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400 Commonwealth Drive, Warrendale, PA 15096-0001

AEROSPACE MATERIAL SPECIFICATION

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AMS 4211

Issued

JUL 2000

Aluminum Alloy, Plate
6.2Zn - 1.9Cu - 2.1Mg - 0.10Zr (7040-T7451)
Solution Heat Treated, Stress Relieved, and Overaged

UNS A97040

1. SCOPE:

1.1 Form:

This specification covers an aluminum alloy in the form of plate.

1.2 Application:

This plate has been used typically for parts requiring a high level of mechanical properties and good resistance to stress-corrosion cracking, but usage is not limited to such applications.

2. APPLICABLE DOCUMENTS:

The issue of the following documents in effect on the date of the purchase order form a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been canceled and no superseding document has been specified, the last published issue of that document shall apply.

2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

| | |
|----------|---|
| AMS 2355 | Quality Assurance Sampling and Testing of Aluminum Alloys and Magnesium Alloys, Wrought Products (Except Forging Stock) and Flash Welded Rings |
| MAM 2355 | Quality Assurance Sampling and Testing of Aluminum Alloys and Magnesium Alloys, Wrought Products (Except Forging Stock) and Flash Welded Rings, Metric (SI) Units |
| AMS 2750 | Pyrometry |

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AMS 4211**SAE****AMS 4211****2.2 ASTM Publications:**

Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

| | |
|-------------------|--|
| ASTM B 594 | Ultrasonic Inspection of Aluminum-Alloy Wrought Products for Aerospace Applications |
| ASTM B 660 | Packing/Packaging of Aluminum and Magnesium Products |
| ASTM B 666/B 666M | Identification Marking of Aluminum and Magnesium Products |
| ASTM E 466 | Conducting Constant Amplitude Axial Fatigue Tests of Metallic Materials |
| ASTM G 34-72 | Exfoliation Corrosion Susceptibility in 2xxx and 7xxx Series Aluminum Alloys (EXCO Test) |
| ASTM G 47 | Determining Susceptibility to Stress-Corrosion Cracking of High-Strength Aluminum Alloy Products |

2.3 ANSI Publications:

Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

| | |
|---------------|--|
| ANSI H35.2 | Dimensional Tolerances for Aluminum Mill Products |
| ANSI H35.2(M) | Dimensional Tolerances for Aluminum Mill Products (Metric) |

3. TECHNICAL REQUIREMENTS:**3.1 Composition:**

Shall conform to the percentages by weight shown in Table 1, determined in accordance with AMS 2355 or MAM 2355.

TABLE 1 - Composition

| Element | min | max |
|-----------------------|-----------|------|
| Silicon | -- | 0.10 |
| Iron | -- | 0.13 |
| Copper | 1.5 | 2.3 |
| Manganese | -- | 0.04 |
| Magnesium | 1.7 | 2.4 |
| Chromium | -- | 0.04 |
| Zinc | 5.7 | 6.7 |
| Titanium | -- | 0.06 |
| Zirconium | 0.05 | 0.12 |
| Other Elements, each | -- | 0.05 |
| Other Elements, total | -- | 0.15 |
| Aluminum | remainder | |

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3.2 Solution Heat Treat at 880 to 900 °F (471 to 482 °C). Stretch to produce a nominal permanent set of 2% but not less than 1-1/2% nor more than 3%, and precipitation heat treat at 250 °F ± 10 (121 °C ± 6) for 6 to 12 hours followed by 330 °F ± 10 (166 °C ± 6) for 15 to 21 hours to the T7451 temper. Pyrometry shall be in accordance with AMS 2750.

3.2.1 Plate shall receive no further straightening operations after stretching.

3.3 Properties:

Plate shall conform to the following requirements, determined in accordance with AMS 2355 or MAM 2355 on the mill produced product and as specified herein.

