



GUIDE FOR

MATERIALS AND WELDING FOR STAINLESS STEELS

APRIL 2019

**American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862**

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Foreword

This Guide has been developed to give minimum requirements for properties, manufacturing processes and fabrication techniques applicable to common types of stainless steels used in the marine and offshore industries.

Austenitic stainless steels have different compositions and properties but also have many common characteristics. The materials cannot be hardened by heat treatment and are essentially nonmagnetic in the annealed condition. Austenitic stainless steels have excellent corrosion resistance, good formability and outstanding fracture toughness especially at cryogenic temperatures. Accordingly, austenitic stainless steels are widely used in the marine and offshore industries in structural members, pressure vessels and piping systems.

Ferritic-austenitic (duplex) stainless steels are two-phase structures consisting of ferrite and austenite. The most attractive characteristics of duplex is the combination of properties including high strength and excellent resistance to chloride stress corrosion cracking. The standard duplex grade has 22 wt. % chromium and is not sensitive to inter-granular corrosion. For harsher environments, super duplex grade may need higher alloy elements such as 25 wt. % chromium for improved pitting resistance. Duplex stainless steels are also widely used in marine and offshore applications, such as chemical tankers and sour service environments.

One challenge with stainless steels is that they may be susceptible to solidification cracking during welding. Cracking in stainless steel welds may be caused by low melting eutectic phases containing impurities, such as sulfur, phosphorus and other alloy elements. Nitrogen also has a complex effect on the weld metal microstructure and cracking. Nitrogen picked up during welding may significantly increase the risk of cracking. In addition, for duplex stainless steel welding, the ratio of ferrite to austenite may be difficult to control in the weld metal and heat affected zone.

This Guide covers four chapters pertaining to materials and welding for stainless steels:

- Chapter 1 contains general requirements for austenitic and duplex stainless steels.
- Chapter 2 contains the requirements for rolled materials, forgings, castings, pipes and stainless steel clad plates.
- Chapter 3 contains the requirements for various types of welding filler metals and the applicable base metals.
- Chapter 4 contains the requirements for welding procedures and welder qualification, production welding and fabrication, fabrication verification and nondestructive testing of production welds.

The general requirements and practices in this Guide provide qualification of materials and quality control in production and fabrication from raw materials to the end use in ships, offshore units, pressure vessels, piping systems or components.

This Guide becomes effective on 1 April 2019.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.



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MATERIALS AND WELDING FOR STAINLESS STEELS

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CHAPTER 1 General Requirements

SECTION 1 General Requirements for Stainless Steels

1 Scope

1.1 General

In general, the requirements defined in Section 2-1-1 for Hull Construction and Section 2-3-1 for Machinery, Boilers, Pressure Vessels, and Piping of the *ABS Rules for Materials and Welding (Part 2)* are to be applied, unless there are specific requirements for stainless steels in this Guide.

The austenitic and ferritic-austenitic (duplex) stainless steel grades contained in this guide follow the existing standard grades designations given in ASTM, AISI, SAE, JIS, UNS, EN or other equivalent Standards.

This Guide covers chromium, chromium-nickel and chromium-manganese-nickel austenitic and duplex stainless steels. Ferritic, martensitic and precipitation-hardened stainless steels are to be produced in accordance with applicable recognized industry standards.

The weldability of stainless steels is different from carbon or low alloy steel as given in Section 2-4-1 of the *ABS Rules for Materials and Welding (Part 2)*, therefore, welding requirements specified in this Guide are applicable. In addition, reference is to be made to the recognized welding code such as AWS D1.6 or equivalent.

In the case that requirements are not consistent between this Guide and ABS Rules or industry standards, higher requirements than this Guide are to be followed.

1.3 Application

Austenitic and duplex stainless steel products in this Guide are to be primarily used during the construction of cargo tanks, storage tanks, process pressure vessels and piping for carrying chemicals, liquefied gases and other general applications.

Austenitic stainless steels can be used for cryogenic applications. For elevated temperature applications, chemical composition, mechanical properties, high temperature mechanical properties and heat treatment are to be submitted to ABS for review.

Duplex stainless steels are generally to be used for a temperature range of -20°C (-4°F) to 275°C (527°F). For applications outside of this temperature range, the details and specifications are to be submitted to ABS for review and acceptance.

For application of stainless steels in Liquefied Gases application, reference is to be made to Section 5C-8-6 of the *ABS Rules for Building and Classing Steel Vessels (Steel Vessel Rules)*.

For application of stainless steels in propeller castings, reference is to be made to Section 2-3-15 of the *ABS Rules for Materials and Welding (Part 2)* and Appendix 7-A-10 of the *ABS Rules for Survey after Construction (Part 7)*.

3 Testing and Inspection

The general requirements for the testing and inspection are defined in 2-1-1/1 and 2-3-1/1 of the *ABS Rules for Materials and Welding (Part 2)*. In addition, the specific requirements defined in this Guide are also applicable to stainless steels.

3.1 General

All materials subject to test and inspection, intended for use in the construction of hulls and equipment of vessels classed or proposed for classification, are to be to the satisfaction of the Surveyor and in accordance with the following requirements or an equivalent standard/specification. Materials, test specimens and mechanical testing procedures with characteristics differing from those prescribed herein may be approved depending upon application, due regard being given to established practices in the country where the material produced and the purpose to be intended (such as the type of vessel and intended service), the nature of the construction of the vessel, and the parts to be used.

3.3 Approval of Manufacturers

3.3.1 Steel Works

All products for hull construction are to be manufactured at steel works approved by ABS for the type and grade of stainless steels contemplated. The suitability of the products for welding and assumed forming is to be demonstrated during the initial approval test at the steel works. Approval of the steel works for rolled stainless steel products is to be in accordance with Chapter 2, Appendix 1.

3.3.2 Procedures and Production Controls

It is the manufacturer's responsibility to maintain effective procedures and production controls during the production and adhere to the manufacturing specifications. Should any deviation from the procedures and controls occur that could produce an inferior product, the manufacturer is to carry out a thorough investigation to determine the cause of the deviation and establish countermeasures to prevent its reoccurrence. A complete investigation report is to be submitted to the ABS Surveyor. ABS reserves the right to request a closer survey until the cause is resolved to the satisfaction of the Surveyor. Each affected piece is to be tested to the satisfaction of the attending Surveyor prior to distribution from the steel works. In addition, the frequency of testing for subsequent products may be increased to gain confidence in the quality.

3.3.3 Suppliers other than Steel Works

For suppliers other than steel works, such as stainless steel forgings, castings, pipes and clad plates, the approval of facility is to comply with procedures in the applicable Section in this Guide and/or obtain specific instruction approved by ABS.

3.3.4 Radiation

It is the manufacturer's responsibility to confirm that raw materials, semi-finished/finished cast products or wrought steel products are produced within radioactive contamination limits as permitted by an appropriate regulatory body/agency, as applicable to the location of manufacturer. Radiation levels and reference to the allowed limits are to be specified and documented in manufacturer's QA/QC procedures.

3.5 Test and Test Data

3.5.1 Witnessed Tests

The designation (W) indicates that a Surveyor is to witness the testing unless the plant is enrolled and product is manufactured under ABS's Quality Assurance Program.

3.5.2 Manufacturer's Data

The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.

3.5.3 Other Tests

The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with the requirements.

Chapter 1, Appendix 1 has a complete listing of indicated designations for the various tests called out.

3.7 Certification on the Basis of the ABS Quality Assurance Program for Rolled Products

Upon application, consideration will be given to the acceptance of plates, shapes and bars without witnessing of mechanical tests by the Surveyor, on the basis of compliance with ABS's Quality Assurance Program.

3.9 Rejection of Previously Accepted Material

In the event of any material proving unsatisfactory while in the process of being worked, it is to be rejected, notwithstanding any previous certificate of satisfactory testing.

3.11 Calibrated Testing Machines

The Surveyor is to be satisfied that the testing machines are maintained in a satisfactory and accurate condition including a record of the dates and by whom the machines were rechecked or calibrated. All tests are to be carried out to a recognized national or international Standard (e.g., ISO 17025 or equivalent) by competent personnel.

3.13 Reference Documents

References are given in Chapter 1, Appendix 2 of this Guide to various specifications from the American Society for Testing and Materials (ASTM), American Welding Society (AWS), American Society of Mechanical Engineers (ASME) or other equivalent specification designations without year notations. Unless otherwise noted, the latest issue of the specification is to be used.

