



Designation: ~~A1021/A1021M – 05 (Reapproved 2015)~~ A1021/A1021M – 20

Standard Specification for Martensitic Stainless Steel Forgings and Forging Stock for High-Temperature Service¹

This standard is issued under the fixed designation A1021/A1021M; 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 (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope ~~Scope~~*

1.1 This specification covers martensitic chromium stainless steel forgings, forged bar, and forging stock for high temperature service. The mechanical properties are developed by suitable heat treatment, as indicated for each alloy.

1.2 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable M specification designation (SI units), the inch-pound units shall apply. The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system ~~may~~ are not ~~be~~ necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other. Combining other, and values from the two systems may result in nonconformance with the standard shall not be combined.

1.3 Supplementary requirements of an optional nature are provided for use at the option of the purchaser. The supplementary requirements shall apply only when specified individually by the purchaser in the purchase order or contract.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and health environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

[A275/A275M Practice for Magnetic Particle Examination of Steel Forgings](#)

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

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

[E112 Test Methods for Determining Average Grain Size](#)

[E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials](#)

[E381 Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings](#)

[E562 Test Method for Determining Volume Fraction by Systematic Manual Point Count](#)

3. Ordering Information

3.1 In addition to the ordering information required by Specification [A788/A788M](#), the purchaser shall specify the grade designation, heat treatment condition, class and finish, and include a sketch or written description of the forging with the inquiry and order.

4. General Requirements

4.1 Materials supplied to this specification shall conform to the requirements of Specification [A788/A788M](#), including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of

¹ 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.

Current edition approved ~~March 1, 2015~~ May 1, 2020. Published ~~March 2015~~ May 2020. Originally approved in 2001. Last previous edition approved in ~~2010~~ 2015 as ~~A1021/A1021M-05 (2010)~~ A1021/A1021M-05 (2015). DOI: ~~10.1520/A1021_A1021M-05R15~~ 10.1520/A1021_A1021M-20.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the ~~standard's~~ standard's Document Summary page on the ASTM website.

*A Summary of Changes section appears at the end of this standard

Specification **A788/A788M** constitutes non-conformance with this specification. In case of conflict between the requirements of this specification and Specification **A788/A788M**, this specification shall prevail.

5. Manufacture

5.1 *Melting Process*—All melting processes of Specification **A788/A788M** are permitted unless the purchaser invokes Supplementary Requirement S1.

5.2 *Forging Process*—Either the closed impression die or the open die, including ring rolling, forging processes may be utilized unless the purchaser specifies a process.

5.3 *Heat Treatment*—Quenched and tempered classes shall be heat-treated in accordance with **Table 1**.

5.3.1 *Number of Heat Treatments*—Heat treatment as defined in **Table 1** shall consist of austenitizing, quenching, and tempering. Retempering is permitted but purchaser approval is required for more than one complete reheat treatment.

5.4 *Stress Relief*—When heat treatment for mechanical properties is followed by straightening, a stress-relieving heat treatment is required in accordance with **Table 1**.

5.4.1 *Quenching after Stress Relief*—Liquid quenching of stress-relieved forgings is prohibited.

5.5 *Finish*—Forgings may be furnished in one of the following hot-finished conditions:

5.5.1 *Finish F*—As forged without descaling.

5.5.2 *Finish FD*—Forged and descaled.

5.5.3 *Finish RT*—Rough turned or rough machined to specified dimensions. Billets or blooms ordered as forging stock shall be furnished with a ground, machined, or descaled surface unless otherwise specified in the ordering document.

5.6 *Camber*—Camber shall not exceed ¼ in. [5 mm] in 5 ft [150 cm].

6. Chemical Composition

6.1 The steel shall conform to the requirements for chemical composition prescribed in **Table 2**.

7. Mechanical Properties

7.1 *Tension, Impact, Stress Rupture, and Hardness Tests*—All testing shall be performed after heat treatment and stress relief, as applicable. The material and test specimens shall meet the requirements of **Table 3** if fully heat-treated or **Table 4** if annealed. Mechanical property requirements, including hardness, do not apply to forging stock when it is to be tested after forging and heat treatment. Tensile and impact tests shall be performed in accordance with Test Methods and Definitions **A370**.

