newly manufactured, remanufactured or replacement parts shall be in conformance with an actual product definition (OPD or CPD).

The OPD or CPD shall include but is not limited to:

- a) validation records;
- b) verification records;
- c) engineering drawings;
- d) quality control requirements;

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- e) welding requirements;
- f) maintenance and testing requirements;
- g) technical data sheets;
- h) operations manual.

Quality control records and marking for remanufactured equipment and parts shall be in conformance with Section 10.

4.5.2 Hardness Testing

Hardness testing requirements shall meet the following.

- a) Hardness testing methods shall be in accordance with 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 manufacturer's or remanufacturer's specifications.
- c) When equipment is a weldment composed of different material designations, hardness testing shall be performed on each component part of the weldment after the final heat treatment (including stress relieving). The results of these hardness tests shall satisfy the hardness value requirements for each respective part.
- d) The hardness testing used to qualify each part shall be performed after the last heat treatment cycle (including stress-relieving heat treatment cycles) and after completing exterior machining operations.
- e) The average 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) Hardness measurements on wellbore-wetted parts manufactured from carbon low-alloy and martensitic stainless type steels shall exhibit maximum values in accordance with NACE MR0175/ISO 15156 (all parts) and minimum values equal to or greater than those specified in the edition of API 16A under which it was manufactured.
- g) Hardness measurement results shall be added to the PHF.

4.5.3 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 in accordance with the quality control requirements of Section 4.
- 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.
- d) The OEM or CEM shall define and document the extent to which dimensions shall be verified and recorded.

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- e) Newly machined or skim cut API 6A ring grooves shall conform to API 6A before final factory acceptance testing (FAT).
- f) Any dimensional or surface finish allowance outside of the API 6A ring groove specification after pressure testing shall have acceptance criteria noted in the CPD.

4.5.4 Traceability

Traceability includes the following:

- a) Parts and material shall be traceable in accordance with 4.7.
- b) Identification shall be maintained on materials and parts, to facilitate traceability, as required by documented manufacturer requirements.
- c) Manufacturer documented traceability requirements shall include provisions for maintenance or replacement of identification marks and identification control records.
- d) Welds without sufficient documentation/traceability in the PHF to meet the design specification of the manufacturer or the required RSL of the product shall be removed.

4.5.5 Chemical Analysis

Chemical analysis shall be required for remanufactured pressure-controlling, pressure-containing, and pressure-retaining parts/members, base metal, and filler material.

- a) Chemical analysis shall be performed when a material test record is not available.
- b) Chemical analysis shall be performed in accordance with the remanufacturer's written procedure.
- c) The chemical composition shall be in conformance with the requirements of the edition of API 16A under which it was manufactured.

4.5.6 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 manufacturer's or remanufacturer's written specification.
- c) Acceptance criteria shall be in accordance with manufacturer's written specifications.
- d) Non-well-fluid-wetted and nonsealing surfaces shall be examined in accordance with manufacturer's written specifications.

4.5.7 Surface NDE

Surface NDE requirements shall meet the following.

- a) For surface NDE of ferromagnetic materials, accessible well-fluid-wetted surfaces and accessible sealing surfaces of each finished part shall be inspected after final heat treatment and final machining operations by either MP or LP methods.

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- b) For surface NDE of nonferromagnetic materials, accessible well-fluid-wetted surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by the LP method.
- c) LP examination shall be in accordance with procedures specified in ASTM E165/E165M.
- d) MP examination shall be in accordance with procedures specified in ASTM E709. Prods are not permitted on well-fluid-wetted surfaces or sealing surfaces.

4.5.8 Acceptance Criteria for MP and LP

4.5.8.1 General

NOTE Inherent indications not associated with a surface rupture (i.e. magnetic permeability variations, nonmetallic stringer, etc.) are not considered relevant indications.

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

Acceptance criteria for surfaces other than pressure contact (metal-to-metal) sealing surfaces shall meet the following:

- a) No relevant indication with a major dimension equal to or greater than 5 mm (0.2 in.).
- b) No more than 10 relevant indications in any continuous 10 cm² (2.5 in.²) area.
- c) Four or more relevant indications in a line separated by less than 1.6 mm (0.062 in.) (edge to edge) are unacceptable.

4.5.8.3 Acceptance Criteria for Pressure Contact (Metal-to-Metal) Sealing Surfaces

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

4.5.9 Weld NDE

Welds shall be surface NDE and visually inspected.

Weld NDE requirements shall meet the following.

- a) Essential welding variables and equipment shall be monitored, and completed weldments and the entire accessible weld shall be examined in accordance with the methods and acceptance criteria of this standard.
- b) 100 % of all 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.

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- g) Surface porosity and exposed slag are not permitted on or within 3 mm (0.125 in.) of sealing surfaces.

4.5.10 Weld NDE—Surface Examination (Other Than Visual)

Weld NDE surface examination requirements shall meet the following:

- a) 100 % of all pressure-containing repair welds, weld metal overlay welds, and repaired fabrication welds shall be examined by either MP or LP methods after all welding, PWHT, and machining operations are completed;
- b) the examination shall include 13 mm (0.5 in.) of adjacent base material on both sides of the weld;
- c) acceptance criteria for MP and LP shall be in conformance with API 16A.

4.5.11 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.

4.5.12 Weld NDE—Volumetric Examination of Weld

4.5.12.1 Sampling

Sampling requirements shall meet the following:

- a) 100 % of all pressure-containing welds and 100 % of the weld volume shall be examined by either radiography, ultrasonic, or AE methods after completion of all welding and PWHT;
- b) Repair welds for which the repair is greater than 25 % of the original wall thickness or 25.4 mm (1 in.) (whichever is less), shall be examined by either radiography, ultrasonic, or AE methods after completion of all 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;
- d) Equipment with untraceable pressure-containing welds that are not subjected to 100 % volumetric NDE are classified as RSL 1 product.

4.5.12.2 Radiography Examination

Radiography examination requirements shall meet the following:

- a) Radiographic examinations shall be performed in accordance with procedures specified in 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.

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- 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.

4.5.12.3 Radiography Examination Acceptance Criteria

The following shall not be accepted:

- a) any type of crack, zone of incomplete fusion or penetration;
- b) any elongated slag inclusion that has a length equal to or greater than specified in Table 1;
- 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 BPVC Section VIII, Division 1.

4.5.12.4 Ultrasonic Examination

Ultrasonic examinations shall be performed in accordance with procedures specified in ASME BPVC Section V.

Table 1—Weld Inclusion Criteria

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

4.5.12.5 Ultrasonic Examination Acceptance Criteria

The following shall not be accepted:

- a) any indication whose signal amplitude exceeds the reference level;
- b) any linear indication interpreted as a crack, incomplete joint penetration, or incomplete fusion;
- c) any slag indication with amplitude exceeding the reference level whose length exceeds that specified in Table 1.

NOTE If a weld joins two members having different thicknesses at the weld, t is taken as the thinner of the two thicknesses.

4.5.12.6 Acoustic Emission Examination

If used, AE examination requirements shall meet the following:

- a) AE examinations shall be performed in accordance with procedures specified in ASTM E569/E569M;

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- b) the AE examination shall be conducted throughout the duration of the hydrostatic “in-plant” test.

4.5.12.7 Acoustic Examination Acceptance Criteria

Evaluation and acceptance criteria shall be as follows.

- a) During the first pressurization cycle, any rapid increase in AE events or any rapid increase in AE count rate shall require a pressure hold. If either of these conditions continues during the pressure hold, the pressure shall be immediately reduced to atmospheric pressure and the cause determined. There shall be no leakage at any time during the test.
- b) During the second pressurization cycle, the requirements of the first pressurization cycle shall apply, and in addition, the following AE indications shall not be accepted:
 - 1) any AE event during any pressure hold;
 - 2) any single AE event that produces more than 500 counts or that produces a single attribute equivalent to 500 counts;
 - 3) three or more AE events from any circular area whose diameter is equal to the weld thickness or 25.4 mm (1 in.), whichever is greater;
 - 4) two or more AE events from any circular area [having a diameter equal to the weld thickness or 25.4 mm (1 in.), whichever is greater] that emitted multiple AE events during the first pressurization.

Welds that produce questionable AE response signals (i.e. AE signals that cannot be interpreted by the AE examiner) shall be evaluated by radiography in accordance with 4.5.12.2. If the construction of the pressure vessel does not permit interpretable radiographs to be taken, ultrasonic examination may be substituted for radiography in accordance with 4.5.12.4. Final acceptance (or rejection) of such welds shall be based on the radiographic or ultrasonic results, as applicable.

4.5.12.8 Weld NDE—Hardness Testing

Weld NDE hardness testing requirements shall meet the following.

- a) Accessible pressure-containing, non-pressure-containing, 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(s), after completion of all heat treatment and machining operations.
- c) When equipment is a weldment composed of different material designations one hardness test is required in each base material.
- d) The hardness recorded in the procedure qualification record (PQR) shall be the basis for acceptance if the weld is not accessible for hardness testing.
- e) Hardness testing shall be performed in accordance with one of the following:
 - 1) those procedures specified in ASTM E18, ASTM E110 (Rockwell), or ISO 6506-1;
 - 2) those procedures specified in ASTM E10, ASTM E110 (Brinell), or ISO 6508-1;
 - 3) the value of the hardness test shall be stamped on the part adjacent to the test location as per 4.5.2. It is permissible for hardness marking to be covered by other components after assembly.

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4.5.12.9 Hardness Examination Acceptance Criteria

Hardness values shall conform to the following.

- a) At least one hardness test shall be performed on each part tested, at a location determined by the manufacturer's or remanufacturer's specifications.
- b) The hardness testing used to qualify each part shall be performed after the last heat treatment cycle (including stress-relieving heat treatment cycles) and after completion of all exterior machining operations.
- c) The actual value of the hardness test shall be stamped on the part adjacent to the test location. It is permissible for hardness marking to be covered by other components after assembly.
- d) When equipment is a weldment composed of different material designations, the manufacturer or remanufacturer shall perform hardness tests on each component part of the weldment after the final heat treatment (including stress relieving). The results of these hardness tests shall satisfy the hardness value requirements for each respective part.
- e) Hardness measurements on parts manufactured from carbon low-alloy and martensitic stainless type steels shall exhibit maximum values in accordance with NACE MR0175/ISO 15156 (all parts) and should exhibit minimum values equal to or greater than those specified in Table 2.

Table 2—Minimum Hardness Requirements

API Material Designation	Minimum Hardness (Brinell)
36K	140 HBW
45K	140 HBW
60K	174 HBW
75K	W

- f) In the event that it is necessary to report the hardness test results in other measurement units, conversions shall be made in accordance with ASTM E140 or ISO 18265.
- g) In the event that a part does not exhibit the required minimum hardness level, the part may be considered to have an acceptable hardness if the measured value satisfies the following requirements:
 - 1) the relation between minimum YS, ultimate tensile strength, and hardness of the material is a documented record (see 8.4.3), and the finite element analysis and/or strain gauge measurements show that the correlated YS taken from the hardness levels is greater than the minimum YS needed to meet the allowable stress requirements as per the edition of API 16A under which it was manufactured.
 - 2) the ultimate tensile strength, as determined from the tensile tests results, shall be used with the hardness measurements in order to determine the minimum acceptable hardness value for parts manufactured from the same heat.
- h) The minimum acceptable hardness value for any part shall be determined by Equation (1):

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$$HBW_C = \left[\frac{UTS}{UTS_{QTC}} \right] \times HBW_{QTC} \quad (1)$$

where

HBW_C is the minimum acceptable Brinell hardness for the part after the final heat treatment cycle (including stress-relieving cycles);

UTS is the minimum acceptable ultimate tensile strength specified for the applicable strength level, i.e. 483 MPa (70,000 psi), 586 MPa (85,000 psi), or 655 MPa (95,000 psi);

UTS_{QTC} is the ultimate tensile strength determined from the QTC tensile tests;

HBW_{QTC} is the Brinell hardness value observed on the QTC.

- i) The hardness recorded in the PQR shall be the basis for acceptance if the weld is not accessible for hardness testing.

4.5.13 Volumetric NDE Parts

4.5.13.1 Sampling

The volumetric inspection (radiography or ultrasonic) shall be performed on the repaired welds after stress-relief treatments or re-tempering to reduce hardness.

4.5.13.2 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 specified in ASTM A388/A388M (except immersion method may be used) and ASTM E428.
- b) Calibration: Distance amplitude curve (DAC) shall be based on 1.6 mm (0.062 in.) flat-bottom hole for metal thicknesses through 38.1 mm (1.5 in.), on 3.2 mm (0.125 in.) flat-bottom hole for metal thicknesses from 38.1 mm (1.5 in.) through 152 mm (6 in.), and on 6.4 mm (0.25 in.) flat-bottom hole for metal thicknesses exceeding 152 mm (6 in.).

4.5.13.3 Acceptance Criteria Ultrasonic Examination

The following acceptance criteria shall apply:

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

NOTE Multiple indications are 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.

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4.5.13.4 Radiographic Examination

Radiographic examination of parts shall be performed in accordance with methods specified in 4.5.12.2.

4.5.13.5 Acceptance Criteria Radiographic Examination

The following acceptance criteria shall apply:

- a) no cracks, laps, or bursts;
- b) no elongated indications with length greater than specified in Table 1.

4.5.14 Heat Treatment Equipment

Heat treatments shall be performed utilizing equipment qualified in conformance with Annex G.

4.5.15 Nonmetallic Parts

Inspection of nonmetallic parts shall be in conformance with API 16A.

4.5.16 Annular Packers when Shipped in a BOP

Annular packing elements shipped in assembled BOPs shall conform to API 16A.

4.5.17 End Connections

4.5.17.1 Flanges

Type 6B and 6BX blind flanges shall conform to the dimensional requirements of API 6A.

4.5.17.2 Hubs

Dimensions of 16B and 16BX hubs shall conform to API 16A with applicable size and pressure rating.

4.5.17.3 Other End Connections

The design and configuration of OECs shall conform to the edition of API 16A under which it was manufactured. The OEM or CEM product definition requirements shall be met.

4.5.17.4 Adapters And Spools

End connections shall meet the all the design and material requirements of the edition of API 16A under which they were manufactured. Connections shall have a size designation and pressure rating.

4.5.18 Bolting Specification

Bolting specification for RSL 1 shall meet at a minimum the bolting requirements of API 16A, Third Edition.

Bolting specification for RSL 2 and RSL 3 shall meet the bolting requirements of API 16A.

NOTE See Table 3 for RSL Quality Control Requirements.

Applicable traceability of bolting, including inspection of bolting, for the respective RSL shall be documented in the PHF and Certificate Of Conformance (COC).

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Oversizing of nut threads or under sizing of bolt threads is not permissible.

Manufacturers (OEM and CEM) shall have a documented procedure for qualification of bolting manufacturers used for replacement of existing fasteners in the repair and remanufacturing process.

Manufacturers (OEM and CEM) shall have documented specifications that include the thread form and dimensions of studs, nuts, and bolts for replacement of existing fasteners in the repair and remanufacturing process.

4.5.19 Assembled Equipment

Assembled equipment shall meet the following requirements.

- a) A drift test is required on ram BOP, annular BOP, hydraulic connectors, drilling spools, and adapters in accordance with API 16A.
- b) The quality control requirements shall include pressure tests and hydraulic operating system tests, for each assembled equipment unit in conformance with 7.2.
- c) Serialization shall be recorded on assembled equipment and shall be carried out in accordance with the CEM written specification.
- d) 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).
- e) The hydrostatic proof or shell test pressure shall be determined by the rated working pressure for the equipment and be in conformance with 7.2.

4.6 4.6 Quality Control Records

4.6.1 General

The quality control records required by this standard are those documents and records necessary to substantiate that materials and equipment made to this standard conform to the specified requirements.

4.6.2 NACE Records Requirements

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

4.6.3 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.

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 requirements, whichever is longer.

Records required by this standard shall be signed and dated.

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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.

4.6.4 Records Maintained by Remanufacturer

4.6.4.1 General

The remanufacturer shall retain documents and records as required in 4.6.4.2.

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

4.6.4.2 Parts or Components Records

The following records shall be retained.

- 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 (QTC);
 - 3) impact tests (QTC, as required);
 - 4) hardness tests (QTC).
- e) NDE personnel qualification records;
- f) NDE records:
 - 1) surface NDE records;
 - 2) volumetric NDE records;
 - 3) full penetration fabrication;
 - 4) weld volumetric NDE records;
 - 5) repair weld NDE records;
- g) hardness test records;

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- h) welding process records:
 - 1) welder identification,
 - 2) welding procedure specification (WPS),
 - 3) filler material heat/lot number,
 - 4) PWHTs and dehydrogenation heat treatments (DHTs).
- i) heat treatment records:
 - 1) actual temperature,
 - 2) actual times at temperature.
- j) hydrostatic pressure test records;
- k) critical dimensions and critical areas as defined by the OEM or CEM.

4.7 Repair and Remanufacture Specification Levels

Remanufactured parts/assemblies shall be classified using one of the repair and remanufacture specification levels (RSLs) in accordance in Table 3.

NOTE The RSL is an indication of the level of traceability and/or conformance of parts or assemblies to API 16A.

Table 3—Quality Control Requirements

A) Base Material			
Tensile Testing	RSL 1	RSL 2	RSL 3
All pressure-containing parts material qualification tensile testing is in conformance with the API 16A revision under which it was manufactured.			X
The base material of pressure-containing parts material qualification tensile testing is in conformance with the API 16A revision under which it was manufactured.		X	
No tensile testing is available for pressure-containing parts. As a minimum, hardness testing required.	X		
All pressure-controlling parts material qualification tensile testing is in conformance with the API 16A revision under which it was manufactured.			X
The base material of pressure-controlling parts material qualification tensile testing is in conformance with the API 16A revision under which it was manufactured.		X	
No tensile testing is available for wellbore wetted pressure-controlling parts. As a minimum, hardness testing required.	X		
No tensile testing is available for pressure-controlling parts not exposed to the wellbore. As a minimum, hardness testing required.		X	
Impact Testing	RSL 1	RSL 2	RSL 3

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All pressure-containing parts material qualification impact testing is in conformance with the API 16A revision under which it was manufactured.			X
Only the base material of pressure-containing parts material qualification impact testing in conformance with the API 16A revision under which it was manufactured.		X	
No impact testing is available for pressure-containing parts.	X		
All pressure-controlling parts material qualification impact testing in conformance with the API 16A revision under which it was manufactured.			X
Only the base material of pressure-controlling parts material qualification impact testing in conformance with the API 16A revision under which it was manufactured.		X	
No impact testing is available for wellbore wetted pressure-controlling parts.	X		
No impact testing is available for pressure-controlling parts not exposed to the wellbore.		X	
Hardness Testing	RSL 1	RSL 2	RSL 3
Hardness values conform to the OPD or CPD minimum design criteria.			X
Hardness values do not meet the OPD or CPD minimum design criteria under which it was manufactured requiring an engineering review which may require derating of the equipment.	X		
B) Weld Material			
Mechanical Properties	RSL 1	RSL 2	RSL 3
Mechanical properties (yield strength 0.2 % offset, ultimate tensile strength, elongation, reduction area, impact values, etc.) of all welds meet the OPD or CPD requirements.			X
Mechanical properties (yield strength 0.2 % offset, ultimate tensile strength, elongation, reduction area, impact values, etc.) of structural welds do not meet the OPD or CPD requirements, requiring an engineering review which may require derating of the equipment.	X		
Mechanical properties (yield strength 0.2 % offset, ultimate tensile strength, elongation, reduction area, impact values, etc.) of structural welds meet the OPD or CPD requirements.		X	
All welds have sufficient documentation/traceability in the PHF to meet the design specification of the manufacturer.			X
All structural welds have sufficient documentation/traceability in the PHF to meet the design specification of the manufacturer.		X	
One or more structural welds do not have sufficient documentation/traceability in the PHF to meet the design specification of the manufacturer, requiring an engineering review which may require derating of the equipment.	X		
Welding performed utilizing ASME BPVC Section IX P-number grouping methodology.	X		
Welding performed utilizing qualified weld procedures for the specific materials being joined.			X
C) Critical Dimensions and Critical Areas	RSL 1	RSL 2	RSL 3
All critical dimensions and critical areas as defined by the OEM or CEM, are in as-new tolerance condition.			X

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Critical dimensions and critical areas as defined by the OEM or CEM, are out of tolerance for as-new equipment but meet the allowable wear allowances.		X	
Critical dimensions and critical areas as defined by the OEM or CEM, are out of allowable wear tolerance but are accepted by an engineering review in the PHF, documenting any operational limitations.	X		
D) Traceability	RSL 1	RSL 2	RSL 3
All pressure-containing, pressure-retaining, and pressure-controlling equipment is fully traceable in accordance with the API 16A revision under which it was manufactured as well as the manufacturer standards and the history of the equipment is completely documented.			X
All pressure-containing, pressure-retaining, and pressure-controlling equipment is traceable only back to heat-treatment lot but not in accordance with both the API 16A revision under which it was manufactured and the manufacturer standards.		X	
There are gaps in the repair/remanufacture history of the equipment, but the original material traceability is available from the owner.		X	
E) Replacement Parts	RSL 1	RSL 2	RSL 3
Assembly contains replacement parts that meet or exceed the requirements under which the original assembly was manufactured.			X
Assembly contains replacement parts that do not meet or exceed the requirements under which the original assembly was manufactured.		X	
Traceability of at least one piece of pressure-containing, pressure-retaining, or pressure-controlling equipment has been lost, and the properties of the material have been identified by taking coupons out of the base material.		X	
Material properties are not available for at least one pressure-containing, pressure-retaining, or pressure-controlling part.	X		
The original serialization is lost and the remanufacturer has designated a new unique identifier for the part or assembly.	X		
Corrosion-resistant overlay verification not in conformance with Figure 4 and marking not in conformance with 10.4.	X		
Overlay in ring groove declared corrosion resistant using ASTM A967 copper sulfate test as depicted in Figure 4—Logic for Classification as Corrosion Resistant.	X		
Previous API 16A edition replacement parts are used in an API 16A latest edition assembly.		X	
All parts in the assembly meet or exceed the edition under which the assembly or equipment was originally manufactured.			X
F) Volumetric NDE Parts—Sampling	RSL 1	RSL 2	RSL 3
Volumetric NDE of all parts is fully traceable in conformance with the API 16A under which it was manufactured and or remanufactured.			X
After losing traceability for the part, the entire volume of each part shall be volumetrically inspected (radiography or ultrasonic) after heat treatment for defects and prior to machining operations that limit effective interpretation of the results of the examination.		X	
Equipment with untraceable pressure-containing welds that have not been subjected to 100 % volumetric NDE.	X		

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G) Bolting	RSL 1	RSL 2	RSL 3
Bolting meets the requirements of API 16A, Third Edition.	X		
Bolting meets the requirements of API 16A.			X
NOTE The X indicates the maximum RSL a unit can obtain if the applicable condition exists.			

