Specification for Marine Drilling Riser Couplings

API SPECIFICATION 16R
FIRST EDITION, JANUARY 1997

EFFECTIVE DATE: JUNE 1, 1997

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Exploration and Production Department

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Specification for Marine Drilling Riser Couplings

1 SCOPE

1.1 Purpose

This specification pertains to the design, rating, manufacturing and testing of marine drilling riser couplings. Coupling capacity ratings are established to enable the grouping of coupling models according to their maximum stresses developed under specific levels of loading, regardless of manufacturer or method of make-up. This specification relates directly to API Recommended Practice 16Q, which pertains to the design, selection, and operation of the marine drilling riser system as a whole.

1.2 Organization

This specification is organized into distinct sections for easy reference. Section 3 contains a description of the function of marine riser couplings, along with the definition of relevant terms. Section 4 includes service classifications and design criteria. Materials and welding requirements are included in Section 5 and dimensions in Section 6. Section 7 covers quality control. Design qualification testing requirements are spelled out in Section 8, and product marking requirements are provided in Section 9. Section 10 defines requirements for operation and Maintenance manuals. Appendixes A, B, and C provide analysis, testing, and design, information.

2 REFERENCES

This specification includes by reference, either in total or in part, the API and industry standards listed in this section. The latest edition of these standards shall be used unless otherwise noted.

API

RP 16Q	*Design, Selection, Operation and Maintenance of Marine Drilling Riser Systems*
Spec 6A	*Specification for Wellhead and Christmas Tree Equipment*

ASME[1]

Boiler and Pressure Vessel Code, Sections V, VIII, and IX

ASTM[2]

A-370	*Mechanical Testing of Steel Products*
E-10	*Brinell Hardness of Metallic Materials*
E-18	*Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials*
E-92	*Vickers Hardness of Metallic Materials*
E-94	*Radiographic Testing*
E-165	*Liquid Penetrant Examination*
E-709	*Magnetic Particle Examination*
E-747	*Design, Manufacture and Material Grouping Classification of Wire Image Quality Indicators Used for Radiography*

AWS[3]

AWS D1.1	*American Welding Society Structural Welding Code*

3 DEFINITIONS

3.1 Function

A marine riser coupling provides a means of quickly connecting and disconnecting riser joints. The coupling box or pin (depending on design type) provides a support to transmit the weight of the suspended riser string to the riser handling spider while running or retrieving the riser. Additionally, the coupling may provide support for choke, kill and auxiliary lines, and load reaction for buoyancy devices.

3.2 Nomenclature

For the purposes of this specification, the following definitions apply. A comprehensive list of definitions pertaining to marine drilling riser systems is contained in API Recommended Practice 16Q.

3.2.1 auxiliary line: An external conduit (excluding choke and kill lines) arranged parallel to the riser main tube for enabling fluid flow. Examples of these lines include a control system fluid line, a buoyancy control line, and a mud boost line.

3.2.2 buoyancy: Devices added to the riser joints to reduce their submerged weight.

3.2.3 choke and kill (C&K) lines: External conduits, arranged parallel to the main tube, used for circulation of fluids to control well pressure. Choke and kill lines are primary pressure-containing members.

3.2.4 coupling: A mechanical means for connecting two joints of riser pipe end-to-end.

3.2.5 marine drilling riser: A tubular conduit serving as an extension of the wellbore from the well control equipment on the wellhead at the seafloor to a floating drilling rig.

[1]American Society of Mechanical Engineers, 1950 Stemmons Freeway, Dallas, Texas 75207.
[2]American Society of Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187.
[3]American Welding Society, Inc., 550 Northwest LeJeune Road, Miami, Florida 33126.

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3.2.6 preload: Compressive bearing load developed between box and pin members at their interface; this is accomplished by elastic deformation induced during makeup of the coupling.

3.2.7 rated load: A nominal applied loading condition used during coupling design, analysis, and testing based on a maximum anticipated service loading. Under the rated working load, no average section stress in the riser coupling shall exceed allowable limits established in this specification.

3.2.8 riser coupling box: The female coupling member.

3.2.9 riser joint: A section of riser pipe having ends fitted with a box and a pin, typically including integral choke, kill and auxiliary lines.

3.2.10 riser main tube: The basic pipe from which riser joints are fabricated.

3.2.11 riser coupling pin: The male coupling member.

3.2.12 stress amplification factor (SAF): Equal to the local peak alternating stress in a component (including welds) divided by the nominal alternating stress in the pipe wall at the location of the component. This factor is used to account for the increase in the stresses caused by geometric stress amplifiers which occur in riser components.

3.3 Design Types

Coupling designs may or may not require coupling preload. Coupling design types include, but are not limited to, the types defined in this section.

3.3.1 breech-block coupling: A coupling which is engaged by partial rotation of one member into an interlock with another.

3.3.2 collet-type coupling: A coupling having a slotted cylindrical element joining mating coupling members.

3.3.3 dog-type coupling: A coupling having dogs which act as wedges mechanically driven between the box and pin for engagement.

3.3.4 flange-type coupling: A coupling having two flanges joined by bolts.

3.3.5 threaded coupling: A coupling having matching threaded members to form engagement.

4 DESIGN

4.1 Service Classifications

The coupling manufacturer shall provide design information for each coupling size and model which defines load capacity rating. These data are to be based on design load (defined in 4.5) and verified by testing (specified in 8.2).

4.1.1 SIZE

Riser couplings are categorized by size of the riser main tube. Riser pipe outer diameter and wall thickness (or wall thickness range) for which the coupling is designed shall be documented.

4.1.2 RATED LOAD

The rated loads listed in this paragraph provide a means of general classification of coupling models based on stress magnitude caused by applied load. To qualify for a particular rated load, neither calculated nor measured stresses in a coupling shall exceed the allowable stress limits of the coupling material when subjected to the rated load. The allowable material stresses are established in 4.6.