7.2 *Test Specimens*—Forgings may be lot tested. Test specimens may be obtained from production forgings or from separately forged test blanks prepared from the stock used to make the finished part. Forgings that are lot tested shall be produced from the same heat of steel and heat treated at the same time. Separately forged test blanks shall receive essentially the same type of hot-working and forging reduction as the production forgings; however, a longitudinally forged bar with dimensions not less than T by T by $3T$ may be used to represent a ring forging. The dimension T shall be representative of the heaviest effective cross section of the forging.

7.3 *Test Specimen Orientation*—Mechanical property requirements are for samples oriented in the direction of grain flow. Unless otherwise specified in the purchase order, manufacturers may orient the samples in any direction provided the mechanical property requirements are met.

7.4 *Test Specimen Location*—When transverse or circumferential specimens are tested, they shall be taken from as close as possible to a mid-radius or mid-wall location of the forging. When longitudinal specimens are tested, they shall be taken from extensions. Extending the axial length of a larger section of a forging for a sufficient distance over a smaller section is also an acceptable location for transverse or circumferential specimens.

TABLE 1 Heat Treatment, °F [°C]

| | Grade A | Grade B | Grade C | | Grade D | Grade E | | Grade F |
|------------------|------------------------|------------------------|-------------------------|-------------------------|--------------------------|--------------------------|------------------------|--------------------------|
| | Class 1 & 2 | Class 1 | Class 1 | Class 2 | Class 1 & 2 | Class 1 | Class 2 | |
| Austenitizing | 1725-1775 [940-970] | 1600-1750 [870-955] | 1825-1875 [995-1025] | 1725-1875 [940-1025] | 1875-1925 [1025-1050] | 2075-2125 [1135-1165] | 1725-1775 [940-970] | 2000-2050 [1095-1120] |
| Quenching | Air or liquid | Air or liquid | Air or liquid | Air or liquid | Air or liquid | Air or liquid | Air or liquid | Rapid air or oil |
| Single Tempering | 1050 min [565 min] | 1050 min [565 min] | 1050 min [565 min] | 1050 min [565 min] | 1150 min [620 min] | 1250 min [675 min] | 1100 min [595 min] | 1185 min [640] min |
| Double Tempering | ... | ... | 1025 min [550 min] | 1025 min [550 min] | ... | ... | ... | ... |
| Stress Relieving | 1025 min [550 min] | 1025 min [550 min] | 1000 min [540 min] | 1000 min [540 min] | 1100 min [595 min] | 1200 min [650 min] | 1050 min [565 min] | 1135 min [610] min |

TABLE 2 Chemical Requirements^A

| UNS Designation Type—Similar to | Composition % | | | | | |
|------------------------------------|--------------------------|--------------------|-------------|-------------|------------|------------|
| | Grade A | Grade B | Grade C | Grade D | Grade E | Grade F |
| | | S41005 | S41428 | S42225 | | |
| | 403/410 SS UNS S41000 | 403/410 SS MOD. | XM-32 Mod | 422 SS | UNS S41041 | UNS S42226 |
| Carbon | 0.15 | 0.10-0.15 | 0.10-0.17 | 0.20-0.25 | 0.13-0.18 | 0.15-0.20 |
| Manganese | 1.00 | 0.25-0.80 | 0.65-1.05 | 0.50-1.00 | 0.40-0.60 | 0.50-0.80 |
| Phosphorus | 0.018 | 0.018 | 0.020 | 0.025 | 0.030 | 0.020 |
| Sulfur | 0.015 | 0.015 | 0.015 | 0.010 | 0.030 | 0.010 |
| Silicon | 1.00 | 0.50 | 0.35 | 0.50 | 0.50 | 0.20-0.60 |
| Nickel | 0.75 | 0.75 | 2.25-3.25 | 0.50-1.00 | 0.50 | 0.30-0.60 |
| Chromium | 11.5-13.5 | 11.5-13.0 | 11.25-12.75 | 11.0-12.5 | 11.5-13.0 | 10.0-11.5 |
| Molybdenum | 0.50 | 0.50 | 1.50-2.00 | 0.90-1.25 | 0.20 | 0.80-1.10 |
| Vanadium | ... | Report only | 0.25-0.40 | 0.20-0.30 | ... | 0.15-0.25 |
| Tungsten | ... | 0.10 | 0.10 | 0.9-1.25 | ... | 0.25 |
| Nitrogen | ... | 0.08 | 0.020-0.045 | Report only | ... | 0.04-0.08 |
| Aluminum | ... | 0.025 | 0.025 | 0.025 | 0.050 | 0.05 |
| Columbium | ... | 0.20 | ... | ... | 0.15-0.45 | 0.35-0.55 |
| Cobalt | ... | ... | ... | 0.20 | ... | 0.25 |
| Titanium | ... | 0.05 | 0.05 | 0.025 | ... | 0.05 |
| Copper | ... | 0.50 | 0.50 | 0.50 | ... | ... |
| Tin | ... | 0.05 | 0.05 | 0.02 | ... | 0.04 |
| Lead | ... | ... | ... | ... | ... | 0.005 |

^A Maximum or range unless otherwise specified.