5 Quality Management System Requirements

5.1 General

The organization shall establish, document, implement, and maintain a management system that minimally conforms to the requirements of Section 5 of this standard for all products and services provided per API 16AR.

NOTE Registration to an internationally recognized QMS that covers manufacturing activities such as API Q1 or ISO 9001 meets the requirements of 5.1.

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.

5.2 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 any 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 conformance to 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.

5.3 Training and Awareness

The organization shall:

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- 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;

5.4 Control of Testing, Measuring, and Monitoring Equipment

The remanufacturer shall maintain a documented procedure that 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 any 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.

5.5 Contract Review

5.5.1 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.

5.5.2 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.

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5.6 Purchasing 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.

5.7 Design and Development

5.7.1 Design and Development Planning

The organization shall maintain a documented procedure to plan and control the design and development of the product, including the use of service-related products.

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 organization 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 organization shall ensure the supplier meets the requirements of 5.7 and provide objective evidence that the supplier has met these requirements.

5.7.2 Design Documentation

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

5.7.3 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;

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- d) historical performance and other information derived from previous similar designs;
- e) other applicable requirements including:
 - 1) requirements provided from an external source;
 - 2) requirements for products and service-related products, including its functional and technical requirements.

5.7.4 Design Verification

The design and development requirements shall be examined and confirmed to be in conformance with specified requirements of the contract and API 16A.

NOTE Design verification activities may include one or more of the following:

- a) confirming the accuracy of design results through the performance of alternative calculations;
- b) review of design output documents independent of activities of design and development;
- c) comparing new designs to similar proven designs.

5.7.5 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.

Wherever practicable, 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 any necessary actions shall be maintained.

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

5.7.6 Control of Design and Development Changes

Design and development changes shall be identified and records maintained. 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.

5.8 Control of Nonconforming Product

5.8.1 General

The organization shall ensure that product that 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.

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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.

5.8.2 Field Nonconformity Analysis

The documented procedure for nonconforming product shall include requirements for identifying, documenting, and reporting incidents of field nonconformities 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 nonconformance.

Records of the nature of nonconformities and any subsequent actions taken shall be maintained.

6 Responsibilities

6.1 General

The flow chart in Annex D shall be used to determine the entity (OEM, CEM, or equipment owner) with responsibility for maintaining the design of the equipment or component.

When the equipment owner is controlling the specifications of the part, assembly, or system, they have assumed design responsibility of the hybrid system.

6.2 Manufacturer

The manufacturer shall be responsible for:

- a) conformance to the standard in manufacturing, documentation (MDB), and certification;
- b) maintaining the OPD or CPD and the ongoing product design status;
- c) documenting design changes resulting from a malfunction or failure history of drill-through equipment in the OPD or CPD;
- d) auditing approved repair facilities to the requirements of this product standard to ensure conformance;
- e) retention of MDB and 16AR records for a minimum of 10 years;
- f) preparation and maintaining the availability of an operations manual in accordance with API 16A, in effect at the time of manufacture.

6.3 Remanufacturer

The remanufacturer shall be responsible for:

- a) conformance to the API 16AR standard in repair and remanufacture, the documentation required in the PHF in relation to the service provided;

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- b) providing the equipment owner with an overview of equipment traceability and conformance to the OPD or CPD before selecting and agreeing the RSL in the purchase order;
- c) auditing repair and remanufacture approved facilities to the requirements of this product standard to ensure conformance;
- d) retention of API 16AR remanufacture records for a minimum of 10 years in conformance with Annex C.

6.3.1 Failure Reporting

In the case that the remanufacturer has become the CEM for the equipment, they shall also be responsible for:

- a) reporting in writing all failures or malfunctions experienced with drill-through equipment after repair and remanufacture and any design changes in the OPD or CPD that prevent meeting the functional requirements to every known equipment owner of the drill-through equipment within three weeks after notification of the occurrence.
- b) communicating any design changes to the OPD or CPD, resulting from a malfunction or failure history, to every equipment owner using the affected equipment within 30 days after the design change.

6.4 Equipment Owner Input

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

- a) equipment MDB records;
- b) equipment PHF records;
- c) equipment certification records;
- d) documenting requirements for the PHF;
- e) the requested RSL for the product;
- f) TPI requirements.

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

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

7 Repair/Remanufacture Specification Level Minimum Requirements

7.1 General

Quality control requirements for specific equipment and parts as documented in 4.5 shall meet or exceed the agreed RSL as documented in the customer purchase order.

The RSL for the entire system/assembly shall not be higher than the lowest RSL of a part.

NOTE Annex H can be used to determine the RSL for the system/assembly.

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Parts that do not meet the minimum of RSL 1 quality requirements defined in 4.7 shall not be identified as in conformance with this standard.

7.2 Factory Acceptance Testing

7.2.1 General

Drill-through equipment shall be subjected to a hydrostatic proof test. Water with soluble oil that also provides corrosion protection in the vapor phase should be used as the testing fluid to avoid corrosion of the drill-through equipment. The type of soluble oil and concentration used shall be documented in the test records. Water can be used in the bore for pressure testing, but requires preservation of the drill-through equipment afterwards.

7.2.2 Hydrostatic Testing

7.2.2.1 General

Drill-through equipment shall be tested with its sealing mechanisms in the open position, if applicable.

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

New pressure-containing parts or members and remanufactured equipment shall be subjected to a hydrostatic test of 1.5 times rated working pressure.

For equipment with end or outlet connections having different working pressures, the lowest rated working pressure shall be used to determine the shell pressure test.

The low pressure test shall always precede the high pressure test.

The timing of pressure tests shall not start until the test pressure has stabilized.

7.2.2.2 Low Pressure Test

A 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.

7.2.2.3 High Pressure Test

A pressure at least equal to the rated working pressure of the equipment shall be applied for not less than 10 minutes after stabilization.

The allowable test pressure tolerance above rated working pressure shall be 5 % of rated working pressure or 3.45 MPa (+500 psi), whichever is less.

7.2.2.4 Acceptance Criteria

There shall be no visible leakage.

During the entire hold period, the pressure shall not drop below the minimum required test pressure.

7.2.3 Skim Cut of Sealing Surfaces

After skim cutting, the equipment shall be subjected to a hydrostatic test meeting one of the following criteria:

- a) pressure test to 1.5 times the rated working pressure, or
- b) pressure test to 1.0 times the rated working pressure, provided that all the following conditions are met:

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- 1) Pressure testing to rated working pressure has been specified by the equipment owner.
- 2) Prior to pressure testing of the newly machined ring groove, the connection and sealing surface dimensions and surface finish are in conformance with:
 - i) API 6A or API 16A or
 - ii) design verified and validated OEM or CEM specifications for OEC or proprietary ring groove sealing surfaces.
- 3) Weld overlay repair(s) if performed are in conformance with a qualified WPS that neither requires PWHT nor affects the mechanical properties of the base metal.
- 4) Certificate states that the hydrostatic pressure test was run at rated working pressure.
- 5) Skim cutting performed on OEC or proprietary ring groove sealing surfaces follows the design ownership as depicted in Annex D.

7.2.4 Operating Chamber Pressure Test

The hydraulic operating system shall be tested on each assembled BOP and hydraulic connector per the quality control testing requirements in API 16A.

After repair, the hydraulic operating chamber shall be tested at a minimum test pressure equal to 1.0 times the operating chamber's rated working pressure.

New components that are hydraulic pressure-containing parts or members (excluding ram shafts and annular pistons) shall be tested to 1.0 times rated working pressure or to manufacturer specification requirements before use, whichever is higher.

After remanufacture of the hydraulic pressure-containing components, the hydraulic operating chamber shall be tested at a minimum test pressure equal to 1.5 times the operating chamber's rated working pressure.

7.2.5 Hydraulic Connector Pressure Test

7.2.5.1 General

Each hydraulic connector shall be subjected to a low pressure test and a hydrostatic proof test. The hydraulic operating chamber pressure used shall be equal to or less than the manufacturer's specified operating pressure.

After repair of the hydraulic circuits, they shall be tested at a minimum test pressure equal to 1.0 times the operating chamber's rated working pressure.

After remanufacturing of the hydraulic circuits, they shall be tested at a minimum test pressure equal to 1.5 times the operating chamber's rated working pressure.

The test fluids used shall conform to 7.2.1.

Pressure testing and acceptance criteria shall conform to 7.2.2, 7.2.3 and 7.2.4.

7.2.5.2 Sealing Mechanism Test, Hydraulic Connector

7.2.5.2.1 The connector with a blind flange or blind hub on top shall be locked on the test stump or mandrel using the manufacturer's recommended operating pressure and be tested in two stages:

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- a) the operating/locking pressure shall be removed during the pressure testing,
- b) the operating/locking pressure shall be applied and blocked during the pressure testing.

7.2.5.2.2 If the gasket profile contains a secondary sealing surface, then the sealing mechanism test shall be repeated using the secondary sealing surface of the gasket.

Documentation shall include:

- a) record of equipment used (e.g. hydraulic connector model, size and type, and gasket type);
- b) record of locking pressure and corresponding unlocking pressure(s);
- c) record of applied wellbore pressure(s).

7.2.5.3 Locking Mechanism Test, Hydraulic Connector

7.2.5.3.1 This test shall verify the operation of both the primary and (if so equipped) secondary locking mechanisms at rated working pressure and establishes the lock/unlock pressure relationship.

The test shall be conducted using an assembled connector with a test stump or mandrel.

The connector shall be stroked to the locked position on and off the stump or mandrel, and the lock/unlock pressure relationship shall be within the manufacturer's stated limits.

- a) lock and unlock the hydraulic connector at least six times to the full stroke length using the manufacturer's recommended operation pressure;
- b) if the connector has a secondary unlock system, repeat six locking and unlocking cycles using the secondary unlock system using the manufacturer's recommended operating pressure.

7.2.5.3.2 Documentation shall include:

- a) record of equipment used (e.g. hydraulic connector model, size and type, and gasket type);
- b) record of locking pressure(s) and corresponding unlocking pressure(s);
- c) record of the lock/unlock pressure relationship in comparison against the manufacturer's written design specifications.

7.2.6 Closed-preventer Test

Each ram and annular BOP shall be subjected to a closed-preventer test after the hydrostatic proof test.

The hydraulic operating system pressure used shall be equal to or less than the manufacturer's specified operating pressure.

The test fluids used for closed preventer tests shall conform to 7.2.1.

The timing of closed-preventer tests shall not start until the test pressure has stabilized.

Closed-preventer tests shall be performed at low and high pressures, with the low pressure test always preceding the high pressure test.

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Closed preventer high pressure test shall be performed at 1.0 times rated working pressure.

The pipe ram preventer tests shall be performed with the matching size tubular for the rams being tested. Variable-bore rams (VBRs) shall be tested on the minimum and maximum tubular sizes for their range.

The annular test shall require pressure-testing in conformance with API 16A. Other additional sizes can be specified by the customer.

Pressure testing and acceptance criteria shall conform to 7.2.2.2, 7.2.2.3 and 7.2.2.4.

7.2.7 Shear Test

Shear testing may be performed, if specified by the equipment owner and agreed with the remanufacturer.

7.2.8 Ram Lock Test

NOTE The ram lock test determines the ability of the BOP's ram-locking device to maintain a wellbore pressure seal after removing the closing and/or locking pressure(s).

The ram lock test shall apply to each included ram that is designed to operate with the ram-locking system.

The preventer shall be pressure tested at low and high wellbore pressure after the rams are closed, the locks engaged, and then all operating pressure(s) released.

Loose operator assembly locking systems shall be tested in accordance with the manufacturer's requirements specified in the purchase order.

7.2.9 Loose Ram Blocks

Repaired or remanufactured loose rams shall be inspected and tested in conformance to the OPD or CPD.

Hardness checks, NDE and inspection of critical dimensions shall be performed on loose rams that have been remanufactured.

7.2.10 Loose Annular Pressure-controlling Components

Loose annular pressure-controlling components repaired and remanufactured shall require inspection of critical dimensions, critical areas, NDE, and hardness checks, as specified in the product definition.

7.2.11 Loose BOP or Hydraulic Connector Pressure-containing Components

Pressure-containing BOP or hydraulic connector bodies (including bonnet/door annular tops [heads or covers]), when shipped separately (not part of an assembled BOP or hydraulic connector), shall include hydrostatic pressure tests meeting the requirements of 7.2.2 and 7.2.4.

7.2.12 Elastomeric Seal Requirements

Elastomer components used shall be in conformance with the requirements of API 16A under which they were manufactured.

7.2.13 Wellbore Sealing Components and Consumables

If the manufacturer or remanufacturer provides components for testing and those parts/components are removed after testing when conformance has been proven, the equipment owner shall add those components when putting the system into service.

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Traceability shall be maintained of the parts added to maintain conformance to the standard and to maintain the equipment's RSL.

Independent ram assemblies and operator assemblies shall be treated as a separate component from the BOP.

7.2.14 Operating Sealing Components and Consumables

Identification of non-wellbore nonmetallic components, such as elastomeric seals used in ram and annular type BOP actuation systems, shall be in accordance with the manufacturer written specifications.

Ram assemblies and operators shall be provided with a separate certificate showing conformance or compatibility (where applicable).

Specialized components, including proprietary design BOP seals and packing units, shall be stored in accordance with the OEM/CEM recommendations.

7.2.15 Drift Test

A drift test shall be required on ram BOP, annular BOP, hydraulic connectors, drilling spools, and adapters.

After the closed-preventer test, a drift mandrel shall be passed through the bore of the assembly after completion of pressure testing, with no external force being applied to the drift.

Annular drift testing shall occur within 30 minutes after closing pressure has been removed, with no external force being applied to the drift.

Drift mandrel dimensions shall be in conformance with API 16A.

7.2.16 Visual Inspection

After final acceptance, testing equipment shall be visually inspected for wear or damage and results shall be recorded.

7.3 Dimensional Check

For repair and remanufacture, the sealing dimensions shall be within product definition (OPD/CPD) tolerances.

Corrosion shall be removed and parts dimensionally validated to be in conformance with the product definition (OPD/CPD)

Wear tolerances defined in the product definition (OPD or CPD) shall be used to verify if the part is suitable for service.

Dimensional checks shall include the following as a minimum:

- a) wear of all critical sealing surfaces as defined in the product definition,
- b) flange and bore dimensions,
- c) pressure-retaining components,
- d) pressure-controlling components,

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- e) any critical areas per the product definition.

Dimensions shall be documented by a technician who is competent to record and take measurements in accordance with the established QMS.

7.4 NDE—Initial Inspection

The following inspections shall be performed before proceeding with repair and remanufacturing of pressure controlling and pressure containing parts.

- a) Pressure-containing and pressure-controlling parts and other parts that require any processes from which the temperature input affect its hardness, shall be hardness tested as per 4.5.2.
- b) Accessible well-fluid-wetted surfaces shall be inspected by magnetic particle inspection (MPI) or dye penetrant inspection (DPI).
- c) All welds shall be inspected by MPI or DPI.
- d) External surfaces shall be 100 % visually inspected.
- e) Anomalies found during the visual inspection shall be further investigated with MPI, DPI or NDE techniques as per 4.4.5.
- f) Unacceptable indications, as per 4.5 shall be removed.

If full weld records are not available, all machined surfaces of the components with missing records shall be acid etched to determine the location of previous welds.

7.5 Inspection on Closure Bolting

If closure bolting or other closing devices are intended for reuse, they shall undergo a thorough inspection that includes:

- a) wet MPI, DPI, PAUT or new technology as per 4.4.5, evaluating the threads and non-threaded areas of the part,
- b) threads (internal/external) inspection for wear and stretch,
- c) bolt holes threads inspected for wear and stretch,
- d) bolt holes verified for weld repairs and etched when traceability of repairs has been lost,
- e) full-dimensional inspection of the closure bolting.

7.6 Visual Inspection at Disassembly

All parts shall be 100 % visually inspected.

Inspection shall include but are not limited to:

- a) critical areas and body structure,
- b) threaded lifting bolt holes,

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- c) sealing surfaces,
- d) door/bonnet assembly alignment,
- e) straightness of parts,
- f) flatness of seal areas,
- g) damage to running surfaces,
- h) corrosion/pitting.

7.7 Replacement Parts

Replacement parts shall meet or exceed the requirements under which the original assembly was manufactured to obtain an RSL 3 designation for the assembly.

Assemblies with replacement parts that do not meet or exceed the requirements under which the original assembly was manufactured shall not be designated higher than RSL 2.

Replacement parts shall be in conformance with the OPD or CPD and shall be documented in the PHF.

Unique markings of the part shall provide the traceability that allows verification of the part design status.

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

7.8 General Equipment Specifications

Equipment repaired and remanufactured under API 16AR shall meet the general equipment standard in conformance with Annex A.

7.9 Documentation

Repair and remanufacture activities performed on the product shall be fully documented, supported by the required certification, and added to the PHF as defined in Annex C.

Documentation shall provide traceability as required under API 16A.

7.10 Failure Reporting

The organization performing the repair and remanufacturing shall take on the internal responsibilities of the manufacturer for failure reporting in conformance with API 16A.

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 API 16A.

8 Materials

8.1 General

Material requirements shall be in conformance with API 16A.

This section describes the performance, processing and compositional requirements for materials used in:

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- a) pressure-containing parts or members,
- b) pressure-controlling parts or members,
- c) pressure-retaining parts,
- d) other parts.

All parts shall as a minimum satisfy the OPD or CPD design requirements for the product repaired and remanufactured under this standard.

Metallic materials exposed to wellbore fluids and gases shall meet the design requirements of NACE MR0175/ISO 15156 (all parts). Permitted exclusions allow shear blades not to be sulfide stress cracking (SSC) resistant. For shear blades that do not conform to these hardness limitations, their suitability for, and their sealing capability in, SSC environment are the responsibility of the user.

8.2 Metallic Parts

A written material specification shall be required for all new manufactured parts or parts to a weldment of metallic pressure-containing, pressure-controlling, and pressure-retaining parts.

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 RSL 1 or RSL 2, it is recognized that some of this information may not be available.

8.3 Nonmetallic Parts

Each manufacturer (OEM and CEM) shall have written specifications for all elastomeric materials used in the repair and remanufacture of drill-through equipment.

These specifications shall include the following physical tests and limits for acceptance and control:

- a) acceptance and/or rejection criteria;
- b) physical property requirements;

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- c) material qualification, which shall meet the equipment temperature and pressure class requirement;
- d) storage and age-control requirements;
- e) hardness in accordance with ASTM D2240 or ASTM D1415;
- f) tensile and elongation properties in accordance with ASTM D412 or ASTM D1414;
- g) compression set in accordance with ASTM D395 or ASTM D1414;
- h) immersion (fluid compatibility) testing in accordance with ASTM D471 or ASTM D1414;
- i) test liquid, temperature, and duration of test shall be defined.

8.4 Base Metal Material Identification

8.4.1 General

In order to start the remanufacturing process, material composition shall be established.

8.4.2 Material Test Records

8.4.2.1 If MTRs for metallic parts are not available, the following shall be tested and documented to establish material property requirements for pressure-containing members to meet RSL 1:

- a) determining hardness and approximate tensile values,
- b) determining chemical composition.

