## AZ63A: Postweld heat treatments for magnesium alloy castings

| Alloy | Welding rod | Temper before welding | Desired temper after welding | Postweld heat treatment |
|---|---|---|---|---|
| AZ63A | AZ63A or AZ92A(a) | F | T4 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b) |
| | | F | T6 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b), plus 5 h at 220 °C (430 °F) |
| | | T4 | T4 | 30 min at 385 ± 6 °C (725 ± 10 °F) |
| | | T4 or T6 | T6 | 30 min at 385 ± 6 °C (725 ± 10 °F), plus 5 h at 220 °C (430 °F) |
| AZ81A | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| AZ91C | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c), plus 4 h at 215 °C (420 °F) or 16 h at 170 °C (340 °F) |
| AZ92A | AZ92A | T4 | T4 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c), plus 4 h at 260 °C (500 °F) or 5 h at 220 °C (430 °F) |
| EQ21A | EQ21A | T4 or T6 | T6 | 1 h at 505 ± 6 °C (940 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| EZ33A | EZ33A | F or T5 | T5 | 2 h at 345 °C (650 °F)(d), and/or 5 h at 215 °C (420 °F), or 24 h at 220 °C (430 °F) |
| HK31A | HK31A(g) | T4 or T6 | T6 | 16 h at 205 °C (400 °F)(e) |
| HZ32A | HZ32A(g) | F or T5 | T5 | 16 h at 315 °C (600 °F) |
| QE22A | QE22A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| QH21A | QH21A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE43A | WE43A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE54A | WE54A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZC63A | ZC63A | T4 or T6 | T6 | 1 h at 425 ± 6 °C (795 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZE41A | ZE41A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F)(f) |
| ZH62A | ZH62A(g) | F or T5 | T5 | 12 h at 250 °C (480 °F)(f) |
| ZK51A | ZK51A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F) |

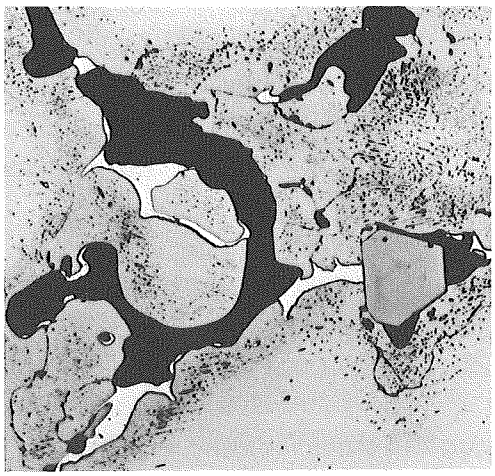
(a) AZ63A rod must be used for welding AZ63A in the F temper because 12 h at 385 °C (725 °F) causes germination in welds made with AZ92A rod; AZ92A rod normally is used for welding AZ63A in the T4 or T6 condition unless AZ63A rod is required by specifications. (b) Preheat to 260 °C (500 °F); heat to specified temperature at no more than 83 °C/h (150 °F/h). (c) Use carbon dioxide or sulfur dioxide atmosphere. (d) Heating for 2 h at 345 °C (650 °F) results in slight loss of creep strength. (e) Alternative treatment: 1 h at 315 °C (600 °F), plus 16 h at 205 °C (400 °F). (f) Alternative treatment: 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F). (g) Or EZ33A

## AZ63A: Typical tensile properties of sand castings at elevated temperatures

Tested as soon as specimens reached testing temperature

| Testing temperature °C | Testing temperature °F | Tensile strength MPa | Tensile strength ksi | Yield strength MPa | Yield strength ksi | Elongation in 50 mm (2 in.), % |
|---|---|---|---|---|---|---|
| **F temper** | | | | | | |
| 24 | 75 | 197 | 28.6 | 94 | 13.7 | 4.5 |
| 65 | 150 | 210 | 30.5 | ... | ... | 3.0 |
| 93 | 200 | 208 | 30.1 | ... | ... | 4.5 |
| 120 | 250 | 191 | 27.7 | ... | ... | 7.5 |
| 150 | 300 | 166 | 24.1 | ... | ... | 20.5 |
| 205 | 400 | 105 | 15.3 | ... | ... | 50.5 |
| 260 | 500 | 71 | 10.3 | ... | ... | 38.0 |
| **T4 temper** | | | | | | |
| 24 | 75 | 254 | 36.8 | 94 | 13.6 | 10.0 |
| 65 | 150 | 253 | 36.7 | ... | ... | 9.0 |
| 93 | 200 | 236 | 34.3 | ... | ... | 7.0 |
| 120 | 250 | 207 | 30.0 | ... | ... | 9.0 |
| 150 | 300 | 154 | 22.4 | ... | ... | 33.2 |
| 205 | 400 | 101 | 14.6 | ... | ... | 38.0 |
| 260 | 500 | 75 | 10.9 | ... | ... | 26.0 |
| **T6 temper** | | | | | | |
| 35 | 95 | 232 | 33.7 | 122 | 17.7 | 5.5 |
| 93 | 200 | 248 | 36.0 | 119 | 17.3 | 11.0 |
| 120 | 250 | 223 | 32.4 | 114 | 16.5 | 11.0 |
| 150 | 300 | 169 | 24.5 | 103 | 15.0 | 15.0 |
| 205 | 400 | 121 | 17.5 | 83 | 12.0 | 17.0 |
| 260 | 500 | 83 | 12.0 | 61 | 8.8 | 15.0 |
| 315 | 600 | 57 | 8.2 | 39 | 5.6 | 20.0 |

**AZ63A: Microstructure.** Massive $Mg_{32}(Al,Zn)_{49}$ (white) in as-cast specimen etched with 50% picral to protect $Mg_2Si$ (hexagonal particle) from HF, then with 5% HF to blacken $Mg_{17}Al_{12}$ and distinguish it from $Mg_{32}(Al,Zn)_{49}$, then with 10% picral to darken the matrix. 500×



# AZ81A

A magnesium-aluminum-zinc alloy

**Chemical Composition. Composition Limits.** 7.0 to 8.1 Al, 0.4 to 1.0 Zn, 0.13 Mn min, 0.30 Si max, 0.10 Cu max, 0.01 Ni max, 0.30 max other (total), bal Mg

**Consequence of Exceeding Impurity Limits.** Excessive Si causes brittleness. Excessive Cu degrades mechanical properties and corrosion resistance. Excessive Ni degrades corrosion resistance

**Specifications (U.S. and/or Foreign).** (ASTM) Sand castings: B 80. Ingot: B 93. Permanent mold castings: B 199. Investment castings: B 403; SAE J465. Former SAE alloy number: 505; UNS M11810; (Government) Sand castings: QQ-M-56. Permanent mold castings: QQ-M-55; (Foreign) Elektron A8. (British) BS 2970 MAG1. (German) DIN 1729 3.5812. (French) AIR 3380 G-A9

## Characteristics

**Product Forms.** Sand and permanent mold castings

**Applications/Typical Uses.** Sand and permanent mold casting, which have good strength combined with excellent ductility and toughness, are used in the solution treated condition (T4 temper)

## Mechanical Properties

See Tables for typical tensile properties of sand castings at elevated temperatures, and for typical creep properties of AZ81A-T6 sand castings

## Fabrication Properties

A castable, weldable alloy. Gas-shielded, metal arc welding with AZ92A rod has "very good" rating

## Recommended Heat Treating Practice

Solution treating to the T4 temper is the most commonly used heat treatment

**Solution Heat Treating.** A281A is treated at 415 °C (775 F) for 16 to 24 h. Maximum treatment temperature is 420 °C (785 °F)