TABLE 3 Mechanical Properties—Quenched & Tempered Classes

| | Grade A | | Grade B | | Grade C | | Grade D | | Grade E | | Grade F |
|--|-----------|-----------|-----------|------------|------------|-----------|-----------|-----------|-----------|-----------|---------|
| | Class 1 | Class 2 | Class 1 | Class 1 | Class 2 | Class 1 | Class 2 | Class 1 | Class 2 | Class 1 | |
| Tensile strength, KSI min [MPa] | 100 [690] | 110 [760] | 110 [760] | 145 [1000] | 160 [1105] | 140 [965] | 140 [965] | 115 [795] | 110 [760] | 140 [965] | |
| Tensile strength, ksi min [MPa] | 100 [690] | 110 [760] | 110 [760] | 145 [1000] | 160 [1105] | 140 [965] | 140 [965] | 115 [795] | 110 [760] | 140 [965] | |
| Yield Strength min, KSI [MPa], 0.2 % Offset | 70 [485] | 80 [550] | 90 [620] | 115 [795] | 120 [825] | 90 [620] | 100 [690] | 75 [515] | 80 [550] | 100 [690] | |
| Yield Strength min, ksi [MPa], 0.2 % Offset | 70 [485] | 80 [550] | 90 [620] | 115 [795] | 120 [825] | 90 [620] | 100 [690] | 75 [515] | 80 [550] | 100 [690] | |
| Elongation in 2 in., min % | 20 | 18 | 18 | 15 | 16 | 13 | 13 | 15 | 18 | 15 | |
| Reduction of area, min, % | 60 | 50 | 50 | 30 | 50 | 30 | 35 | 50 | 55 | 45 | |
| Impact Strength, min, avg., CV, RT, ft-lb [J] | 30 [41] | 25 [34] | 30 [41] | 30 [41] | 40 [54] | 8 [11] | 13 [18] | 20 [27] | 25 [34] | 8 [11] | |
| Impact Strength, min of one specimen per Test Methods A370, CV, RT, ft-lb [J] | 20 [27] | 17 [23] | 20 [27] | 20 [27] | 27 [36] | 5 [7] | 9 [12] | 13 [18] | 17 [23] | 5 [7] | |
| Impact Strength, min of one specimen, CV, RT, ft-lb [J] | 20 [27] | 17 [23] | 20 [27] | 20 [27] | 27 [36] | 5 [7] | 9 [12] | 13 [18] | 17 [23] | 5 [7] | |
| Hardness, Brinell, max | 255 | 269 | 269 | 352 | 375 | 331 | 331 | 277 | 262 | 321 | |
| Hardness, Rockwell C, max | 26 | 28 | 28 | 38 | 40 | 36 | 36 | 29 | 27 | 34 | |

TABLE 4 Mechanical Properties—Annealed Classes

| | Grade A | Grade B | Grade C | Grade D | Grade E | Grade F |
|---------------------------|---------|---------|---------|---------|---------|---------|
| | Class 3 | Class 2 | Class 3 | Class 3 | Class 3 | Class 2 |
| Hardness, Brinell, max | 248 | 248 | 311 | 248 | 248 | 302 |
| Hardness, Rockwell C, max | 24 | 24 | 33 | 24 | 24 | 32 |

7.5 *Number Of Tests*—Where more than one location is designated on a forging drawing, tension tests shall be made from each location.

7.6 *Hardness*—The manufacturer shall perform Brinell or Rockwell hardness testing after final heat treatment and after machining to the forging drawing requirements. Hardness tests shall be performed in accordance with Test Methods and Definitions A370.

7.7 *Stress rupture testing of Grade F* shall be conducted in accordance with [Table 5](#) using a combination test bar in accordance with Test Methods [E292](#). Rupture must occur in the smooth section of each test specimen. The test may be discontinued after the time specified, provided notation in the certification. Stress rupture testing is not required on bars less than 1/2 in. in diameter or thickness.