The rated loads are as follows:

a. 0.500 million pounds.
b. 1.000 million pounds.
c. 1.250 million pounds.
d. 1.500 million pounds.
e. 2.000 million pounds.
f. 2.500 million pounds.

4.1.3 STRESS AMPLIFICATION FACTOR

The calculated SAF values for the coupling shall be documented at the pipe-to-coupling weld and at the locations of highest stress in the pin and box. SAF is a function of pipe size, and wall thickness. It is calculated as follows:

$$SNA = \frac{Local\ peak\ alternating\ stress}{Nominal\ alternating\ stess\ in\ BHE\ pipe} \quad (1)$$

4.1.4 RATED WORKING PRESSURE

Riser couplings shall be designed to provide a pressure seal between joints. The manufacturer shall document the rated internal working pressure for each coupling design.

4.2 Riser Loading

A drilling riser's ability to resist environmental loading depends primarily on tension. Environmental loading includes the hydrodynamic forces of current and waves and the motions induced by the floating vessel’s dynamic response to waves and wind.

The determination of a riser's response to the environmental loading and determination of the mechanical loads acting upon and developed within the riser require specialized computer modeling and analysis. The general procedure used to determine riser system design loads and responses is described in API Recommended Practice 16Q.

Additional sources of applied load that are not included in the rated load may significantly affect the coupling design and shall be included in design calculations.

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4.2.1 LOADS INDUCED BY CHOKE AND KILL AND AUXILIARY LINES

Riser couplings typically provide support for choke and kill and auxiliary lines. This support constrains the lines to approximate the curvature of the riser pipe. Loads can be induced on the coupling from pressure in the lines, imposed deflections on the lines, and the weight of the lines. The manufacturer shall document those loads induced by choke, kill, and auxiliary lines for which the coupling has been designed.

4.2.2 LOADS INDUCED BY BUOYANCY

Riser couplings may provide support for buoyancy, which induces loads on the couplings. The manufacturer shall document the buoyancy thrust loads for which the coupling has been designed.

4.2.3 LOADS INDUCED DURING HANDLING

Temporary loads are induced by suspending the riser from the handling tool and/or spider. The manufacturer shall document the riser handling loads for which the coupling is designed and how these loads are applied.

4.3 Determination of Stresses by Analysis

Design of riser couplings for static loading (4.6) and determination of the Stress and Amplification Factors (4.7) require detailed knowledge of the stress distribution in the coupling. This information shall be acquired by finite element analysis and subsequently validated by prototype strain gauge testing. A finite element analysis of the riser coupling must be performed and documented. The analysis must provide accurate or conservative peak stresses, and shall include any deleterious effects of loss of preload from wear, friction, and manufacturing tolerances. Suggestions for the analysis can be found in Appendix A. The following shall be documented and included in the analysis:

a. Hardware and software used to perform the analysis.
b. Grid size.
c. Applied loads.
d. Preload losses.
e. Material considerations.

4.4 Stress Distribution Verification Test

After completion of the design studies, a prototype (or multiple prototypes) of the riser coupling shall be tested to verify the stress analysis. The testing has two primary objectives: to verify any assumptions which were made about preloading, separation behavior, and friction coefficients and to substantiate the analytical stress predictions.

Strain gauge data shall be used to measure preload stresses as they relate to make-up load or displacement. Friction coefficients shall be varied (including at least two values) to establish sensitivity.

The coupling design load shall be applied to verify any assumption made in the analysis regarding separation.

Strain gauges shall be placed as near as physically possible to at least five of the most highly stressed regions as predicted by the finite element analyses performed in accordance with 4.3 and in five locations away from stress concentrations. Rosettes shall be used. All strain gauge readings and the associated loading conditions shall be recorded in a manner that they may be retained as part of the coupling design documentation.

Normal design qualification tests may be performed simultaneously with this stress distribution verification testing. These are defined in 8.2.

Note: It is often difficult to acquire sufficient strain data to totally correlate with the analytical results. High stress areas may be inaccessible and are sometimes so small that a strain gauge gives an average rather than the peak value. The testing should serve to verify the pattern of strain in regions surrounding the critical points.

4.5 Coupling Design Load

The coupling design load represents the maximum load carrying capacity of the coupling. The manufacturer shall establish the design load for each coupling design based on the methods and criteria given in this specification. Neither calculated nor measured stresses in a coupling shall exceed the allowable stress limits of the coupling material when subjected to the design load. The allowable material stresses are established in 4.6. The coupling's rated load (4.1.2) must be equal to or less than the coupling's design load.

For simplicity, the design loading condition is taken to be axisymmetric tension. In using this simplification, riser bending moment is converted to equivalent tension (T_{EQ}.) The coupling design load can be specified either as an axisymmetric tension of magnitude T_{DESIGN} or it may be considered to be any combination of tension (T) and bending moment (M) so that:

$$T + \frac{Mc}{I} A = T + M \frac{32t(d_o - t)^2}{d_o^4 - (d_o - 2t)^4} = T + T_{ER} = T_{DESIGN}$$

Where:
- c = mean radius of riser pipe.
- I = moment of inertia of riser pipe.
- A = cross-sectional area of riser pipe.
- d_o = outside diameter of riser pipe.
- t = wall thickness of riser pipe.

Using this relationship, the calculated riser pipe stress at the middle of the pipe wall caused by pure bending is treated the same as that caused by pure tension. To classify a particular coupling design, only the axisymmetric tensile load (T_{DESIGN}) case need be considered.

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While the coupling design load provides a means of grouping coupling models regardless of manufacturer or method of makeup, it does not include all loads affecting coupling design. Auxiliary loads as defined in 4.2 shall also be included in the evaluation of coupling designs.

4.6 Design for Static Loading

4.6.1 GENERAL

The design of a riser coupling for static loading requires that it support the design load and preload, if any, while keeping the maximum cross-sectional stresses within specified allowable limits.

4.6.2 RISER COUPLING STRESSES

For all riser coupling components except bolts, stress levels shall be kept below the values provided in Appendix C.