5 Defects

All materials are to be free from cracks, injurious surface flaws, injurious laminations and similar defects. Except as indicated for specific materials, welding or dressing for the purpose of repairing defects is not permitted unless sanctioned by the Surveyor. In such cases where sanction is required for materials to be so treated, the Surveyor may prescribe further investigation and necessary treatment; then, if found satisfactory, the treated part is to be stamped with the Surveyor's identification mark using special marking pen for stainless steels.

Surface defects may be removed by grinding. Rectification of defects by other methods will be subject to the special consideration.

7 Identification of Materials

The manufacturer is to adopt a system for the identification and tracking of ingots, slabs, finished plates, shapes, forgings, castings and pipes to enable the material to be traced to its original heat, and the Surveyor is to be given every facility for so tracing the material.

9 Manufacturer's Documentation

The requirements for manufacturer's certificates are defined in 2-1-1/7 and 2-3-1/7 of the *ABS Rules for Materials and Welding (Part 2)*.

The supplier is to enable the materials to be traced to its original heat number, lot number, test and re-test results. Supplier is to furnish the Material Test Report (MTR) as follows:

- i) Purchaser's name and order number
- ii) Specifications or grades
- iii) Manufacturing process such as melting, casting, rolling, and forging
- iv) Dimensions
- v) Weight
- vi) Heat Number/Identification of Materials
- vii) Lot Number

- viii) Chemical composition
- ix) Mechanical properties
- x) Corrosion test results if required
- xi) Nondestructive test results if required
- xii) Identification number of piece, including test specimen number where appropriate
- xiii) Address to which material is dispatched

11 Marking, Retest and Rejection

11.1 Identification of Specimens

Where test specimens are required to be selected by the Surveyor, they are not to be detached until stamped with his identification mark, nor are they to be detached until the material has received its final treatment.

If any test specimen shows defective machining or develops defects, it may be discarded and another specimen substituted, except that a retest is not allowed for forgings if a defect develops during testing which is caused by rupture, cracks or flakes in the steel.

11.3 Retests

If the results of the mechanical tests do not conform to the requirements specified, re-test samples representative of the product or product batch are to be taken in accordance with the following relevant sections of the *ABS Rules for Materials and Welding (Part 2)*.

- i) 2-1-2/9.11: Tensile retest for Hull Construction
- ii) 2-1-2/11.7: Charpy retest for Hull Construction
- iii) 2-1-1/9.5: Elongation retest for Hull construction
- iv) 2-3-1/9.5: Elongation retest for Machinery, Boilers, Pressure Vessel and Piping
- v) 2-3-2/1.13: Tensile retest for Machinery, Boilers, Pressure Vessel and Piping

11.5 Marking

In addition to appropriate identification markings of the manufacturer, ABS markings, indicating satisfactory compliance with the requirements and as furnished by the Surveyor, are to be stamped on all products in such locations as to be discernible after machining and installation.

The finished products are to be clearly marked including:

- AB/Grade such as AB/304L, and AB/2205
- AB/31803 for the UNS designation 31803 for rolled stainless steel, stainless steel forgings and pipes, which does not have an ABS designated grade
- Heat Number or Identification of Materials for traceability

If dual certification is applied, all requirements of both grades or designations are to be met and verified.

For stainless steels, the marking paint or ink is not to contain detrimental amounts of harmful metals or metal salts, such as zinc, lead or copper, which may cause corrosive attack upon heating.

11.7 Rejection

2-1-2/9.13 of the *ABS Rules for Materials and Welding (Part 2)* is applicable for rejection.

In cases where a set of test specimens fails to meet the test and re-test requirements, the material from which such specimens have been taken is to be rejected and the required marking withheld or obliterated, unless the manufacturer elects to submit each piece individually, or to resubmit the lot after rework.

Any material that has unacceptable injurious discontinuities observed prior to or subsequent to acceptance at the manufacturer's plant is subject to rejection.

13 Standard Test Specimens

The requirements for preparations of specimens for tension test, impact test, and bend test are defined in 2-1-1/11 and 2-3-1/11 of the *ABS Rules for Materials and Welding (Part 2)*. At the discretion of ABS, the standard test specimens may be accepted in accordance with other equivalent industry standards for example, ASTM A370, E10, or E23.

15 Charpy Test

The requirements for Charpy tests are defined in 2-1-1/11.11 of the *ABS Rules for Materials and Welding (Part 2)*.

Note: For 1-1/15, “Charpy Test”: With the agreement of ABS (and the Administration for Liquefied Gases carriers, ref Section 5C-8-6 of the *Steel Vessel Rules*), impact tests may be waived for austenitic stainless steels. However, where it is found or suspected that grades might not be met the required 41 Joules (30 ft-lbf) in the longitudinal direction, ABS will request confirmatory Charpy tests.

17 Definition and Determination of Yield Point and Yield Strength

The yield strength and UTS are defined in 2-1-1/13 and 2-3-1/13 of the *ABS Rules for Materials and Welding (Part 2)*.

During tension testing, austenitic and duplex stainless steels usually do not exhibit the yield phenomenon observed with ferritic steels. Therefore, the yield point is determined by the 0.2% or 1.0% proof stress. A line parallel to the straight elastic portion of the load/extension graph is plotted at a distance of 0.2% or 1.0% of the extensometer gauge length. The proof yield is determined as the point where the 0.2% or 1% parallel line intersects the load extension curve.

19 Elongation

The elongation value is, in principle, valid only if the distance between the fracture and the nearest gauge mark is not less than one-third of the original gauge length. However, the result is valid, irrespective of the location of the fracture, if the percentage of elongation after the fracture is equal to or greater than the required value.

Generally, the elongation, A_5 , is determined on a proportional gauge length, $5.65\sqrt{S_0} = 5d$, but may also be given for other specified gauge lengths. The minimum elongation requirement in this Guide is based on the 50 mm (2 in.) gauge length.

21 Nondestructive Test

The requirements for nondestructive testing are to be defined in each Section of this Guide.

23 Fracture Toughness Test

If specified or required, the requirements for fracture toughness test are defined in 2-1-1/23 of the *ABS Rules for Materials and Welding (Part 2)*.



CHAPTER 1 General Requirements

APPENDIX 1 List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying

1 Test and Test Data

- i) *Witnessed Tests.* The designation (W) indicates that a Surveyor is to witness the testing unless the plant is enrolled and product is manufactured under ABS's Quality Assurance Program.
- ii) *Manufacturer's Data.* The designation (M) indicates that test data is to be provided by the manufacturer without verification by a Surveyor of the procedures used or the results obtained.
- iii) *Other Tests.* The designation (A) indicates those tests for which test data is to be provided by the supplier and audited by the Surveyor to verify that the procedures used and random tests witnessed are in compliance with the requirements.

Chapter 1, Section 1 General Requirements for Stainless Steels	
1-1/13	Standard Test Specimens (W)
1-1/15	Charpy (W)
1-1/15	Tensile Test (W)
Chapter 2, Section 1 Rolled Stainless Steels	
2-1/9	Ladle Analysis (M) Product Analysis (M)
2-1/13	Microstructure (W), if specified
2-1/15	Tensile Test (W) Charpy Test (W)
2-1/17	Corrosion Test (A) Test Results (W)
2-1/19	Inspection (A)
Chapter 2, Section 2 Stainless Steel Forgings	
2-2/9	Ladle Analysis (M)
2-2/13	Tensile Test (W) Charpy Test (W) Hardness Test (W)
2-2/15	Corrosion Test (A) Test Results (W), if specified
2-2/17	Inspection (A)

Chapter 2, Section 3 Stainless Steel Castings	
2-3/9	Ladle Analysis (M)
2-3/13	Tensile Test (W) Charpy Test (W) Hardness Test (W)
2-3/15	Corrosion Test (A) Test Results (W), if specified
2-3/17	Dye Penetrant Inspection (A) Ultrasonic Inspection (A)
Chapter 2, Section 4 Stainless Steel Pipes	
2-4/9	Ladle Analysis (M) Product Analysis (M)
2-4/13	Tensile Test (W) Charpy Test (W) Hardness Test (W) Bend Test (W) Flatten Test (W)
2-4/15	Corrosion Test (A) Test Results (W)
2-4/17	Hydrostatic Test (W)
2 4/19	Dimension Verification (A)
2 4/21	Inspection (A)
Chapter 2, Section 5 Stainless Steel Clad Plates	
2-5/9	Chemical Composition (M)
2-5/13	Tensile Test (W) Charpy Test (W) Shear Test (W) Bend Test Bonding Strength (W)
2-5/15	Corrosion Test (A) Test Results (W)
2-5/17	Inspection (A)



CHAPTER 1 General Requirements

APPENDIX 2 List of Reference Documents

1 Reference Documents

Frequently-used reference documents are listed in this Appendix for relevant standards from the American Society for Testing and Materials (ASTM), American Welding Society (AWS), American Society of Mechanical Engineers (ASME) and other equivalent specification designations. Unless otherwise noted, the latest issue of the specification is to be used.

