



# Standard Specification for Stainless Steel Forgings, Ferritic/Austenitic (Duplex), for Pressure Vessels and Related Components<sup>1</sup>

This standard is issued under the fixed designation A1049/A1049M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification covers ferritic/austenitic (duplex) stainless steel forgings for boilers, pressure vessels, and associated equipment in grades that are also found in Specification [A182/A182M](#).

1.2 The purchaser may specify in the order or contract any appropriate supplementary requirements that are provided in Specification [A788/A788M](#).

1.3 Unless the order specifies the applicable “M” specification designation the material shall be furnished to the inch-pound units.

1.4 The values stated in either inch-pound or SI (metric) units are to be regarded separately as standard. Within the text and tables, the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

## 2. Referenced Documents

### 2.1 *ASTM Standards:*<sup>2</sup>

[A182/A182M Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service](#)

[A370 Test Methods and Definitions for Mechanical Testing of Steel Products](#)

[A388/A388M Practice for Ultrasonic Examination of Steel Forgings](#)

[A745/A745M Practice for Ultrasonic Examination of Austenitic Steel Forgings](#)

[A788/A788M Specification for Steel Forgings, General Requirements](#)

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.06 on Steel Forgings and Billets.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

[A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels](#)

[E165/E165M Practice for Liquid Penetrant Examination for General Industry](#)

[G48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution](#)

### 2.2 *Other Standards:*

[ASME Boiler and Pressure Vessel Code](#)<sup>3</sup>

[NACE MR0175/ISO15156 Petroleum and Natural Gas Industries—Materials for Use in H<sub>2</sub>S—Containing Environments in Oil and Gas Production](#)<sup>4</sup>

## 3. Ordering Information and General Requirements

3.1 Material supplied to this specification shall conform to the requirements of Specification [A788/A788M](#), which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

3.1.1 If the requirements of this specification are in conflict with the requirements of Specification [A788/A788M](#), the requirements of this specification shall prevail.

3.1.2 The purchaser may require that the forging be machined to an approved heat treatment drawing indicating the proposed configuration of the forging at the time of the specified solution heat treatment.

3.1.3 The purchaser may approve the use of an alternate liquid quenching medium for cooling from the solution treatment temperature.

3.2 The purchaser shall specify the acceptance criteria for either Methods B or C of Test Methods [A923](#), if supplementary requirement S1 is selected.

3.3 The purchaser shall specify the required minimum pitting resistance equivalent number (PREN) value determined according to the applicable equation in [Table 1](#).

<sup>3</sup> Available from American Society of Mechanical Engineers (ASME), Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

<sup>4</sup> Available from NACE International, 15835 Park Ten Place, Houston, TX 77084, <http://www.nace.org>.

**TABLE 1 Chemical Requirements**

Grade UNS No.	F50 <sup>A</sup> S31200 <sup>A</sup>	F51 <sup>A</sup> S31803 <sup>A</sup>	F52 <sup>A</sup> S32950 <sup>A</sup>	F53 <sup>A</sup> S32750 <sup>A</sup>	F54 <sup>B</sup> S39274 <sup>B</sup>	F55 <sup>B</sup> S32760 <sup>B</sup>	F57 <sup>B</sup> S39277 <sup>B</sup>	F59 <sup>A</sup> S32520 <sup>A</sup>	F60 <sup>A</sup> S32205 <sup>A</sup>	F61 <sup>A</sup> S32550 <sup>A</sup>
Carbon, max	0.030	0.030	0.030	0.030	0.030	0.030	0.025	0.030	0.030	0.04
Manganese, max	2.00	2.00	2.00	1.20	1.00	1.00	0.80	1.50	2.00	1.50
Phosphorous, max	0.045	0.030	0.035	0.035	0.030	0.030	0.025	0.035	0.030	0.040
Sulfur, max	0.030	0.020	0.010	0.020	0.020	0.010	0.002	0.020	0.020	0.030
Silicon, max	1.00	1.00	0.60	0.80	1.00	1.00	0.80	0.80	1.00	1.00
Nickel	5.5-6.5	4.5-6.5	3.5-5.2	6.0-8.0	6.0-8.0	6.0-8.0	6.5-8.0	5.5-8.0	4.5-6.5	4.5-6.5
Chromium	24.0-26.0	21.0-23.0	26.0-29.0	24.0-26.0	24.0-26.0	24.0-26.0	24.0-26.0	24.0-26.0	22.0-23.0	24.0-27.0
Molybdenum	1.20-2.00	2.5-3.5	1.00-2.50	3.0-5.0	2.5-3.5	3.0-4.0	3.0-4.0	3.0-5.0	3.0-3.5	2.9-3.9
Nitrogen	0.14-0.20	0.08-0.20	0.15-0.35	0.240.32	0.24-0.32	0.20-0.30	0.23-0.33	0.20-0.35	0.14-0.20	0.10-0.25
Copper	...	...	...	0.50 max	0.20-0.80	0.50-1.00	1.20-2.00	0.50-3.00	...	1.50-2.50
Tungsten	...	...	...	...	1.50-2.50	0.50-1.00	0.80-1.20	...	...	...