For load-carrying bolts in bolted-flange couplings, the manufacturer shall document the design allowable stress levels in the bolts. Acceptance criteria for these bolt stresses shall be based on recognized codes and standards.

4.7 Stress Amplification Factor

Field experience suggests that the most likely cause of a riser coupling failure is propagation of a fatigue crack which has initiated at a point of stress concentration. It is, therefore, incumbent upon the designer to endeavor to minimize the conditions leading to the initiation and propagation of fatigue cracks. The Stress Amplification Factor (SAF) is intended to provide the coupling user with information needed to estimate fatigue damage for a particular application without extensive fatigue testing of the coupling. The SAF is a function of the double amplitude range of alternating stress.

It is important to note that the SAF value depends largely on the exhaustiveness of the finite element analysis and the validity of assumptions in the analysis. Assumptions such as load distribution, the correctness of preloading in field service, and finite element size at critically stressed points necessitate individual evaluation for each design case. Calculation of SAF is not intended to substitute for a comprehensive fatigue life analysis.

The following procedure shall be used for an individual coupling design:

a. Select the rated load from 4.1.2.

b. Perform finite element analysis, as described in 4.3, to determine maximum equivalent combined stresses for the following loads:

1. L_1 = Nominal preload plus 0.2 × rated load.
2. L_2 = Nominal preload plus 0.4 × rated load.
3. L_3 = Nominal preload plus 0.6 × rated load.
4. L_4 = Nominal preload plus 0.8 × rated load.
5. L_5 = Minimum preload plus 0.2 × rated load.
6. L_6 = Minimum preload plus 0.4 × rated load.
7. L_7 = Minimum preload plus 0.6 × rated load.
8. L_8 = Minimum preload plus 0.8 × rated load.

c. Verify the finite element analysis by strain gauge test of prototype in accordance with 4.4.

d. Identify high stress points in the structure and the pipe-to-coupling weld. For each, record the local peak stresses L_1 through L_8 (using von Mises theory, explained in more detail in Appendix C) for loading conditions L_1 through L_8.

e. Calculate the SAFs for the pin and for the box of the coupling. If SAF varies with load or preload, document this variation.

4.8 Design Documentation

For each size, model, and service classification, the following documentation shall be retained by the manufacturer for a period of at least ten years after the manufacture of the last unit of that size, model, and service classification:

a. Design loads (tensile, bending, loads from auxiliary lines, and others) as defined in 4.2.

b. Finite Element Analysis performed in accordance with 4.3.

c. Results of tests performed in accordance with 4.4 and 8.2.

d. Results of SAF and peak stress calculations in accordance with 4.7.

5 MATERIAL SELECTION AND WELDING

5.1 Material Selection

5.1.1 GENERAL

Material selection for each component of the riser coupling shall include consideration of the type of loading, the temperature range, the corrosive conditions, strength requirements, durability, toughness, and the consequences of failure. Documentation of these design parameters shall be retained by the riser system manufacturer throughout the service life of the riser system. All materials used shall conform to a written specification covering chemical composition, physical and mechanical properties, method and process of manufacture, heat treatment, weldability, and quality control. Such written specification may be either a published or manufacturer proprietary document.

All materials for primary load carrying components, including weld metals, shall be low alloy steels having properties, as represented by test coupons conforming to the specifications of 5.1.5. Test coupons shall be cut from a separate or attached block, taken from the same heat, and when applicable, formed similarly and given the same heat treatment as the product material they represent.

5.1.2 CHEMICAL COMPOSITION

All materials shall conform to the chemical composition provided in the manufacturer's written specification. Conform-

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ance with the manufacturer's composition specification shall be demonstrated by mill analysis or test sample verification.

5.1.3 MECHANICAL PROPERTIES

All materials shall meet the minimum and maximum mechanical properties specified in the manufacturer's written specification. Materials for primary load carrying components, including weldments, shall additionally meet the minimum mechanical properties in Table 1.

Table 1—Minimum Mechanical Properties

Property	Minimum Value
Elongation	18%
Reduction of area	35%

Mechanical testing shall be performed per ASTM A-370, E-8 after all heat treatment for mechanical properties and using representative test coupons conforming to the specifications of 5.1.5.

5.1.4 IMPACT TESTING

Materials for components that are in the load path, including weldments, shall meet the following minimum Charpy V-Notch impact values:

a. Average for three specimens: 30 ft-lbs @ -4°F (-20°C).
b. Minimum single value: 21 ft-lbs @ -4°F (-20°C).

Mechanical testing shall be performed per ASTM A-370, E-23 after all heat treatment for mechanical properties and shall use representative test coupons. Notch impact tests shall be performed with the test specimens oriented longitudinally to the grain orientation of the parent metal.

5.1.5 TEST SPECIMENS

Test specimens shall be taken from a qualified test coupon (QTC) as defined by API Specification 6A, PSL3.

5.1.5.1 Tensile and Impact Testing

Tensile and impact test specimens shall be removed from the same QTC after the final QTC heat treatment cycle.
Tensile and impact specimens shall be removed from the QTC so that their longitudinal centerline axis is wholly within the center core ¼ T envelope for a solid QTC or within ¼ inch of the mid-thickness of the thickest section of a hollow QTC (refer to Figure 1).

When a sacrificial production part is used as a QTC, the impact and tensile test specimens shall be removed from the ¼ T location of the thickest section in that part.

5.1.5.2 Hardness Testing

The following steps apply to hardness testing:

a. A minimum of two Brinell hardness tests shall be performed on the QTC after the final heat treatment cycle.
b. Hardness testing shall be performed in accordance with procedures specified in ASTM A 370.
c. The hardness of the QTC shall meet the manufacturer's written specification.

5.2 Welding

Welding procedures and processes shall be in accordance with API Specification 6A, PSL3.