1.1 Chapter 1, Section 1 General Requirements for Stainless Steels

ABS Rules	Materials and Welding (Part 2)
ASTM A262	Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels
ASTM A370	Standard Test Methods and Definitions for Mechanical Testing of Steel Products
ASTM A751	Standard Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
ASTM A923	Standard Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels
ASTM E10	Standard Test Method for Brinell Hardness of Metallic Materials
ASTM E23	Standard Test Methods for Notched Bar Impact Testing of Metallic Materials
ASTM E562	Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count
ASTM G48	Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution
ASTM G78	Standard Guide for Crevice Corrosion Testing of Iron-Base and Nickel-Base Stainless Alloys in Seawater and Other Chloride-Containing Aqueous Environments
NACE MR0175	Materials for use in H ₂ S-containing environments in oil and gas production

1.3 Chapter 2, Section 1 Rolled Stainless Steels

ASTM A240	Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A276	Standard Specification for Stainless Steel Bars and Shapes
ASTM A435	Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates
ASTM A480	Standard Specification for General Requirements for Flat-Rolled Stainless and Heat Resisting Steel Plate, Sheet, and Strip
ASTM A578	Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

BSSA 2018	Selection of 316, 304 and 303 types of stainless steels for seawater applications
EN 10088-2	Stainless Steels Technical Delivery Conditions for Sheet/Plate and Strip of Corrosion Resisting Steels for General Purposes

1.5 Chapter 2, Section 2 Stainless Steel Forgings

ASTM A182	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A314	Standard Specification for Stainless Steel Billets and Bars for Forging
ASTM A336	Standard Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
ASTM A388	Standard Practice for Ultrasonic Examination of Steel Forgings
ASTM A473	Standard Specification for Stainless Steel Forgings
ASTM A745	Standard Practice for Ultrasonic Examination of Austenitic Steel Forgings
ASTM A788	Standard Specification for Steel Forgings, General Requirements
ASTM A965	Standard Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
EN 10228	Non-Destructive Testing of Steel Forgings. Ultrasonic Testing of Austenitic and Austenitic-Ferritic stainless steel forgings

1.7 Chapter 2, Section 3 Stainless Steel Castings

ASTM A297	Standard Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application
ASTM A351	Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure Containing Parts
ASTM A488	Practice for Steel Castings, Welding, Qualification of Procedures and Personnel
ASTM A609	Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
ASTM A703	Standard Specification for Steel Castings, General Requirements, for Pressure Containing Parts
ASTM A743	Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
ASTM A744	Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
ASTM E165	Standard Practice for Liquid Penetrant Examination for General Industry

1.9 Chapter 2, Section 4 Stainless Steel Pipes

ASTM A269	Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
ASTM A312	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
ASTM A358	Standard Specification for Electric-Fusion-Welded Austenitic Chromium-Nickel Stainless Steel Pipe for High-Temperature Service and General Applications
ASTM A403	Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
ASTM E426	Standard Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys

ASTM A789	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
ASTM A790	Standard Specification for Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe
ASTM A813	Standard Specification for Single- or Double-Welded Austenitic Stainless Steel Pipe
ASTM A815	Standard Specification for Wrought Ferritic, Ferritic/Austenitic, and Martensitic Stainless Steel Piping Fittings
ASTM A872	Standard Specification for Centrifugally Cast Ferritic/Austenitic Stainless Steel Pipe for Corrosive Environments
ASTM A928	Standard Specification for Ferritic/Austenitic (Duplex) Stainless Steel Pipe Electric Fusion Welded with Addition of Filler Metal
ASTM A999	Standard Specification for General Requirements for Alloy and Stainless Steel Pipe
ASTM E213	Standard Practice for Ultrasonic Testing of Metal Pipe and Tubing

1.11 Chapter 2, Section 5 Stainless Steel Clad Plates

ASTM A20	Specification for General Requirements for Steel Plates for Pressure Vessel
ASTM A263	Standard Specification for Stainless Chromium Steel-Clad Plate
ASTM A264	Specification for Stainless Chromium-Nickel Steel-Clad Plate

1.13 Chapter 2, Appendix 2 Fatigue Property of Stainless Steels

API 571	Damage Mechanisms Affecting Fixed Equipment in the Refining Industry
ASME BPVC II	Materials Part D-Properties
ASTM	Handbook Volume 19-Fatigue and Fracture

1.15 Chapter 2, Appendix 3 Corrosion Property of Stainless Steels

ASTM G82	Standard Guide for Development and Use of a Galvanic Series for Predicting Galvanic Corrosion Performance
NACE	Corrosion Engineer's Reference Book, 2nd Edition, 1991
NiDI	Design Guidelines for the Selection and Use of Stainless Steel

1.17 Chapter 3, Section 1 Application of Stainless Steel Welding Filler Metals

AWS A5.4	Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding
AWS A5.9	Specification for Bare Stainless Steel Welding Electrodes and Rods
AWS A5.22	Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods
AWS A5.30	Specification for Consumable Inserts
AWS D1.6	Structural Welding Code-Stainless Steel

1.19 Chapter 3, Section 2 Requirements for the Approval of Stainless Steel Welding Filler Metals

ASTM E353	Standard Test Methods for Chemical Analysis of Stainless, Heat Resisting, Maraging and Other Similar Chromium-Nickel-Iron Alloys
ASTM E562	Standard Test Method for Determining Volume Fraction by Systematic Manual Point Count
AWS A5.1	Procurement Guidelines for Consumables-Welding and Allied Processes-Flux and Gas Shielded Electrical Welding Processes

1.21 Chapter 4, Section 1 Welding Procedure Qualification

ASME BPVC IX Welding, Brazing, and Fusing Qualifications

1.23 Chapter 4, Section 2 Welding Operator and Welder Qualification

ISO 3834-2 Comprehensive Quality Requirements for Fusion Welding of Metallic Materials

ISO 3834-3 Standard Quality Requirements for Fusion Welding of Metallic Materials

ISO 5817 Fusion-Welded Joints in Steel, Nickel, Titanium and Their Alloys (Beam Welding Excluded)-Quality Levels for Imperfections

ISO 14732 Qualification Testing of Welding Operators and Weld Setters for Mechanized and Automatic Welding of Metallic Materials

1.25 Chapter 4, Section 3 Production Welding and Fabrication

AWS B1.10 Guide for Nondestructive Inspection of Welds

1.27 Chapter 4, Section 4 Fabrication Verification and Nondestructive Testing of Production Welds

ASNT Nondestructive Testing Handbook

ASNT CP-189 Standard for Qualification and Certification of Nondestructive Testing Personnel

ASNT-TC-1A Personnel Qualification and Certification in Nondestructive Testing

EN 10228 Non-Destructive Testing of Steel Forgings. Ultrasonic Testing of Austenitic and Austenitic-Ferritic stainless steel forgings

ISO 9712 Qualification and Certification of NDT personnel



CHAPTER 2 Requirements for Stainless Steels

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CHAPTER 2 Requirements for Stainless Steels

SECTION 1 Rolled Stainless Steel Plates, Sheet, Strip, Sections and Bars

1 Scope

The general requirements defined in Sections 2-3-2 and 2-3-8 of the *ABS Rules for Materials and Welding (Part 2)* are to be applied, unless there are specific requirements for rolled stainless steels in this Guide.

This Section covers chromium, chromium-nickel and chromium-manganese-nickel rolled stainless steel plate, sheet, strip, sections and bars including requirements for:

- i) Manufacturing process
- ii) Chemical composition
- iii) Mechanical properties
- iv) Corrosion properties
- v) Nondestructive test

The requirements are primarily intended to apply to austenitic and ferritic-austenitic (duplex) stainless steel products with a thickness as follows:

- i) For steel plates, sections and wide flats, all Grades are up to 50 mm (2 in.) in thickness.
- ii) For bars, all Grades are up to 300 mm (12 in.) in OD (Outside Diameter).

Note: Materials may be produced in ferritic, martensitic and precipitation hardened stainless steels in accordance with the applicable recognized industry standards and submitted to ABS for review.

The requirements in this Section cover rolled stainless steels intended to be used for general marine and offshore applications. Alternatively, rolled stainless steels which comply with national or proprietary specifications may be accepted, provided such specifications establish an equivalence to these requirements.