8.4.2.2 Materials to be included in analysis shall include the following elements:

- a) copper,
- b) carbon,
- c) manganese,
- d) silicon,
- e) phosphorus,
- f) sulfur,
- g) nickel,
- h) chromium,
- i) molybdenum.

8.4.3 Vanadium, Determining Hardness and Approximate Ultimate Tensile Values

Determining hardness and approximate tensile values shall be done in accordance with the following.

- a) Brinell:

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- a) ASTM E10 (Brinell),
 - b) ASTM E110 (portable testing),
 - c) ISO 6506-1.
- b) Rockwell:
- a) ASTM E18 (Rockwell),
 - b) ASTM E110 (portable testing),
 - c) ISO 6508-1.
- c) Vickers:
- a) ASTM E384 for Vickers,
 - b) ISO 6507-1.

Hardness conversion shall be done in accordance with ASTM E140 with the exception of nickel-based and austenitic materials.

NOTE The hardness of a material is in principle related to the ultimate tensile strength (UTS) and not to the YS. UTS and YS show a linear correlation with hardness for most steels. However, for steel that shows evidence of strain hardening, a lower strength can be measured for a given hardness. There can be a nonlinear relation between strength and hardness.

If uncertainty exists with respect to the material specification, the material properties as per the RSL (see 4.7) shall be validated.

8.4.4 Determining Chemical Composition

In absence of material specifications for the parts of the system, calibrated positive material identification (PMI) shall be used to confirm that the material from the pressure-containing and pressure-controlling parts meets the requirements of the product definition.

The material identification shall be done using an industry-recognized process that is capable of:

- a) determining carbon content,
- b) determining all alloying elements such that the material can be matched to a base material specification,
- c) determining nickel and sulfur content for NACE MR0175/ISO 15156 (all parts) applications,
- d) determining other types of non-iron based materials (i.e. type of overlay materials).

Prior to welding of carbon and low-alloy steel, all elements in the carbon equivalency formula shall be identified as per ASME BPVC Section IX, QW-403.26:

$$CE = C \% + Mn \% / 6 + (Cr \% + Mo \% + V \%) / 5 + (Ni \% + Cu \%) / 15 \quad (2)$$

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8.5 Pressure-containing Members

8.5.1 Property Requirements

Pressure-containing members shall be manufactured from materials as specified by the manufacturer that conform to API 16A and Table 4 and Table 5 below.

Charpy V-notch impact testing shall conform to 8.5.4.2.

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Table 4—Material Property Requirements for Pressure-containing Members

Material Designation	Yield Strength 0.2 % Offset min.		Tensile Strength min.		Elongation in 50 mm min.	Reduction of Area min.
	MPa	(psi)	MPa	(psi)	%	%
36K	248	36,000	483	70,000	21	None specified
45K	310	45,000	483	70,000	19	32
60K	414	60,000	586	85,000	18	35
75K	517	75,000	655	95,000	18	35
Nonstandard	As specified	As specified	As specified	As specified	15	20

Table 5—Material Applications for Pressure-containing Members

Part	Rated Working Pressure					
	13.8 MPa (2,000 psi)	20.7 MPa (3,000 psi)	34.5 MPa (5,000 psi)	69.0 MPa (10,000 psi)	103.5 MPa (15,000 psi)	138.0 MPa (20,000 psi)
Body	36K, 45K, 60K, 75K				45K, 60K, 75K	60K, 75K
End connections	60K				75K	
Blind flanges	60K				75K	
Blind hubs	60K				75K	

Nonstandard materials may be used that have a specified minimum YS that is not less than that of the lowest strength standard material permitted for the applications above.

8.5.2 Heat Treating

NOTE 1 In principle, parts in the remanufacturing process can be fully normalized or annealed and again heat treated [quenched and tempered (Q&T)] with the aim to restore the material properties that are in conformance with the minimum requirements of API 16A.

NOTE 2 Although normalizing or annealing may lead to distortion of dimensions, surfaces, and tolerances of the part, it may in some occasions be economical to do so.

Parts that are to be Q&T and include existing welds shall have all the weld material removed before the heat treating process.

QTC shall be required after the heat treatment (normalized or annealed + Q&T) is completed.

Care should be taken in loading of material within furnaces such that the presence of one part does not adversely affect the heat treating response of any other part.

Temperature and times for heat treatment shall be determined in accordance with the manufacturer's or remanufacturer's written specification.

Quenching shall be performed in accordance with the manufacturer's or remanufacturer's written specifications.

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- a) Water quenching—The temperature of the water or water-based quenching medium shall not exceed 38 °C (100 °F) at the start of the quench, nor exceed 49 °C (120 °F) at the completion of the quench.
- b) Oil quenching—The temperature of any oil-quenching medium shall be greater than 38 °C (100 °F) at the start of the quench.
- c) Polymer quenching - The temperature of any polymer-quenching medium shall be in conformance with the manufacturer's requirements.

8.5.3 Chemical Composition

8.5.3.1 General

The remanufacturer shall specify the range of chemical composition of the material used to remanufacture pressure-containing members or manufacture replacement pressure-containing members.

Material composition for replacement pressure-containing members shall be determined on a heat basis (or a remelt ingot basis for remelt grade materials) in accordance with the manufacturer's written specification.

8.5.3.2 Composition Limits

The chemical composition limits of pressure-containing members manufactured from carbon and low-alloy steels or martensitic stainless steels shall conform to API 16A.

8.5.4 Material Qualification

8.5.4.1 Tensile Testing

If YS, ultimate tensile strength, elongation and reduction area needs to be reestablished for remanufacturing in order to meet or exceed RSL 2 requirements, a test coupon shall be removed from the part.

Test coupons shall be in conformance with the dimensions as described in 8.5.8.

Tensile tests shall be performed in accordance with the procedures specified in ISO 6892 or ASTM A370.

A minimum of one tensile test shall be performed. The results of the tensile test(s) shall satisfy the applicable requirements of API 16A. If the results of the first tensile tests do not satisfy the applicable requirements, two additional tensile tests may be performed in an effort to qualify the material. The results of each of these additional tests shall be in conformance with the requirements of API 16A.

8.5.4.2 Impact Testing

If impact strength needs to be reestablished for remanufacturing in order to meet or exceed RSL 2 requirements, a test coupon shall be removed from the part.

Test coupons shall be in conformance with the dimensions as described in 8.5.8.

Impact tests shall be performed using the Charpy V-notch technique in accordance with ASTM A370.

In order to qualify material for an API 16A temperature rating T-0, T-20, or T-75, the impact tests shall be performed at or below the test temperature shown in Table 6.

Pressure-containing members for which the impact strength is unknown, and that only require RSL 1, shall not be given a classification higher than T-0.

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A minimum of three impact specimens shall be tested to qualify a part. The average of the impact property value shall be at least the minimum value shown in Table 6. In no case shall an individual impact value fall below $\frac{2}{3}$ the required minimum average. No more than one of the three test results shall be below the required minimum average.

If a test fails, then one retest of three additional specimens (removed from the same part) may be made. The retest shall exhibit an impact value for each specimen equal to or exceeding the required minimum average.

The values listed in Table 6 are the minimum acceptable values for forgings and wrought products tested in the transverse direction and for castings and weld qualifications.

NOTE Forgings and wrought products may be tested in the longitudinal direction instead of the transverse direction, in which case they shall exhibit 27 J (20 ft-lb) minimum average value.

Repairs for equipment rated for 20,000 psi and higher pressure, the Charpy V-notch impact values for weld forgings and wrought products shall conform to API 16A.

Table 6—Acceptance Criteria for Charpy V-notch Impact Tests

Temperature Rating	Test Temperature		Minimum Impact Value Required for Average of Each Set of Three Specimens		Minimum Impact Value Permitted for One Specimen Only per Set	
	°C	(°F)	J	(ft-lb)	J	(ft-lb)
T-0	−18	0	20	15	14	10
T-20	−29	−20	20	15	14	10
T-75	−59	−75	20	15	14	10

8.5.5 Qualification Test Coupons

QTCs used for reestablishing the material properties shall be removed from the part requiring weld repair.

NOTE A QTC may be taken from an equal size part from the same heat number as the part requiring weld repair to represent the impact and/or tensile properties, provided it satisfies the requirements of this standard.

The properties exhibited by the QTC shall represent the properties of the material comprising the equipment it qualifies.

8.5.5.1 Equivalent Round

The area from which a trepan core is taken shall meet the QTC dimensional requirements of API 16A.

8.5.6 Processing

8.5.6.1 Melting Practices

Processing the QTC shall not be permitted by using a melting practice cleaner than that of the material it qualifies.

EXAMPLE A QTC made from a remelt grade or vacuum-degassed material does not qualify material from the same primary melt that has not experienced the identical melting practice.

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NOTE Remelt grade material removed from a single remelt ingot may be used to qualify other remelt grade material that has been processed in like manner and is from the same primary melt. No additional alloying is permitted on these individual remelt ingots.

8.5.6.2 Welding

Welding on the QTC shall be prohibited, except for attachment-type welds.

8.5.6.3 Heat Treating

Heat treatment operations shall be performed utilizing “production-type” equipment certified in accordance with the manufacturer or remanufacturer written specification. “Production-type” heat treatment equipment shall be considered equipment that is routinely used to process parts.

The QTC shall experience the same specified heat treatment processing as the parts it qualifies.

The QTC shall be heat treated using the manufacturer or remanufacturer specified heat treatment procedures.

When the QTC is not heat treated as part of the same heat treatment load as the parts it qualifies, the austenitizing (or solution heat treat) temperatures for the QTC shall be within 14 °C (25 °F) of those for the parts.

The tempering temperature for the part shall be no lower than 14 °C (25 °F) below that of the QTC. The upper limit shall be no higher than permitted by the heat treatment procedure for that material. The cycle time of the QTC at each temperature shall not exceed that for the parts.

8.5.7 Tensile and Impact Testing

Removal of tensile and impact specimens from multiple QTCs shall be permitted as long as the multiple QTCs have been exposed to the same heat treatment cycle(s).

Standard-size impact specimens of cross-section 10 mm (0.39 in.) × 10 mm (0.39 in.) shall be used, except where there is insufficient material, in which case the next smaller standard-size impact specimen obtainable shall be used. When it is necessary to prepare sub-size impact specimens, the reduced dimension shall be in the direction parallel to the base of the V-notch.

Tensile and impact specimens shall be removed from the part such that their longitudinal centerline axis is wholly within the center core 0.25T envelope for a solid QTC or within 1 mm (0.039 in.) of the mid-thickness of the thickest section of a hollow QTC.

NOTE For QTCs larger than the dimensions specified in API 16A, the test specimens do not need be removed from a location farther from the QTC surface than that would be applicable if the specified QTC dimensions were used.

When a sacrificial production part is used as the QTC, the test specimens shall be removed from a section of the part satisfying the dimensional requirements of the QTC for that production part.

8.5.8 Hardness Testing

A hardness test shall be performed on the QTC after the final heat treatment cycle.

Hardness testing shall be performed in accordance with procedures specified in ASTM E10, ASTM E18, ASTM E110, ASTM E384, ISO 6506-1, ISO 6507-1 or ISO 6508-1.

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9 Welding Requirements

9.1 General

The welding requirements of this standard shall be the minimum for joining, overlaying, and repairing pressure-containing and load-bearing parts by welding and for qualification of welding procedures.

Welding of components exposed to wellbore fluid shall conform to the welding requirements of NACE MR0175/ISO 15156 (all parts). Verification of conformance shall be established through implementation of the remanufacturer's written WPS and the supporting PQR.

When material specifications for pressure-containing and pressure-retaining components require impact testing, verification of conformance shall be established through implementation of the remanufacturer's WPS and supporting PQR.

Welding shall be performed in accordance with a WPS that has been written and qualified in accordance with ASME BPVC Section IX.

The WPS shall describe all the essential, nonessential, and supplementary essential variables in conformance with ASME BPVC Section IX.

The PQR shall record the essential, and supplementary essential (if required) variables of the weld procedure used for the qualification test(s). Both the WPS and PQR shall be maintained as records in accordance with the quality control record requirements from 4.6.3 and 4.6.4.

Pressure-containing welds shall undergo a hardness test after PWHT and shall meet the minimum hardness requirements of the base material per the CPD.

9.2 Weldment Design and Configuration

9.2.1 Pressure-containing Fabrication Weldments

NOTE Pressure-containing fabrication weldments contain and are wetted by wellbore fluid.

Only full-penetration welds fabricated in accordance with the remanufacturer's written specification shall be used. Figures G.1 through G.3 in Annex F are provided for reference.

Welding and completed welds shall meet the quality control requirements of 4.5.

9.2.2 Load-bearing Weldments

NOTE Load-bearing weldments are those subject to external loads and not exposed to wellbore fluids.

Joint design shall be in accordance with the remanufacturer's written procedures.

Welding and completed welds shall meet the quality control requirements of 4.5.

Lifting points shall be designed with a minimum safety factor of 2.5 and load tested to 1.5 times safe working load.

Surface NDE shall be performed after the load test and meet the quality requirements of 4.5.

The safe working load shall be stamped on or near the lift points.

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9.2.3 Repair Welds

Repair welding shall be carried out in accordance with the remanufacturer's WPS.

Repaired welds to pressure-containing members performed subsequent to original heat treatment shall be mapped.

Prior to any weld repair that requires PWHT, a review of the number of cumulative heat treat hours of the welds shall be performed and the WPS used to perform the repair shall be qualified for the additional PWHT time at temperature.

New and remanufacture welds shall be mapped to provide traceability for the weld.

Remanufacture welds shall be mapped on a separate weld map.

Weld maps shall contain the following traceability information:

- a) part sketch denoting new weld/repair area;
- b) part number;
- c) serial number;
- d) welder's stamp or inside diameter (ID) number;
- e) PT/MT report number of verification of defect removal;
- f) WPS used;
- g) filler material heat/batch/lot;
- h) weld flux heat/batch/lot, if used;
- i) number of PWHT hours per weld used for this remanufacturing cycle;
- j) accumulation of all PWHT hours per weld, if available;
- k) number of PWHT hours for base material, if available.

Welding and completed welds shall meet the quality control requirements of 4.5.

9.2.4 Tack Welds

Tack welds made by nonqualified persons are not permitted.

9.2.5 Corrosion-resistant Overlay of Ring Grooves

9.2.5.1 General

NOTE 1 Standard dimensions for the preparation of type SR ring grooves for overlays are specified in API 6A.

NOTE 2 Dimensions for the preparation of OEC ring grooves for overlay are specified by the manufacturer.

If equipment has metal-overlaid, corrosion-resistant ring grooves, the ring gasket type and number shall be followed by "CRA" to designate a nickel-based alloy or "SST" to designate an austenitic stainless steel.

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After final inspection of the overlay, the logic in Figure 3 shall be used to determine if the surface can be classified as corrosion resistant.

Type 347 and 309 austenitic stainless steel shall have a range of 5 FN to 11 FN.

NOTE 3 FN = ferrite number, and Fe = iron content.

Ballot Draft

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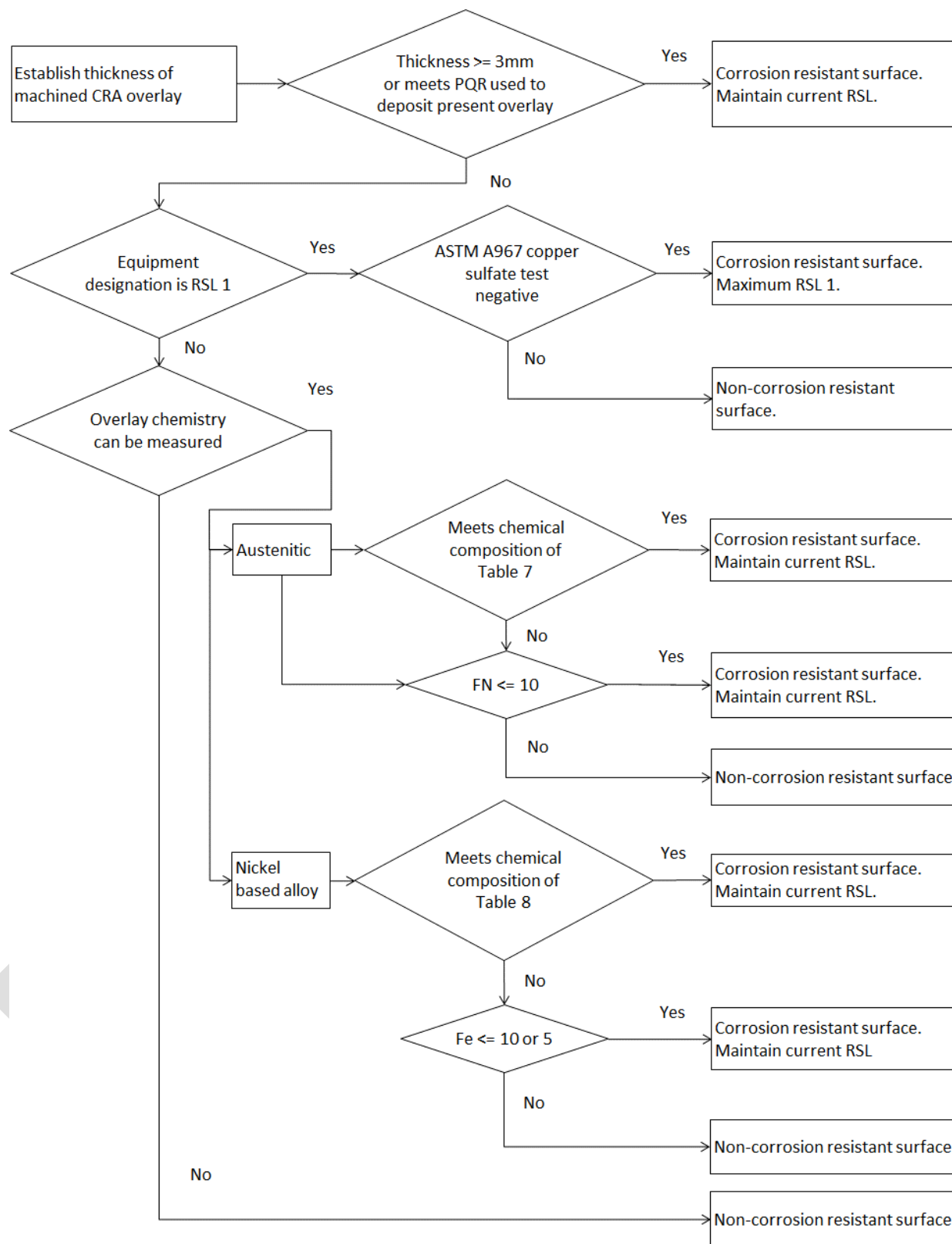


Figure 3—Logic for Classification as Corrosion Resistant

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9.2.5.2 Thickness

The overlay thickness remaining after finish machining operation shall be measured and verified to be in conformance with the minimum thickness requirements.

The minimum thickness of the finished corrosion-resistant weld overlay applied to equipment surfaces shall be at least 3 mm (0.125 in.) or the minimum thickness allowed for API 6A ring grooves.

If the overlay thickness is not verified and does not meet the acceptance criteria in 9.2.5, the overlay area shall be documented as non-corrosion-resistant in the equipment certification document and the CRA or SST designation on the stamping shall be removed.

9.2.5.3 Ferrite Requirements for Austenitic Stainless Steel Overlay

The ferrite content of the final layer of weld overlay shall be in the range of 3 FN to 10 FN, except for Type 347, which shall have a range of 5 FN to 11 FN. The minimum FN may be reduced to 3 FN provided the remanufacturer submits data verifying that hot cracking will not occur using the lower FN consumable to be used in production and this is approved by the equipment owner.

Magnetic instruments for measuring ferrite shall be calibrated annually per AWS A4.2M.

Measurements of Fe and FN shall be performed on at least three different positions on the overlay or overlay repair.

9.2.5.4 Application

The following shall apply for corrosion-resistant overlay.

- a) PWHT: End and outlet connections with corrosion-resistant weld-overlaid ring grooves shall be subjected to PWHT when required by the WPS.
- b) Ring joint grooves preparation for welding: API ring grooves for welding shall be prepared in accordance with API 6A.
- c) API ring grooves shall be inspected in accordance with API 6A quality control requirements.
- d) Other weld preparations.

Other weld preparations may be used if the mechanical properties of the deposited weld metal equal or exceed the minimum specified design properties of the base metal.

9.2.5.5 Quality Control Requirements

The remanufacturer shall use a written procedure that provides controls for consistency meeting the specified material surface properties in final machined condition.

9.2.5.6 Additional Overlay Requirements

NOTE Welding general requirements for overlays can be found in 9.5.1.4, and welding procedure qualifications requirements for overlays can be found in 9.5.2.3.

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9.3 Welding Controls

9.3.1 Procedures

The remanufacturer's system for controlling welding shall include procedures for monitoring, updating, and controlling the qualification of welders, welding operators, and the use of WPSs.

9.3.2 Application

Welding shall be performed by personnel qualified in accordance with the requirements of ASME BPVC Section IX.

Welding shall be performed in accordance with written WPS and qualified in accordance with ASME BPVC Section IX. The WPS shall describe all the essential, nonessential, and supplementary essential (in accordance with ASME BPVC Section IX) variables. Welders and welding operators shall have access to, and shall conform to, the welding parameters as defined in the WPS.