6 DIMENSIONS AND WEIGHTS

6.1 Coupling Dimensions

Riser couplings are categorized by sizes of the mating riser pipe. Riser pipe and the associated couplings are generally sized to be compatible with a specific blowout preventer (BOP) stack size. Compatible blowout preventer bore and riser outer diameter combinations are shown in Table 2. The make-up length, butt weld to butt weld, shall be documented.

Table 2—Compatible BOP Bore and Riser Outer Diameter Combinations

BOP Bore	Riser Outer Diameter
13 5/8″ (346.1 mm) BOP	16″ (406.4 mm) riser
16 3/4″ (425.5 mm) BOP	18 5/8″ (473.1 mm) riser
18 3/4″ (476.3 mm) BOP	20″ (508 mm) or 21″ (533.4 mm) riser
20 3/4″ (527.1 mm) BOP	22″ (558.8 mm) or 24″ (609.6 mm) riser
21 1/4″ (539.8 mm) BOP	24″ (609.6 mm) riser

Note: A given coupling size may be used with a range of riser pipe outside diameters, wall thicknesses, and material yield strengths.

6.2 Coupling Weight

The coupling weight for each coupling size shall be documented. The weight of a riser coupling shall include the sum of the in-air weights of the structural components of the coupling, the lock mechanisms, and the brackets or clamps that support the end extremities of auxiliary and choke and kill lines. The coupling weight includes the in-air weight of any and all parts that contribute to the submerged, in-service weight of the coupling.

7 QUALITY CONTROL

7.1 General

All records required by this specification shall be retained by the manufacturer for a period of ten years after the manufacture of the last unit of that size, model, and service classification.

7.2 Raw Material Conformance

7.2.1 TRACEABILITY

Parts in the primary load path shall be traceable to the individual heat and heat treatment lot.

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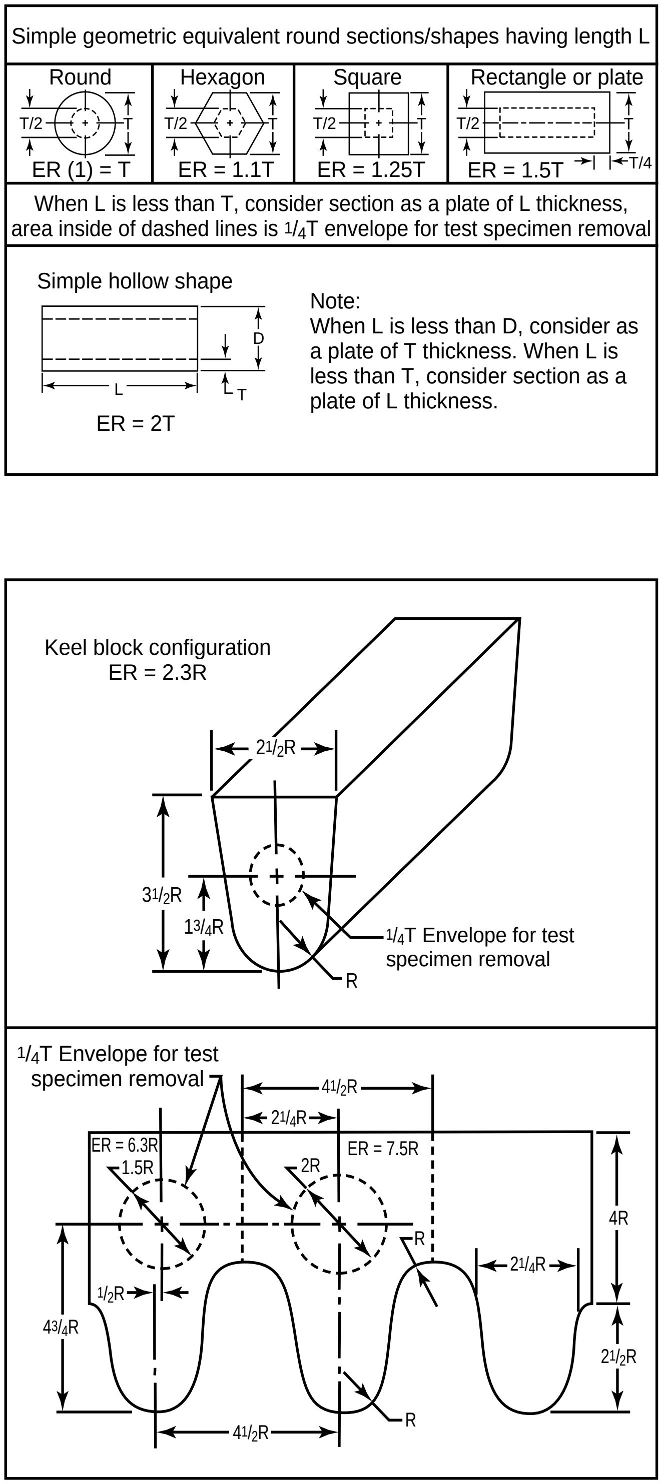

Figure 1—Equivalent Round Models

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

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

7.2.2 CHEMICAL ANALYSIS

Chemical analysis shall be performed in accordance with a recognized industry standard.

The chemical composition shall be in accordance with the manufacturer's written specification.

7.3 Manufacturing Conformance

The manufacturer shall retain drawings and documentation by serial number and part number regarding material properties, heat numbers, riser tube dimensions, minimum through bore, service classifications, and date of manufacture, as well as design documentation as required by 4.8. In addition, the following steps are required.

7.3.1 VISUAL EXAMINATION

The requirements for visual examination are as follows:

a. Each part shall be visually examined.
b. Visual examinations of castings and forgings shall be performed in accordance with the manufacturer's written specification.
c. Acceptance criteria is in accordance with manufacture's written specifications.

7.3.2 SURFACE NONDESTRUCTIVE EXAMINATION (NDE)

All surfaces of each finished part shall be inspected in accordance with this section.

7.3.2.1 Surface NDE Ferromagnetic Materials

Well fluid wetted surfaces and all accessible sealing surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by either magnetic particle (MP) or liquid penetrant (LP) methods.