3 Reference Documents

ASTM A240	Specification for chromium and chromium-nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
ASTM A276	Standard Specification for Stainless Steel Bars and Shapes
ASTM A435	Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates
ASTM A480	Standard Specification for General Requirements for Flat-Rolled Stainless and Heat Resisting Steel Plate, Sheet, and Strip
ASTM A578	Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
ASTM A923	Standard Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

BSSA 2018	Selection of 316, 304 and 303 types of stainless steels for seawater applications
EN 10088-2	Stainless Steels Technical Delivery Conditions for Sheet/Plate and Strip of Corrosion Resisting Steels for General Purposes

5 Approval of Manufacturers

All materials are to be manufactured at steel works which have been approved by ABS for the type, delivery condition, grade and thickness of stainless steels which are being supplied.

The general requirements of 1-1/3.3 are applicable. Chapter 2, Appendix 1 contains additional requirements for manufacturer's approval of rolled stainless steels.

Rolled stainless steels are to meet the requirements in Chapter 2, Section 1 during production.

7 Manufacturing Process

The steel is to be manufactured by electric-arc, electric-induction, or other suitable melting process and ladle refined. The reduction ratio is to be a minimum of 5 to 1 from continuously cast slab to products, unless it is approved by ABS.

For large diameter round bar, an alternative reduction ratio maybe considered subject to ABS for review.

9 Chemical Composition

Chemical composition is to be tested in accordance with ASTM A751 or equivalent recognized standard. Heat and product analysis are to be reported. Heat analysis is to be taken from the ladle after refining. Product analysis, if required by the standard, is to be taken from the finished product.

The chemical composition is to comply with 2-1/Table 1 of this Guide or approved specifications for the applicable stainless steel grade.

For the same or similar designations of stainless steels, different standards specify chemical compositions that may vary to some extent. Chemical compositions determined by ABS as marginally outside of the ranges of 2-1/Table 1 of this Guide can be considered, provided the mechanical and corrosion properties are maintained.

11 Heat Treatment

All materials specified in Chapter 2, Section 1 are to be supplied in the solution treated condition in accordance with the applicable standards and meet the required mechanical properties.

13 Microstructure

If required by the applicable standard or specification, metallography is to be carried out in accordance with an applicable standard. The inspection is to be performed with suitable magnification. The inspection method (refer to ASTM A923) is to be suitable to detect detrimental chromium-rich intermetallic, such as sigma phase, that may reduce the ductility, toughness and corrosion resistance of the alloy.

15 Mechanical Properties

The mechanical properties are to comply with the requirements specified in 2-1/Table 2 for the applicable stainless steel grade.

Notes:

- 1 *Same Heat.* Metal produced by a single cycle of a batch melting process, the product form could be a slab, billet or single ingot.
- 2 *Same Lot.* Pieces of steel, with the same nominal dimensions and from a single heat, which are subsequently heat treated as part of the same continuous operation (or batch). The same nominal dimensions are represent rolled products up to 5 mm (0.2 in.) within the thickness of the test piece.
- 3 *Plates and Wide Flats Greater than 600 mm in Width.* One set of mechanical tests is to include one longitudinal tensile, one transverse tensile and three transverse Charpy V-Notch.
- 4 *Plates and Wide Flats Less than 600 mm in Width.* One set of mechanical tests is to include one longitudinal tensile and three longitudinal Charpy V-Notch.
- 5 *Plates, Sections and Bars.* One set of mechanical tests is to include one longitudinal tensile and three longitudinal Charpy V-Notch.
- 6 *Sheets and Strips.* One tensile test is to be taken in the longitudinal direction. Charpy test is not required unless it is requested.
- 7 *Liquefied Gases Application.* Section 5C-8-6 of the *Steel Vessel Rules*.

15.1 Test Specimens and Procedures

Test specimens and procedures are to be in accordance with the applicable requirements of 2-1-1/11 and 2-3-1/11 of the *ABS Rules for Materials and Welding (Part 2)*, ASTM A370, E10, E23 or other equivalent industry standards, and any additional specific requirements in this Section.

15.3 Test Frequency

Unless otherwise agreed or required, one set of mechanical tests is to be taken per heat per lot, or per 20 tons (40,000 lb), whichever is more stringent.

15.5 Additional Test Frequency

For plates and wide flats for cargo tanks, secondary barriers and pressure vessels of liquefied gas tanks, one set of mechanical properties are to be tested from one end of one plate per heat per lot when the mass and length do not exceed 5 tons (10,000 lb) and 15 meters (50 feet). When the mass or the length exceeds the limits, two sets of mechanical properties are to be tested from both ends of the test plate.

For plates from coils, tension tests are to be made from not less than two coils from each heat, however, the test frequency is to comply with 2-1/15.3, as a minimum. Where a single coil is to be certified, tension test specimens from that coil solely need be tested. Two tension tests are to be made from each coil tested. One tension test specimen is to be obtained from a location immediately prior to the first plate produced and a second test specimen obtained from the approximate center lap from the end of the coil. When the coiled material from one heat differs by 1.6 mm ($1/16$ in.) or more in thickness, test specimens are to be obtained from both the thinnest and the thickest rolled material. If the coil mass exceeds 20 tons, testing will additionally be required from two locations representing the start and end of the coil.

15.7 Test Specimen Location

Unless otherwise agreed, the location of mechanical test specimens is to be in accordance with the applicable requirements of 2-1-1/11 and 2-3-1/11 of the *ABS Rules for Materials and Welding (Part 2)*, or recognized standards.

Test pieces are to represent the products properties, for example:

- i) Where ingot casting is used, the test pieces are to represent the top of the ingot.
- ii) Test pieces are to be taken from the thickest sections from the same heat and lot. Test results may be used to represent rolled products up to 5 mm (0.2 in.) within the thickness of the test piece.

15.9 Test Temperature

Tensile tests are to be carried out at room temperature, unless it is required by the specification for the tensile properties to be established at a higher or lower temperature, this will depend upon the service requirements.

Charpy V-Notch tests are to be performed at:

- i) -196°C (-320°F) for austenitic stainless steels with the design temperature lower than -105°C (-157°F). For Liquefied Gases application, refer to Section 5C-8-6 of the *Steel Vessel Rules*.
- ii) -20°C (-4°F) or 5°C (41°F) below design temperature for duplex stainless steels, whichever is lower.

17 Corrosion Properties

Unless otherwise agreed, materials are to be subjected to an inter-crystalline corrosion tests to demonstrate that the materials are not susceptible to inter-granular corrosion from precipitation of Chromium-rich carbides at grain boundaries.

One corrosion test is to be carried out for each tensile test according to ISO 3651-2, ASTM A262, Practice E, Copper-Copper Sulphate-Sulphuric Acid or the equivalent recognized standard. The bent samples are to be free from cracks indicating the presence of inter-granular attack and are to pass the visual inspection.

Other corrosion tests such as ASTM G48 for pitting and crevice corrosion, ASTM G78 for crevice corrosion in sea water may be required depending upon the application and heat cycling associated with the heat treatment or repairs.

19 Steel Plates with Specified Minimum Through Thickness Properties

In general, through thickness testing is not performed on 300-series austenitic stainless steels; however, if specified, the requirements of 2-1-1/17 of the *ABS Rules for Materials and Welding (Part 2)* can be applied.

21 Permissible Variations in Dimensions

The requirements for permissible variations in dimensions are defined in 2-1-1/15 and 2-3-1/15 of the *ABS Rules for Materials and Welding (Part 2)*.

For plates, sheets and strips intended for use in the construction of cargo tanks, the negative thickness tolerance is to be in accordance with 2-1-1/15.3, and is not to exceed 0.3 mm (0.012 in.) or 6% under the specified thickness, whichever is less. The average thickness is not to be less than the nominal thickness.

For plates, sheets and strips intended for use in the construction of pressure vessels, a negative thickness tolerance is not allowed.

The tolerances on thickness of sections and bars are to comply with the requirements of a recognized standard.

23 Inspection

Unless otherwise agreed or required, one plate is to be ultrasonically examined per heat per lot in accordance with Specification ASTM A578/A578M, Level B based on continuous scanning over 100% of the plate surface. Other equivalent industry standards may be accepted.

25 Marking, Retests and Rejection

The requirements for marking, retest and rejection are defined in 1-1/11. The finished products are to be clearly marked with the following information:

- AB/Grade or designation, such as AB/304L, AB/2205
- Heat Number or equivalent Number for traceability

If dual certification is requested, all requirements of both grades or designations are to be met and verified.