The welding personnel shall be capable of reading the language the WPS is written in.

9.3.3 Designed Welds

For welds that are considered part of the design of a production part, the remanufacturer shall specify the requirements for the intended weld.

Dimensions of groove and fillet welds with tolerances shall be documented in the remanufacturer's specification. Recommended weld preparation design dimensions can be found in Annex F, Figures F.1 through F.3.

9.3.4 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.).

NOTE It is recommended that the weld area and an additional 6 in. around the area are heated to the minimum preheat temperature.

9.3.5 Instrument Calibration

Instruments to verify temperature, voltage, and amperage shall be serviced and calibrated in accordance with the written specification of the remanufacturer performing the welding.

9.3.6 Welding Machine Calibration

Welding machine inspections and calibrations shall be in accordance with the written specification of the remanufacturer performing the welding.

The welding machine inspections shall validate that the Amperage and Voltage shown on the display(s) is within tolerance under load.

Welding machines shall be calibrated in conformance with the welding machine manufacturer requirements.

The documentation of the calibration, shall validate that variables are within manufacturer tolerance.

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The difference between actual and display settings (system accuracy) shall be compared to manufacturers specifications and the system be recalibrated when needed.

Measuring devices used for welding machine calibration shall be traceable to NIST or equivalent internationally recognized standard.

9.3.7 Materials

9.3.7.1 Welding Consumables

Welding consumables shall conform to American Welding Society (AWS) or the consumable manufacturer's approved specifications.

The remanufacturer shall have a written procedure for storage 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.

9.3.7.2 Deposited Weld Metal Properties

The deposited weld metal mechanical properties shall meet or exceed the minimum design mechanical properties of the base material. Verification of properties shall be established through the implementation of the remanufacturer's WPS and supporting PQR. When materials of differing strength are joined, the weld metal shall meet the minimum requirements of the lesser strength material.

9.3.7.3 Postweld Heat Treatment

PWHT of components shall be in accordance with the remanufacturer or manufacturer written procedures.

Furnace PWHT shall be performed in equipment meeting the requirements specified by in Annex G and performed in accordance with the remanufacturer procedure.

Local PWHT may be performed with a qualified written procedure.

Local PWHT shall consist 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. Localized flame heating is permitted provided the flame is baffled to prevent direct impingement on the weld and base material.

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

When PWHT is required, test coupons that include weld material shall be postweld heat treated with the nominal temperature and maximum time to be used in production. The YS 0.2 % offset, ultimate tensile strength, elongation, and reduction area shall meet or exceed the base metal design criteria.

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

Prior to PWHT, welds (excluding overlay) made on low-alloy steels with the SMAW, SAW, or FCAW processes that are allowed to cool below the minimum preheat temperature, shall be subjected to a DHT immediately after completion of welding, unless the electrode used is classified by the filler metal manufacturer with a diffusible-hydrogen designator of H4 (e.g., E7018-H4).

The DHT for the weldment shall be held at a minimum of 450 °F (232 °C) for 2 hours minimum prior to slow cooling under insulation or in still air.

Welding procedures and/or additional associated procedures shall specify the following if PWHT or additional heat treatment is required:

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- 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.

If not specified on the WPS, the heating and cooling rates shall be identified in a documented PWHT procedure.

Heating and cooling rates shall be in conformance with ASME BPVC Section VIII, Division 1 for furnace heating and cooling rates and ASME B31.1 for local heating and cooling rates or manufacturers documented procedures.

9.4 Welding Procedure and Performance Qualifications

9.4.1 General

Weld procedures, welders, and welding operators shall be qualified in accordance with the qualification and test methods of ASME BPVC Section IX, as amended below.

All personnel performing welding operations shall have an annual eye examination in accordance with AWS D17.1.

9.4.2 Base Metals

9.4.2.1 General

The remanufacturer shall use ASME BPVC Section IX P-number materials and base metal groupings.

Materials used for qualification that are not listed in ASME BPVC Section IX shall be qualified separately and conform to ASME BPVC Section IX.

9.4.2.2 Equivalent P-numbers

The remanufacturer shall establish an equivalent P-number (EP) grouping for carbon and low-alloy steels not listed in ASME BPVC Section IX with a carbon equivalent (CE) less than or equal to 0.43 for <1 in. or less and 0.45 for >1 in. material thickness [see 8.4.4, Equation (2)].

Additionally, carbon and low-alloy steels not listed in ASME BPVC Section IX with an allowable CE as identified above shall have a maximum carbon content less than or equal to 0.23 % (by weight) and shall have a maximum YS of 60 ksi (414 MPa).

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The remanufacturer shall have a written specification that identifies the unassigned base metal by industrial specification, type, and grade, or by chemical analysis and mechanical properties.

Qualification of a base material with a similar chemistry and at a specified strength level shall qualify that base material chemistry at all lower strength levels.

9.4.2.3 Base Metals with Modified Chemistries and Mechanical Properties

NOTE 1 Many low-alloy steels with CEs and YSs greater than those identified in 9.4.2.2 have modified chemistries that differ from the recognized ASME BPVC Section IX P-numbers.

NOTE 2 Welding procedure qualification of base metals with modified chemical and mechanical properties may be performed using the similar industrial specification materials, when the following conditions are satisfied:

- a) the modified base metal chemistry is similar to a recognized industrial specification listed in ASME BPVC Section IX;
- b) the industrial base material used during qualification is heat treated/conditioned to a minimum YS that meets or exceeds the minimum YS of the modified base material requiring welding qualification; and
- c) the remanufacturer writes a separate material specification identifying the chemistry, chemistry range, material form (cast, forged, plate, shape, etc.), the heat treat cycle(s) for the various thicknesses and corresponding minimum YSs, and the mechanical properties (including ultimate tensile strength, toughness, and hardness).

Welding performed utilizing ASME BPVC Section IX P-number grouping methodology shall not be designated more than RSL 1.

Welding performed utilizing qualified weld procedures for the specific materials being joined shall be designated as RSL 3.

Qualification of a base material with a similar chemistry at a specified strength level shall qualify that modified base material chemistry at all lower strength levels.

The CE of the industrial base metal shall be within 10 % of the modified alloy's maximum CE.

NOTE 3 AISI grouping of modified 41XX and modified 86XX are considered different alloys and cannot be used to qualify each other.

NOTE 4 Steels containing 0.30 % carbon (± 0.03 %) cannot be used to qualify alloys with nominal 0.40 % carbon and greater. Additionally, low-alloy steels containing 0.15 % carbon maximum cannot be used to qualify materials with greater than 0.18 % carbon.

Unassigned materials with different carbon levels shall be qualified separately; maximum CE for production welds shall be no greater than $0.03 + \text{CE of the test piece}$.

9.4.3 Welding Consumables

Welding consumables shall be specified in each WPS and shall conform to AWS/SFA classifications or the consumable manufacturer's approved specifications. When consumables are used that do not meet AWS/SFA classifications, the WPS shall be limited to the brand and trade name qualified.

9.4.4 Chemical Analysis

Chemical analysis of the base materials and filler metal for the test weldment shall be obtained from the supplier or obtained by testing and shall be part of the PQR.

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If the A-number of the filler material is not available, the chemical analysis of the weld deposit shall be in the PQR.

9.4.5 Heat Treat Condition

Testing shall be carried out with the test weldment in the postweld heat treated condition. PWHT of the test weldment shall be in conformance with the remanufacturer's written specifications.

9.4.6 Procedure Qualification Record

The PQR shall record essential and supplementary essential (when required by ASME) variables of the weld procedure used for the qualification test(s). Both the WPS and the PQR shall be maintained as records in accordance with the requirements of Section 4.

9.5 Other Welding Qualification requirements

9.5.1 ASME BPVC Section IX, Article I—Welding General Requirements

9.5.1.1 General

Article I of ASME BPVC Section IX shall apply with additions as given below.

9.5.1.2 Hardness Testing

9.5.1.2.1 General

Hardness testing shall be conducted across the weld and base material HAZ cross-section and shall be recorded as part of the PQR.

Results on all pressure-containing and pressure-controlling parts exposed to wellbore fluid shall be in conformance with NACE MR0175/ISO 15156 (all parts) requirements.

The remanufacturer shall specify the hardness testing locations in accordance with 9.5.1.2.2, 9.5.1.2.3, and 9.5.1.4.1 as applicable.

Hardness testing shall be performed in accordance with procedures specified in ASTM E10, ASTM E18, ASTM A370, ASTM E384, ISO 6506-1, ISO 6507-1 or ISO 6508-1.

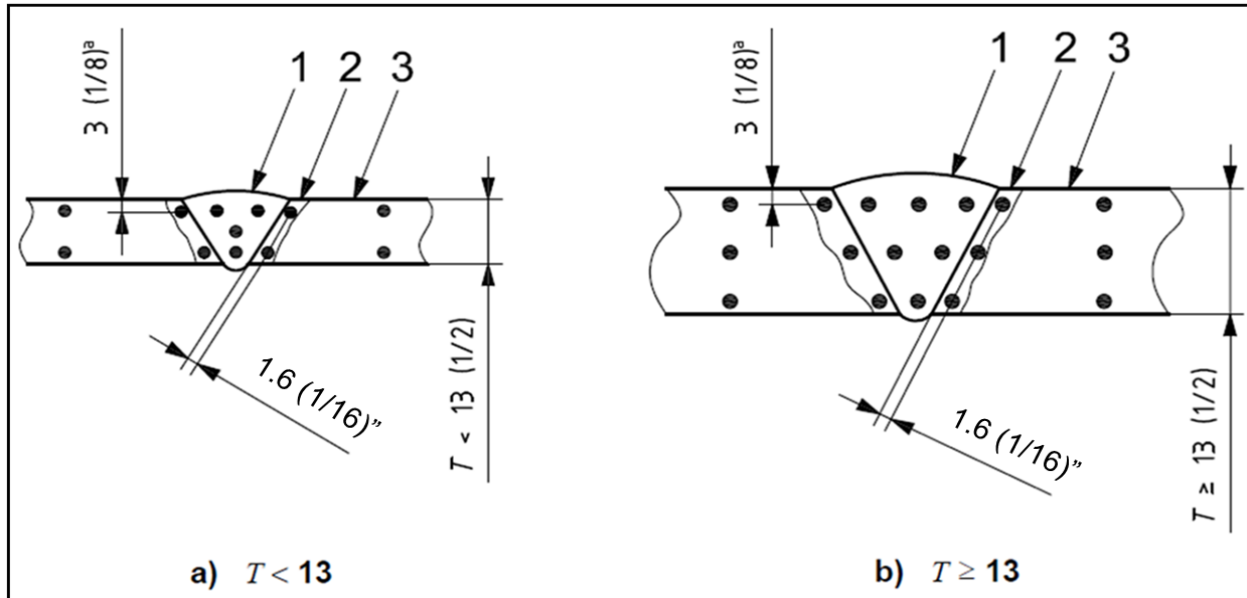
Hardness results shall not be converted but reported in the actual scale used.

9.5.1.2.2 Rockwell Method (ISO 6508-1)

If the Rockwell method is selected by the remanufacturer, the following procedure shall be used:

- a) For a weld cross-section thickness less than 13 mm (0.5 in.), four hardness tests each shall be made in the base material(s), the weld, and the HAZ.
- b) For a weld cross-section thickness equal to or greater than 13 mm (0.5 in.), six hardness tests each shall be made in the base material(s), the weld, and the HAZ.
- c) HAZ hardness tests shall be performed in the base material within 1.6 mm (0.062 in.) of the weld interface and at least one each within 3 mm (0.125 in.) from top and bottom of the weld. See Figure 5 for test locations.

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Key

- 1 weld
- 2 HAZ
- 3 base
- ^a Typical.

Dimensions in millimeters (inches)

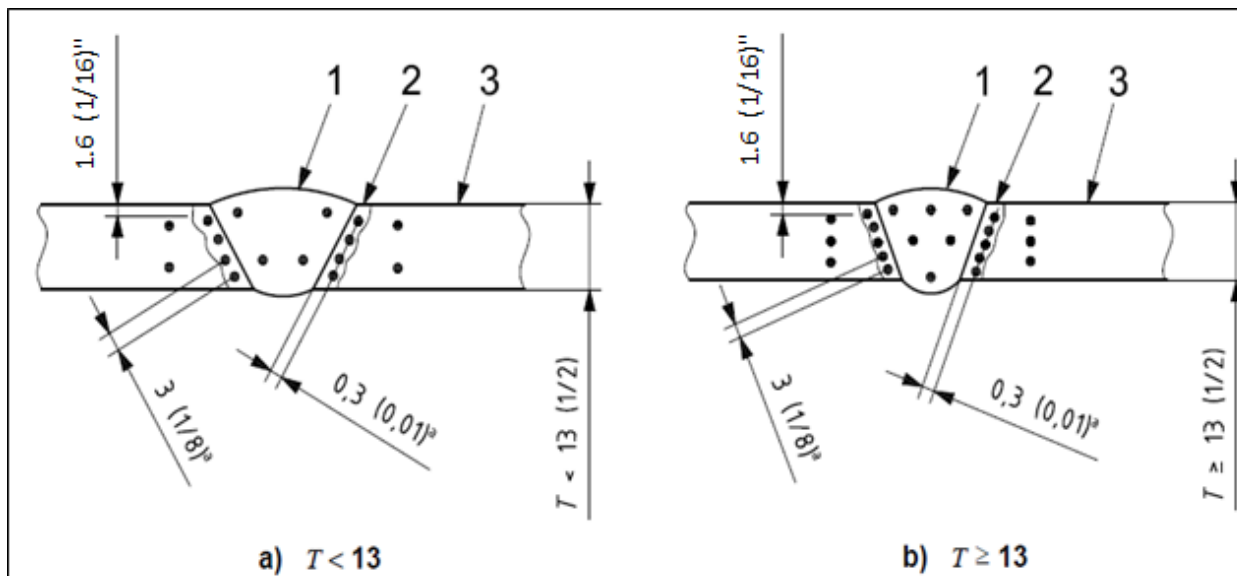
Figure 4—Rockwell Hardness Test Locations

9.5.1.2.3 Vickers Method (ISO 6507-1)

If the Vickers method is selected by the remanufacturer, the following procedure shall be used:

- a) For a weld cross-section thickness less than 13 mm (0.5 in.), four hardness tests each shall be made in the base materials and the weld.
- b) For a weld cross-section thickness equal to or greater than 13 mm (0.5 in.), six hardness tests each shall be made in the base material(s) and the weld.
- c) Multiple HAZ hardness tests equally spaced 3 mm (0.125 in.) apart shall be performed in each of the base materials within 0.25 mm (0.01 in.) of the weld interface and at least one within 1.6 mm (0.062 in.) from the top and the bottom of the weld. See Figure 5 for test locations.

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Key

- 1 weld
- 2 HAZ
- 3 base
- a Typical.

Dimensions in millimeters (inches)

Figure 5—Vickers Hardness Test Locations

9.5.1.2.4 Hardness Testing (Optional)—Minimum Mechanical Properties

For the purpose of hardness inspection and qualifying production weldments, a minimum of three hardness tests in the weld metal shall be made and recorded as part of the PQR. These tests shall be made by the same methods used to inspect production weldments. These tests may be used to qualify weld metal with hardness less than shown in 4.5.12.9 by the method shown in the same subsection.

9.5.1.3 Impact Testing

When impact testing is required by the base material specification, the testing shall be performed in accordance with ASTM A370 using the Charpy V-notch technique. Results of testing in the weld and base material HAZ shall meet the minimum requirements of the base material. Records of results shall become part of the PQR.

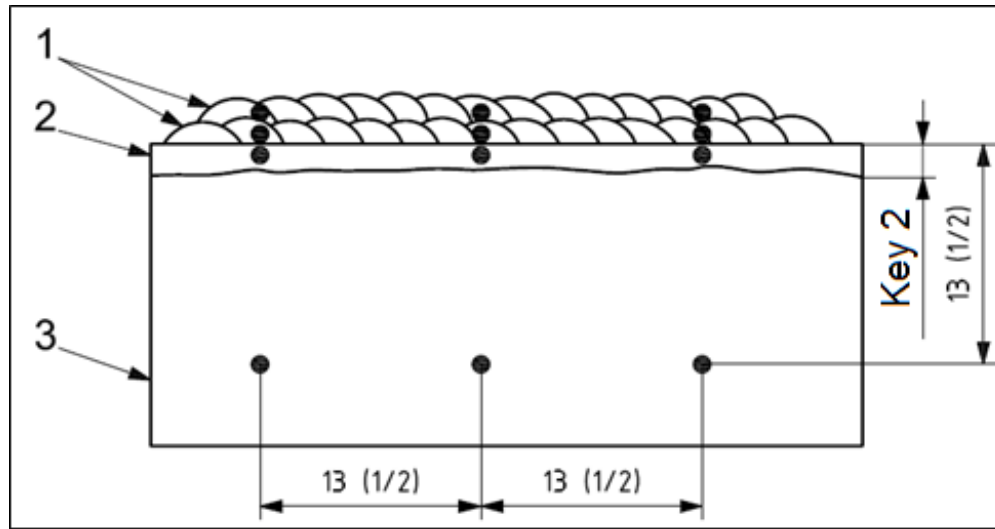
Impact testing for welding qualification other than overlay shall follow Annex I.

9.5.1.4 Corrosion-resistant Overlay

9.5.1.4.1 Hardness Testing for Overlay

Hardness test shall be performed at a minimum of three test locations in each base material, the HAZ, and in each layer of the overlay up to a maximum of two layers in conformance with the test locations specified in Figure 6.

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Key

- 1 weld
- 2 HAZ for Rockwell within 1.6 mm (0.062 in.); for Vickers and Rockwell 15N as close the fusion line as possible but no more than 1 mm (0.039 in.)
- 3 base

Dimensions in millimeters (inches)

Figure 6—Hardness Test Locations for Weld Overlay

Using the Vickers or Rockwell 15N measurement methods, hardness impressions shall be entirely within the HAZ and located as close as possible to, but no more than 1 mm (0.039 in.) from, the fusion boundary between the weld overlay and HAZ.

For corrosion-resistant ring groove overlay, chemical analysis shall be performed in the weld metal in accordance with the requirements of ASME *BPVC* Section IX at a location of 3 mm (0.125 in.) or less from the original base metal surface.

The average of three or more test results from the cross-section hardness in the overlay shall be equal or greater than 83 HRB and recorded as part of the PQR. The chemical composition of the deposited weld metal at that location shall be as specified by the remanufacturer.

9.5.1.4.2 Mechanical Properties of Base Metal

Base metal shall retain the minimum mechanical property requirements after PWHT.

The minimum mechanical properties from the base metal shall be established through mechanical testing, including tensile and impact testing.

If the overlay material is considered as part of the manufacturer's or API 16A design criteria, mechanical testing, including tensile and impact, of the overlay material is required.

The remanufacturer shall ensure the mechanical properties are met and results are included in the PQR.

9.5.1.4.3 Guided-bend Tests for Overlay

Guided-bend tests and acceptance criteria shall be in accordance with ASME *BPVC* Section IX, to confirm weld-overlay material bond integrity.

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9.5.1.4.4 Mechanical Properties Base Material

The mechanical properties of the base material after heat treatment shall be in conformance with the minimum mechanical property requirements of API 16A. The remanufacturer shall specify the methods used to ensure these mechanical properties and shall record the results as a part of the PQR in conformance with ASME BPVC Section IX.

9.5.2 ASME BPVC Section IX, Article II—Welding Procedure Qualifications

9.5.2.1 General

Article II of ASME BPVC Section IX shall apply with additions as shown in this section.

9.5.2.2 Heat Treatment

The PWHT of the test weldment and the production weldment shall be in the same range as that specified on the WPS. Allowable range for the PWHT on the WPS shall be a nominal temperature of ± 14 °C (± 25 °F). The stress-relieving heat treatment(s) time(s) at temperature(s) of production parts shall be equal to or greater than the minimum qualified for the test weldment.

For Q&T and normalized and tempered materials, all thermocouples for the upper PWHT holding temperature on the WPS shall be below the actual tempering temperature of the base material.

The WPSs shall be qualified to cover all PWHT cycles of the weld, HAZ, and base material.

9.5.2.3 Corrosion-resistant Overlay

9.5.2.3.1 Chemical Analysis Overlay

Chemical analysis shall be performed on the weld metal in accordance with the requirements of ASME BPVC Section IX, at a location 3 mm (0.12 in.) or less from the original base metal surface. The chemical composition of the deposited weld metal at that location shall be as specified by the CEM.

For austenitic or 300 series stainless steels, the chemical composition shall be given in Table 7.

Table 7—Chemical Composition of Austenitic or 300-series Stainless Steels

Element	Composition % mass fraction
Nickel	8.0 min
Chromium	16.0 min
Carbon	0.08 max

When austenitic stainless steel overlays are called out by design, preference should be given to the use of Type 316L filler metal.

For the nickel-based alloy unified numbering system (UNS) N06625, the chemical composition of the overlay surface after welding and machining shall meet one of the classes given in Table 8.