<sup>A</sup> PREN = Cr + 3.3(Mo) + 16(N)

<sup>B</sup> PREN = Cr + 3.3(Mo + ½ W) + 16(N)

NOTE 1—The required PREN value for both the tungsten bearing forging Grades with the superscript *B* and the non-tungsten bearing Grades with the superscript *A* frequently lies between 33 and 40 depending on service experience, so that the Purchaser shall specify the required minimum PREN value (see 3.3).

3.4 When Practice **A745/A745M** is the basis for ultrasonic examination in accordance with 7.1, the purchaser shall specify whether Quality levels 1 or 2 form the basis for acceptance. Supplementary requirement S4 permits the purchaser to specify Practice **A388/A388M** in lieu of Practice **A745/A745M**, in which case the purchaser must also specify the acceptance criteria.

3.5 When Supplementary requirement S3, for pitting corrosion testing, of Test Methods **G48** is specified, the purchaser shall identify the method and test temperature to be used.

3.6 When Supplementary requirement S5 for the liquid penetrant examination of forgings in the final machined configuration is specified, the purchaser shall specify the necessary acceptance criteria, if the requirements of S19 in Specification **A788/A788M** are not sufficient.

#### 4. Materials and Manufacture

4.1 Steel melting and forging shall be in accordance with Specification **A788/A788M**.

##### 4.2 Heat Treatment:

4.2.1 Forgings may be machined before solution annealing at the manufacturer's option, unless the purchaser requires that machining to a prescribed configuration be done before heat treatment (see 3.2).

4.2.2 All forgings shall be reheated to the required temperature for solution treatment followed, unless otherwise agreed with the purchaser, by water quenching. With the purchaser's consent (see 3.1.3) some other liquid quenching medium may be used to rapidly cool the forging.

4.2.3 The solution treatment temperature is dependant on the ordered Grade or composition (UNS number) and shall be as listed in **Table 2**.

4.2.4 The forgings shall be held at the specified solution treatment temperature for a minimum of 30 min per inch of maximum heat-treated section thickness.

#### 5. Chemical Requirements

5.1 The heat analysis taken in accordance with Specification **A788/A788M** shall comply with **Table 1** for the ordered Grade.

**TABLE 2 Solution Heat Treatment**

UNS Designation	Grade	Solution Temperature °F [°C]	Water Quench <sup>A</sup> to Below °F [°C]
S31200	F 50	1925 [1050] min	200 [95]
S31803	F 51	1870 [1020] min	200 [95]
S32950	F 52	1825-1875 [1000-1025]	200 [95]
S32750	F 53	1880 [1025] min	200 [95]
S39274	F 54	1920-2060 [1050-1125]	200 [95]
S32760	F 55	2010-2085 [1100-1140]	200 [95]
S39277	F 57	1940 [1060] min	200 [95]
S32520	F 59	1975-2050 [1080-1120]	200 [95]
S32205	F 60	1870 [1020] min	200 [95]
S32550	F 61	1920-2060 [1050-1125]	200 [95]

<sup>A</sup> Water quenching is required unless the use of another liquid quenching medium is approved by the purchaser (see 3.1.3).

5.2 A PREN value is included as a requirement in **Table 1** depending on the specified Grade and this will further restrict the chemical requirements.

5.3 The manufacturer shall use the product analysis provisions of Specification **A788/A788M** to obtain a product analysis from a forging representing each heat or multiple heat.

5.4 Dual marking is permitted when the actual values of the listed elements match two or more of the Grades in **Table 1**; however, grade substitution such as combining a tungsten bearing Grade with one that has no requirement for tungsten is not permitted.

#### 6. Mechanical Properties

6.1 *Requirements*—The material shall conform to the requirements for mechanical properties prescribed in **Table 3**. The mechanical testing requirements of Test Methods **A370** and Specification **A788/A788M** apply.

6.2 *Number of Tension Tests*—The number and location of tension tests are based on the solution-treated weight of the forging(s) from the same heat and solution treated in the same furnace charge.

6.2.1 For forgings weighing less than 5000 lb [2250 kg] as heat treated one tension test shall be required. This may be taken from an integral prolongation from one forging or from a forged test bar. Separate forged test bars shall have been forged in the same manner, and with equivalent forging

**TABLE 3 Tensile Strength and Hardness Requirements**

UNS Designation	Grade	Tensile Strength ksi [MPa] Minimum or Range	Yield Strength 0.2 % Offset ksi [MPa] Minimum	Elongation % in 2 in. or 50 mm Minimum	Reduction of Area % Minimum	Brinell Hardness HB Maximum
S31200	F 50	100-130 [690-900]	65 [450]	25	50	...
S31803	F 51	90 [620]	65 [450]	25	45	...
S32950	F 52	100 [690]	70 [485]	15	45	...
S32750	F 53	116 [800]	80 [550]	15	45	310
S39274	F 54	116 [[800]	80 [550]	15	30	310
S32760	F 55	109-130 [750-900]	80 [550]	25	45	...
S39277	F 57	118 [815]	85 [585]	25	50	...
S32520	F 59	112 [770]	80 [550]	25	40	...
S32205	F 60	95 [655]	70 [485]	25	45	...
S32550	F 61	109 [750]	80 [550]	25	50	...

reduction as the forgings they represent, and shall not be less than the represented forgings in heat-treated section thickness.