27 Material Test Report (MTR)

The manufacturer is to provide the required type of material test report giving the following information, as a minimum:

- i) Purchaser's name and order number
- ii) Specifications or grades
- iii) Manufacturing process, for example, melting, casting, rolling, heat treatment etc
- iv) Dimensions or thickness
- v) Weight
- vi) Heat Number
- vii) Lot Number
- viii) Chemical composition
- ix) Mechanical properties
- x) Corrosion testing if required
- xi) Nondestructive test if required
- xii) Identification number of piece, including test specimen number where appropriate

TABLE 1
Chemical Composition of Rolled Stainless Steels

Grade		Chemical Composition, wt. % ⁽¹⁾⁽⁴⁾										
Type	UNS Designation	C ⁽²⁾	Si	Mn	P	S	Cr	Ni	Mo ⁽³⁾	Cu	N	Other
Austenitic Stainless Steels												
304	S30400	0.070	0.75	2.00	0.045	0.030	17.5-19.5	8.0-10.5	-	-	0.10	-
304L	S30403	0.030	0.75	2.00	0.045	0.030	17.5-19.5	8.0-12.0	-	-	0.10	-
316	S31600	0.080	0.75	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	-	0.10	-
316L	S31603	0.030	0.75	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	-	0.10	-
316LN	S31653	0.030	0.75	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	-	0.10-0.16	-
317	S31700	0.080	0.75	2.00	0.045	0.030	18.0-20.0	11.0-15.0	3.00-4.00	-	0.10	-
317L	S31703	0.030	0.75	2.00	0.045	0.030	18.0-20.0	11.0-15.0	3.00-4.00	-	0.10	-
317LN	S31753	0.030	0.75	2.00	0.045	0.030	18.0-20.0	11.0-15.0	3.00-4.00	-	0.10-0.22	-
321	S32100	0.080	0.75	2.00	0.045	0.030	17.0-19.0	9.0-12.0	-	-	0.10	Ti 5×(C+N) min,0.70max
347	S34700	0.080	0.75	2.00	0.045	0.030	17.0-19.0	9.0-13.0	-	-	-	Nb 10×Cmin, 1.00max
Ferritic-Austenitic Duplex Stainless Steels												
-	S31803	0.030	1.00	2.00	0.030	0.020	21.0-23.0	4.5-6.5	2.5-3.5	-	0.08-0.20	-
2205	S32205	0.030	1.00	2.00	0.030	0.020	22.0-23.0	4.5-6.5	3.0-3.5	-	0.14-0.20	-
2507 ⁽⁵⁾	S32750	0.030	0.80	1.20	0.035	0.020	24.0-26.0	6.0-8.0	3.0-5.0	0.50	0.24-0.32	-

Notes:

- 1 Maximum, if range or minimum is not indicated.
- 2 Carbon analysis is to be reported to nearest 0.01% except for low-carbon type (0.03% or less), which is to be reported to nearest 0.001%.
- 3 For 316L and 316LN rolled stainless steels to be used in cargo tanks of chemical carriers or stagnant/low flow (less than 1 m/second) sea water, the Mo-content is not to be less than 2.5%.
- 4 Chemical compositions determined by ABS as marginally outside of the ranges can be considered, provided the mechanical and corrosion properties are maintained.
- 5 %Cr + 3.3%Mo + 16%N ≥ 41 represents pitting resistance equivalent.

TABLE 2
Mechanical Property Requirements of Rolled Stainless Steels

Type	UNS Designation	Tensile Strength, MPa (ksi), Min	Yield Strength, ⁽¹⁾ MPa (ksi), Min		Elongation, 50 mm (2 in.) gage, %, Min	Hardness, ⁽⁵⁾ HBW (HRB/HRC), Max	Charpy V-Notch	
			R _{p0.2}	R _{p1.0}			Min. Average, J (ft-lbf)	Test Temp., °C (°F)
Austenitic Stainless Steels								
304	S30400	515 (75)	205 (30)	245 (36)	40	201 HBW (92) HRB	27 (20) Trans. 41 (30) Long.	-196 (-320) ⁽²⁾⁽³⁾
304L	S30403	485 (70)	170 (25)	210 (31)	40	201 HBW (92) HRB		
316	S31600	515 (75)	205 (30)	245 (36)	40	217 HBW (95) HRB		
316L	S31603	485 (70)	170 (25)	210 (31)	40	217 HBW (95) HRB		
316LN	S31653	515 (75)	205 (30)	245 (36)	40	217 HBW (95) HRB		
317	S31700	515 (75)	205 (30)	245 (36)	35	217 HBW (95) HRB		
317L	S31703	515 (75)	205 (30)	245 (36)	40	217 HBW (95) HRB		
317LN	S31753	550 (80)	240 (35)	280 (41)	40	217 HBW (95) HRB		
321	S32100	515 (75)	205 (30)	245 (36)	40	217 HBW (95) HRB		
347	S34700	515 (75)	205 (30)	245 (36)	40	201 HBW (92) HRB		
Ferritic-Austenitic Duplex Stainless Steels								
-	S31803	620 (90)	450 (65)	-	25	293 HBW (31) HRC	27 (20) Trans. 41 (30) Long.	-20 (-4) ⁽⁴⁾
2205	S32205	655 (95)	450 (65)	-	25	293 HBW (31) HRC		
2507	S32750	795 (116)	550 (80)	-	15	310 HBW (32) HRC		

Notes:

- The specified yield strength at both 0.2% and 1.0% are to be documented for austenitic stainless steels.
- Charpy tests are required for austenitic stainless steels for materials with design temperatures below -105°C (-157°F). For Liquefied Gases applications, refer to Section 5C-8-6 of the *Steel Vessel Rules*.
- If required by specification or standard, Charpy tests for austenitic stainless steels are to be taken at 5°C (41°F) below design temperature.
- Charpy tests for ferritic-austenitic duplex stainless steels are to be taken at -20°C (-4°F) or 5°C (41°F) below design temperature, whichever is lower.
- Hardness is to be provided for information only.
- For sour service, rolled stainless steel products used in equipment/components are to comply with the applicable part of NACE MR0175/ISO 15156: Materials for use in H₂S containing environment in oil and gas production.



CHAPTER 2 Requirements for Stainless Steels

SECTION 2 Stainless Steel Forgings

1 Scope

The general requirements defined in Sections 2-1-6 and 2-3-7 of the *ABS Rules for Materials and Welding (Part 2)* are to be applied, unless there are specific requirements for stainless steel forgings in this Guide.

This Section covers the requirements for austenitic and ferritic-austenitic (duplex) stainless steel forgings including:

- i) Manufacturing process
- ii) Chemical composition
- iii) Mechanical properties
- iv) Corrosion properties
- v) Nondestructive testing

Note: Forgings and forged bars may be produced in ferritic, martensitic and precipitation hardened stainless steels in accordance with the applicable recognized industry standards and submitted to ABS for review.

The requirements in this Section cover stainless steel forgings intended to be used for general marine and offshore applications. Alternatively, forgings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

3 Reference Documents

ASTM A182	Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
ASTM A314	Standard Specification for Stainless Steel Billets and Bars for Forging
ASTM A336	Standard Specification for Alloy Steel Forgings for Pressure and High-Temperature Parts
ASTM A388	Standard Practice for Ultrasonic Examination of Steel Forgings
ASTM A473	Standard Specification for Stainless Steel Forgings
ASTM A745	Standard Practice for Ultrasonic Examination of Austenitic Steel Forgings
ASTM A788	Standard Specification for Steel Forgings, General Requirements
ASTM A965	Standard Specification for Steel Forgings, Austenitic, for Pressure and High Temperature Parts
ASTM E165	Standard Practice for Liquid Penetrant Examination for General Industry
NACE MR0175	Materials for use in H ₂ S-containing environments in oil and gas production

5 Approval of Manufacturers

All materials are to be manufactured at facilities which have been approved by ABS.

Raw materials for forgings such as cast stainless steels or semi-finished products such as billet, bloom etc., are to be manufactured at a facility approved by ABS.

A manufacturing procedure is to be submitted to ABS for approval.

ABS approval is valid for 5 years subjected to annual verification and/or endorsement by the attending Surveyor. The Surveyor is permitted at any time to monitor important aspects of forging production, including but not limited to die preparation and die maintenance, forging temperatures, forging reduction or upset, heat treatment and inspection.

Stainless steel forgings are to meet the applicable requirements in Chapter 2, Section 2 during production.

7 Manufacturing Process

Stainless steels are to be produced by one of the following processes:

- i) Electric arc-furnace;
- ii) Electric-induction furnace;
- iii) Vacuum furnace, or;
- iv) One of the former followed by vacuum or electroslag-consumable remelting.