Alternative solution treatment: purpose is to prevent germination (excessive grain growth). Material is treated 6 h at 415 ± 6 °C (775 ± 10 °F), 2 h at 352 ± 6 °C (665 ± 10 °F), 10 h at 415 ± 6 °C (775 ± 10 °F)

See Table for postweld heat treatment of AZ81A

In solution treating, Mg-Al-Zn alloys are loaded into furnace at 260 °C (500 °F) and brought to temperature over 2 h period, at a uniform rate of temperature increase

### AZ81A-T6: Postweld heat treatments for magnesium alloy castings

| Alloy | Welding rod | Temper before welding | Desired temper after welding | Postweld heat treatment |
|---|---|---|---|---|
| AZ63A | AZ63A or AZ92A(a) | F | T4 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b) |
| | | F | T6 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b), plus 5 h at 220 °C (430 °F) |
| | | T4 | T4 | 30 min at 385 ± 6 °C (725 ± 10 °F) |
| | | T4 or T6 | T6 | 30 min at 385 ± 6 °C (725 ± 10 °F), plus 5 h at 220 °C (430 °F) |
| AZ81A | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| AZ91C | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c), plus 4 h at 215 °C (420 °F) or 16 h at 170 °C (340 °F) |
| AZ92A | AZ92A | T4 | T4 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c), plus 4 h at 260 °C (500 °F) or 5 h at 220 °C (430 °F) |
| EQ21A | EQ21A | T4 or T6 | T6 | 1 h at 505 ± 6 °C (940 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| EZ33A | EZ33A | F or T5 | T5 | 2 h at 345 °C (650 °F)(d), and/or 5 h at 215 °C (420 °F), or 24 h at 220 °C (430 °F) |
| HK31A | HK31A(g) | T4 or T6 | T6 | 16 h at 205 °C (400 °F)(e) |
| HZ32A | HZ32A(g) | F or T5 | T5 | 16 h at 315 °C (600 °F) |
| QE22A | QE22A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| QH21A | QH21A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE43A | WE43A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE54A | WE54A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZC63A | ZC63A | T4 or T6 | T6 | 1 h at 425 ± 6 °C (795 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZE41A | ZE41A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F)(f) |
| ZH62A | ZH62A(g) | F or T5 | T5 | 12 h at 250 °C (480 °F)(f) |
| ZK51A | ZK51A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F) |

(a) AZ63A rod must be used for welding AZ63A in the F temper because 12 h at 385 °C (725 °F) causes germination in welds made with AZ92A rod: AZ92A rod normally is used for welding AZ63A in the T4 or T6 condition unless AZ63A rod is required by specifications. (b) Preheat to 260 °C (500 °F); heat to specified temperature at no more than 83 °C/h (150 °F/h). (c) Use carbon dioxide or sulfur dioxide atmosphere. (d) Heating for 2 h at 345 °C (650 °F) results in slight loss of creep strength. (e) Alternative treatment: 1 h at 315 °C (600 °F), plus 16 h at 205 °C (400 °F). (f) Alternative treatment: 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F). (g) Or EZ33A

### AZ81A-T6: Typical tensile properties of sand castings at elevated temperatures

Properties determined using separately cast test bars

| Testing temperature | | Tensile strength | | Yield strength | | Elongation in |
|---|---|---|---|---|---|---|
| °C | °F | MPa | ksi | MPa | ksi | 50 mm (2 in.), % |
| 21 | 70 | 275 | 40.0 | 83 | 12.0 | 15.0 |
| 93 | 200 | 260 | 37.5 | 83 | 12.0 | 20.0 |
| 150 | 300 | 190 | 27.5 | 80 | 11.5 | 24.5 |
| 205 | 400 | 140 | 20.0 | 76 | 11.0 | 29.0 |
| 260 | 500 | 97 | 14.0 | 72 | 10.5 | 35.0 |

### AZ81A-T6: Typical creep properties of sand castings

Properties determined using separately cast test bars

| Time under load, h | Tensile stress resulting in total extension(a) of 0.1% MPa | 0.1% ksi | 0.2% MPa | 0.2% ksi | 0.5% MPa | 0.5% ksi |
|---|---|---|---|---|---|---|
| **At 93 °C (200 °F)** | | | | | | |
| 1 | 39 | 5.6 | 58 | 8.4 | 86 | 12.5 |
| 10 | 37 | 5.4 | 55 | 8.0 | 83 | 12.0 |
| 100 | 36 | 5.2 | 51 | 7.4 | 81 | 11.8 |
| **At 150 °C (300 °F)** | | | | | | |
| 1 | 37 | 5.4 | 53 | 7.7 | ... | ... |
| 10 | 28 | 4.0 | 45 | 6.5 | 62 | 9.0 |
| 100 | 15 | 2.2 | 24 | 3.5 | 46 | 6.6 |
| **At 205 °C (400 °F)** | | | | | | |
| 1 | 23 | 3.4 | 41 | 6.0 | ... | ... |
| 10 | 12 | 1.7 | 21 | 3.1 | ... | ... |
| 100 | 7 | 1.0 | 12 | 1.7 | 21 | 3.0 |

(a) Total extension equals initial extension plus creep extension

# AZ91A, AZ91B, AZ91C, AZ91D, AZ91E

A magnesium-aluminum-zinc alloy

**Chemical Composition. Composition Limits of AZ91A.** 8.3 to 9.7 Al, 0.13 Mn min, 0.35 to 1.0 Zn, 0.50 Si max, 0.10 Cu max, 0.03 Ni max, 0.30 max other, bal Mg

**Composition Limits of AZ91B.** 8.3 to 9.7 Al, 0.13 Mn min, 0.35 to 1.0 Zn, 0.50 Si max, 0.35 Cu max, 0.03 Ni max, 0.30 max other, bal Mg

**Composition Limits of AZ91C.** 8.1 to 9.3 Al, 0.13 Mn min, 0.40 to 1.0 Zn, 0.30 Si max, 0.10 Cu max, 0.01 Ni max, 0.3 max other (total), bal Mg

**Composition Limits of AZ91D.** 8.3 to 9.7 Al, 0.15 Mn min, 0.35 to 1.0 Zn, 0.10 Si max, 0.005 Fe max, 0.030 Cu max, 0.002 Ni max, 0.02 max other (each), bal Mg

**Composition Limits of AZ91E.** 8.1 to 9.3 Al, 0.17 to 0.35 Mn, 0.4 to 1.0 Zn, 0.20 Si max, 0.005 Fe max, 0.015 Cu max, 0.0010 Ni max, 0.01 max other (each), 0.30 max other (total)

**Consequence of Exceeding Impurity Limits.** Corrosion resistance decreases with increasing Fe, Cu, or Ni content. More than 0.5% Si decreases elongation. If Fe content exceeds 0.005% in AZ91D or AZ91E, the permissible Fe-Mn ratio will not exceed 0.032, and corrosion resistance will rapidly decrease.