For all other compositions, the chemical analysis of the overlay shall conform to the specified limits of the remanufacturer's written specification.

Welds for use in hydrogen sulfide service shall conform to the requirements of NACE MR 0175/ISO 15156 (all parts).

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Table 8—Chemical Composition of the Nickel-based Alloy UNS06625

Class	Element	Composition % mass fraction
Fe 5	Iron	5.0 max
Fe 10	Iron	10.0 max

9.5.2.3.2 Corrosion-resistant Overlay Other than Ring Grooves

The provisions of 9.2.5 shall apply to the use of corrosion-resistant weld overlay for bodies, bonnets, clamp hub end connections, and end outlet connections for the purposes other than API 6A standard ring grooves.

The remanufacturer shall use a written procedure that provides controls for consistently meeting the remanufacturer specified material surface properties in the final machined condition. As a minimum, this shall include inspection methods and acceptance criteria.

Qualification shall be in accordance with Articles II and III of ASME *BPVC* Section IX for corrosion-resistant weld metal overlay or hard facing weld metal overlay as applicable.

9.5.2.4 Hole Repair Procedure Qualification

Procedure qualification for bolt, tapped, and blind hole repairs shall include the following.

- Base material shall be of the same P-number and group number per ASME *BPVC* Section IX. If not listed in ASME *BPVC* Section IX, the base material shall be of the same type and in the highest strength heat treated condition that the procedure will be qualified for.
- The hole repair weld procedure qualification shall demonstrate that the minimum mechanical properties for the product can be met.

NOTE The base metal size should anticipate a heat sink similar that used in remanufacturing.

9.5.3 ASME *BPVC* Section IX, Article III—Welding Performance Qualifications

9.5.3.1 General

Article III of ASME *BPVC* Section IX shall apply with additions as shown in this subsection.

9.5.3.2 Bolt, Tapped, and Blind Hole Repair Performance Qualification

The welder or welding operator shall perform an additional repair welding performance qualification test using a mock-up hole (refer to Annex F, Figure F.3).

The repair welding qualification test hole shall be qualified by radiography in conformance with 4.5.12, or shall be cross-sectioned through the centerline of the hole in two places 90° apart and shall be examined by NDE in accordance with 4.5.12. This evaluation shall include the total depth of the hole.

The repair weld qualification shall be restricted by the following essential variables for performance controls.

- The hole diameter used for the performance qualification test is the minimum diameter qualified. Any hole with a diameter greater than that used for the test shall be considered qualified.
- The depth-to-diameter ratio of the test hole shall qualify all repairs to holes with the same or smaller depth-to-diameter ratio.

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- c) The performance qualification test shall have straight parallel walls. If any taper, counter-bore, or other aid is used to enhance the hole configuration of the performance test, that configuration shall be considered an essential variable.

For welder performance qualification, ASME BPVC Section IX P-1 base metals may be used for the test coupon in place of the low-alloy steels covered by the API 16A.

9.5.4 ASME BPVC Section IX, Article IV—Welding Data

Article IV of ASME BPVC Section IX shall apply as written.

Mechanical test specimens shall be removed from the procedure QTC for welding procedure qualification (see Figure 7).

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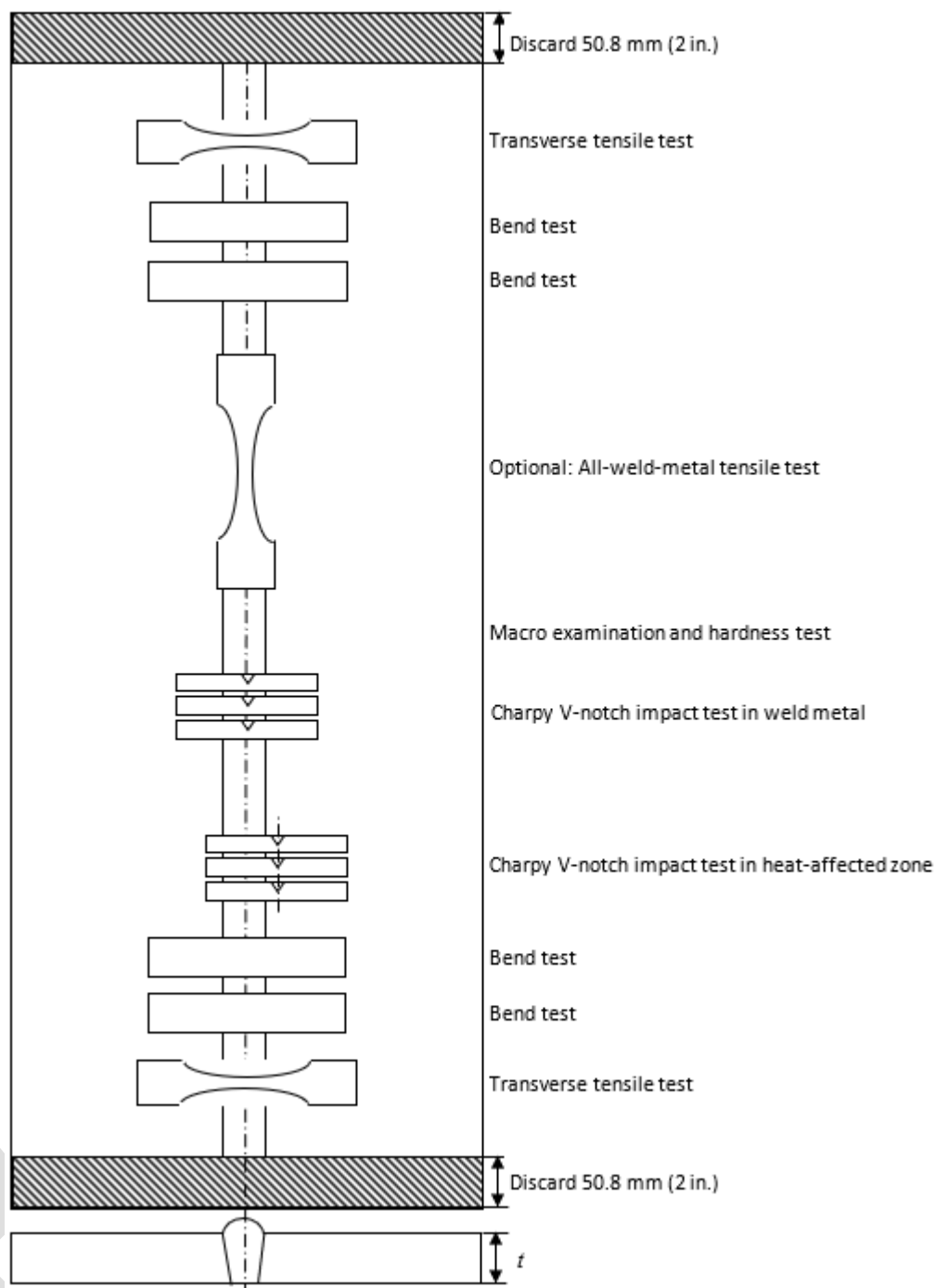


Figure 7—Typical Mechanical Specimen Removal for Welding Procedure Qualification

9.6 Other Requirements

Where metallic permanent backing material is permitted, the P-number or its nominal chemical composition shall be specified in the WPS and/or the applicable fabrication drawing. For joints between similar materials, the chemical composition of backing materials shall match the nominal base metal chemical composition.

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Temporary attachments welded to the base metal shall be compatible with the base metal and welded in accordance with a qualified weld procedure.

Temporary attachments shall be removed by gouging or grinding and the base metal restored to its original condition before final heat treatment (if required), pressure testing, and final acceptance. The base metal shall be inspected with MT or PT upon removal of the attachment.

9.7 Documentation Requirements

Repair and remanufacture records shall be included in the PHF.

An operation manual for the repaired or remanufactured product shall be provided by the OEM or CEM.

The operations manual shall also include bolt torquing procedures and bolting lubrication recommendations.

10 Marking Requirements

10.1 General

Parts that are repaired or remanufactured shall be marked.

The repair and remanufacture marking requirements are in addition to and shall not replace original marking requirements of API 16A.

Location of marking for metallic equipment that is repaired or remanufactured shall be in accordance with table 9.

Table 9—Marking Requirements and Location

Marking	Ram Blowout Preventer	Annular Blowout Preventer	Hydraulic Connector	Operators	Drilling Spools, Spacer Spools, Mandrels, and Adapters	Loose Connection	OECs (Integral and Loose) ^d	Clamps	Ram Blocks
RPR / RMFR name or API 16AR Reg. No.	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body	Body
Unique certificate number	Name plate	Name plate	Name plate	Name plate or body	Name plate				
RPR / RMFR	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body	Body
Date of RPR/RMFR	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body	Body
API 16A revision for RPR/RMFR acceptance	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body	Body
Model or type	Name plate	Name plate	Name plate	Name plate or body				Name plate or body	

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Marking	Ram Blowout Preventer	Annular Blowout Preventer	Hydraulic Connector	Operators	Drilling Spools, Spacer Spools, Mandrels, and Adapters	Loose Connection	OECs (Integral and Loose) ^d	Clamps	Ram Blocks
Size	Name plate ^a	Name plate ^a	Name plate ^a	Name plate or body ^a	Name plate ^a	Connection OD ^{a, b, c}	Connection OD	Name plate or body ^e	
Rated working pressure	Name plate ^a	Name plate ^a	Name plate ^a	Name plate or body ^a	Name plate ^a	Connection OD ^{a, b, c}	Connection OD	Name plate or body ^e	
Metallic temperature rating	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body	
Serial number (if applicable)	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body	Body
Part number	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body	Body
API 16A product description code as repaired or remanufactured	Name plate	Name plate	Name plate	Name plate or body	Name plate	Connection OD ^{a, b, c}	Connection OD	Name plate or body ^e	
Hydr system rated working pressure	Name plate	Name plate	Name plate	Name plate or body					
Hydr system recommended operating pressure	Name plate	Name plate	Name plate	Name plate or body					
Top connection	Name plate	Name plate	Name plate		Name plate				
Top gasket type	Name plate	Name plate	Name plate		Name plate				
Bottom connection	Name plate	Name plate	Name plate		Name plate				
Bottom gasket type	Name plate	Name plate	Name plate		Name plate				
Outlet connection	Name plate	Name plate	Name plate		Name plate	Connection OD ^{a, b, c}	Connection OD ^c	Name plate or body	
Outlet gasket type	Name plate	Name plate	Name plate		Name plate	Connection OD ^{a, b, c}	Connection OD ^c	Name plate or body	
a) All type 16B and 16BX hub connections shall be marked on the neck of the connection, 12 mm (1/2 in) max. from the required length of the neck. b) All flanges shall be marked in accordance with API 6A. c) If the ring groove is overlaid with corrosion-resistant material, it shall be marked "CRA." d) All API 6A OECs shall be marked in an easily accessible and readable area selected by the manufacturer. e) The size designation in the PDC may be replaced by the two-digit clamp number in accordance with API 16A. If the clamp number is used, the rated working pressure code shall be replaced by the letters "CC."									

Date of RPR/RMFR/MFR shall be marked month and year e.g. March 2016 is coded as 0316

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Unknown information for markings for equipment that is repaired or remanufactured shall be left blank.

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 and remanufacture that reduce original API 16A ratings shall be noted on the repair and 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 Corrosion-resistant Overlay

When equipment has weld-metal-overlaid ring grooves, the ring gasket type and number shall be followed by "CRA" to designate a nickel-based alloy or "SST" to designate an austenitic stainless steel.

10.4 Wellbore Nonmetallic Components

For identification of wellbore nonmetallic components, such as ram and annular-type BOP packers and seals, the remanufacturer shall have a written procedure for affixing the required codification to the product or its package.

The remanufacturer shall retain a COC for nonmetallic sealing materials and molded sealing assemblies to manufacturer's written requirements.

The remanufacturer's part number shall be marked on the component and uses the alphanumeric code system as defined in API 16A.

10.5 Non-wellbore Nonmetallic Components

Identification of non-wellbore nonmetallic components, such as elastomeric seals used in ram and annular type BOP actuation systems, shall be in conformance with the OPD or CPD specification.

10.6 Specific Codification Requirements of Equipment

Ring gaskets shall be marked in accordance with API 6A.

Low-alloy studs and nuts shall be marked in accordance with API 16A.

Closure bolting shall be marked in accordance with API 16A.

Wellbore nonmetallic components shall be marked with an alphanumeric code system in the sequence denoted in API 16A.

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

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11 Storing and Shipping

11.1 Storing Periods Greater than 30 Days

11.1.1 Draining after Testing

Equipment shall be drained after testing and prior to storage.

11.1.2 Corrosion Prevention

Prior to storage, parts and equipment shall have exposed metallic surfaces protected with a corrosion preventative that does not become fluid at temperatures below 50 °C (125 °F).

11.1.3 Connection-surface Protection

Connection faces and ring gasket grooves shall be protected with durable covers.

11.1.4 Hydraulic Operating System

The hydraulic operating system shall be flushed with a nonfreezing, corrosion-inhibiting fluid in accordance with the equipment manufacturer's written procedures.

Ports shall be plugged prior to storing.

NOTE Equipment may be stored with customer-specified control fluid to avoid contamination with corrosion inhibiting fluid.

NOTE It is recommended to attach weatherproof labels on the outside of the connector near the operating control ports "Shipped with fluid xxxxx."

CAUTION Mixing of OEM or CEM control fluids can create highly caustic compounds. These compounds can cause extreme damage to lip seal elastomers.

11.1.5 Elastomeric Seals

Elastomeric seals shall be stored in accordance with the manufacturer's written procedures.

11.1.6 Ring Gaskets

Loose ring gaskets shall be wrapped or boxed for storage and shipping.

11.1.7 Galvanic Corrosion

Preservation procedures shall be implemented that mitigate the effect of galvanic corrosion.

11.2 Shipping

Equipment shall be shipped in accordance with the remanufacturer's written procedures.

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12 Certification

12.1 General

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

The certificate shall contain a statement from the company's authorized representative verifying that all relevant records have been reviewed and found to be in conformance to the applicable standard.

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 repair and remanufacturing of drill-through equipment performed in conformance with this standard, the OEM or CEM shall issue a COC.

NOTE The COC confirms the equipment meets the requirements of the CPD.

Replacement parts shall be in conformance with the CPD.

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

12.3 Certificate of Service

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

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

COS's issued under this standard, shall follow the requirements of 0.

12.4 Statement of Fact

On completion of drill-through equipment inspections, testing and/or repair which meets the reduced / limited scope defined by the equipment owner a SOF shall be issued.

SOF's issued under this standard, shall follow the requirements of Annex K.

NOTE The SOF does not fulfill the requirements of a COC or other documents verifying product definition.

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Annex A **(normative)**

General Equipment Specifications

A.1 General

NOTE This annex provides specifications for repair and remanufacture of equipment covered by the scope of API 16AR.

A.2 BOPs and Drilling Spools

A.2.1 Size Designation

Equipment to which this standard is applicable shall have a vertical through-bore dimension (drift diameter) corresponding with the size designation as per API 16A.

A.2.2 Service Conditions

A.2.2.1 Rated Working Pressure

The rated working pressure shall be determined by the lowest pressure rating of all integral end or outlet connections. Equipment to which this standard is applicable shall be rated in only the rated working pressures defined in API 16A.

A.2.2.2 Temperature Ratings

A.2.2.2.1 General

Minimum temperature is the lowest ambient temperature to which the equipment may be subjected. Maximum temperature is the highest temperature of the fluid that may flow through the equipment.

A.2.2.2.2 Temperature Ratings for Metallic Materials

Equipment shall be repaired or remanufactured such that the metallic parts meet the temperature classification marked on the assembly identification plate as per API 16A.

Equipment manufactured under API 16A from which traceability is lost or from which material properties cannot be reconstructed shall be temperature classified to T-0.

A.2.2.2.3 Temperature Ratings for Nonmetallic Sealing Materials

Wellbore elastomeric materials shall meet the temperature classification as per API 16A.

Other elastomeric seals shall be designed to operate within the temperature ranges specified in the OEM's written specifications or OPD.

A.2.2.2.4 Wellbore Elastomeric Materials

The purchaser shall provide the temperature range for which wellbore elastomeric materials must operate.

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A.2.3 Outlet Connections

The purchaser shall determine the number, location, size, pressure, and temperature ratings for all outlet connections.

NOTE The pressure rating for the BOP or drilling spool is determined by the lowest pressure rating of all end or outlet connections.

Flanged end and outlet connections shall be in conformance to the dimensional requirements of API 6A and API 16A, prior to assembly and testing.

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Annex B (normative)

Manufacturing Data Book Requirements

The below mentioned document contents for the construction of the manufacturing data book provides the minimum traceability requirements for manufacturing of pressure control equipment.

Manufacturing Data Book

Document Contents	Delivered to Equipment Owner	Maintained by Manufacturer
Date of manufacturing/assembly	√	√
Purchase order number/sales order number	√	√
Date of factory acceptance testing	√	√
Part and serial numbers of equipment and location (including elastomers)	√	√
Assembly drawings	√	√
Manufacturer's COC—include listing of the specification(s) to which equipment is certified	√	√
Design verification documentation		√
Third-party review certificate	When in purchase order	√
Third-party approval certificate	When in 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	√	√
Material specification number	√	√
WPS/PQR third-party customer review records	As required on purchase order	√
NDE records:		
a) surface NDE records	√	√
b) volumetric NDE	√	√
c) repair weld NDE records	√	√

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Document Contents	Delivered to Equipment Owner	Maintained by Manufacturer
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)	√	√.
Bolting traceability records as per API 16A	√	√
<i>Documentation required as defined in API 16A is retained by the OEM/CEM for required retention period</i>		√

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Annex C (normative)

Product History File Requirements

Traceability shall be provided by the remanufacturer in the product history file for the parts repaired, remanufactured or replaced in conformance with this specification.

Product History File

Document Contents	Delivered to Equipment Owner	Maintained by Remanufacturer
Manufacturing data book	For newly manufactured 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 includes the standard to which equipment is certified to	√ Conformance to Annex E	√
Serial numbers of equipment and location	√	√
Parts traceability records	√ Listing RSLs and PR of parts	√
PMI test	√	√
Material specification number	√	√
Welding process records (if applicable)		

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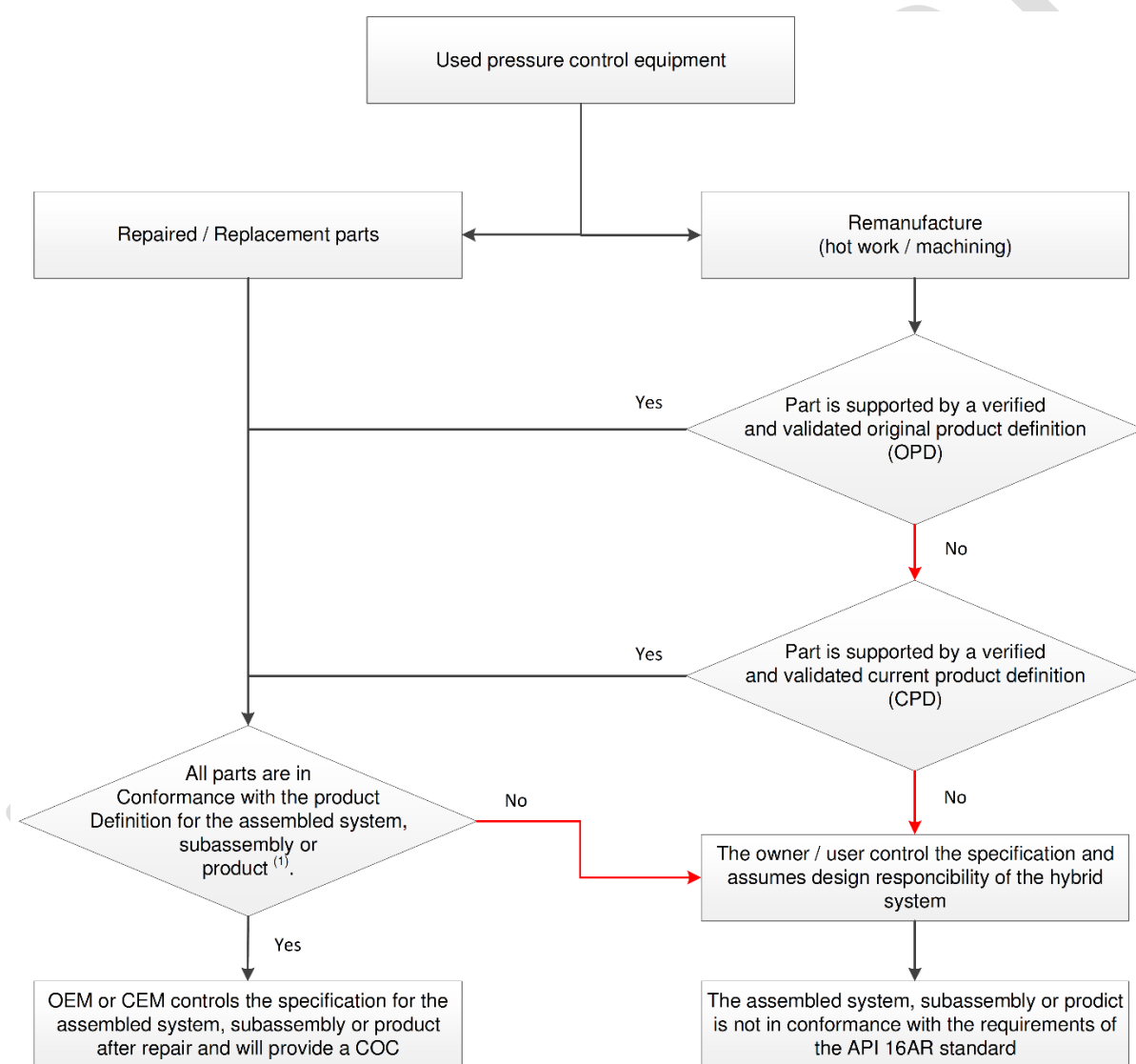
Document Contents	Delivered to Equipment Owner	Maintained by Remanufacturer
Weld datasheet that includes: — welder ID — filler metal — welding consumable records — heat and/or batch number — WPS # — weld map — weld inspection records — PWHT records — sketch of local PWHT heater size location and thermocouples location	√	√
Documentation as defined in API 16AR is 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 16A	√	√
Engineering reviews (for deviations to the OPD or CPD) Operational limitations related to the engineering review	√	√
Statement of fact that includes: — description of the work done — pressure tests records — disassembly records — origin and serial numbers of parts replaced	√	√
COS	√	√

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Annex D (normative)

Design Ownership

If alterations to the design to API 16A equipment (whose limitations are tested during API 16A PR1 or PR2 validation testing) are made by anyone other than the OEM, the assembly, part, or component shall not be considered an OEM product. The party that performs these alterations shall be then designated as the CEM. The CEM shall design verify and validate the product to API 16A PR1 or PR2 when the design ownership has changed. Validation testing level (PR1 or PR2) after design ownership changes shall be documented on the COC and MDB or PHF.