Refining and optional separate degassing may be necessary depending on the standard specification applicable to the grade.

Vacuum melting or re-melting processes are not to be specified for nitrogen-stabilized austenitic stainless steel grades, such as Grades 317LN and 316LN.

At the discretion of ABS, Grade 347 is to be stabilization treated, which consists of holding the forging at 815 to 870°C (1500 to 1600°F) for not less than 2.4 min/mm (1 hour/inch) of the thickness and then cooling in the furnace or in still air.

The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practice and is to be carried out before the final heat processing or heat treatment, unless otherwise approved. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain stainless steel components, subsequent machining of all flame cut or arc-air gouging surfaces may be required.

The plastic deformation during forging is to be sufficient as to produce soundness, uniformity of structure and satisfactory mechanical properties after final heat processing or heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

Unless otherwise required and approved, the total reduction ratio is to be at least:

- i) For forgings made from ingots or from forged blooms or billets, 3:1 where $L > D$ and 1.5:1 where $L \leq D$
- ii) For forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leq D$
- iii) For forgings made by upsetting, the length after upsetting is not to be more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1.5:1, not more than one-half of the length before upsetting
- iv) For rolled bars used in lieu of forgings, 6

L and D are the length and diameter, respectively, of the part of the forging under consideration.

A sufficient discard is to be made from each ingot to be free from piping and undue segregation. The forging process is to have ample power to adequately flow the metal within the maximum cross-section of the forging.

When two or more forgings are joined by welding to form a component, the proposed welding procedure specification is to be submitted for approval.

9 Chemical Composition

Chemical composition is to be tested in accordance with ASTM A751 or equivalent recognized standards. Heat and product analysis are to be reported. Heat analysis is to be taken from the ladle after refining. Product analysis, if required by the standard, is to be taken from the finished product.

The chemical composition is to comply with 2-2/Table 1 of this Guide or approved specifications for the applicable stainless steel grade.

11 Heat Treatment

11.1 General

Heat treatment facilities used in producing ABS certified forgings are to be included in the forge approval including subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of forge approval.

Heat treatment details are to be included in the approval documentation.

Forge qualification is to include all of the heat treatment facilities that the forge will use.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the nondestructive test requirements of the ABS Rules/Guides or applicable standard, and that there is a feedback system to confirm the same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment, an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification, to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed upon with the Surveyor.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered.

The forge is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

After forging and before reheating for heat treatment, forgings are to be allowed to cool in a manner to prevent injury and to accomplish transformation.

Upon the completion of forging operations, austenitic and duplex stainless steel forgings are to be solution annealed and quenched in water, oil or a polymer water solution. Direct quenching after completion of forging without subsequent reheating to the temperatures prescribed for the grade is not permissible.

If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat-treated. If a forging is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment with good control to prevent the sensitization of stainless steels.

Note: Forgings and forged bars in ferritic, martensitic and precipitation hardened stainless steels are to be heat treated in accordance with the standard specification applicable to the grade and are to be submitted to ABS for review.

11.3 Retreatment

The manufacturer may reheat-treat the forging, but not more than three additional times.

13 Mechanical Properties

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each forging or forging lot.

For Liquefied Gases application, the mechanical properties of forgings are to follow the requirements of Section 5C-8-6 of the *Steel Vessel Rules*.

13.1 Tensile and Charpy Properties

The tensile and Charpy properties of forgings are to conform to the requirements of 2-2/Table 2.

13.3 Hardness

Each forging, except those with rough machined weights of less than 113 kg (250 lb), is to be hardness tested to meet the requirements in 2-2/Table 2 of this Guide, unless the applicable standard requires hardness test irrespective of weight.

For sour service, stainless steel forgings used in equipment or components are to comply with the applicable part of NACE MR0175/ISO 15156: *Materials for use in H₂S containing environment in oil and gas production*.

13.5 Test Procedure and Specimens

Test specimens and procedures are to be in accordance with the applicable requirements of 2-1-1/11 and 2-3-1/11 of the *ABS Rules for Materials and Welding (Part 2)*, ASTM A370, E10, E23 or other equivalent industry standards. Specific requirements in this Section supersede industry Standards.

13.5.1 Location and Orientation of Specimens

Mechanical properties are to be determined from tensile test specimens taken from prolongations having a sectional area not less than the body of the forging. The length of the prolongation is to be such that the distance from the test specimen mid-gauge to the end of the prolongation is to be 89 mm (3.5 in.) or one-half the forging section thickness or diameter, whichever is more. The tensile test specimens may be taken in a direction parallel to the axis of the forging in the direction in which the metal is most drawn out. In lieu of axial tests, test specimens may be taken tangentially or radially to the axes of the forging with the agreement of ABS. The test specimens are to be located at any point midway between the center and the surface of solid forgings and at any point midway between the inner and outer surfaces of the wall of hollow forgings.

Notes:

- 1 Longitudinal: The axis of the test piece is parallel to the principal direction of forging product.
- 2 Tangential/Radial: The axis of the test piece is tangential to the principal direction of the forging product.

13.5.2 Alternative Tests Specimens and Hollow-drilled Specimens

In lieu of prolongations, subject to the Surveyor's agreement, the test specimens may be taken as follows.

- i) A sacrificial forging product per heat per lot
- ii) A forged qualification test coupon representative of the actual forged products in terms of size, chemistry, forging ratio and heat treatment cycle
- iii) A test specimen may be taken from forgings with a hollow drill, provided the drill hole will not be detrimental to the final product

13.5.3 Very Small Forgings

In the cases of very small forgings weighing less than 113 kg (250 lb) each, where the foregoing procedures are impractical, a special forging may be made for the purpose of obtaining test specimens, provided the Surveyor is satisfied that these test specimens are representative of the forgings submitted for test. In such cases, the special forgings are to have the same chemistry, same amount of working and reduction as the forgings represented and is to be heat-treated with those forgings.

13.5.4 Identification of Specimens

Forgings and test materials are to be heat treated together in the same furnace, and quenched in the same bath/tank.

The test specimens are not to be detached from the forgings until the final heat treatment of the forgings has been completed and test specimens have been stamped by the Surveyor for identification. Where the material identification system of the manufacturer is found acceptable to ABS and is maintained in that condition through initial and periodical verification by ABS, it may be considered in lieu of stamping by the Surveyor before detachment.

In case of the qualification test coupon as per 2-2/13.5.2ii), the test coupon identification is to be the same as the forgings and full traceability is to be maintained to the satisfaction of the Surveyor.

13.7 Test Frequency and Position

Unless otherwise agreed or required, the test frequency and position are to be defined as follows.

13.7.1 Tension Tests

- i) *Large Forgings.* In the case of large forgings with rough machined weights of 3180 kg (7000 lb) or over, one tension test is to be taken from each end of the forging. In the case of ring or hollow cylindrical forgings, the tests may be taken 180 degrees apart from the same end of the forging.
- ii) *Intermediate-Sized Forgings.* In the case of forgings with rough machined weights less than 3180 kg. (7000 lb), except as noted in the following paragraph, at least one tension test is to be taken from each forging.
- iii) *Small Forgings.* In the case of small forgings with weight at time of heat treatment less than 1000 kg (2200 lb) and one tension test specimen may be taken from one forging as representative of a lot, provided the forgings in the lot are of a similar size, are of one grade and kind only, are made from the same heat and are heat-treated in the same furnace charge. The total mass of the furnace charge is not to exceed 6000 kg (13200 lb).
- iv) *Sleeves, Couplings and Nut Forgings.* In the case of ring-type or cylinder-type forgings for use as sleeves, coupling or nuts, the tension test is to be taken from a full-size prolongation left on one end of each individual forging. Test specimens are to be in a longitudinal orientation at mid-wall of the ring or cylinder as close as practical to the end of the rough machined surface of the forging.
- v) *Continuous Heat Treatment.* Whereby a furnace incorporates a method of controlled moving of the component from the charging end, through the furnace at a predetermined temperature and time, to the discharging end. Test coupon sampling procedures are to be specially agreed with ABS.

13.7.2 Hardness Tests

- i) *Large, Intermediate and Small Sized Forgings.* Each forging, except those with rough machined weights of less than 113 kg (250 lb), is to be hardness tested to meet the requirements of 2-2/Table 2. Forgings are to be tested at locations 180 degrees apart on each end.
- ii) *Discs, Rings and Hollow Forgings.* Each forging except, those with rough machined weights of less than 113 kg (250 lb), is to be hardness tested to meet the requirements of 2-2/Table 2. Forgings are to be tested at the approximate mid-radius and 180 degrees

apart on each flat surface of the forging; the testing locations on opposite sides are to be offset by 90 degrees.