**Specifications (U.S. and/or Foreign).** (AMS) Die castings: AZ91A, 4490. Sand castings: AZ91C, 4437; AZ91E, 4446; (ASTM) Die Castings: AZ91A, AZ91B, and AZ91D, B 94. Sand castings: AZ91C and AZ91E, B 80. Permanent mold castings: AZ91C and AZ91E, B 199. Investment castings: AZ91C and AZ91E, B 403. Ingot: B 93; SAE J465. Former SAE alloy numbers: AZ91A, 501; AZ91B, 501A; AZ91C, 504; UNS AZ91A: M11910. AZ91B: M11912. AZ91C: M11914. AZ91D: M11916. AZ91E: M11921; (Government) Die castings: AZ91A, QQ-M-38. Permanent mold castings: AZ92C, QQ-M-55 and MIL-M-46062. Sand castings: AZ91C, QQ-M-56, and MIL-M-46062; (Foreign) Elektron AZ91. (British) BS 2970 MAG3. (French) AIR 3380 G-AZ91. (German) DIN 1729 3.5912

## Characteristics

**Product Forms.** Products include die castings, sand castings, permanent mold castings, and investment castings

**Applications/Typical Uses.** AZ91A, AZ91B, and AZ91D (which have the same nominal composition except for iron, copper, and nickel contents) are die casting alloys used in the as-cast condition (F temper). AZ91D is a high-purity alloy which has excellent corrosion resistance; it is the most commonly used magnesium die casting alloy. AZ91A and AZ91B can be made from secondary metal, reducing the cost of the alloy; they must be used when maximum corrosion resistance is not required. AZ91E is a high-purity alloy with excellent corrosion resistance used in pressure-tight sand and permanent mold castings with high tensile strength and moderate yield strength. AZ91C is used in sand and permanent mold castings when maximum corrosion resistance is not required

**AZ91: Typical room-temperature mechanical properties of AZ91A, AZ91B, AZ91C, AZ91D, and AZ91E castings**

| Property | AZ91A, AZ91B, and AZ91D | | AZ91C and AZ91E | |
|---|---|---|---|---|
| | F temper | F temper | T4 temper | T6 temper |
| Tensile strength, MPa (ksi) | 230 (33) | 165 (24) | 275 (40) | 275 (40) |
| Tensile yield strength, MPa (ksi) | 150 (22) | 97 (14) | 90 (13) | 145 (21) |
| Elongation in 50 mm (2 in.), % | 3 | 2.5 | 15 | 6 |
| Compressive yield strength at 0.2% offset, MPa (ksi) | 165 (24) | 97 (14) | 90 (13) | 130 (19) |
| Ultimate bearing strength, MPa (ksi) | ... | 415 (60) | 415 (60) | 515 (75) |
| Bearing yield strength, MPa (ksi) | ... | 275 (40) | 305 (44) | 360 (52) |
| Hardness | | | | |
| HB | 63 | 60 | 55 | 70 |
| HRE | 75 | 66 | 62 | 77 |
| Charpy V-notch impact strength, J (ft · lbf) | 2.7 (2.0) | 0.79 (0.58) | 4.1 (3.0) | 1.4 (1.0) |

## Corrosion Properties

For excellent corrosion resistance: AZ91D and AZ91E. For less than maximum corrosion resistance: AZ91A, AZ91B, AZ91C

## Mechanical Properties

See Table for typical room-temperature properties of AZ91A, AZ91B, AZ91C, AZ91D, AZ91E castings

See Table for typical tensile properties of A291 sand castings at elevated temperatures

## Fabrication Properties

**Weldability.** AZ91C and AZ91E can be readily welded by the gas-shielded arc process using AZ91C or AZ91A rod; stress relief required. AZ91A, AZ91B, and AZ91D not weldable

**Hot-Shortness Temperature.** 400 °C (750 °F)

## Recommended Heat Treating Practice

A291C is commonly solution treated to T4 temper or solution treated and artificially aged to T6 temper

**Solution Heat Treating.** AZ91C-F to T4 temper: 415 °C (775 °F) for 16 to 24 h. Maximum treating temperature is 418 °C (785 °F)

Alternative treatment for AZ91-C-F to T4 temper: purpose is to prevent germination (excessive grain growth): 6 h at 415 ± 6 °C (775 ± 10 °F), 2 h at 352 ± 6 °C (665 ± 10 °F), 10 h at 415 ± 6 °C (775 ± 10 °F)

**Note:** In solution treating, Mg-Al-Zn alloys are loaded into furnace at 260 °C (500 °F) and brought to temperature over 2 h period at a uniform rate of temperature increase

**Aging.** AZ91C in F temper is aged to T5 temper by heating to 168 °C (335 °F) for 16 h

Alternative treatment for AZ91C-F to T5 temper: 4 h at 215 ± 6 °C (420 ± 10 °F)

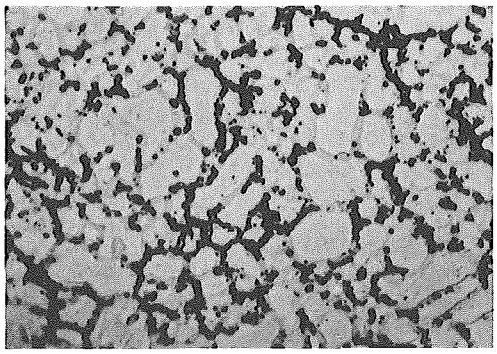
**Solution Treating AZ91-C-F to T6 Temper and Subsequent Aging:**

- For solution treating: Treat at 415 °C (775 °F) for 16 to 24 h. Maximum treatment temperature is 418 °C (785 °F)
- For aging: Treat at 168 °C (335 °F) for 16 h
- Alternative solution treatment. Purpose is to avoid germination (excessive grain growth): 6 h at 415 ± 6 °C (775 ± 10 °F), 2 h at 352 ± 6 °C (665 ± 10 °F), 10 h at 415 ± 6 °C (775 ± 10 °F)
- Alternative aging treatment: 5 to 6 h at 215 ± 6 °C (420 ± 10 °F)

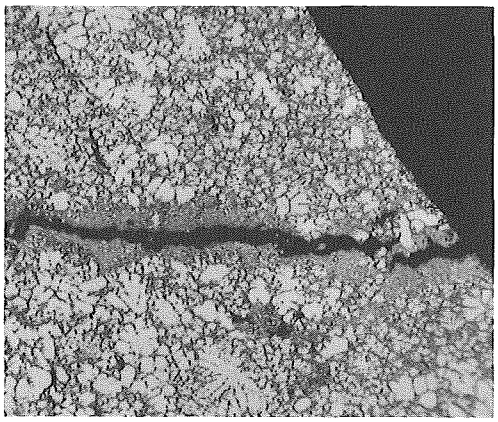
**Note:** After solution treatment and before subsequent aging, castings are cooled to room temperature by fast fan cooling, except where otherwise indicated. Use carbon dioxide, sulfur dioxide, or 0.5 to 1.5% sulfur hexafluoride in carbon dioxide as protective atmosphere at temperature above 400 °C (750 °F)

See Table for postweld heat treatment of AZ91A-T4 and T6 castings

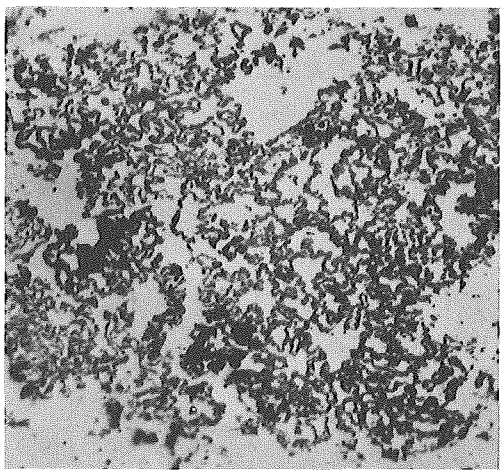
**AZ91A-F: Microstructure.** AZ91A-F die casting. Massive $Mg_{17}Al_{12}$ compound at the boundaries of small, cored grains. Segregation (coring) in the grains and absence of precipitated discontinuous $Mg_{17}Al_{12}$ are results of the rapid cooling rate of die castings. 500×