7.3.2.2 Surface NDE Non-ferromagnetic Materials

All accessible well fluid wetted surfaces of each finished part shall be inspected after final heat treatment and after final machining operations by liquid penetrant method.

7.3.2.3 Methods

Magnetic particle examination (MP) shall be in accordance with procedures specified in ASTM E-709. Yoke prods are not permitted on well fluid wetted surfaces or sealing surfaces.

Liquid penetrant examination (LP) shall be in accordance with procedures specified in ASTM E-165.

7.3.2.4 Definitions for MP and LP

Indications pertaining to MP and LP are defined as follows:

a. Relevant indication: Only those indications with major dimensions greater than 1⁄16 inch shall be considered relevant. Inherent indications not associated with a surface rupture (for example, magnetic permeability variations and non-metallic stringers) are considered non-relevant. If magnetic particle indications are believed to be non-relevant, they shall be examined by liquid penetrant surface NDE methods or removed and reinspected to prove their non-relevancy.
b. Linear indication. Indication in which the length is equal to or greater than three times its width.
c. Rounded indication. Indication which is circular or elliptical with its length less than three times the width.

7.3.2.5 Acceptance Criteria for MP and LP

Acceptance criteria for surfaces other than pressure contact sealing surfaces are as follows:

a. No relevant indication with a major dimension equal to or greater than 3⁄16 inch.
b. No more than ten relevant indications in any continuous 6-square inch area.
c. Four or more relevant indications in a line separated by less than 1⁄16 inch (edge to edge) are unacceptable.

Acceptance criteria for pressure contact (metal-to-metal) sealing surfaces specifies there are to be no relevant indications in these surfaces.

7.3.3 WELD NDE

7.3.3.1 General

When examination is required, essential welding variables and equipment shall be monitored. The entire weld (including a minimum of ½ inch of surrounding base metal) shall be examined in accordance with the methods and acceptance criteria of this section.

7.3.3.2 Weld Prep NDE—Visual

One hundred percent of all surfaces prepared for welding shall be visually examined prior to initiating welding. Examinations shall include a minimum of ½ inch of adjacent base metal on both sides of the weld.

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Weld NDE surface preparation acceptance is per the manufacturer's written specification.

7.3.3.3 Post Weld Visual Examination

All welds shall be examined according to manufacturer's written specification.

All pressure containing welds shall have complete joint penetration.

Undercut shall not reduce the thickness in the area (considering both sides) to below the minimum thickness.

Surface porosity and exposed slag are not permitted on or within surfaces.

7.3.3.4 Weld NDE—Surface (other than visual)

One hundred percent of all welds in the primary load path, pressure containing welds, repair and weld metal overlay welds, and repaired fabrication welds shall be examined by either magnetic particle or liquid penetrant methods after all welding postweld heat treatment and machining operations are completed. Acceptable defect size may be established by industry accepted procedures or the following size criteria may be used.

Methods, definitions and acceptance criteria for magnetic particle and liquid penetrant examinations shall be the same as 7.3.2 except for the following:

a. No relevant linear indications.

b. No rounded indications greater than two-thirds of weld thickness.

c. No rounded indications greater than ⅛ inch for welds whose depth is ¾ inch or less or 3⁄16 inch for welds whose depth is greater than ¾ inch.

7.3.3.5 Repair Welds

At a minimum, all repair welds shall be examined using the same methods and acceptance criteria as used for the base metal (7.3.3.4).

Examination shall include ½ inch of the adjacent base metal on all sides of the weld.

Surfaces of ground out area for repair welds shall be examined prior to welding to ensure defect removal to the acceptance criteria of fabrication welds (7.3.3.2).

7.3.3.6 Weld NDE—Volumetric for Fabrication Weld

7.3.3.6.1 General

One hundred percent of welds in the primary load path shall be examined by either radiography or ultrasonic methods after all welding, postweld heat treatment, and machining operations. All repair welds in which the repair is greater than 25 percent of the original wall thickness or 1 inch (whichever is less) shall be examined by either radiography or ultrasonic methods after all welding, and postweld heat treatment operations. Examinations shall include at least on all sides of the weld.

7.3.3.6.2 Radiography

Radiographic examinations shall be performed in accordance with procedures specified in ASTM E-94, to a minimum equivalent sensitivity of 2 percent. Both X-ray and gamma ray radiation sources are acceptable within the inherent thickness range limitation of each. Real time imaging and recording/enhancement methods may be used when the manufacturer has documented proof that the methods will result in a minimum equivalent sensitivity of 2 percent. Wire type image quality indicators are acceptable for use per ASTM E-747.

Acceptance criteria specifies that no type of crack, zone of incomplete fusion, or penetration shall be allowed. No elongated slag inclusion shall be allowed which has a length equal to or greater than shown in Table 3.

Table 3—Maximum Length of Elongated Slag Inclusion for Radiography

Weld Thickness (T) (inches)	Inclusion Length (inches)
Less than 0.76	0.25
0.76 to 2.25	0.33 T
Greater than 2.25	0.75

In addition, there may be no 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. No rounded indications in excess of those specified in ASME Boiler and Pressure Vessel Code, Section VIII. Division I, Appendix 1 are permitted.

7.3.3.6.3 Ultrasonic

Ultrasonic examinations shall be performed in accordance with procedures specified in ASME Boiler and Pressure Vessel Code, Section V, Article 5.

No indications whose signal amplitude exceeds the reference level shall be allowed. No linear indications interpreted as cracks, incomplete joint penetration or incomplete fusion shall be allowed. No slag indications shall be allowed with amplitudes exceeding the reference level whose length exceeds the values shown in Table 4.

7.3.3.7 Weld NDE—Hardness Testing

All pressure containing, non-pressure containing, and repair welds shall be hardness tested.