- iii) *Very Small Forgings.* In cases of involving very small forgings weighing less than 113 kg (250 lb) each, the hardness tests may be made from broken tension test specimens, or on a special forging representing the lot.
- iv) Hardness tests in other locations may be specified and required by an applicable standard.

13.9 Test Temperature

Tensile tests are to be carried out at room temperature, unless it is required for the tensile properties to be established at a higher or lower temperature.

Charpy V-Notch tests are to be performed at:

- i) -196°C (-320°F) for austenitic stainless steels with the design temperature lower than -105°C (-157°F). For Liquefied Gases application, refer to Section 5C-8-6 of the *Steel Vessel Rules*.
- ii) -20°C (-4°F) or 5°C (41°F) below design temperature for duplex stainless steels, whichever is lower.

15 Corrosion Properties

Depending upon application or requirements in specification or standard, inter-granular corrosion testing of stainless steel forgings is to be agreed between purchaser and supplier.

Where inter-granular corrosion properties are required, materials are to be subjected to an inter-crystalline corrosion test to demonstrate that the materials are not susceptible to inter-granular corrosion from precipitation of chromium-rich carbides at grain boundaries.

One corrosion test is to be carried out for each tensile test according to ISO 3651-2, ASTM A262, Practice E, Copper-Copper Sulphate-Sulphuric Acid or the equivalent recognized standard. The bent samples are to be free from cracks indicating the presence of inter-granular attack and are to pass the visual inspection.

Other corrosion tests such as ASTM G48 for pitting and crevice corrosion, ASTM G78 for crevice corrosion in sea water may be required depending upon the application and heat cycling associated with the heat treatment or repairs.

17 Inspection

The general requirements defined in Appendix 2-A7 of the *ABS Rules for Materials and Welding (Part 2)* are to be applied.

After final heat treatment, all forgings are to be examined by the Surveyor and should be free from defects. The finish is to be free of scale, cracks, seams, laps, fins, cold shuts, laminations, nicks, gouges, pipe, shrinkage, porosity and burst indications.

Surface inspection is to be performed using liquid penetrant examination in accordance with a recognized standard such as ASTM E165.

Ultrasonic volumetric inspection is to be tested in accordance with a recognized standard such as ASTM A388 or A745.

If radiography is applied, it is to be carried out in accordance with a recognized standard or practice for radiography of stainless steels.

19 Rectification of Defective Forgings

Defects may be removed by grinding or chipping and grinding, provided that the component dimensions remain acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours. Complete elimination of the defective material is to be verified by liquid penetrant testing.

In certain applications, weld repair of stainless steel forgings may be prohibited.

Repair welding of forgings, if permitted, is to have prior approval by ABS. In such cases, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures are to be submitted for approval.

Weld procedures for all types of welds are to be appropriately qualified to the satisfaction of the attending Surveyor.

Before undertaking the repair welding of forgings the manufacturer is to prove to the satisfaction of the Surveyor that the welders or welding operators are duly qualified for the work intended.

The forging manufacturer is to maintain records of repairs and subsequent inspections that are traceable to each forging repaired. The records are to be presented to the Surveyor on request.

Temporary welds made for operations such as lifting, handling and staging are to be carried out according to qualified welding procedures and qualified welders/operators and are to be removed, ground and inspected using suitable approved, nondestructive examination methods.

Depending upon the application or specific requirements in the purchase order, inter-granular corrosion testing of weld repaired stainless steel forgings maybe be required subject to the agreement between purchaser and supplier.

21 Identification, Marking, Retests and Rejection

Marking, retests and rejection requirements are to comply with 1-1/11.

21.1 Identification

The manufacturer is to adopt a system of identification which will enable forgings to be traced to the original cast at any point during production, and the Surveyor is to be given full facilities for tracing the forgings, when required.

21.3 Retests

With reference to 1-1/11.3, if satisfactory results are obtained from both of the additional tests, the forging or batch of forgings is acceptable. If one or both retests fail, the forging or batch of forgings is to be rejected. The manufacturer may reheat-treat forgings that have failed. After reheat-treating, the forgings are to be submitted for all mechanical testing and meet the requirements in accordance with 2-2/Table 2.

21.5 Marking

In addition to appropriate identification markings of the manufacturer ABS markings, indicating satisfactory compliance with the requirements and as furnished to the Surveyor, are to be stamped on all forgings in such locations as to be discernible after machining and installation. In addition, the stainless steel grade is to be stamped, for example, AB/304, AB/304L, AB/316L, and AB/2205.

21.7 Rejection

Any forging that has injurious discontinuities observed prior to or subsequent to acceptance at the manufacturer's plant is to be subject to rejection.

23 Material Test Report (MTR)

The manufacturer is to provide the required type of materials test report giving the following particulars for each forging or batch of forgings which has been accepted.

- i) Purchaser's name and order number
- ii) Description of forgings and steel quality
- iii) Identification number
- iv) Steelmaking process, cast number and chemical analysis of ladle sample
- v) Results of mechanical tests

- vi) Results of corrosion tests, if required
- vii) Results of nondestructive tests, if applicable
- viii) Details of heat treatment, including temperature and holding times
- ix) Specification

TABLE 1
Chemical Composition of Stainless Steel Forgings

Grade			Chemical Composition, wt. % ⁽¹⁾⁽⁴⁾										
Type	UNS Designation	ASTM Grade	C ⁽²⁾	Si	Mn	P	S	Cr	Ni	Mo ⁽³⁾	Cu	N	Other
Austenitic Stainless Steels													
304	S30400	F304	0.080	1.00	2.00	0.045	0.030	18.0-20.0	8.0-11.0	-	-	-	-
304L	S30403	F304L	0.030	1.00	2.00	0.045	0.030	18.0-20.0	8.0-13.0	-	-	0.10	-
316	S31600	F316	0.080	1.00	2.00	0.045	0.030	16.0-18.0	10.0-14.0	2.00-3.00	-	-	-
316L	S31603	F316L	0.030	1.00	2.00	0.045	0.030	16.0-18.0	10.0-15.0	2.0-3.0	-	0.10	-
316LN	S31653	F316LN	0.030	1.00	2.00	0.045	0.030	16.0-18.0	11.0-14.0	2.00-3.00	-	0.10 - 0.16	-
317L	S31703	F317L	0.030	1.00	2.00	0.045	0.030	18.0-20.0	11.0-15.0	3.00-4.00	-	-	-
321	S32100	F321	0.080	1.00	2.00	0.045	0.030	17.0-19.0	9.0-12.0	-	-	-	Ti5×(C+N) min,0.70m ax
347	S34700	F347	0.080	1.00	2.00	0.045	0.030	17.0-20.0	9.0-13.0	-	-	-	-
Ferritic-Austenitic Duplex Stainless Steels													
-	S31803	F51	0.030	1.00	2.00	0.035	0.015	21.0-23.0	4.5-6.5	2.5-3.5	-	0.10 - 0.20	-
2205	S32205	F60	0.030	1.00	2.00	0.030	0.020	22.0-23.0	4.5-6.5	3.0-3.5	-	0.14 - 0.20	-
2507 ⁽⁵⁾	S32750	F53	0.030	0.80	1.20	0.035	0.020	24.0-26.0	6.0-8.0	3.0-5.0	0.5	0.24 - 0.32	-

Notes:

- 1 Maximum, if range or minimum is not indicated.
- 2 Carbon analysis is to be reported to nearest 0.01% except for low-carbon type (0.03% or less), which is to be reported to nearest 0.001%.
- 3 For 316L and 316LN stainless steel forgings to be used in cargo tanks of chemical carriers or stagnant/low flow (less than 1 m/second) sea water, the Mo-content is not to be less than 2.5%.
- 4 Chemical compositions determined by ABS to be marginally outside of the ranges can be considered, provided the mechanical and corrosion properties are maintained.
- 5 %Cr + 3.3%Mo + 16%N ≥ 41, represents pitting resistance equivalent.