3.4.1 Tensile Properties: Shall be as specified in Table 2.

TABLE 2A - Minimum Tensile Properties, Inch/Pound Units

| Nominal Thickness Inches | Specimen Orientation | Tensile Strength ksi | Yield Strength at 0.2% Offset ksi | Elongation in 2 inches or 4D % |
|-----------------------------|-------------------------|----------------------------|--|--------------------------------------|
| Over 3.001 to 4.000, incl | Longitudinal | 70.0 | 62.0 | 9 |
| | Long-Trans. | 71.0 | 62.0 | 6 |
| | Short Trans. | 69.0 | 59.0 | 3 |
| Over 4.001 to 5.000, incl | Longitudinal | 70.0 | 62.0 | 9 |
| | Long-Trans. | 71.0 | 62.0 | 5 |
| | Short Trans. | 68.0 | 58.0 | 3 |
| Over 5.001 to 6.000, incl | Longitudinal | 70.0 | 62.0 | 8 |
| | Long-Trans. | 70.0 | 61.0 | 4 |
| | Short Trans. | 68.0 | 58.0 | 3 |
| Over 6.001 to 7.000, incl | Longitudinal | 69.0 | 62.0 | 7 |
| | Long-Trans. | 69.0 | 60.0 | 4 |
| | Short Trans. | 67.0 | 57.0 | 3 |
| Over 7.001 to 8.000, incl | Longitudinal | 68.0 | 61.0 | 6 |
| | Long-Trans. | 69.0 | 60.0 | 4 |
| | Short Trans. | 66.0 | 57.0 | 3 |
| Over 8.001 to 9.000, incl | Longitudinal | 68.0 | 61.0 | 6 |
| | Long-Trans. | 68.0 | 59.0 | 4 |
| | Short Trans. | 66.0 | 56.0 | 3 |

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TABLE 2B - Minimum Tensile Properties, SI Units

| Nominal Thickness Millimeters | Specimen Orientation | Tensile Strength MPa | Yield Strength at 0.2% Offset MPa | Elongation in 50.8 mm or 4D % | Elongation in 50.8 mm or 5D % |
|----------------------------------|-------------------------|----------------------------|--|--|--|
| Over 76 to 102, incl | Longitudinal | 483 | 427 | - | 8 |
| | Long-Trans. | 490 | 427 | - | 5 |
| | Short Trans. | 476 | 407 | - | 2 |
| Over 102 to 127, incl | Longitudinal | 483 | 427 | - | 8 |
| | Long-Trans. | 490 | 427 | - | 5 |
| | Short Trans. | 469 | 400 | - | 2 |
| Over 127 to 152, incl | Longitudinal | 483 | 427 | - | 7 |
| | Long-Trans. | 483 | 421 | - | 4 |
| | Short Trans. | 469 | 400 | - | 2 |
| Over 152 to 178, incl | Longitudinal | 476 | 427 | - | 6 |
| | Long-Trans. | 476 | 414 | - | 3 |
| | Short Trans. | 462 | 393 | - | 2 |
| Over 178 to 203, incl | Longitudinal | 469 | 421 | - | 5 |
| | Long-Trans. | 476 | 414 | - | 3 |
| | Short Trans. | 455 | 393 | - | 2 |
| Over 203 to 229, incl | Longitudinal | 469 | 421 | - | 5 |
| | Long-Trans. | 469 | 407 | - | 3 |
| | Short Trans. | 455 | 386 | - | 2 |

3.3.2 Corrosion-Resistance: Resistance to stress-corrosion cracking and to exfoliation-corrosion shall be considered acceptable if the plate conforms to the requirements of 3.3.2.1 and 3.3.2.2.

3.3.2.1 Electrical Conductivity: Shall be not lower than 30.0% IACS (International Annealed Copper Standard) (22.6 MS/m), determined on the surface of the tensile coupon.

3.3.2.2 Stress-Corrosion Susceptibility Factor (SCF): Shall be not greater than 32.0 (220), determined by subtracting the electrical conductivity, AA.A% IACS (12 times BB.B MS/m) from the long-transverse yield strength, XX.X ksi (YYY MPa).

3.3.2.2.1 Example: For plate 4.0 inches (102 mm) nominal thickness:

TABLE 3A

| Inch/Pound Units | | |
|------------------|--------------|-----------------------|
| 33.5 | unacceptable | 73.1 ksi - 39.6% IACS |
| 28.6 | acceptable | 68.8 ksi - 40.2% IACS |

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TABLE 3B

| SI Units | | |
|------------|--------------|---------------------|
| MS/m = 232 | unacceptable | 504 MPa - 12 x 23 |
| MS/m = 194 | acceptable | 474 MPa - 12 x 23.3 |

- 3.3.2.3 Plate not meeting the requirements of 3.3.2.1 shall be given additional precipitation heat treatment or reheat treated. After such treatment, if all specified properties are met, the plate is acceptable.
- 3.3.3 Exfoliation-Corrosion Test: Plate shall not exhibit exfoliation-corrosion greater than that illustrated by Photo B, Figure 2, of ASTM G 34-72.
- 3.3.4 Stress-Corrosion Test: Specimens shall show no evidence of stress-corrosion cracking when stressed in the short-transverse direction at 35.0 ksi (241 MPa) for 20 days in accordance with ASTM G 47.
- 3.3.5 Fracture Toughness: When specified, plate shall meet the values for K_{1c} specified in Table 4. For T-L and L-T test directions on plate over 3 to 4 inches (76 to 102 mm), inclusive, in nominal thickness, use specimens 2-inch (51-mm) minimum thickness centered at T/2; and for plate over 4 inches (102 mm) in nominal thickness, use specimens 2-inch (51-mm) minimum thickness centered at T/4. For the S-L test direction, the test specimen shall be centered at T/2. Required specimen orientation(s) shall be specified by purchaser.