NOTE 1 RSL requirements preclude the traceability requirements in the product definition.

Figure D.1—Design Ownership Flow Diagram

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Ballot Draft

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Annex E

(normative)

Minimum Requirements for Certificate of Conformance

E.1 General

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

E.2 Certificate Requirements

E.2.1 Company Information

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

- a) company name;
- b) company address;
- c) company telephone number.

E.2.2 Certification Identification

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

E.2.3 Certificate Issue Date

The COC shall contain the date when it is issued.

E.2.4 Customer Information

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

E.2.5 Assurance

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

The certificate shall contain a statement or list that confirms which API 16A 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 and remanufacture.

E.2.6 Ratings

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

- a) rated working pressure;

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- b) rated temperature of metallic components;
- c) design temperature of nonmetallic components;
- d) environmental limits, in conformance with API 16A under which the equipment was manufactured.

E.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 of each assembly or part number;
- c) description of the part or assembly, including PR level if applicable;
- d) unique number traceable to an item through a serial or batch number;
- e) RSL designation of the part or assembly;
- f) API 16A revision used to define material requirements for the assembly or part.

E.2.8 Reasons for Current RSL Designation and Other Technical Information

The certificate shall contain a statement or list that confirms the RSL level of the part or assembly and reason for the RSL designation.

E.2.9 Other Technical information

Any operational limitations or exclusions for the product or part.

E.2.10 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.

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Example

Company Logo	Company Name Company Address Company Telephone Number	<div style="border: 2px solid black; padding: 5px; display: inline-block;"> QR Code or Bar Code </div>
--------------	--	---

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 drill-through equipment remanufactured per the above purchase order and as listed below have been repaired and remanufactured in conformance with:

- API Standard 16AR, *Standard for Repair and Remanufacture of Drill-through Equipment*, Second 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 16A, "Specification for Drill-through Equipment," 3rd Edition

-

-

-

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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.	
Remanufacture specification level (RSL)	
Other limitation:	

D. List of inspected equipment:

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

E. Reasons for current RSL determination:

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

Signature

Signature

Name:
Title:

Name:
Title:

Company disclaimer or Quality disclaimer (if needed).

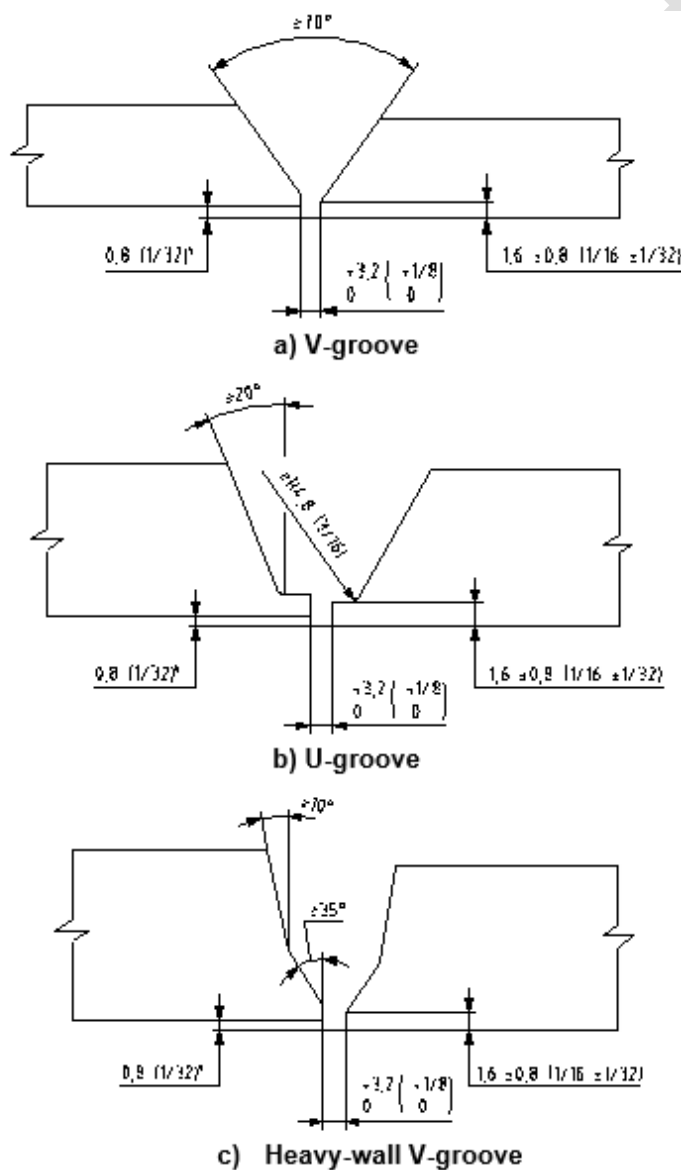
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Annex F (informative)

Recommended Weld Preparation Design Dimensions

Recommended weld preparation designs and dimensions shown in this annex (Figures F.1, F.2, F.3, and F.4) should be considered for joining parts through welding.

Dimensions in millimeters (inches) unless otherwise indicated.



Key

a Maximum misalignment.

Figure F.1—Typical Weld Grooves for Pipe Butt Joints

Dimensions in millimeters (inches) unless otherwise indicated



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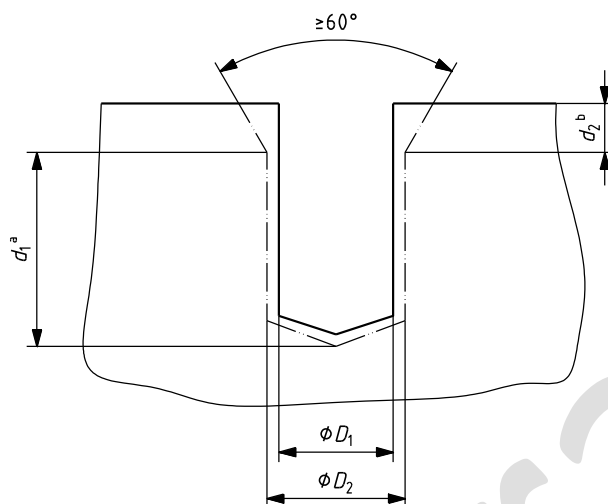
- a Maximum misalignment (unless removed by machining).
- b Remove to sound metal by machining.
- c Maximum misalignment.
- d Backing shall be removed. Material shall be compatible with base material.

Figure F.2—Typical Attachment Welds

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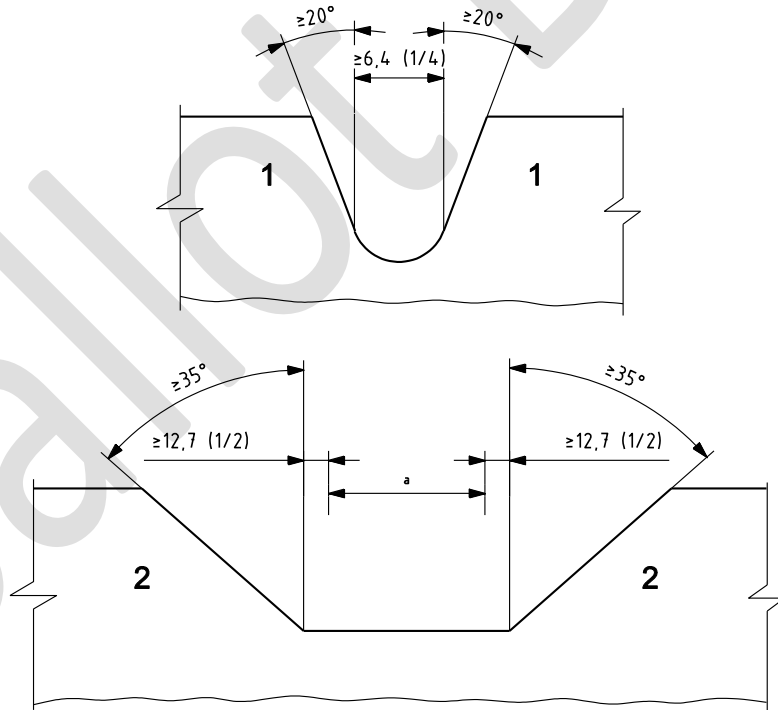
Dimensions in millimeters (inches) unless otherwise indicated



Key

- a Ratio of d_1 to D_2 shall not exceed 1.5:1.
- b Depth required to maintain a maximum of 1.5:1 depth, d_1 , to diameter, D_2 , ratio.

Figure F.3—Typical Repair Welds



Key

- 1 side
- 2 end

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^a Original area.

Figure F.4—Repairs

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Annex G

(normative)

Qualification of Heat Treating Equipment

G.1 General

Heat treatment of parts and QTCs shall be performed with equipment meeting the requirements of this annex.

G.2 Temperature Tolerance

The temperature at any point in the working zone shall not vary by more than $\pm 14^{\circ}\text{C}$ ($\pm 25^{\circ}\text{F}$) from the furnace set-point temperature after the furnace working zone has been brought up to temperature (SAE AMS 2750E, Class 5 or better). Furnaces that are used for tempering, aging, and/or stress relieving shall not vary by more than $\pm 8^{\circ}\text{C}$ ($\pm 15^{\circ}\text{F}$) from the furnace set-point temperature after the furnace working zone has been brought up to temperature.

G.3 Furnace Calibration

G.3.1 General

Heat treatment of production parts shall be performed with heat treating equipment that has been calibrated and surveyed.

G.3.2 Records

Records of furnace calibration and surveys shall be maintained for a period not less than 3 years.

G.3.3 Temperature Survey Method for Calibration of Batch-type Furnaces

A temperature survey within the furnace working zone(s) shall be performed on each furnace at the maximum and minimum temperatures for which each furnace is to be used.

A minimum of nine thermocouple test locations shall be used for all furnaces having a working zone greater than 0.3 m^3 (10 ft^3).

For each 3.5 m^3 (125 ft^3) of furnace working zone surveyed, at least one thermocouple test location shall be used, up to a maximum of 40 thermocouples. See Figures H.1 and H.2 for examples of thermocouple locations.

NOTE 1 For furnaces having a working zone less than 0.3 m^3 (10 ft^3), the temperature survey may be made with a minimum of three thermocouples located either at the front, center and rear, or at the top, center, and bottom of the furnace working zone.

After insertion of the temperature-sensing devices, readings shall be taken at least once every 3 minutes to determine when the temperature of the furnace working zone approaches the bottom of the temperature range being surveyed.

Once the furnace temperature has reached the set-point temperature, the temperature of all test locations shall be recorded at 2-minute intervals, maximum, for at least 10 minutes. Then readings shall be taken at 5-min intervals, maximum, for sufficient time (at least 30 minutes) to determine the recurrent temperature pattern of the furnace working zone.

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Before the furnace set-point temperature is reached, none of the temperature readings shall exceed the set-point temperature by more than 14 °C (25 °F).

After the furnace control set-point temperature is reached, no temperature reading shall vary beyond the limits specified. The temperatures within each furnace shall be surveyed within 1 year prior to use of the furnace for heat treatment.

When a furnace is repaired or rebuilt, a new temperature survey shall be carried out before the furnace is used for heat treatment, subject to the following.

- Repairs that return the furnace to the condition it was in at the time of the last furnace survey and calibration or repairs that do not affect the temperature tolerance of the furnace shall not require a new temperature survey and calibration.
- The SAE AMS 2750E sections on furnace modifications and furnace repairs shall be used to determine whether a new furnace survey is required.
- Furnace repairs and modifications shall be documented and the responsible quality assurance organization shall make determination whether an additional furnace survey and calibration is required based on the repairs or modifications in accordance with AMS 2750E.

NOTE 2 The scenarios in this annex are merely examples for illustration purposes only. They are not to be considered exclusive or exhaustive in nature. Each company develops its own approach.

G.3.4 Continuous-type Furnaces Method

Furnaces used for continuous heat treatment shall be calibrated in accordance with procedures specified in SAE AMS-H-6875B.

G.4 Instruments

G.4.1 General

Automatic controlling and recording instruments shall be used.

Thermocouples shall be located in the furnace working zone(s) and protected from furnace atmospheres by means of suitable protective devices.

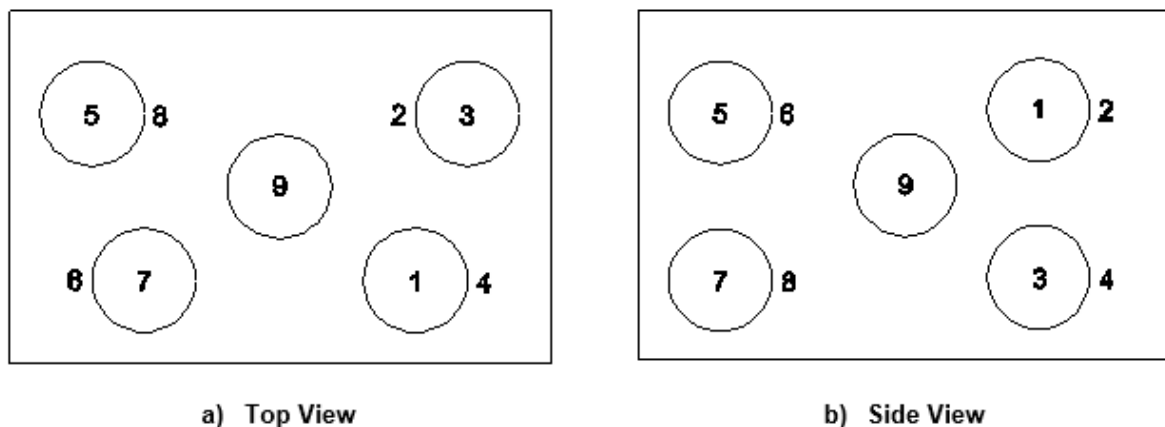


Figure G.1—Thermocouple Locations—Rectangular Furnace (Working Zone)

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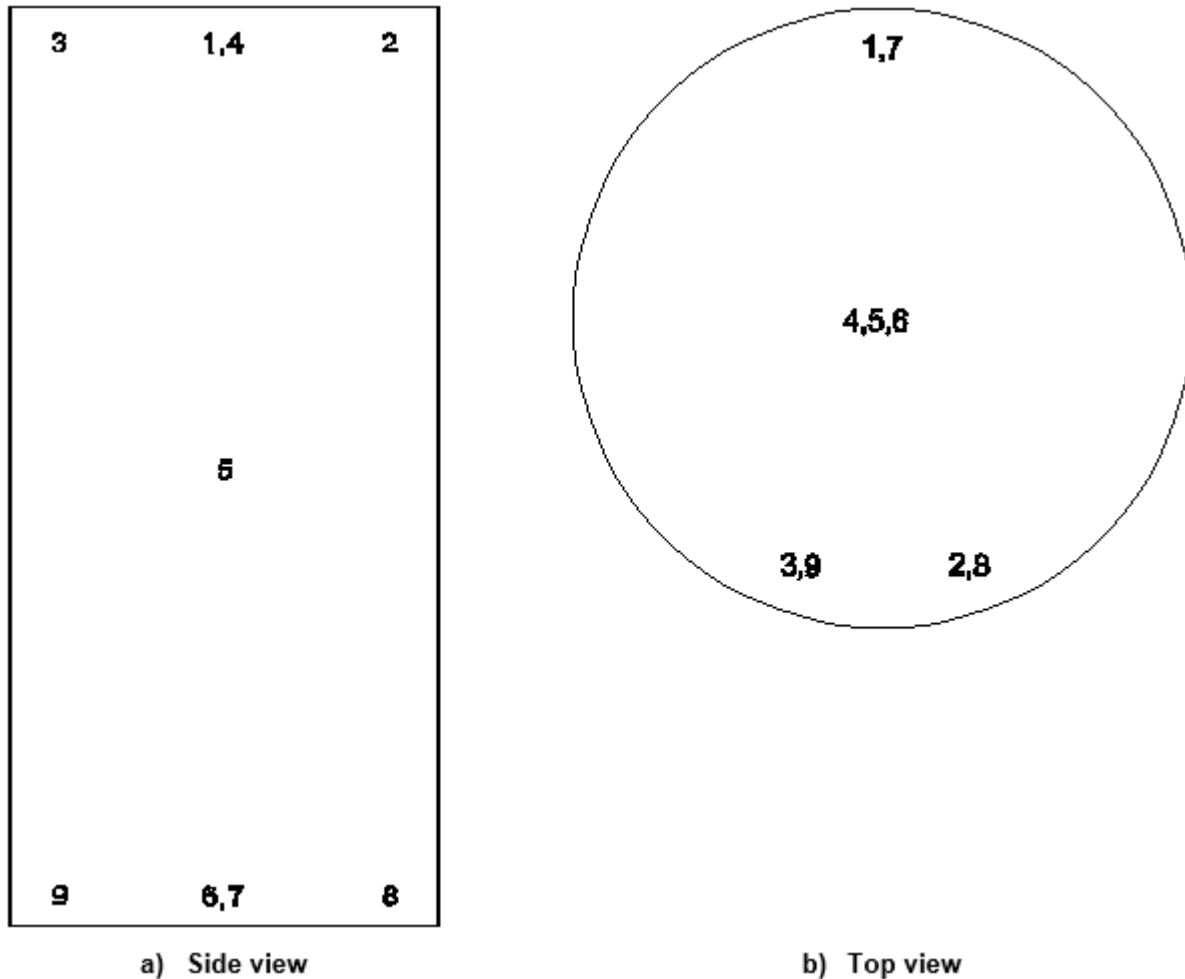


Figure G.2—Thermocouple Locations—Cylindrical Furnace (Working Zone)

G.4.2 Accuracy

The controlling and recording instruments used for the heat treatment processes shall be accurate to ± 1 % of their full-scale range.

G.4.3 Calibration

Temperature-controlling and -recording instruments shall be calibrated at least once every 3 months. Equipment used to calibrate the production equipment shall be accurate to ± 0.25 % of full-scale range.

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Annex H (informative)

Remanufacture and Replacement Parts

Figure H.1 can be used to assess the RSL for remanufactured and replacement parts, and illustrates the requirements of the specification.