TABLE 2
Mechanical Property Requirements of Stainless Steel Forgings

Grade			Tensile Strength, MPa (ksi), Min	Yield Strength, ⁽¹⁾ MPa (ksi), Min <i>R_{p0.2}</i>	Elongati on, 50 mm (2 in.) gage, %, Min	Reduction of Area, %, Min	Hardness, ^(5,7) HBW (HRB/HRC), Max	Charpy V-Notch	
Type	UNS Designation	ASTM Grade						Min. Average, J (ft-lbf)	Test Temp., °C (°F)
Austenitic Stainless Steels									
304	S30400	F304	485 (70)	205 (30)	30	45	201 HBW (92) HRB	27 (20) Trans. 41 (30) Long.	-196 (-320) ^(2,3)
304L	S30403	F304L	450 (65)	170 (25)	30	45	201 HBW (92) HRB		
316	S31600	F316	485 (70)	205 (30)	30	45	217 HBW (95) HRB		
316L	S31603	F316L	450 (65)	170 (25)	30	45	217 HBW (95) HRB		
316LN	S31653	F316LN	515 (75)	205 (30)	30	45	217 HBW (95) HRB		
317L	S31703	F317L	450 (65)	170 (25)	30	45	217 HBW (95) HRB		
321	S32100	F321	515 (75)	205 (30)	30	45	217 HBW (95) HRB		
347	S34700	F347	485 (70)	205 (30)	30	45	217 HBW (95) HRB		
Ferritic-Austenitic Duplex Stainless Steels									
-	S31803	F51	620 (90)	450 (65)	25	45	293 HBW (31) HRC	27 (20) Trans. 41 (30) Long.	-20 (-4) ⁽⁴⁾
2205	S32205	F60	655 (95)	450 (65)	25	45	293 HBW (31) HRC		
2507	S32750	F53 ⁽⁶⁾	800 (116)	550 (80)	15	-	310 HBW (32) HRC		

Notes:

- 1 The specified yield strength at both 0.2% and 1.0% are to be documented for austenitic stainless steels.
- 2 Charpy tests are required for austenitic stainless steels for materials with design temperatures below -105°C (-157°F). For Liquefied Gases applications, refer to Section 5C-8-6 of the *Steel Vessel Rules*.
- 3 If required by specification or standard, Charpy tests for austenitic stainless steels are to be taken at 5°C (41°F) below design temperature.
- 4 Charpy tests for ferritic-austenitic duplex stainless steels are to be taken at -20°C (-4°F) or 5°C (41°F) below design temperature, whichever is lower.
- 5 In general, Hardness values are target values. The maximum hardness values may be mandatory if it is required by specification or application.
- 6 Brinell Hardness for F53 is to be 310 max.
- 7 For sour service, stainless steel forgings used in equipment/components are to comply with the applicable part of NACE MR0175/ISO 15156: Materials for use in H₂S containing environment in oil and gas production.



CHAPTER 2 Requirements for Stainless Steels

SECTION 3 Stainless Steel Castings

1 Scope

The general requirements defined in Sections 2-1-5 and 2-3-9 of the *ABS Rules for Materials and Welding (Part 2)* are to be applied, unless there are specific requirements for stainless steel castings in this Guide.

This Section covers the requirements for austenitic and ferritic-austenitic (duplex) stainless steel castings.

- i) Manufacturing process
- ii) Chemical composition
- iii) Mechanical properties
- iv) Corrosion properties
- v) Nondestructive test

Note: Castings may be produced in ferritic, martensitic and precipitation-hardened stainless steels in accordance with the applicable recognized industry standards and submitted to ABS for review.

The requirements in this Section cover stainless steel castings intended to be used for general marine and offshore applications. Alternatively, castings which comply with national or proprietary specifications may be accepted, provided such specifications give reasonable equivalence to these requirements.

For application of stainless steels in propeller casting, reference is to be made to Section 2-3-15 of the *ABS Rules for Materials and Welding (Part 2)* and Appendix 7-A-10 of the *ABS Rules for Survey after Construction (Part 7)*.

3 Reference Documents

ASTM A297	Standard Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application
ASTM A351	Standard Specification for Castings, Austenitic, Austenitic-Ferritic (Duplex), for Pressure Containing Parts
ASTM A488	Practice for Steel Castings, Welding, Qualification of Procedures and Personnel
ASTM A609	Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
ASTM A703	Standard Specification for Steel Castings, General Requirements, for Pressure-Containing Parts
ASTM A743	Standard Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application
ASTM A744	Standard Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
ASTM E165	Standard Test Method for Liquid Penetrant Examination
NACE MR0175	Materials for use in H ₂ S-containing environments in oil and gas production

5 Approval of Manufacturers

All materials are to be manufactured at facilities which have been approved by ABS.

If a foundry elects to purchase cast materials from other facilities, those facilities are to be approved by ABS.

A manufacturing procedure is to be submitted to ABS for approval.

The Surveyor is permitted at any time to monitor important aspects of casting production, including but not limited to mold preparation and chaplet positioning, pouring times and temperatures, mold breakout, repairs, heat treatment and inspection.

Stainless steel castings are to meet the applicable requirements in Chapter 2, Section 3 during production.

7 Manufacturing Process

The stainless steels are to be produced by one of the following processes:

- i) Electric arc-furnace
- ii) Electric-induction furnace
- iii) Vacuum furnace, or
- iv) One of the former followed by vacuum or electroslag-consumable remelting

Refining and optional separate degassing may be necessary depending on the standard specification applicable to the grade.

At the discretion of ABS, Grade 347 is to be stabilization treated, which consists of holding the forging at 815 to 870°C (1500 to 1600°F) for not less than 2.4 min/mm (1 hour/inch) of the thickness and then cooling in the furnace or in still air.

For stainless steel casting flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognized good practices and is to be carried out before the final heat processing or heat treatment, unless otherwise approved. Preheating is to be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut or arc-air gouging surfaces may be required.

When two or more castings are joined by welding to form a component, the proposed welding procedure specification is to be submitted for approval.

9 Chemical Composition

Chemical composition is to be tested in accordance with ASTM A751 or an equivalent recognized standard. Heat and product analysis are to be reported. Heat analysis is to be taken from the ladle after refining. Product analysis, if required by the standard, is to be taken from the finished product.

The chemical composition is to comply with 2-3/Table 1 of this Guide or approved specifications for the applicable stainless steel grade.

11 Heat Treatment

11.1 General

Heat treatment facilities used in producing ABS certified castings are to be included in the foundry approval including subcontracted heat treatment facilities. Approved subcontracted facilities will be included in the scope of foundry approval.

Heat treatment details are to be included in the approval documentation.

Foundry qualification is to include all of the heat treatment facilities that the castings will use.

An independent heat treatment facility can obtain approval, provided that it is documented and verified that the facility is capable of producing heat treated products that meet the mechanical properties of the specification and the nondestructive test requirements of the ABS Rules/Guides or applicable standard, and that there is a feedback system to confirm the same during production.

If additional sub-contracted or independent facilities are selected to carry out heat treatment, an ABS approval is to be obtained for the new facility.

The ABS Surveyor is to attend the heat treatment facility during qualification to verify that the heat treatment process is carried out according to specification.

During production, the extent of monitoring is to be agreed with the Surveyor.

A sufficient number of thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform, unless the temperature uniformity of the furnace can be verified at regular intervals.

Heat treatment is to be carried out in properly constructed furnaces which are efficiently maintained with adequate means to control and record temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large castings, alternative methods of heat treatment will be specially considered.

The foundry is to maintain records of heat treatment, identifying the furnace used, furnace charge, date, temperature and time at temperature, together with the number and location of thermocouples. The records are to be available to the Surveyor upon request.

After casting and before reheating for heat treatment, castings are to be allowed to cool in a manner that prevents injury and accomplishes transformation.

Upon completion of casting operations, austenitic and duplex stainless steel castings are to be solution annealed and quenched in water, oil or a polymer water solution. Direct quenching after completion of casting without subsequent reheating to the temperatures prescribed for the grade is not permissible.

If for any reason a casting is subsequently heated for further hot working, the casting is to be re-heat-treated. If a casting is locally reheated or any straightening operation is performed after the final heat treatment, consideration is to be given to a subsequent stress relieving heat treatment with good control to prevent the sensitization of stainless steels.

Note: Casting in ferritic, martensitic and precipitation hardened stainless steels are to be heat treated in accordance with the standard specification applicable to the grade and are to be submitted to ABS for review.

11.3 Retreatment

The manufacturer may re-heat-treat the casting, but not more than three additional times.

13 Mechanical Properties

Test material, sufficient for the required number of tests and for possible retest purposes, is to be provided for each casting or casting lot.

For Liquefied Gases application, the mechanical properties of castings are to follow the requirements of Section 5C-8-6 of the *Steel Vessel Rules*.

For application of stainless steels in propeller casting, reference is to be made to Section 2-3-15 of the *ABS Rules for Materials and Welding (Part 2)* and Appendix 7-A-10 of the *ABS Rules for Survey after Construction (Part 7)*.

13.1 Tensile and Charpy Properties

The casting tensile and Charpy properties are to conform to the requirements of 2-3/Table 2.