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Table 4—Reference Level Length—Maximum Amplitude of Slag Indication for Ultrasonic Examinations

Weld Thickness (T) (inches)	Inclusion Length (inches)
Less than 0.76	0.25
0.76 to 2.25	0.33 T
Greater than 2.25	0.75

Hardness testing shall be performed in accordance with one of the following:

a. Vickers Method (ASTM E 92); ASTM E-10 (see Paragraph 5.2.4).
b. ASTM E-18.

At least one hardness test shall be performed in both the weld and in the adjacent unaffected base metal after all heat treatment and machining operations.

Hardness values shall meet the requirements of the manufacturer's written specification.

8 TESTING

8.1 Purpose

In addition to the stress distribution verification test prescribed in 4.4, three types of full-scale design qualification tests shall be performed: a load test to establish the rated load of the coupling design, a makeup test to demonstrate the ability of the coupling to be correctly made up in the field and the repeatability of proper make-up, and an internal pressure test to check pressure integrity and seal effectiveness. These tests shall be performed on a full-scale coupling specimen(s) to qualify the design of each coupling model.

Optional performance tests listed in Appendix B may also be included. A cyclic load or fatigue test may be performed to verify fatigue calculations and to check that no areas of stress concentration were overlooked in the design analysis. Cyclic testing to failure yields a data point to aid in predicting fatigue life. Other optional performance testing may be included to substantiate serviceability. To assure validity of the test results, the testing machine must be qualified and calibrated and so documented. The test coupling for all verification and qualification tests must be built to standard dimensions and manufacturing tolerances and have standard finishes, coatings, and materials. These tests and those described in 4.4 are for design evaluation only; they are not intended for in-service readiness testing.

8.2 Design Qualification Tests

8.2.1 LOAD RATING TEST

Axisymmetrical tensile load shall be applied to qualify the coupling design for a rated load per Section 4.1.

8.2.2 MAKEUP TEST

The manufacturer's standard makeup tools shall be used to apply preload to the coupling. Strain gauge readings from selected points on the coupling, performed in accordance with 4.4, should corroborate the values used in the analysis performed per 4.3. Measured preload stresses shall meet or exceed the minimum required preload stresses over at least ten successive makeup sequences.

8.2.3 INTERNAL PRESSURE TEST

Internal water pressure equal to the coupling rated working pressure shall be applied with no structural failure or leaks.

9 MARKING

9.1 Stamping

All riser couplings manufactured in accordance with this specification shall be marked on an appropriate external surface with the information listed in 9.2. Metal impression stamp shall be used in low stressed area on both box and pin ends.

9.2 Required Information

The following information is required:

a. Manufacturer's name or mark and part number.
b. Rated load.
c. Rated working pressure.
d. Nominal diameter.
e. Identifying serial number.
f. Date of manufacture.

Note: Additional traceable information is specified in Section 7.

Note: The rated load or rated working pressure of the coupling may be greater than that of an assembled riser joint.

10 OPERATION AND MAINTENANCE MANUALS

The manufacturer shall provide operation and maintenance manuals which shall include, at a minimum, the information listed in this section.

10.1 Equipment Description

A written description, drawings and applicable schematics shall be provided for the riser coupling and interfacing equipment as follows:

a. The riser coupling box, pin, locks, brackets, etc.
b. Riser handling tool.
c. All makeup and preload tools.
d. Riser coupling box and pin protectors.

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10.2 Guidelines for Coupling Usage

The following information should be addressed:

a. Use of the handling tool and its interface with the coupling.
b. Coupling makeup including when applicable, detailed procedures for correctly applying coupling preload.

10.3 Maintenance Instructions

The following information should be provided:

a. Graphic chronological schedule of routine maintenance tasks.
b. Sample maintenance forms or check lists as necessary.
c. Log sheets for recording cumulative use of each riser coupling.
d. Storage instructions and replacement schedule for rubber goods and other consumables.
e. Specified lubricants, corrosion inhibitors, etc.
f. Procedure and schedule for fatigue crack inspections. Manufacturer shall identify highly stressed areas to be inspected.

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APPENDIX A—STRESS ANALYSIS

For non-axisymmetric couplings, three-dimensional analysis is necessary to account for variation in stress around the circumference. If the coupling has axial planes of symmetry (planes which include the pipe axis), the three-dimensional analysis may be based on a single sector bounded by two such planes. For example, a coupling having six planes of symmetry would require analysis of a 30-degree sector (one-twelfth). The axial loading on such a 30-degree sector can be considered to be that caused by the design tension uniformly distributed around the pipe. Determination of the equivalent load for bending is discussed in 4.5.

The use of finite element analysis permits determination of stresses in complex structures, but accuracy of the analysis is largely dependent on the skill of the analyst. Care and judgement must be exercised in developing the finite element model. For example, highly stressed regions of the structure require a fine mesh of elements. Therefore, the analyst must predict where high stresses are likely to occur. Some stresses will be affected by the structural properties of the riser pipe. Therefore, the model must be continued far enough away from critical areas to ensure that results are free from boundary effects. Finally, the finite element model should be designed so that the finite elements are not distorted beyond their ability to produce accurate results.

Analysis of the effects of preload and the possibility of separation may require special treatment in the finite element analysis. All components that affect the stiffness of the coupling shall be considered in the model. If separation can occur, then provision for it must be included in the analysis if possible. If not possible, then an iterative method involving several solutions shall be required.

Maximum stresses almost always occur at surfaces. The finite element model should be designed so that in critical regions, stresses are calculated on the surface as well as near it.

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APPENDIX B—OPTIONAL QUALIFICATION TESTS

Test couplings used to perform the optional qualification tests should meet the requirements stated in 8.2.

B.1. Cyclic Load Test

To simulate in-service load fluctuations, tension plus cyclic bending loads may be applied (as well as internal pressure) to represent a chosen loading condition. Extended testing can be conducted to compare with fatigue life predictions.

B.2 Spider Load Reaction Test

The ability of the coupling to carry the most severe loads applied when a long string of riser supporting a BOP stack is hung off on the spider may be checked. The loads experienced when landing on and hanging from the spider while running and pulling riser may be simulated. When simulating the spider hangoff loads, only the box or pin end (whichever hangs in the spider) should be loaded.