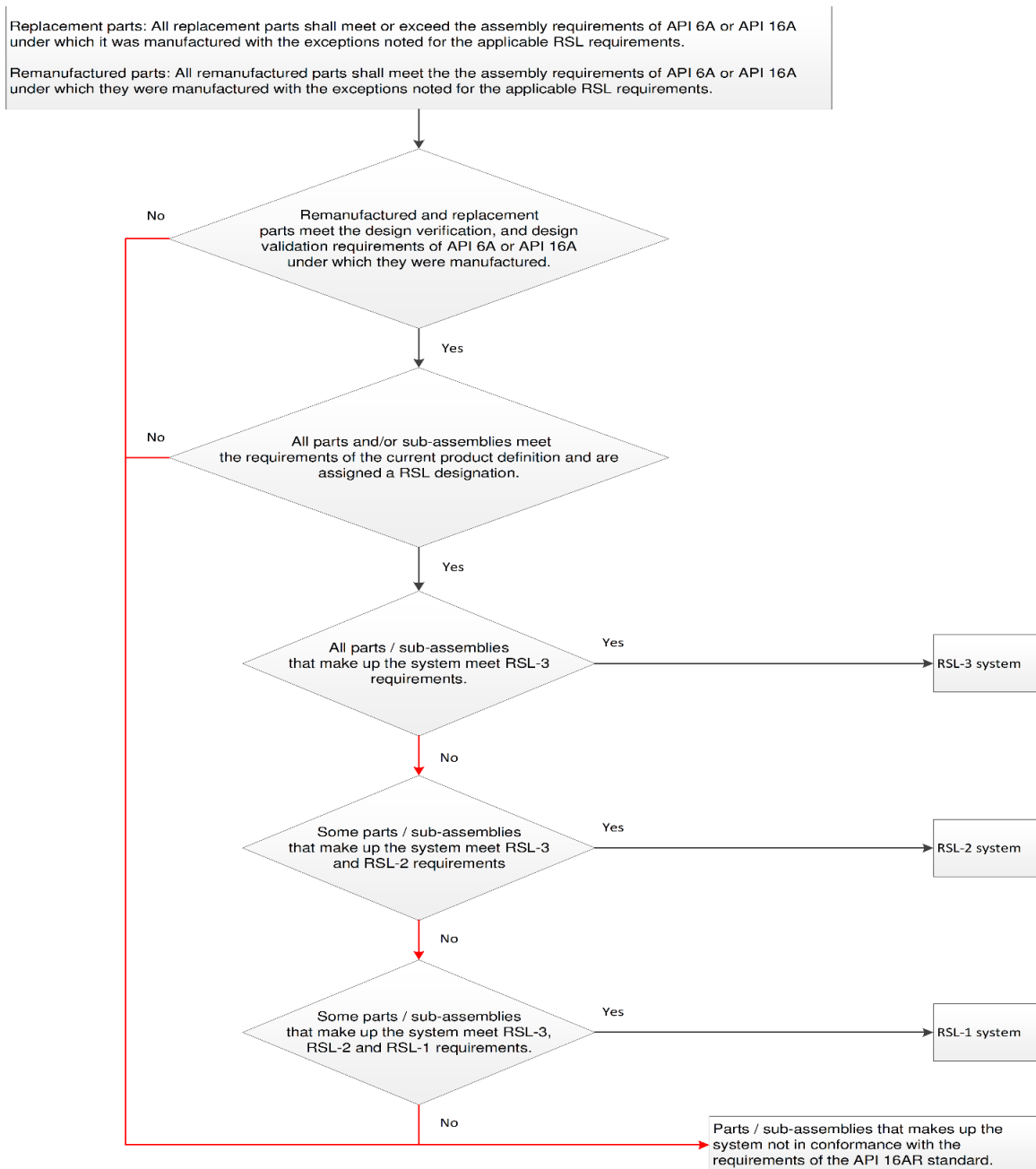


Figure H.1—Flow Diagram for Remanufactured and Replacement Parts

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Annex I

(normative)

Charpy V-notch Impact Tests Location for Weld Qualification

When impact testing is required, the testing shall be performed in accordance with the Charpy V-notch technique of ASTM A370.

U-groove Charpy specimen shall not be allowed.

Results of testing in the weld metal and fusion line (FL) shall meet the minimum design requirements for both average and minimum toughness requirements.

If one of the three specimens falls below the minimum allowed toughness requirement, then two additional Charpy test specimens shall be taken from that area. Each additional Charpy test specimen shall be at or above the minimum toughness requirement. Records of all results shall become part of the PQR.

If two or more of the valid Charpy test specimen fall below the minimum, a new coupon shall be welded. Mechanical testing, required for validating the PQR, shall be repeated for welding of a new coupon.

The number and location of Charpy V-notch impact test specimen shall be in accordance with Figure I.1 following the sampling requirements in relation with the material thickness and weld type and weld thickness used for the qualification:

- a) Single sided welds on material less or equal to 19 mm (0.75 in.)—Charpy specimens shall be taken from within 2 mm (0.08 in.) from the external surface, subject to the requirements for multi-process and double-sided welds;
- b) Double sided welds on material less or equal to 19 mm (0.75 in.)—Charpy specimens shall be taken from within 2 mm (0.08 in.) from both internal and external surfaces, subject to the requirements for multi-process and double-sided welds;
- c) Single sided and double sided welds on material greater than 19 mm (0.75 in.) to less than 38 mm (1.5 in.)—Charpy specimens shall be taken within 2 mm (0.08 in.) from both internal and external surface, subject to the requirements for multi-process and double-sided welds;
- d) Single sided and double sided welds on material greater or equal to 38 mm (1.5 in.)—Charpy specimens shall be taken within 2 mm (0.08 in.) from both internal and external surface, subject to the requirements for multi-process and double-sided welds.

Single pass welds and single pass welds used on the backside of a weldment shall be qualified on a separate WPS.

The thickness of a single pass weld shall be less than or equal to 12.5 mm (0.49 in.).

When impact testing is required, sets of three test specimens shall be removed from the weld metal and from FL.

If multiple welding processes are used to produce the weldment, the weld metal and FL test specimens shall be removed for each welding process.

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When a process is used for only root and hot pass in a test weldment, using a similar strength and family of filler metal (A-number from ASME Section IX) independent testing for root and hot pass shall not be required. However, if an independent WPS for the root and hot pass process is used or required, all required testing shall be carried out on a weld deposit of sufficient thickness.

Weld metal from the root region containing consumed tack welds made with different weld metal that remain in the final weldment shall be qualified.

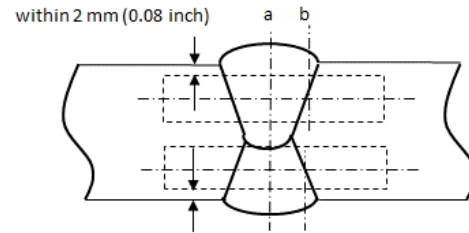
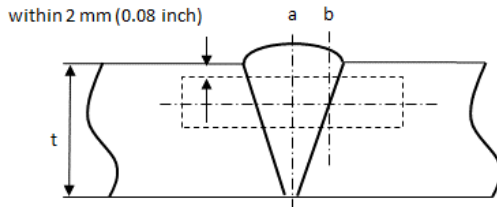
Existing weld qualifications made for carbon and low alloy steels, such as AISI 4130, AISI 8630, or ASTM A182 F22, with the GTAW process and that have higher CVN values in the WM compared to the HAZ and/or FL shall be supported by a engineering deposition.

NOTE 1 The preferred method for Charpy V-notch Impact Tests Location for Weld Qualification requires sets of three test specimens to be removed from the weld metal (WM) center line and fusion line (FL).

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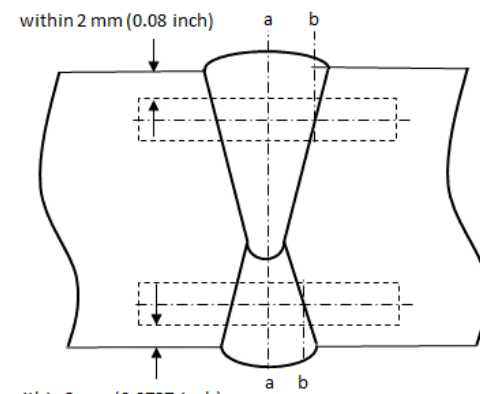
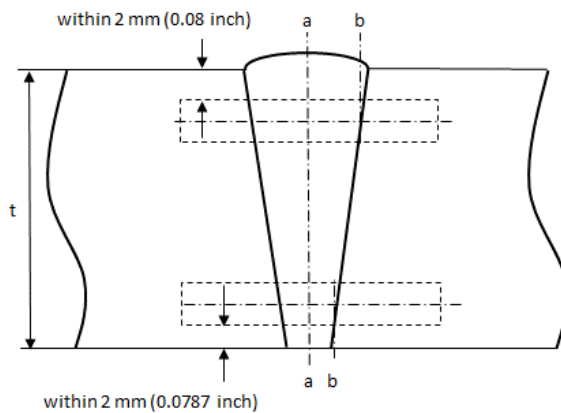
Single sided weld**Double sided weld**

Weld thickness $t \leq 19$ mm (0.75 inch)



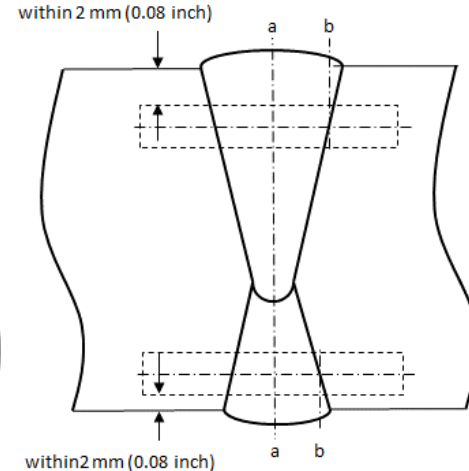
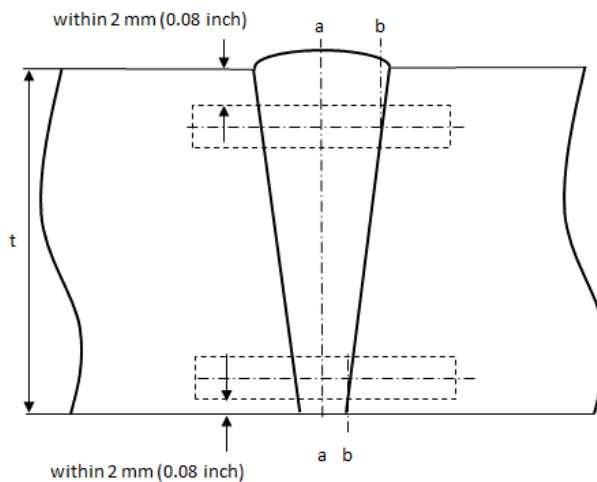
within 2 mm (0.0787 inch)

Weld thickness $t > 19 < 38$ mm ($> 0.75 < 1.5$ inch)



within 2 mm (0.0787 inch)

Weld thickness $t \geq 38$ mm (1.5 inch)



within 2 mm (0.08 inch)

Key

- a On weld center.
- b On fusion line (FL).

Figure I.1—Location of Charpy V-notch Impact Test

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Annex J

(normative)

Minimum Requirements for Certificate of Service

J.1 General

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

J.2 Certificate Requirements

J.2.1 Company Information

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

- a) company name;
- b) company address;
- c) company telephone number.

J.2.2 Certification identification

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

J.2.3 Certificate Issue Date

The COS shall contain the date when it is issued.

J.2.4 Customer Information

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

J.2.5 Assurance

The COS shall indicate that the equipment has been inspected, repaired and successfully tested 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 16AR.

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.

A.1.1 Ratings

The certificate shall include a list of applicable ratings, including a minimum of:

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- 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.

NOTE If one or more of the above ratings are unknown, it is acceptable to enter "unknown" as the rating

J.2.6 Work Performed

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

J.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 of each assembly or part number;
- c) description of the part or assembly, including PR level if applicable;
- d) number traceable to an item such as a serial or batch number if originally provided;

J.2.8 Other technical information

Any operational limitations or exclusions for the product or part.

J.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.

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Annex K

(normative)

Minimum Requirements for Statement of Fact

K.1 General

This annex provides the minimum requirements for the Statement of Fact for equipment covered by the scope of API Standard 16AR.

Format changes are allowed.

K.2 Statement Requirements

K.2.1 Company Information

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

- a) company name;
- b) company address;
- c) company telephone number.

K.2.2 Statement Issue Date

The SOF shall contain the date when it is issued.

K.2.3 Customer Information

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

K.2.4 Assurance

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

The SOF can serve as notification that a particular area or part that was serviced is FFS.

K.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.

K.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 of each assembly or part number;

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- c) description of the part or assembly, including PR level if applicable;
- d) number traceable to an item such as a serial or batch number if originally provided.

K.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 L

(normative)

PAUT for Bolts and Shafts

L.1 General

Phased Array Ultrasonic Testing (PAUT) examination shall be performed in accordance with a written procedure, in conformance with ASME BPVC, Section V, article 4 and ASME BPVC, Section V, article V, Mandatory Appendix IV, Inservice Examination of Bolts.

Changes of identified essential variables from the specified value, or range of values, shall require requalification of the written procedure.

PAUT inspections shall meet the requirements for that inspection in conformance with the OPD or CPD.

L.2 Personnel Qualification

Inspection personnel shall be certified as a UT Level 2 or 3 conforming to ISO 9712 or ASNT SNT-TC-1A or equivalent.

In addition, inspection personnel shall be certified to a minimum of PAUT Level 2 that conforms with ISO 9712 or ASNT SNT-TC-1A.

NDE personnel responsible for testing shall have a valid near vision acuity to Jaeger-J1 or equivalent tested annually and color vision documented eyesight certificate which shall be carried out in conformance with ISO 9712 or ASNT SNT-TC-1A.

Personnel other than medical professional or NDE Level 3 performing annual eye examinations shall have documented training by a medical professional or NDE Level 3.

NDE personnel responsible for setup, field calibration, collecting data, and interpreting data shall be -qualified to perform these inspections in accordance with the written procedure.

The NDE Level 3 shall verify that the NDE Level 2 personnel performing the inspections are trained and competent for use of the PAUT equipment in conformance with ASME section V, article 1 and article 4.

An NDE Level 3 certified in Ultrasonic Testing shall develop and approve the test technique, written procedure, and scan plans.

The service provider or client shall have the right to require personnel to demonstrate their capabilities to perform to the requirements of the qualified procedure.

L.3 Equipment Qualification

L.3.1 General

The PAUT equipment used to qualify the procedure shall conform to the requirements of ASME section V, article 4.)

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The required PAUT setups to capture the full volume of the bolt / shaft shall be captured in the final approved scan plan.

The PAUT equipment qualified, shall be capable to clearly detect the reference reflectors.

PAUT reference reflectors shall be in conformance with L.3.2.

The PAUT unit shall be capable of acquiring sufficient data during the data acquisition without interruption.

The results shall quantify both depth and locations of indications.

Equipment used for qualification shall describe the length of bolt / shaft that is under inspection.

The same couplant used for qualification shall be used for inspection.

L.3.2 PAUT Reference Reflectors

Reflectors used for PAUT shall not exceed the maximum dimensions as shown in Table L1.

Table L.1—Reflector Dimensions

Bolt/shaft Diameter	Notch Depth ¹	Notch Length
< 20 mm (0.8 in.)	<= 2 mm (0.08 in.) ²	2 mm (0.08 in.)
< 50 mm (2 in.)	<= 2 mm (0.08 in.)	3 mm (0.12 in.)
>= 50 mm (2 in.) < 75 mm (3 in.)	<= 2 mm (0.08 in.)	4 mm (0.16 in.)
>= 75 mm (3 in.)	<= 2.5 mm (0.1 in.)	4 mm (0.16 in.)
¹ Notch depth shall be measured from the bottom of the thread root to the bottom of the notch.		
² Reflector notch depth specified by OEM or CEM		

Reflector dimensions not meeting Table N.1 requirements, shall be specified and documented by the OEM or CEM.

Reflector dimensions based on fracture mechanics shall be provided by the OEM or CEM.

The OEM or CEM shall specify the relevant indication in the scan plan which requires the bolt or shaft to be removed for additional surface and / or volumetric NDE.

Relevant indication(s) shall be 40% of the reference amplitude of the notch depth.

The markings shall be comparable to the bolt/shaft head markings, raised or stamped.

The surface finish / condition shall be comparable to that of the test bolt / shaft.

The bolt/shaft calibration specimen shall contain reference reflectors representative of the failure modes common for the product or manufactures design requirements.

Bolt/shaft calibration specimen shall be of the same size and shape as the actual object to be inspected or reference inspections proof that diameters can vary without changing the sensitivity of the measurement.

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The reference reflectors shall be placed in high stress, corrosion or other crack initiation areas of the bolt / shaft where failure can occur and include Near Field region of the sound path where no complimentary setup is included.

Notch location(s) shall be equal or greater than one bolt / shaft diameter from each end.

Each plunge reflector shall be rotated at least 60 degrees with respect to the main bolt, stud or thread rod axis.

Reflectors at the bolt head radius, stud or thread rod end shall be 180 degrees rotated.

Wire reflector to be rotated 180 degrees with the plunge reflector on the bottom of the bolt, stud or thread rod axis.

Examples of reflectors on simulator bolt, simulator stud and simulated threaded bar are shown in Figure L.1, Figure L.2, and Figure L.3.

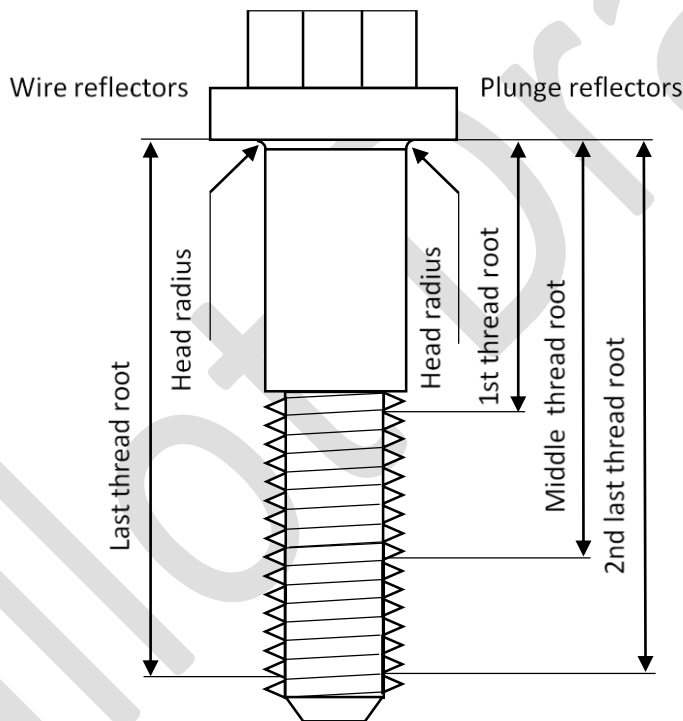


Figure L.1—Simulator Bolt

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Wire reflectors Plunge reflectors

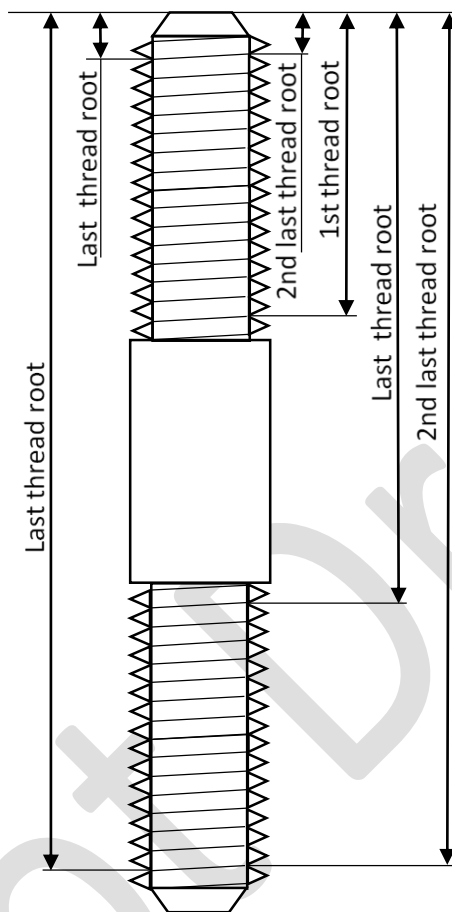


Figure L.2—Simulator Stud

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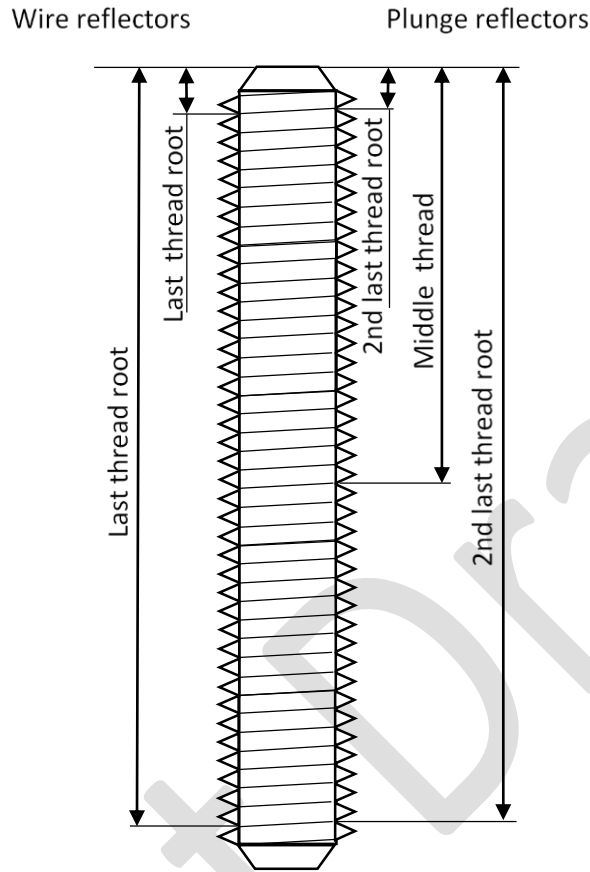


Figure L.3—Simulator Threaded Bar

L.3.3 PAUT Inspection Scanner, Encoder, and Data Acquisition Software

The PAUT inspection scanner shall support encoded scanning and be designed for the NDE inspection to be performed, either automated or semi-automated.