TABLE 4A - Minimum Fracture Toughness Parameters, Inch/Pound Units

| Nominal Thickness, Inches | L-T ksi | T-L ksi | S-L ksi |
|------------------------------|------------|------------|------------|
| Over 3.000 to 4.000, incl | 31 | 26 | 24 |
| Over 4.000 to 5.000, incl | 30 | 25 | 24 |
| Over 5.000 to 6.000, incl | 29 | 23 | 24 |
| Over 6.000 to 7.000, incl | 27 | 22 | 23 |
| Over 7.000 to 8.000, incl | 26 | 22 | 23 |
| Over 8.000 to 9.000, incl | 26 | 21 | 22 |

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TABLE 4B - Minimum Fracture Toughness Parameters, SI Units

| Nominal Thickness, Millimeters | L-T MPa | T-L MPa | S-L MPa |
|-----------------------------------|------------|------------|------------|
| Over 76.20 to 101.60, incl | 34 | 28 | 26 |
| Over 101.60 to 127.00, incl | 33 | 27 | 26 |
| Over 127.00 to 152.40, incl | 32 | 25 | 26 |
| Over 152.40 to 177.80, incl | 30 | 24 | 25 |
| Over 177.80 to 203.20, incl | 28 | 24 | 25 |
| Over 203.20 to 229.00, incl | 28 | 23 | 24 |

- 3.3.6 **Fatigue Resistance:** When specified, 4 to 9-inch (102 to 229-mm) thick plate shall meet the values for fatigue life specified in Table 5. Two fatigue specimens from each end of the plate shall be sampled in the long transverse grain direction. These specimens are to be removed from the T/2, W/2 location. Fatigue testing shall be conducted in air at 70 °F + 5 (21 °C + 3) in accordance with ASTM E 466. They are to be tested at an R-ratio of 0.1, at a maximum stress of 35.0 ksi (241 MPa) and shall meet the fatigue requirements shown in Table 5. When agreed upon by the supplier and purchaser, alternate specimen location and test conditions, and fatigue life requirements may be used.

TABLE 5 - Fatigue Life Requirements

| | |
|-------------------------|----------------|
| Minimum cycles per test | 90,000 cycles |
| Average of 4 tests | 120,000 cycles |
| Runout | 300,000 cycles |

3.4 Quality:

Plate, as received by purchaser, shall be uniform in quality and condition, sound, and free from foreign materials and from imperfections detrimental to usage of the plate.

- 3.4.1 Each plate shall be ultrasonically inspected in accordance with ASTM B 594 and shall meet the requirements of 3.4.1.1 or 3.4.1.2 as applicable.
- 3.4.1.1 Plates weighing 2000 pounds (907 kg) and under shall meet the requirements for ultrasonic class A for plate 3.001 to 8.000 inches (76 to 203.20 mm) in nominal thickness.
- 3.4.1.2 The ultrasonic class for plates weighing over 2000 pounds (907 kg) or over 8.000 inches (203.20 mm) in nominal thickness shall be as agreed upon by purchaser and vendor.

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3.5 Tolerances:

Shall conform to all applicable requirements of ANSI H35.2 or ANSI H35.2M.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection:

The vendor of plate shall supply all samples for vendor's tests and shall be responsible for the performance of all required tests. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the plate conforms to the specified requirements.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Composition (3.1), tensile properties (3.3.1), corrosion resistance (3.3.2), tolerances (3.5), ultrasonic soundness (3.4.1) and, when specified, fracture toughness (3.3.5) and fatigue (3.3.6) are acceptance tests and shall be performed on each inspection lot.

4.2.2 Periodic Tests: Tests for exfoliation corrosion resistance (3.3.3) and stress-corrosion resistance (3.3.4) are periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.3 Sampling and Testing:

Shall be in accordance with AMS 2355 or MAM 2355 and the following:

4.3.1 Tensile specimens shall be taken with axis of specimens parallel to each applicable grain flow direction specified in Table 2.

4.3.2 When fracture toughness testing is specified, specimens shall be taken from the center width of at least one plate in each lot for each specimen orientation specified by purchaser.

4.3.3 When fatigue testing is specified, specimen shall be taken from at least one plate in each lot, at the location given in 3.3.6.

4.4 Reports:

The vendor of the plate shall furnish with each shipment a report stating that the product conforms to the chemical composition, tolerances, and ultrasonic tests, and showing the numerical results of tests on each inspection lot to determine conformance to the other acceptance test requirements. This report shall include the purchase order number, inspection lot number(s), AMS 4211, size and quantity. The report shall also identify the producer, the product form, and the size of the mill product.