**AZ91A-F: Microstructure.** Hot tear in an AZ91A-F die casting. Tear occurred in an area of compound segregation that was last to solidify and least resistant to stress caused by mold restriction during solidification shrinkage. 75×



**AZ91A-F: Microstructure.** Segregation of thin oxide skin in an AZ91A-F die casting. This type of skin forms whenever molten metal surfaces are exposed to the atmosphere for a few seconds. 250×



## AZ91C-T6: Typical tensile properties of sand castings at elevated temperatures

| Testing temperature | | Tensile strength | | Tensile yield strength | | Elongation in |
|---|---|---|---|---|---|---|
| °C | °F | MPa | ksi | MPa | ksi | 50 mm (2 in.), % |
| 150 | 300 | 185 | 27 | 97 | 14 | 40 |
| 205 | 400 | 115 | 17 | 83 | 12 | 40 |

## AZ91: Postweld heat treatments for magnesium alloy castings

| Alloy | Welding rod | Temper before welding | Desired temper after welding | Postweld heat treatment |
|---|---|---|---|---|
| AZ63A | AZ63A or AZ92A(a) | F | T4 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b) |
| | | F | T6 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b), plus 5 h at 220 °C (430 °F) |
| | | T4 | T4 | 30 min at 385 ± 6 °C (725 ± 10 °F) |
| | | T4 or T6 | T6 | 30 min at 385 ± 6 °C (725 ± 10 °F), plus 5 h at 220 °C (430 °F) |
| AZ81A | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| AZ91C | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c), plus 4 h at 215 °C (420 °F) or 16 h at 170 °C (340 °F) |
| AZ92A | AZ92A | T4 | T4 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c), plus 4 h at 260 °C (500 °F) or 5 h at 220 °C (430 °F) |
| EQ21A | EQ21A | T4 or T6 | T6 | 1 h at 505 ± 6 °C (940 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| EZ33A | EZ33A | F or T5 | T5 | 2 h at 345 °C (650 °F)(d), and/or 5 h at 215 °C (420 °F), or 24 h at 220 °C (430 °F) |
| HK31A | HK31A(g) | T4 or T6 | T6 | 16 h at 205 °C (400 °F)(e) |
| HZ32A | HZ32A(g) | F or T5 | T5 | 16 h at 315 °C (600 °F) |
| QE22A | QE22A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| QH21A | QH21A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE43A | WE43A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE54A | WE54A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZC63A | ZC63A | T4 or T6 | T6 | 1 h at 425 ± 6 °C (795 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZE41A | ZE41A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F)(f) |
| ZH62A | ZH62A(g) | F or T5 | T5 | 12 h at 250 °C (480 °F)(f) |
| ZK51A | ZK51A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F) |

(a) AZ63A rod must be used for welding AZ63A in the F temper because 12 h at 385 °C (725 °F) causes germination in welds made with AZ92A rod: AZ92A rod normally is used for welding AZ63A in the T4 or T6 condition unless AZ63A rod is required by specifications. (b) Preheat to 260 °C (500 °F); heat to specified temperature at no more than 83 °C/h (150 °F/h). (c) Use carbon dioxide or sulfur dioxide atmosphere. (d) Heating for 2 h at 345 °C (650 °F) results in slight loss of creep strength. (e) Alternative treatment: 1 h at 315 °C (600 °F), plus 16 h at 205 °C (400 °F). (f) Alternative treatment: 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F). (g) Or EZ33A

# AZ92A

A magnesium-aluminum-zinc alloy

**Chemical Composition. Composition Limits.** 8.3 to 9.7 Al, 0.10 Mn min, 1.6 to 2.4 Zn, 0.30 Si max, 0.25 Cu max, 0.01 Ni max, 0.30 max other (total), bal Mg

**Consequence of Exceeding Impurity Limits.** Excessive Cu or Ni degrades corrosion resistance. More than 0.5% Si decreases elongation

**Specifications (U.S. and/or Foreign).** (AMS) Sand castings: 4434. Investment castings: 4453. Permanent mold castings: 4484; (ASTM) Ingot: B 93. Sand castings: B 80. Permanent mold castings: B 199. Investment castings: B 403; SAE J465. Former SAE alloy number: 500; UNS M11920; (Government) Sand castings: QQ-M-56 and MIL-M-46062. Permanent mold castings: QQ-M-55 and MIL-M-46062

## Characteristics

**Product Forms.** Sand Castings, permanent mold castings, investment castings

**Applications/Typical Uses.** Pressure-tight sand and permanent mold castings with high tensile strength and good yield strength

### Typical tensile properties of AZ92A sand castings

Properties determined using separately cast test bars.

| Temper | Tensile strength MPa | Tensile strength ksi | Yield strength MPa | Yield strength ksi | Elongation, %(a) |
|---|---|---|---|---|---|
| F | 170 | 25 | 97 | 14 | 2 |
| T4 | 275 | 40 | 97 | 14 | 10 |
| T5 | 170 | 25 | 115 | 17 | 1 |
| T6 | 275 | 40 | 150 | 22 | 3 |
| T7 | 275 | 40 | 145 | 21 | 3 |

(a) In 50 mm (2 in.)

## Mechanical Properties

See Table for typical tensile properties of AZ92A sand castings at elevated temperatures

**Hardness.** F temper: 65 HB or 76 HRE. T4 temper: 63 HB or 75 HRE. T5 temper: 69 HB or 80 HRE. T6 temper: 81 HB or 88 HRE. T7 temper: 78 HB or 86 HRE

## Fabrication Properties

A weldable casting alloy. Gas-shielded, arc welding with AZ92A rod is rated "Good." Stress relief after welding is required

## Recommended Heat Treating Practice

Common heat treatments are for solution treated T4 temper and for solution treated and artificially aged T6 temper

**Solution Heat Treating.** To obtain T4 temper, material is treated at 410 °C (765 °F) for 16 to 24 h. Maximum treatment temperature is 415 °C (775 °F)

Alternative treatment for T4 temper. Purpose is to prevent germination (excessive grain growth): Treat 6 h at 410 ± 6 °C (765 ± 10 °F), 2 h at 352 ± 6 °C (665 ± 10 °F), 10 h at 410 ± 6 °C (765 ± 10 °F)

**Note:** In solution treating, Mg-Al-Zn alloys are loaded into furnace at 260 °C (500 °F) and brought to temperature over 2 h period, at uniform rate of temperature increase.

**Aging.** Aging to T5 temper is done in the as-fabricated F condition. Material is aged at 260 °C (500 °F) for 4 h

**Solution Treating to T6 Temper Followed by Aging:**

- Solution treating is at 410 °C (765 °F) for 16 to 24 h. Maximum treatment temperature is 415 °C (775 °F)
- Aging is at 218 °C (425 °F) for 5 h
- An alternative solution treating procedure is designed to prevent germination (excessive grain growth). It consists of treating 6 h at 410 ± 6 °C (765 ± 10 °F), 2 h at 352 ± 6 °C (665 ± 10 °F), 10 h at 410 ± 6 °C (765 ± 10 °F)

**Note:** After solution treating and before aging, castings are cooled to room temperature by fast fan cooling, except where otherwise indicated. Use carbon dioxide, sulfur dioxide, or 0.5 to 1.5% sulfur hexafluoride in carbon dioxide at temperatures above 400 °C (750 °F)

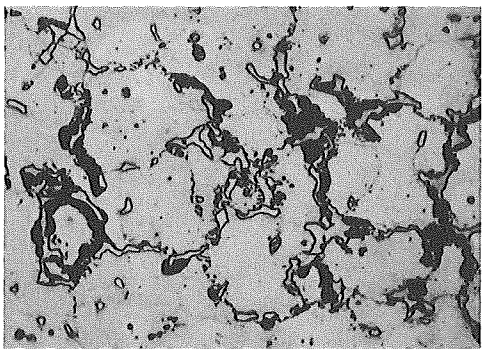
See Table for postweld heat treatments for AZ92A castings in T4 and T6 tempers