The same PAUT inspection scanner shall be used for both calibration and qualification of the NDE inspection method.

The following information shall be made available during the PAUT Inspection scanner qualification process:

- a) portable or stationary scanner;
- b) image of scanner;
- c) encoder hardware and software details;
- d) software details including revision number, transfer rate, data storage and number of active channels.

L.3.4 Probe(s), Materials, and Couplant

The UT frequency and size of the probe used shall be capable of detection of the entire length of bolt or shaft.

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The number of elements, size, gap, shape and pitch of elements shall be such that it provides necessary resolution of indications across the diameter and length of part under examination.

The following information shall be recorded for probe(s) as part of the system qualification process:

- a) probe manufacturer and type; including frequency, pitch and number of elements;
- b) probe sensitivity variation within +/- 3db;
- c) probe dimensions;
- d) material used to prevent probe wear;
- e) couplant type used.

L.4 Qualification Specimen

Personnel performing the test on the qualification specimen shall determine that the system is qualified to detect the types of defects associated with the bolting by using a flawed bolt with seeded defects that represent a realistic size and appearance of defects in all parts of the cross-section.

The qualification specimen shall be comparable in size and shape with the part under test.

L.5 Scan Plan

The content of the scan plan shall list the people and equipment qualification requirements.

Changes made in the scan plan that differs from the qualification shall require requalification.

The scan plan shall include at least the following:

- a) file name;
- b) part description and scan-plan sketch with dimensions;
- c) part Number;
- d) material type;
- e) PAUT procedure number and revision;
- f) instrument manufacturer and type;
- g) software and revision;
- h) probe manufacturer and type, including frequency, number of elements and dimensions;
- i) scanner type and manufacturer;
- j) scanning surface(s) and direction(both sides, single side, circumference);
- k) offset to bolt edge;

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- l) range settings;
- m) focal settings;
- n) processing features used;
- o) for E-scan;
- p) element start and stop;
- q) resolution;
- r) for S-scan;
- s) element start and stop;
- t) angular range;
- u) angular resolution;
- v) acceptance criteria;
- w) encoding requirements;
- x) essential variables and non-essential variables as per L.5.1;
- y) OEM / CEM NDE Level 3 Approval (Printed Full Name, Signature, Certificate number).

When requested in the purchase order, an independent review of the scan plan shall be provided to the customer.

L.5.1 Essential Variables and Nonessential Variables

The scan plan and the procedures shall be developed addressing the essential variables in conformance with Table L.2.

Table L.2—Requirements of Phased Array Linear Scanning Examination Procedures

Requirements (as Applicable)	Workmanship		Fracture Mechanics	
	Essential	Nonessential	Essential	Nonessential
Configurations examined, including design thickness and base material product form.	X	—	X	—
Surfaces from which examination is performed.	X	—	X	—
Surface condition (examination surface, calibration block).	X	—	X	—
Reference system and marking.	X	—	X	—
Personnel qualification requirements.	X	—	X	—
Personnel performance demonstration (if required).	X	—	X	—
Primary reference reflector and level.	X	—	X	—
Calibration [calibration block(s) and technique(s)].	X	—	X	—

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Requirements (as Applicable)	Workmanship		Fracture Mechanics	
	Essential	Nonessential	Essential	Nonessential
Standardization method and reflectors (wedge delay ¹ , sensitivity, TCG).	X	—	X	—
Computerized data acquisition.	X	—	X	—
Wedge cut/natural refracted angle ¹ .	X	—	X	—
Wedge contouring and/or stabilizing features ¹ .	X	—	X	—
Wedge height ¹ .	X	—	X	—
Wedge roof angle, if applicable ¹ .	X	—	X	—
Wedge type (solid wedge, water column, etc.) ¹ .	X	—	X	—
Wedge material ¹ .	X	—	X	—
Scanner type and fixturing.	X	—	X	—
Search unit mechanical fixturing device (manufacturer and model), adhering and guiding mechanism.	X	—	X	—
Search unit separation, if applicable.	X	—	X	—
Couplant brand name or type.	—	X	—	X
Instrument manufacturer and model, including all related operating modules.	X	—	X	—
Instrument software and revision ² .	X	—	X	—
Use of separate data analysis software and revision ² .	X	—	X	—
Search unit type (linear, dual linear, dual matrix, tandem, etc.).	X	—	X	—
Search unit detail (frequency, element size, number pitch, gap dimensions, element shape).	X	—	X	—
Technique(s) (straight beam, angle beam, contact, and/or immersion).	X	—	X	—
Angle(s) and mode(s) of wave propagation in the material.	X	—	X	—
Direction and extent of scanning.	X	—	X	—
Scanning technique (line vs. raster).	X	—	X	—
Scanning technique (automated vs. semiautomated).	X	—	X	—
Scanning (manual vs. encoded).	X	—	X	—
Scan increment (decrease in overlap).	X	—	X	—
Use of scan gain over primary reference level.	X	—	X	—
Virtual aperture size (i.e., number of elements, effective height, and element width).	X	—	X	—
Focus length and plane (identify plane projection, depth, or sound path, etc.).	X	—	X	—
For E-scan:				

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Requirements (as Applicable)	Workmanship		Fracture Mechanics	
	Essential	Nonessential	Essential	Nonessential
• Range of element numbers used (i.e., 1–126, 10–50, etc.).	X	—	X	—
• Element incremental change (i.e., 1, 2, etc.).	X	—	X	—
• Rastering angle.	X	—	X	—
• Aperture start and stop numbers.	X	—	X	—
<u>For S-scan:</u>				
— Aperture element numbers (first and last).	X	—	X	—
— Decrease in angular range used (i.e., 40 deg to 50 deg, 50 deg to 70 deg, etc.).	X	—	X	—
— Maximum angle incremental change (i.e., 1/2 deg, 1 deg, etc.).	X	—	X	—
For compound E-scan and S-scan: all E-scan and S-scan variables apply.	X	—	X	—
Digitizing frequency.	X	—	X	—
Net digitizing frequency (considers digitization frequency together with points quantity or other data compression).	X	—	X	—
Instrument dynamic range setting.	X	—	X	—
Pulser voltage.	X	—	X	—
Pulse type and width.	X	—	X	—
Filters and smoothing.	X	—	X	—
Pulse repetition frequency.	X	—	X	—
Maximum range setting.	X	—	X	—
Use of digital gain.	X	—	X	—
Method for discriminating geometric from flaw indications.	X	—	X	—
Flaw characterization methodology.	X	—	NA	NA
Method for measuring flaw length.	X	—	X	—
Method for measuring flaw height.	NA	NA	X	—
Method for determining indication location relative to surface.	NA	NA	X	—
Method for determining indication relative to other indications.	NA	NA	X	—
Records, including minimum calibration data to be recorded (e.g., instrument settings).	—	X	—	X
Post-exam cleaning.	—	X	—	X

NOTE: NA = not applicable.

¹ Applicable for PAUT weld inspection.

² Use of later software revisions shall be evaluated by the Level 3 for their impact on the functions as used. A limited extension of qualification may be determined to prove software functions. For example, addition of a software feature more capable than that already

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Requirements (as Applicable)	Workmanship		Fracture Mechanics	
	Essential	Nonessential	Essential	Nonessential
qualified may be qualified by reanalysis of existing data. If a revision is implemented, personnel shall receive training in use of the revised software.				

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L.6 Calibration and Verification Requirements

L.6.1 Instrument Periodic Verification

Display height linearity verification: Annually

Amplitude control linearity verification: Annually

Time-based linearity verification: Annually

Transducer element verification: Monthly

L.6.2 System Calibration

Controls which impact instrument linearity (such as filters) shall remain in the same position for examination as for calibration, calibration checks, and instrument linearity verifications.

Reject control shall remain off during all examinations and calibrations.

Search unit cables, adapters, connectors and splitters shall be capable of transmitting and receiving signals in a repeatable manner without altering the produced results.

System calibration shall include the complete ultrasonic examination system.

Focal laws used during calibration shall be identified on the scan plan.

L.6.3.1 The following calibrations shall be performed:

- a) time base;
- b) angle corrected gain;
- c) time corrected gain (TCG);
- d) encoder (within 1% of the distance moved).

The calibration set-up files used shall be saved and stored digitally and be provided to the customer on request.

L.6.3.2 A calibration check on at least one of the reference reflectors shall be made at the following stages of inspection:

- a) at the start and finish of each examination or series of similar examinations;
- b) at 4-hour intervals;
- c) system parameter or component is changed or change in settings is suspected;
- d) change of examination personnel.

If any distance range point has moved on the sweep line by more than 10% of its value or 5% of full sweep (whichever is greater), the distance range calibration shall be corrected.

Recorded indications since the last valid calibration or calibration check, shall be reexamined and their values shall be changed on the data sheets or re-recorded.

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If sensitivity settings change by more than 20% or 2db of its amplitude, the sensitivity calibration shall be corrected and documented in the examination record.

If sensitivity settings decrease, data sheets since the last valid calibration or calibration check shall be marked void.

The area covered by the voided data shall be reexamined.

If sensitivity increases, recorded indications since the last calibration or calibration check shall be reexamined and their values shall be changed in the data sheets or re-recorded.

L.6.3 Calibration Block and Time Corrected Gain (TCG)

Time Corrected Gain Calibration shall be accomplished using calibration blocks that has side drilled holes at depths suitable for the TCG calibration to be accomplished for at least the nominal length of the part to be examined. Primary Reference sensitivity shall then be made on simulator specimen.

The TCG calibration block shall be made from a similar material, with similar grain structure and forming method.

A TCG shall be constructed on the applicable calibration block for each setup to be used.

The TCG process shall include:

- a) Position the search unit to maximize the response from the first Side Drilled Hole (SDH) and adjust instrument gain to establish a reference level of 80% full screen height.
- b) Repeat this process for the applicable SDH's located at greater depths.
- c) The TCG shall encompass the entire area of interest.

Calibration files shall be saved to digital setup file and be verified whenever the setup file is opened.

L.7 Bolt/Shaft Simulator Specimen

The simulator specimen shall conform to L.3.2.

The PAUT equipment and setup shall be capable to detect the reflectors as defined in L.3.2.

The primary reference level shall be identified by adjusting the reference level to match the applicable notch in the simulator specimen.

Primary reference level shall be defined for each respective zone (1/4T, 1/2T, 3/4T, 1T) and positioned approximately 90 deg apart, see figure L4.

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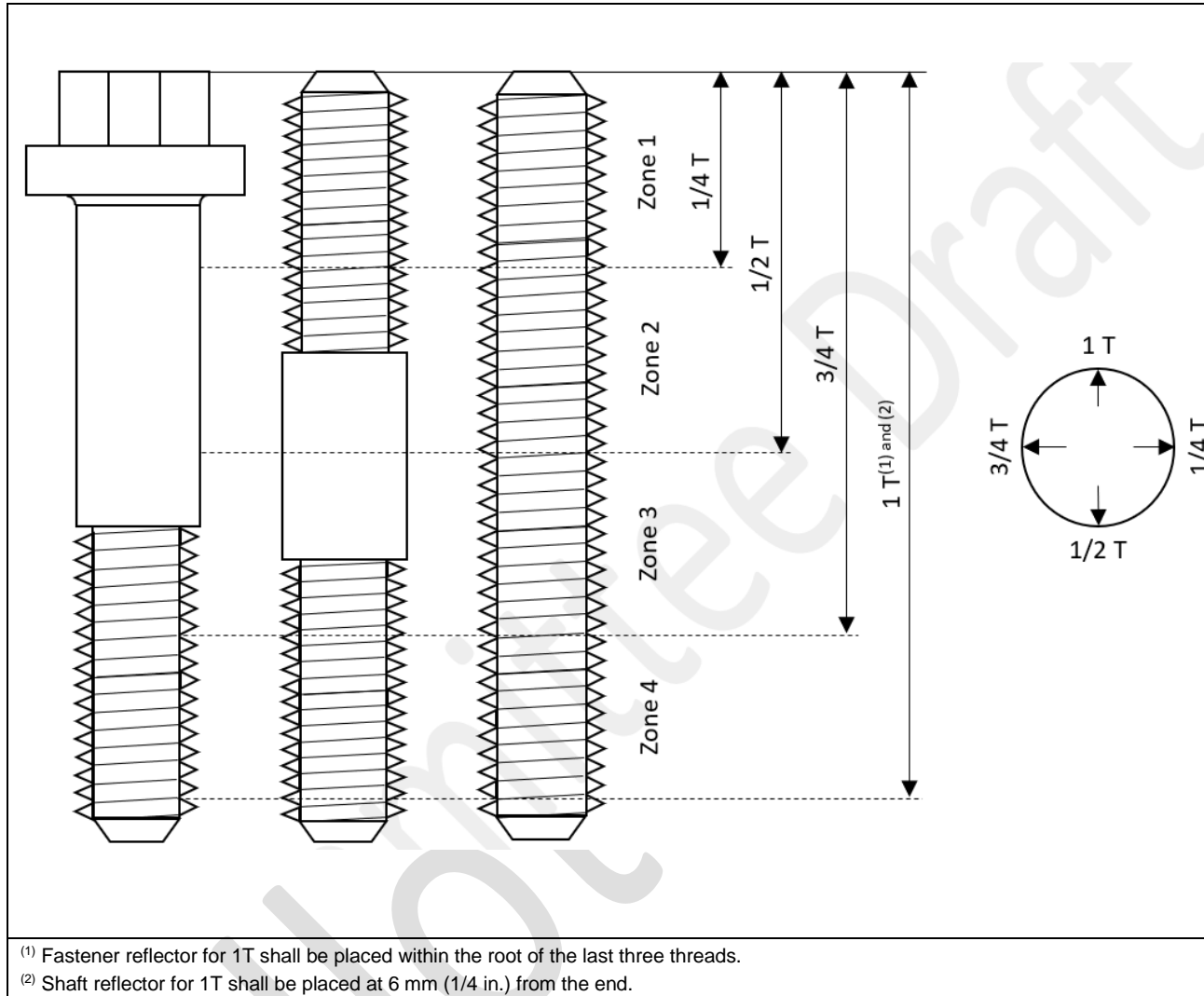


Figure L.4—Primary Reference Level Zones

The reference level shall be set to 80% for scanning the respective zones, at 1/4T, 1/2T, 3/4T and 1T see figure 3.

L.8 Temperature

The surface temperature of the test piece shall not exceed 120°F (50°C) and shall be within 25°F (14°C) of the calibration block and simulator specimen, at time of calibration.

Note: Heating or cooling of calibration specimen or simulator specimen is permissible.

L.9 Surface Preparation For Examination

Transducer contact surface(s) shall be cleaned and free from any burrs that can affect the measurement(s).

Inspection surface(s) shall be as smooth as possible and free from scale.

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Where possible, corrosion products shall be removed on exposed examination surface(s).

L.10 Examination

Examination shall be performed on production component(s) equivalent to the simulator block(s) and be examined for its complete 360° circumference.

Restrictions to the examination shall be identified in the examination report.

L.10.1 Rate of Search Unit Movement

The rate of search unit movement for examination shall be chosen such that clear images are generated.

No more than 5% of the total number of lines collected in a single scan shall be omitted.

Scanning speed shall be adjusted to ensure that all scan lines and adjacent lines are recorded.

L.10.2 Acquisition Rate

The maximum acquisition rate shall be set such that no interference of signals is obtained.

L.10.3 Transfer Correction

Transfer correction shall be performed and the primary reference level raised or lowered by the transfer correction.

Transfer correction shall be set by adjusting the back wall to 80% of the full screen height using the applicable simulator block.

Coupling the transducer to the production part under examination shall be performed to record the difference in amplitude between the production part and the simulator block, which is the transfer correction.

The transfer correction shall be added to amplitude to become the new reference gain.

Where the surface finish requires a transfer correction greater or equal to 6 dB, the measurement shall be approved by a NDE Level 3 prior to examination.

L.10.4 Scanning Sensitivity

Primary reference level shall be increased by a minimum of 6dB during examination.

L.10.5 Evaluation

Final evaluation shall be performed at primary reference level.

The TCG shall be set with Side Drilled Holes (SDH) so that each angle reflects from the same surface.

NOTE The reference blocks as defined in Annex N include notches and are unsuitable for setting up the TCG.

NOTE It is recognized that not all ultrasonic reflectors indicate flaws, since certain geometric conditions (such as bolt threads) may produce indications that are not relevant.

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The location, amplitude and extent of reflectors that produce an amplitude response greater than 40% of the reference level shall be investigated to determine whether the indication originates from a flaw, or is a geometric indication, to the extent that it can be evaluated in terms of the acceptance criteria.

Flaw sizing shall be performed by measuring the vertical extent (in the case of cracks) or the cross-sectional distance (in the case of volumetric / planar flaws) at the 6 dB levels once the flaw has been isolated and the image normalized.

Discontinuities detected by PAUT shall be characterized minimally by defining:

- a) characterization of the flaw;
- b) location and length of the flaw;
- c) depth of the flaw;
- d) volumetric position of the flaw within the bolt or shaft.

L.10.6 Non-relevant Indications

Reflectors equal to, or less than 40% of the reference level shall be considered non-relevant.

Geometric (non-relevant) indications shall be reviewed and recorded if they interfere with the examination (identification, maximum amplitude, location and extent).

Flaw size(s) defined in the scan plan that appear planar or crack-like shall be further investigated and based on requirement, re-examination or other supplemental examination shall be investigated using supplementary NDE method(s) as applicable.

L.10.7 Relevant Indications

Relevant indications shall be defined as indication in the material which produce an amplitude response greater than 40% of the reference level.

Indications greater than 40% of the reference level shall be investigated to the extent that they can be evaluated in terms of acceptance criteria defined in the scan plan.

L.10.8 Defect(s)

Indications shall be established in the acceptance criteria defined in the scan plan.

L.10.9 Flaw Length

The flaw length shall be determined using the 6dB drop method.

The A-scan and S-scan displays shall be used in unison with the screen cursors to perform the 6dB drop method.

L.10.10 Flaw Height

Flaw height sizing shall be assessed using the methods specified in ASTM E-2192, Standard Guide For Planner Flaw Height Sizing by Ultrasonics.

Acceptance criteria for flaw height shall be documented in the scan plan.

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During calibration the flaw height sizing method shall be verified using the calibration block reflectors.

L.10.11 Acceptance criteria

Acceptance criteria shall be defined in the scan plan.

Acceptance criteria shall be supported by an engineering calculation and / or analysis.

Future inspection frequency shall depend on the results from the PAUT investigation.

Flaw size(s) measured shall be mapped and compared to previous measurements.

L.11 Reporting

The following information shall (as a minimum) be recorded in the PAUT examination report:

- a) ultrasonic instrument identification (including manufacturer's serial number);
- b) search unit(s) identification (including manufacturer's serial number, frequency and size, pitch, gap, number of elements);
- c) couplant used, brand name or type;
- d) search unit cable(s) used, type and length;
- e) special equipment when used (search units, shoes, fixtures, automatic scanning equipment, recording equipment, etc.);
- f) computerized program identification and revision when used;
- g) calibration block identification;
- h) simulation block(s) and electronic simulator(s) identification when used;
- i) instrument reference level gain;
- j) instrument calibration or calibration due date;
- k) calibration data [including reference reflector(s), indication amplitude(s), and distance reading(s)];
- l) data correlating simulation block(s) and electronic simulator(s), when used, with initial calibration;
- m) object and drawing references;
- n) material type dimensions;
- o) surface conditions;
- p) temperature of the object;
- q) identification and location of volume scanned;
- r) surface(s) from which examination was conducted;

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- s) areas of restricted access, i.e. limited scanning due to surface condition or inaccessibility due to location;
- t) scan plan (including qualified range of variables);
- u) guiding/scanning mechanism used;
- v) transfer correction values if applicable;
- w) final display processing levels;
- x) supplemental manual technique(s) indication data, if applicable:
 - 1) couplant used, brand name or type;
 - 2) indication data.
- y) flaw characterization;
- z) flaw height sizing method(s);
- aa) instrument settings to include (if applicable), excitation pulse type, duration and voltage settings, averaging, Fast Fourier Transform, digitization rate (e.g., nominal rate as affected by compression and points quantity), rectification, pulse repetition rate, range start and stop, band pass filters, smoothing, focal type, and length;
- bb) focal law parameters, including, as applicable, angle or angular range, focal depth and plane, element numbers used, angular or element incremental change, and start and stop element numbers or start element number;
- cc) extent of testing;
- dd) acceptance level and procedure used;
- ee) sketch, photograph, photocopy, video, written description showing location and information regarding observed indications;
- ff) examination results;
- gg) signatures of personnel responsible for testing, place and date of examination;
- hh) original scanning data, unprocessed, shall be saved electronically and stored for future reference and/or comparison with subsequent inspections.

NOTE Items applicable to calibration may be documented by a separate record, provided this calibration record is included in the examination record.

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