6.2.1.1 When solution treatment is performed in a continuous-type furnace, equipped with recording pyrometers, such that complete heating records are available, a solution annealing charge may be considered as any continuous run for forgings from the same heat not exceeding 8 h.

6.2.2 For forgings weighing over 5000 lb [2250 kg] as heat treated, one tension test shall be taken from each forging from an integral prolongation.

6.3 *Test Orientation*—Tension tests shall be oriented in the longitudinal direction, that is, parallel to the direction of maximum working. For upset forged disks the test specimen axis may be oriented tangentially to the radius of the forging.

6.4 *Test Location*—The location of the longitudinal axis of the tension test specimen shall be located midway between the parallel surfaces of the test extension if added to the periphery of disks, or midway between the center and surface of solid forgings. For bored or hollow forgings the specimen shall be located at midwall. For the special case of forgings that are heat treated solid, but are subsequently bored, the specimen may be taken at the location of the minimum inside diameter after boring instead of the mid-radius position. For tube sheets intended for construction to Section VIII of the ASME Boiler and Pressure Vessel Code, the tension test shall be located in accordance with Supplementary requirement S12 of Specification **A788/A788M**.

6.5 *Hardness*:

6.5.1 For the Grades in **Table 3** that have hardness limits, one hardness test per forging shall be taken after solution heat treatment.

6.5.2 Supplementary requirement S6 may be specified when the application comes under the rules of NACE MR0175/ISO15156.

## 7. Nondestructive Examination

7.1 *Ultrasonic Examination*:

7.1.1 After solution treatment and the necessary machining to comply with the test practice requirements, the forging shall be examined in accordance with Practice **A745/A745M**, except that when Supplementary Requirement S4 has been specified, Practice **A388/A388M** shall be employed.

7.1.2 When Practice **A745/A745M** is used, acceptance shall be based on Quality Level 1 or 2, as specified by the purchaser.

## 8. Rejection, Certification, and Marking

8.1 Rejection, certification, and marking of forgings shall be in accordance with Specification **A788/A788M**.

## 9. Keywords

9.1 austenitic/ferritic stainless steel; duplex stainless steel; forgings; PREN value; pressure vessels

## SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement(s) shall apply only when specified by the purchaser in the contract or order. Additional supplementary requirements that may be applicable are included in Specification **A788/A788M**.

### S1. Detrimental Intermetallic Phase Detection

S1.1 Forgings in Grades F51 (S31803), F52 (S32950), and F60 (S32205) shall be subject to detrimental intermetallic phase detection in accordance with Test Methods **A923**.

S1.2 Method A of Test Methods **A923** shall be followed by either Charpy impact testing to Method B or a ferric chloride corrosion test to Method C at the purchaser's option.

S1.3 The location of the test specimens for testing to methods B or C of Test Methods **A923** shall be as specified in **6.4** unless otherwise denoted by the purchaser.

S1.4 Unless otherwise specified by the purchaser acceptance shall be as specified in Test Methods **A923** for the chosen test method.

## **S2. Charpy Impact Testing**

S2.1 One set of three Charpy V-Notch specimens, prepared and tested in accordance with Test Methods and Definitions **A370** shall be taken from each tension test location and tested to the requirements of the applicable construction code, or as required by the purchaser.

S2.2 Test reporting shall include absorbed energy, lateral expansion, fracture appearance, and test temperature.

## **S3. Corrosion Resistance**

S3.1 Testing for resistance to pitting and crevice corrosion shall be carried out in accordance with Test Methods **G48**. The test temperature shall be as specified by the purchaser (see **3.5**) within the guidelines of Test Methods **G48**, and the actual test temperature shall be reported.

S3.2 The purchaser shall indicate which of the test methods are to be used as well as the acceptance criteria.

## **S4. Ultrasonic Examination**

S4.1 At the purchaser's option Practice **A388/A388M** shall be used instead of Practice **A745/A745M** for ultrasonic examination.

S4.2 The purchaser shall specify the examination criteria including the reference hole size for the DAC curve and the acceptance criteria.

## **S5. Liquid Penetrant Examination**

S5.1 For forgings in the final machined configuration a liquid penetrant examination done in accordance with Practice **E165/E165M** shall be carried out on all accessible surfaces (see **3.6**). The penetrant system to be used shall be specified by the purchaser.

S5.2 The acceptance criteria given in S19 of Specification **A788/A788M** shall apply unless otherwise specified by the purchaser.

## **S6. Hardness Testing**

S6.1 For applications that come under the requirements of NACE MR0175/ISO15156, hardness testing of forgings shall be done as specified in that document.

S6.2 The maximum surface hardness of the forgings shall be in accordance with NACE MR0175/ISO15156.

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