### AZ92A: Typical tensile properties of sand castings at elevated temperatures

| Testing temperature(a) °C | Testing temperature(a) °F | Tensile strength MPa | Tensile strength ksi | Elongation in 50 mm (2 in.) % | Time at temperature, days(b) |
|---|---|---|---|---|---|
| **F temper** | | | | | |
| 93 | 200 | 170 | 25 | 2 | 80 |
| 150 | 300 | 150 | 22 | 3 | 160 |
| 205 | 400 | 110 | 16 | 36 | 160 |
| 260 | 500 | 83 | 12 | 34 | 40 |
| **T4 temper** | | | | | |
| 93 | 200 | 275 | 40 | 8 | 160 |
| 150 | 300 | 180 | 26 | 40 | 160 |
| 205 | 400 | 115 | 17 | 41 | 160 |
| 260 | 500 | 76 | 11 | 52 | 40 |
| **T6 temper** | | | | | |
| 93 | 200 | 260 | 38 | 7 | 160 |
| 150 | 300 | 170 | 25 | 40 | 160 |
| 205 | 400 | 115 | 17 | 43 | 160 |
| 260 | 500 | 76 | 12 | 47 | 40 |

(a) Tested after prolonged heating at testing temperature. (b) Prior to testing

**AZ92A: Microstructure.** Permanent mold casting. $Mg_{17}Al_{12}$ compound: Massive (outlined) at grain boundaries; precipitated (dark) near grain boundaries. Slower cooling rate than that of die castings has resulted in larger grains. 250×

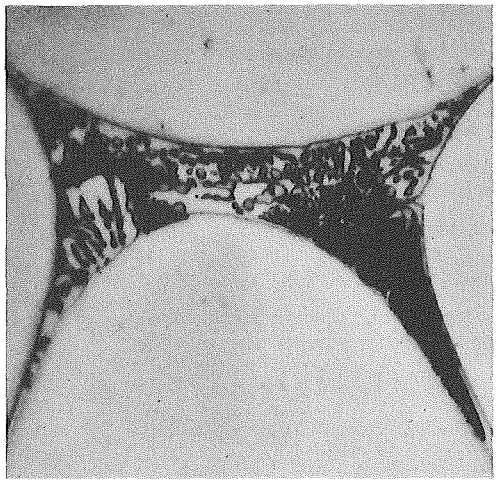


### AZ92A: Postweld heat treatments for magnesium alloy castings

| Alloy | Welding rod | Temper before welding | Desired temper after welding | Postweld heat treatment |
|---|---|---|---|---|
| AZ63A | AZ63A or AZ92A(a) | F | T4 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b) |
| | | F | T6 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b), plus 5 h at 220 °C (430 °F) |
| | | T4 | T4 | 30 min at 385 ± 6 °C (725 ± 10 °F) |
| | | T4 or T6 | T6 | 30 min at 385 ± 6 °C (725 ± 10 °F), plus 5 h at 220 °C (430 °F) |
| AZ81A | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| AZ91C | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c), plus 4 h at 215 °C (420 °F) or 16 h at 170 °C (340 °F) |
| AZ92A | AZ92A | T4 | T4 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c), plus 4 h at 260 °C (500 °F) or 5 h at 220 °C (430 °F) |
| EQ21A | EQ21A | T4 or T6 | T6 | 1 h at 505 ± 6 °C (940 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| EZ33A | EZ33A | F or T5 | T5 | 2 h at 345 °C (650 °F)(d), and/or 5 h at 215 °C (420 °F), or 24 h at 220 °C (430 °F) |
| HK31A | HK31A(g) | T4 or T6 | T6 | 16 h at 205 °C (400 °F)(e) |
| HZ32A | HZ32A(g) | F or T5 | T5 | 16 h at 315 °C (600 °F) |
| QE22A | QE22A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| QH21A | QH21A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE43A | WE43A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE54A | WE54A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZC63A | ZC63A | T4 or T6 | T6 | 1 h at 425 ± 6 °C (795 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZE41A | ZE41A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F)(f) |
| ZH62A | ZH62A(g) | F or T5 | T5 | 12 h at 250 °C (480 °F)(f) |
| ZK51A | ZK51A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F) |

(a) AZ63A rod must be used for welding AZ63A in the F temper because 12 h at 385 °C (725 °F) causes germination in welds made with AZ92A rod; AZ92A rod normally is used for welding AZ63A in the T4 or T6 condition unless AZ63A rod is required by specifications. (b) Preheat to 260 °C (500 °F); heat to specified temperature at no more than 83 °C/h (150 °F/h). (c) Use carbon dioxide or sulfur dioxide atmosphere. (d) Heating for 2 h at 345 °C (650 °F) results in slight loss of creep strength. (e) Alternative treatment: 1 h at 315 °C (600 °F), plus 16 h at 205 °C (400 °F). (f) Alternative treatment: 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F). (g) Or EZ33A

**AZ92A-F: Microstructure.** AZ92A-F sand casting. The appearance of the interdendritic eutectic, a mixture of magnesium solid solution and $Mg_{17}Al_{12}$, was retained in this form by a rapid quench from above the eutectic temperature. 1500×



**AZ92A-F: Microstructure.** AZ92A-F, as-cast. Massive $Mg_{17}Al_{12}$ compound surrounded by lamellar $Mg_{17}Al_{12}$ precipitate. Normal air cooling of zinc-containing magnesium-aluminum alloys produces this type of completely divorced eutectic. 500×

# EQ21

## A magnesium-zirconium-alloy

**Chemical Composition. Composition Limits.** 1.3 to 1.7 Ag, 1.75 to 2.5 Nd-rich rare earths, 0.4 to 1.0 Zr, 0.05 to 0.10 Cu, 0.01 Ni max, 0.3 max other (total), bal Mg

**Consequence of Exceeding Impurity Limits.** Zr content below 0.5% may result in somewhat coarser as-cast grains and lower mechanical properties

**Specifications (U.S. and/or Foreign).** AMS 4417; (ASTM) Sand castings: B 80. Permanent mold castings: B 199. Investment castings: B 403; UNS M16330; (Government) Sand and permanent mold castings: MIL-M-46062; (Foreign) (British) BS 2970 MAG13

## Characteristics

**Product Forms.** Sand castings, permanent mod castings, and investment castings

**Applications/Typical Uses.** Sand and permanent mold castings used in the solution-treated and artificially aged condition (T6 temper), with high yield strengths at service temperatures up to 200 °C (390 °F). Castings have excellent short-time elevated-temperature mechanical properties and are pressure tight and weldable.

## Mechanical Properties

**Tensile Properties.** In T6 temper, tensile strength is 235 MPa (34 ksi); yield strength is 170 MPa (25 ksi); elongation is 2% in 50 mm (2 in.)