B.3 Handling Tool Reaction Test

The ability of the coupling box or pin (as appropriate) to carry the most severe loads applied when a long string of riser supporting a BOP stack is suspended from the handling tool may be checked. The application of dynamic and static loading on the coupling box or pin interface with the handling tool may be simulated.

B.4 Choke and Kill Support Test

The ability of the C&K stabs to hold pressure and the C&K support brackets to react to loads induced by line pressure may be checked. C&K line test pressure may be applied to C&K stabs installed on the coupling and supported by standard brackets.

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APPENDIX C—DESIGN FOR STATIC LOADING

The design of a riser coupling for static loading requires that it support the preload and the design load while keeping the maximum cross-sectional stresses within the allowable limits specified in C.3. Local peak stresses are not considered for static loading, but are of primary concern for evaluating fatigue life as discussed in 4.7.

C.1 Stress Definitions

The following paragraphs define the stress types and stress categories that are pertinent to riser couplings. A thorough understanding of these stresses is necessary to properly design riser couplings.

The following are definitions of stress types that must be considered:

a. *Membrane stress* in a section is the average stress induced by a force normal to the section. It is calculated using the classical equation for normal stress ($S = F/A$).

If a membrane stress is averaged over an entire cross-section, it is a general membrane stress. An example of a *general membrane stress* is the average axial stress in a pipe loaded in tension.

If a membrane stress is averaged only over a localized portion of a cross-section, it is a local membrane stress. An example of a *local membrane stress* is the axial stress averaged over the area adjacent to the window of a dog coupling. Determining the area used for averaging a local stress requires judgement. Using a very small area results in the peak stress, not the local membrane stress. On the other hand, averaging over too large an area results in the general membrane stress, not the local membrane stress.

b. A *bending stress* is a stress induced by a bending moment. It varies linearly with the distance from the centroid of the section and is calculated using the classical mechanics equation for bending stress ($S = M_c/I$).

c. A *pure shear stress* in a section is the average stress induced by a force transverse to the section. It is averaged over the total area of the section and is calculated using the classical shear stress equation ($S = F/A$). An example of a pure shear stress is the average shear stress in the threads of a threaded coupling.

d. A *bearing stress* is the normal stress on the contact surfaces of mating surfaces. It is averaged over the total contact area and is calculated using the classical equation for normal stress ($S = F/A$). An example of a bearing stress is the contact stress between the dogs and the loading shoulder of a dog coupling.

e. All stresses can be classified as primary, secondary, or peak. These stress classifications are discussed in the following paragraphs.

f. A *primary stress* is one that is induced by the external loads or preload and is necessary to satisfy the laws of static equilibrium. Examples of primary stress are the membrane stress in a rod loaded by an axial force and the bending stress in a simple beam.

g. A *peak stress* is a highly localized stress that exists at a discontinuity in the load path. An example of a peak stress is the high localized stress at the root of a thread in a bolt.

h. A *secondary stress* is any stress in the structure which is not a primary stress or peak stress.

C.2 Riser Coupling Stresses

There are six stresses that must be evaluated for each riser coupling:

a. S_{pm} = general primary membrane stress.
b. S_{lm} = local membrane stress.
c. S_{pb} = primary bending stress.
d. S_{se} = secondary stress.
e. S_{sh} = pure shear stress.
f. S_{br} = bearing stress.

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Some of these stresses, such as general primary membrane stresses, can be accurately calculated using hand calculations, but most cannot because of the complex geometry and loading of riser couplings. For this reason, it is required that the stresses in each coupling be calculated with a finite element analysis method as described in 4.3.

The load cases for which a coupling must be analyzed depend on whether or not the coupling is preloaded and if the preload stresses are considered as primary or secondary.

If a coupling is not preloaded, only one load case must be analyzed: design axial tension (coupling design load).

If a coupling is preloaded, the coupling must be analyzed for three load cases: (1) design preload, (2) design preload plus design axial tension, and (3) design axial tension only.

Classifying stresses induced by preload as primary or secondary depends on coupling function and not on overstressing the coupling. If preload stresses are classified as secondary, they are allowed to be twice the yield strength. This can result in large permanent deformations, but not in structural failure.

Some coupling designs can tolerate large permanent deformations without jeopardizing their ability to safely function, while other coupling designs will not function after large permanent deformations. Sealing is an example of a functional requirement that often is affected by large permanent deformation.

If preload stresses are considered as secondary, the designer must demonstrate that the permanent deformations induced by preload will not cause the coupling to lose any necessary functional capability.

Normally, riser couplings exhibit a linear or bilinear relationship between load and stress. For these couplings, stresses at loads other than the analysis loads can be calculated using the rules of linear interpolation or extrapolation. For those couplings with a non-linear relationship between load and stress, linear interpolations or extrapolations cannot be used. These couplings must be analyzed for several values of load, and plots of load versus stress must be developed. The coupling rated load must be determined from these curves.

C.3 Allowable Stresses

Allowable stresses are given for individual stress categories and for combinations of stress categories, and are functions of the material yield strength (S_y). The following are the allowable stresses that must be satisfied in riser couplings for all coupling components except bolts:

$S_{pm} \leq 0.667\ S_y$
$S_{lm} + Spb \leq S_y$
$S_{lm} + S_{pb} + S_{se} \leq 2\ S_y$
$S_{sh} \leq 0.4\ S_y$
$S_{br} \leq S_y$

For bolts in the primary load path, the manufacturer must establish the allowable stress levels for membrane stresses and bending stresses in the bolts.

Bolt stresses, pure shear stresses, and bearing stresses are compared directly with their respective allowables. No manipulation of the finite element data is required.

The other stresses must be linearized, separated into membrane and bending components, categorized, and converted to von Mises effective stresses before they can be compared to the allowable stresses. The following paragraphs describe this procedure in detail.

In general, there are six components of stress across any section: three normal components and three shear stress components.