**Hardness.** 65 to 85 HB

## Fabrication Properties

A castable, weldable alloy. Welding is with gas-shielded arc process, using A292A rod. Stress relief is required after welding

## Recommended Heat Treating Practice

EQ21A is commonly solution treated and artificially aged to T6 condition

**Solution Heat Treating.** EQ21A is solution treated at 525 °C (970 °F) for 4 to 8 h. Maximum treatment temperature is 530 °C (985 °F). Quenching from solution treating temperature is either in water at 65 °C (150 °F) or in some other suitable medium

**Aging After Solution Treating.** The alloy is artificially aged at 200 °C (390 °F) for 16 h

**EQ21A: Postweld heat treatments for magnesium alloy castings**

| Alloy | Welding rod | Temper before welding | Desired temper after welding | Postweld heat treatment |
|---|---|---|---|---|
| AZ63A | AZ63A or AZ92A(a) | F | T4 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b) |
| | | F | T6 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b), plus 5 h at 220 °C (430 °F) |
| | | T4 | T4 | 30 min at 385 ± 6 °C (725 ± 10 °F) |
| | | T4 or T6 | T6 | 30 min at 385 ± 6 °C (725 ± 10 °F), plus 5 h at 220 °C (430 °F) |
| AZ81A | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| AZ91C | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c), plus 4 h at 215 °C (420 °F) or 16 h at 170 °C (335 °F) |
| AZ92A | AZ92A | T4 | T4 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c), plus 4 h at 260 °C (500 °F) or 5 h at 220 °C (430 °F) |
| EQ21A | EQ21A | T4 or T6 | T6 | 1 h at 505 ± 6 °C (940 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| EZ33A | EZ33A | F or T5 | T5 | 2 h at 345 °C (650 °F)(d), and/or 5 h at 215 °C (420 °F), or 24 h at 220 °C (430 °F) |
| HK31A | HK31A(g) | T4 or T6 | T6 | 16 h at 205 °C (400 °F)(e) |
| HZ32A | HZ32A(g) | F or T5 | T5 | 16 h at 315 °C (600 °F) |
| QE22A | QE22A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| QH21A | QH21A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE43A | WE43A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE54A | WE54A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZC63A | ZC63A | T4 or T6 | T6 | 1 h at 425 ± 6 °C (795 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZE41A | ZE41A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F)(f) |
| ZH62A | ZH62A(g) | F or T5 | T5 | 12 h at 250 °C (480 °F)(f) |
| ZK51A | ZK51A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F) |

(a) AZ63A rod must be used for welding AZ63A in the F temper because 12 h at 385 °C (725 °F) causes germination in welds made with AZ92A rod: AZ92A rod normally is used for welding AZ63A in the T4 or T6 condition unless AZ63A rod is required by specifications. (b) Preheat to 260 °C (500 °F); heat to specified temperature at no more than 83 °C/h (150 °F/h). (c) Use carbon dioxide or sulfur dioxide atmosphere. (d) Heating for 2 h at 345 °C (650 °F) results in slight loss of creep strength. (e) Alternative treatment: 1 h at 315 °C (600 °F), plus 16 h at 205 °C (400 °F). (f) Alternative treatment: 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F). (g) Or EZ33A

# EZ33A

A magnesium-chromium alloy

**Chemical Composition. Composition Limits.** 2.5 to 4.0 rare earths, 2.0 to 3.1 Zn, 0.50 to 1.0 Zr, 0.10 Cu max, 0.01 Ni max, 0.30 max other (total), bal Mg

**Specifications (U.S. and/or Foreign).** (AMS) Sand castings: 4442; (ASTM) Sand castings: B 80. Permanent mold castings: B 199. Investment castings: B 403; SAE J465. Former SAE alloy number: 506; UNS M12330; (Government) Sand castings: QQ-M-56. Permanent mold castings: QQ-M-55. Welding rod: MIL-R-6944; (Foreign) Elektron ZRE1. (British) BS 2970 MAG6. (German) DIN 1729 3.5103. (French) AIR 3380 ZRE1

## Characteristics

**Product Forms.** Sand castings, permanent mold castings, investment casting

**Applications/Typical Uses.** Pressure-tight sand and permanent mold castings relatively free from microporosity, used in T5 condition for applications requiring good strength properties up to 260 °C (500 °F)

## Mechanical Properties

**Tensile Properties.** T5 temper, tensile strength is 160 MPa (23 ksi); yield strength is 110 MPa (16 ksi); elongation is 3% in 50 mm (2 in.)

**Hardness.** 50 HB or 59 HRE

## Fabrication Properties

A castable, weldable alloy. Welding properties (gas-shielded metal arc process, using EZ33A rod) are excellent. Preheating may be used, but it isn't necessary. Postweld heat treatment is required

See Tables for typical tensile properties of EZ33A-T5 sand castings at elevated temperature, and for typical creep properties of EZ33A-T5 sand castings

## Recommended Heat Treating Practice

EZ330 is generally heat treated to the T5 temper (artificially aged only)

**Aging.** Alloy is in F (as-fabricated) condition. Aging takes place at 175 ± 6 °C (345 ± 10 °F) over 16 h period

### EZ33A-T5: Typical creep properties of sand castings

Properties determined using separately cast test bars.

| Time under load, h | Tensile stress resulting in total extension(a) of 0.1% MPa | 0.1% ksi | 0.2% MPa | 0.2% ksi | 0.5% MPa | 0.5% ksi | 1.0% MPa | 1.0% ksi |
|---|---|---|---|---|---|---|---|---|
| **At 205 °C (400 °F)** | | | | | | | | |
| 1 | 41 | 6 | 69 | 10 | 89 | 13 | 105 | 15 |
| 10 | 41 | 6 | 62 | 9 | 83 | 12 | 89 | 13 |
| 100 | 34 | 5 | 55 | 8 | 69 | 10 | 76 | 11 |
| 1000 | 28 | 4 | 41 | 6 | 48 | 7 | 55 | 8 |
| **At 260 °C (500 °F)** | | | | | | | | |
| 1 | 34 | 5 | 55 | 8 | 69 | 10 | 83 | 12 |
| 10 | 28 | 4 | 34 | 5 | 48 | 7 | 55 | 8 |
| 100 | 14 | 2 | 21 | 3 | 28 | 4 | 34 | 5 |
| 1000 | 14 | 2 | 14 | 2 | 14 | 2 | 21 | 3 |
| **At 315 °C (600 °F)** | | | | | | | | |
| 1 | 14 | 2 | 21 | 3 | 28 | 4 | 34 | 5 |
| 10 | 14 | 2 | 14 | 2 | 21 | 3 | 21 | 3 |
| 100 | 14 | 2 | 7 | 1 | 14 | 2 | 14 | 2 |
| 1000 | 7 | 1 | 7 | 1 | 7 | 1 | 7 | 1 |

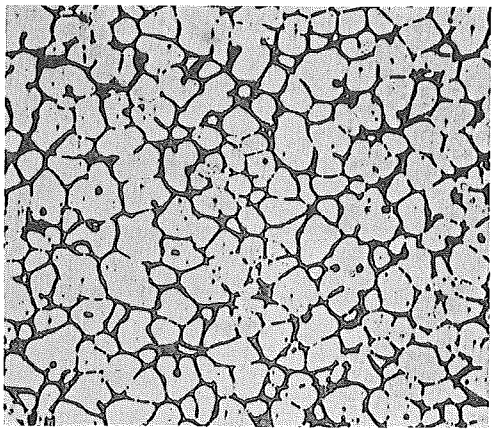
(a) Total extension equals initial extension plus creep extension

### EZ33A-T5: Typical tensile properties of sand castings at elevated temperatures

Properties determined using separately cast test bars.

| Testing temperature °C | °F | Tensile strength MPa | ksi | Yield strength MPa | ksi | Elongation in 50 mm (2 in.), % |
|---|---|---|---|---|---|---|
| 24 | 75 | 160 | 23 | 110 | 16 | 3 |
| 150 | 300 | 150 | 22 | 97 | 14 | 10 |
| 205 | 400 | 145 | 21 | 76 | 11 | 20 |
| 260 | 500 | 125 | 18 | 69 | 10 | 31 |
| 315 | 600 | 83 | 12 | 55 | 8 | 50 |

**EZ33A-T5 sand casting: Microstructure.** Interdendritic network of massive $Mg_9R$ compound. The precipitate in the dendritic grains of magnesium solid solution is not visible. 100×



# HK31A

A magnesium zirconium alloy (*See also* wrought alloy HK31A)

**Chemical Composition. Composition Limits.** 2.5 to 4.0 Th, 0.40 to 1.0 Zr, 0.30 Zn max, 0.10 Cu max, 0.01 Ni max, 0.30 max other (total), bal Mg

**Specifications (U.S. and/or Foreign).** (AMS) Sand castings: 4445; (ASTM) Sand castings: B 80. Permanent mold castings: B 199. Investment castings: B 403; SAE J465. Former SAE alloy number: 507; UNS M13310; (Government) Sand castings: QQ-M-56 and MIL-M-46062. Permanent mold castings: QQ-M-55 and MIL-M-46062

## Characteristics

**Product Forms.** Sand castings, permanent mold castings, investment castings

**Applications/Typical Uses.** Sand castings for use at temperatures up to 345 °C (650 °F)

## Mechanical Properties

**Tensile Properties.** T6 temper, tensile strength is 220 MPa (32 ksi); yield strength is 105 MPa (15 ksi); elongation is 8% in 50 mm (2 in.)

**Hardness.** T6 temper, 66HRE

See Tables for typical tensile properties of HK31A-T6 sand castings at elevated temperatures, and for creep properties of HK31A-T6 sand castings. See Figure for typical stress strain curves for sand cast test bars

## Fabrication Properties

A weldable casting alloy. Welding is with gas-shielded arc process, using EZ33A or HK31A rod (former is preferred). Rating is "very good." Sand castings that have been welded require stress relief

## Recommended Heat Treating Practice

HK31A is typically heat treated to the T6 condition (solution heat treated and artificially aged)

**Note:** HK31A castings must be loaded in furnace which is at temperature, then brought back to temperature as quickly as possible

**Solution Heat Treating.** The alloy is treated at 565 ± 6 °C (1050 ± 10 °F) for 2 h. Maximum heat treatment temperature is 570 °C (1060 °F)

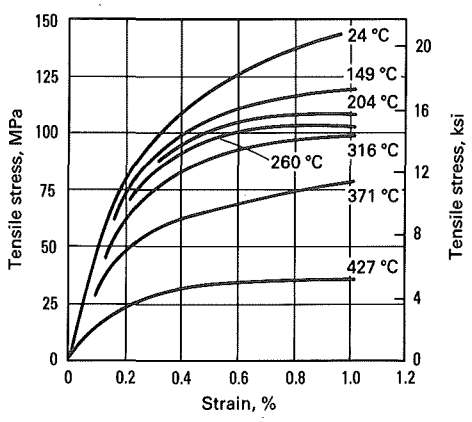
**Note:** After solution treating and before aging, castings are cooled to room temperature by fast fan cooling, except where otherwise indicated. Use carbon dioxide, sulfur dioxide, or 0.5 to 1.5 sulfur hexafluoride in carbon dioxide as protective atmosphere when furnace temperature is above 400 °C (750 °F)

**Aging.** After solution treatment castings are treated 205 ± 6 °C (400 ± 10 °F) for 16 h

See Table for postweld heat treatment of HK31A-T6. See micro of HK31A-T6 sand casting

LIVE GRAPH
Click here to view

**HK31A:** Typical stress-strain curves for separately sand cast test bars




## HK31A-T6: Postweld heat treatments for magnesium alloy castings

| Alloy | Welding rod | Temper before welding | Desired temper after welding | Postweld heat treatment |
|---|---|---|---|---|
| AZ63A | AZ63A or AZ92A(a) | F | T4 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b) |
| | | F | T6 | 12 h at 385 ± 6 °C (725 ± 10 °F)(b), plus 5 h at 220 °C (430 °F) |
| | | T4 | T4 | 30 min at 385 ± 6 °C (725 ± 10 °F) |
| | | T4 or T6 | T6 | 30 min at 385 ± 6 °C (725 ± 10 °F), plus 5 h at 220 °C (430 °F) |
| AZ81A | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| AZ91C | AZ92A or AZ101 | T4 | T4 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 415 ± 6 °C (775 ± 10 °F)(c), plus 4 h at 215 °C (420 °F) or 16 h at 170 °C (340 °F) |
| AZ92A | AZ92A | T4 | T4 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c) |
| | | T4 or T6 | T6 | 30 min at 410 ± 6 °C (765 ± 10 °F)(c), plus 4 h at 260 °C (500 °F) or 5 h at 220 °C (430 °F) |
| EQ21A | EQ21A | T4 or T6 | T6 | 1 h at 505 ± 6 °C (940 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| EZ33A | EZ33A | F or T5 | T5 | 2 h at 345 °C (650 °F)(d), and/or 5 h at 215 °C (420 °F), or 24 h at 220 °C (430 °F) |
| HK31A | HK31A(g) | T4 or T6 | T6 | 16 h at 205 °C (400 °F)(e) |
| HZ32A | HZ32A(g) | F or T5 | T5 | 16 h at 315 °C (600 °F) |
| QE22A | QE22A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| QH21A | QH21A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE43A | WE43A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| WE54A | WE54A | T4 or T6 | T6 | 1 h at 510 ± 6 °C (950 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZC63A | ZC63A | T4 or T6 | T6 | 1 h at 425 ± 6 °C (795 ± 10 °F), quench, 16 h at 205 °C (400 °F) |
| ZE41A | ZE41A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F)(f) |
| ZH62A | ZH62A(g) | F or T5 | T5 | 12 h at 250 °C (480 °F)(f) |
| ZK51A | ZK51A(g) | F or T5 | T5 | 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F) |

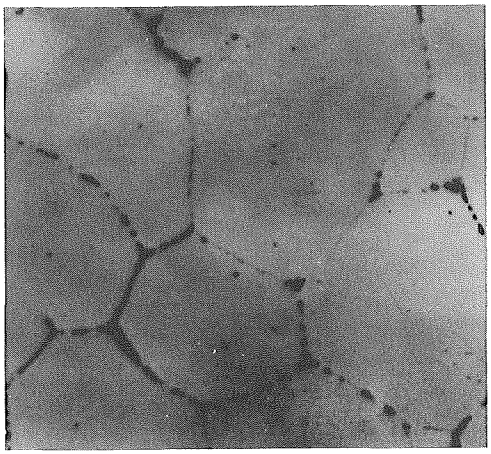
(a) AZ63A rod must be used for welding AZ63A in the F temper because 12 h at 385 °C (725 °F) causes germination in welds made with AZ92A rod: AZ92A rod normally is used for welding AZ63A in the T4 or T6 condition unless AZ63A rod is required by specifications. (b) Preheat to 260 °C (500 °F); heat to specified temperature at no more than 83 °C/h (150 °F/h). (c) Use carbon dioxide or sulfur dioxide atmosphere. (d) Heating for 2 h at 345 °C (650 °F) results in slight loss of creep strength. (e) Alternative treatment: 1 h at 315 °C (600 °F), plus 16 h at 205 °C (400 °F). (f) Alternative treatment: 2 h at 330 °C (625 °F), plus 16 h at 175 °C (345 °F). (g) Or EZ33A

## HK31A-T6: Typical tensile properties of sand castings at elevated temperatures

Properties determined using separately cast test bars.