Each of the significant stress components must be linearized and separated into membrane and bending components.

This is graphically shown in Figure C-1. This figure shows the axial stress across the wall of a riser coupling at a section where the wall thickness changes. The load on the coupling is axial tension. The solid line shows the stress distribution reported by the finite element

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model, and the dashed line represents the linearized stress distribution. The membrane stress component is the average value of the linearized stress distribution and the bending stress component is the difference between the largest and the average values of the linearized stress distribution.

Next, the membrane and bending stress components must be categorized into one of the following stress categories: general primary membrane stress, local membrane stress, primary bending stress, or secondary stress.

For the example in Figure C-1 the membrane stress is the axial stress induced by the axial force. Since this stress is necessary to equilibrate the axial force, it is a general primary membrane stress. The bending stress is induced by the local bending moment caused by the discontinuity in the wall thickness. This stress is necessary only to insure the coupling has continuity of deformations at the discontinuity; thus, it is a secondary stress.

This procedure is repeated for all of the six stress components that are significant; then, the von Mises effective stress is calculated using the following equation:

$$S_e = \frac{1}{\sqrt{2}}[(S_x - S_y)^2 + (S_y - S_x)^2 + (S_z - S_x)^2 + 6(T_{xy}{}^2)] \qquad (2)$$

Where:

S_e = von Mises effective stress.
S_x, S_y, S_z = three normal stress components.
T_{xy}, T_{yz}, T_{zx} = three shear stress components.

Note that all stresses are not included when calculating every von Mises effective stress. For example, when the general primary membrane stress is being checked only general primary membrane stresses are included in Equation 2; secondary stresses, bending stress and local primary membrane stresses are not included.

The maximum shear stress theory of failure can be used in lieu of the von Mises theory of failure. Using the maximum shear stress theory of failure requires that twice the maximum shear stress, defined as the stress intensity, be compared with the allowable stresses instead of the von Mises effective stress. This approach is equal to or slightly conservative when compared to the von Mises approach, but is much easier to use.

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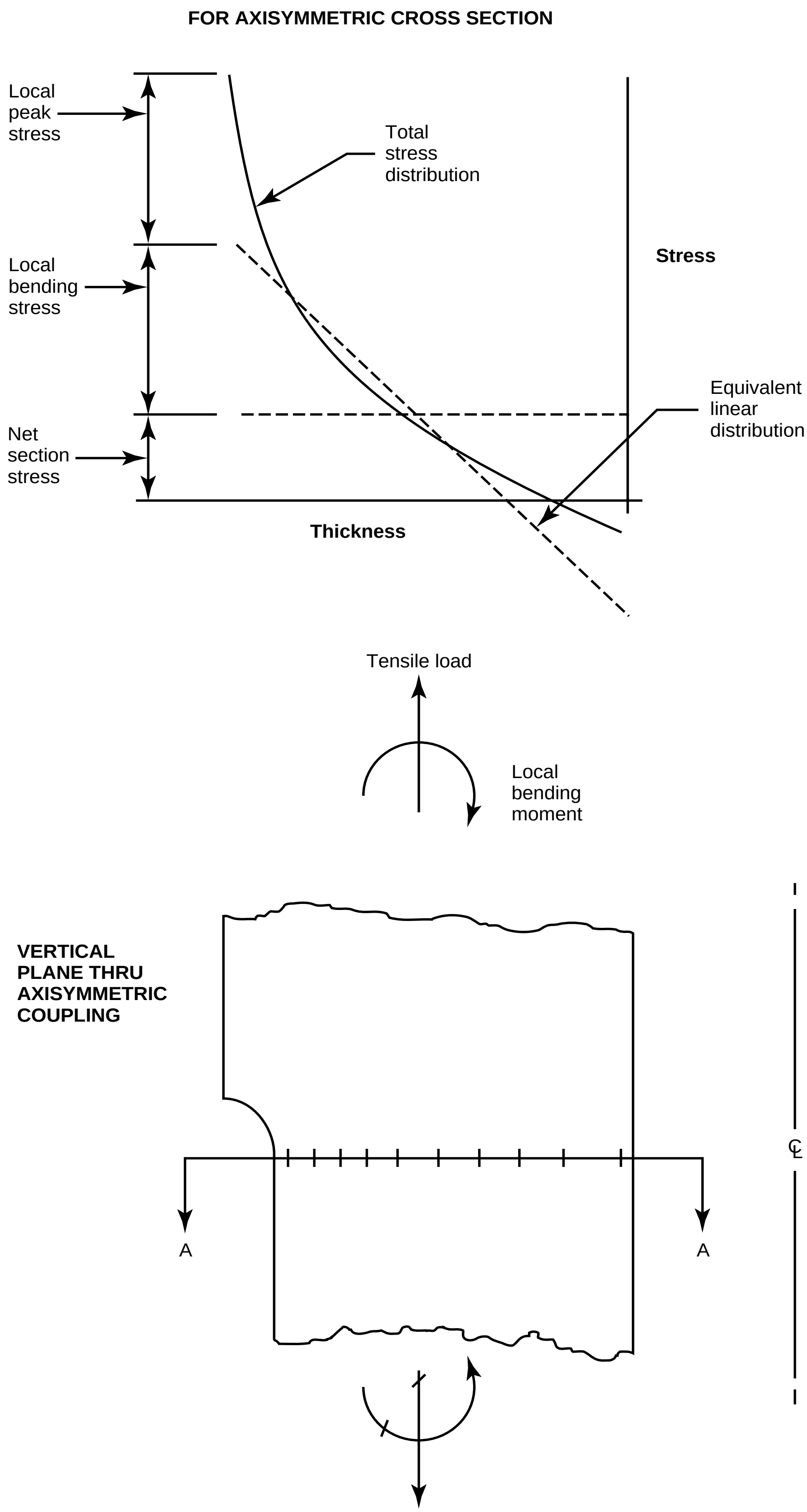

Figure C-1—Stress Distribution Across Section A-A

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