| Testing temperature °C | Testing temperature °F | Tensile strength MPa | Tensile strength ksi | Yield strength MPa | Yield strength ksi | Elongation in 50 mm (2 in.), % |
|---|---|---|---|---|---|---|
| 24 | 75 | 215 | 31 | 110 | 16 | 6 |
| 205 | 400 | 165 | 24 | 97 | 14 | 17 |
| 260 | 500 | 160 | 23 | 89 | 13 | 19 |
| 315 | 600 | 140 | 20 | 83 | 12 | 22 |
| 370 | 700 | 89 | 13 | 55 | 8 | 26 |

**HK31A-T6: Microstructure.** Sand casting. Intergranular particles of massive $Mg_4Th$ compound (gray, outlined). The precipitate in the grains of magnesium solid solution is not visible. 500×



## HK31A-T6: Creep properties of sand castings

Properties determined using separately cast test bars.

| Time under load, h | Tensile stress resulting in total extension(a) of 0.1% MPa | 0.1% ksi | 0.2% MPa | 0.2% ksi | 0.5% MPa | 0.5% ksi | 1.0% MPa | 1.0% ksi |
|---|---|---|---|---|---|---|---|---|
| **At 205 °C (400 °F)** | | | | | | | | |
| 1 | 41 | 6.0 | 71 | 10.3 | 103 | 15.0 | 110 | 16.0 |
| 10 | 40 | 5.8 | 68 | 9.8 | 103 | 15.0 | 110 | 16.0 |
| 100 | 39 | 5.6 | 66 | 9.5 | 103 | 15.0 | 110 | 16.0 |
| 1000 | 37 | 5.4 | 63 | 9.1 | 97 | 14.0 | 109 | 15.8 |
| **At 260 °C (500 °F)** | | | | | | | | |
| 1 | 36 | 5.25 | 69 | 10.0 | 97 | 14.0 | 107 | 15.5 |
| 10 | 30 | 4.4 | 59 | 8.6 | 88 | 12.7 | 100 | 14.4 |
| 100 | 24 | 3.5 | 43 | 6.3 | 67 | 9.7 | 84 | 12.2 |
| 1000 | 21 | 3.1 | 29 | 4.2 | 47 | 6.8 | 52 | 7.6 |
| **At 290 °C (550 °F)** | | | | | | | | |
| 1 | ... | ... | 54 | 7.8 | 85 | 12.3 | ... | ... |
| 10 | ... | ... | 44 | 6.4 | 66 | 9.5 | ... | ... |
| 100 | ... | ... | 31 | 4.5 | 43 | 6.3 | ... | ... |
| 1000 | ... | ... | 17 | 2.5 | 22 | 3.2 | ... | ... |
| **At 315 °C (600 °F)** | | | | | | | | |
| 1 | 29 | 4.15 | 43 | 6.2 | 72 | 10.4 | 85 | 12.3 |
| 10 | 22 | 3.25 | 33 | 4.75 | 50 | 7.2 | 60 | 8.7 |
| 100 | 15 | 2.15 | 20 | 2.9 | 24 | 3.5 | 28 | 4.1 |
| 1000 | 6 | 0.94 | 8 | 1.1 | 10 | 1.4 | 11 | 1.55 |
| **At 350 °C (600 °F)** | | | | | | | | |
| 1 | ... | ... | 30 | 4.4 | 41 | 6.0 | ... | ... |
| 10 | ... | ... | 16 | 2.3 | 22 | 3.2 | ... | ... |
| 100 | ... | ... | 7 | 1.0 | 9 | 1.3 | ... | ... |
| 1000 | ... | ... | 4 | 0.63 | 5 | 0.72 | ... | ... |

(a) Total extension equals initial extension plus creep extension

# HZ32A

A magnesium-zirconium alloy

**Chemical Composition. Composition Limits.** 1.7 to 2.5 Zn, 2.5 to 4.0 Th, 0.10 rare earths max, 0.50 to 1.0 Zr, 0.10 Cu max, 0.01 Ni max, 0.30 max other (total), bal Mg

**Consequence of Exceeding Impurity Limits.** More than 0.1% rare earths causes a loss in creep resistance

**Specifications (U.S. and/or Foreign).** (AMS) Sand castings: 4447; (ASTM) Sand castings: B 80; UNS M13320; (Government) Sand castings: QQ-M-56, MIL-M-46062; (Foreign) Elektron ZT1. (British) BS 2970 MAG8. (German) DIN 1729 3.5105

## Characteristics

**Product Forms.** Sand castings

**Applications/Typical Uses.** Sand castings used in the artificially aged condition (T5 temper), with moderate strength and an optimum combination of properties for medium- and long-time exposure at temperatures above 260 °C (500 °F). Castings are pressure tight, and under long-time exposure can withstand higher stresses and higher temperatures than any other commercially available magnesium alloy

## Mechanical Properties

**Tensile Properties.** T5 temper, tensile strength is 185 MPa (27 ksi); yield strength is 90 MPa (13 ksi); elongation is 4% in 50 mm (2 in.)

**Hardness.** 55 HB

See Table for typical tensile properties of HZ32A-T5 sand castings at elevated temperatures. See Figure for typical stress-strain curves for sand cast test bars

## Fabrication Properties

A weldable casting alloy, using gas-shielded metal arc process and H232A or EZ33A rod. Rating of process: "Fair." Stress relief is required after welding castings with heavy sections

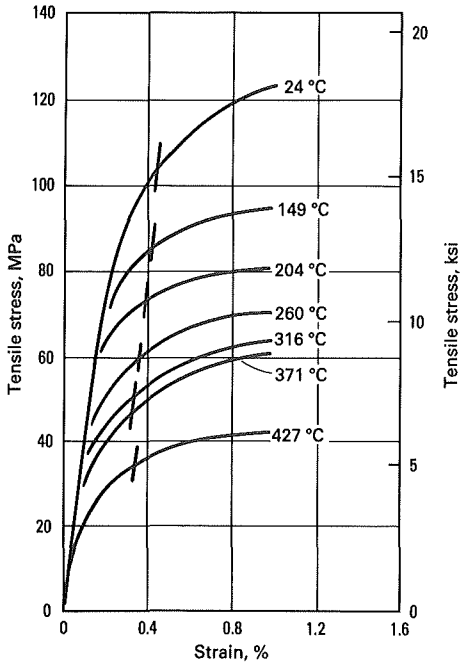
## Recommended Heat Treating Practice

HZ32A is typically heat treated to T5 temper (artificially aged only). When treated, castings are in F condition (as-fabricated)

**Aging.** Castings are treated at 315 ± 6 °C (600 ± 10 °F) for 16 h

For postweld heat treatment, see Table in datasheet for HK31A

**HZ32A-T5.** Typical stress-strain curves for separately sand cast test bars




**HZ32A-T5: Typical tensile properties of sand castings at elevated temperatures**

| Testing temperature | | Tensile strength | | Yield strength | | Elongation in |
|---|---|---|---|---|---|---|
| °C | °F | MPa | ksi | MPa | ksi | 50 mm (2 in.), % |
| 24 | 75 | 200 | 29 | 105 | 15 | 6 |
| 93 | 200 | 180 | 26 | 97 | 14 | 15 |
| 150 | 300 | 150 | 22 | 83 | 12 | 23 |
| 205 | 400 | 115 | 17 | 69 | 10 | 33 |
| 260 | 500 | 97 | 14 | 63 | 9 | 33 |
| 315 | 600 | 83 | 12 | 55 | 8 | 28 |
| 370 | 700 | 69 | 10 | 48 | 7 | 29 |

**HZ32A-T5: Microstructure.** Sand castings. Intergranular Mg-Th compounds: Bunches of acicular compound (dark gray) and small areas of massive $Mg_4Th$. The precipitate within matrix grains is not visible. 2% nital. 250×