KINGSFORM METALWORKS

ENGINEERING TOOLKIT

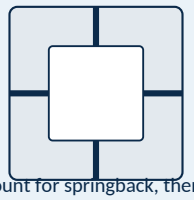
ALUMINUM GUIDE

Alloy selection, temper, fabrication, welding, corrosion control, finishing and procurement

SELECT ALLOY + TEMPER

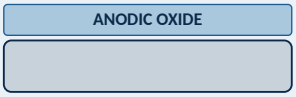
Match strength, formability, weldability, corrosion exposure and product form.

DESIGN FOR FABRICATION



Account for springback, thermal expansion, soft surfaces, HAZ strength and extrusion limits.

CONTROL THE FINISH



Coordinate pretreatment, anodizing or coating with appearance, masking and dimensions.

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KFR-020	1.0	2026-07-18	English
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A4 PDF reference	KingsForm Engineering	info@kingsformmetalworks.com	kingsformmetalworks.com

01 PURPOSE AND SELECTION WORKFLOW

Select aluminum as a complete material-process system

The four-digit alloy number is only the starting point. Temper, product form, thickness, mill route, heat treatment, welding and finishing can change the delivered performance.

CORE PRINCIPLE

Release the material as alloy + temper + product standard + product form + dimensions/tolerances + surface/finish + certification. Do not assume that sheet, extrusion, drawn tube and casting of the same nominal alloy behave identically.

1 Function

Load, stiffness, fatigue, impact, conductivity, temperature, life and safety classification.

2 Alloy family

Non-heat-treatable 1xxx/3xxx/5xxx or heat-treatable 2xxx/6xxx/7xxx.

3 Temper

O, H, T4, T5, T6, T7 and any stress-relieved suffix required by the product.

4 Fabrication

Cutting, forming, extrusion, machining, welding, fastening and finishing sequence.

5 Verification

MTC, hardness/conductivity, dimensions, weld qualification, finish and first-article checks.

ALUMINUM CHANGES THE ENGINEERING BALANCE

LOW MASS - LOWER STIFFNESS

Density is about one-third of steel, but elastic modulus is also about one-third. Equal-strength substitutions may still require geometry changes for stiffness and buckling.

HIGH THERMAL RESPONSE

High conductivity and expansion affect welding, heat sinks, dimensional stability, machining, adhesive cure and mixed-material assemblies.

SURFACE IS FUNCTIONAL

The natural oxide helps corrosion resistance but affects welding, bonding, electrical contact and coating pretreatment. The intended surface route must be defined early.

DO NOT COPY STEEL DETAILS DIRECTLY

Thread engagement, bearing area, weld size, heat distortion, galvanic isolation, bend radius, finish masking and inspection methods usually need aluminum-specific review.

02 ALLOY SERIES AND STRENGTHENING

Understand the alloy family before choosing a grade

Non-heat-treatable alloys gain strength mainly from cold work and solid-solution effects. Heat-treatable alloys gain strength from controlled solution treatment, quenching and aging.

Series	Main alloying concept	Heat treatable?	Typical strengths / attributes	Common fabricated uses
1xxx	Commercially pure aluminum	No	Very high conductivity and formability; low strength	Electrical, reflectors, chemical equipment, deep-drawn parts
2xxx	Al-Cu	Yes	High strength; limited general corrosion resistance; welding often restricted	Aerospace, machined high-strength components
3xxx	Al-Mn	No	Good formability, corrosion resistance and moderate strength	Enclosures, heat exchangers, formed sheet, cookware
4xxx	Al-Si	Depends	Lower melting range; wear or filler-specific uses	Welding filler, brazing sheet, selected cast/wrought products
5xxx	Al-Mg	No	Good weldability and corrosion resistance; medium to high strength	Marine, transport, tanks, sheet structures
6xxx	Al-Mg-Si	Yes	Balanced extrusion, machining, finishing and weldability	Profiles, frames, tubes, general structural fabrications
7xxx	Al-Zn-Mg(-Cu)	Yes	Very high strength; corrosion/SCC and welding limitations vary	Aerospace, tooling, high-strength machined parts

SERIES DOES NOT DEFINE PERFORMANCE

The temper and product route can shift yield strength, elongation, residual stress and corrosion behavior more than the alloy number alone. Use certified product data for design.

DENSITY

about 2.70 g/cm3

Mass estimates

ELASTIC MODULUS

about 69 GPa

Stiffness / deflection

THERMAL EXPANSION

about 23 um/m-K

Heat movement

MELTING RANGE

alloy-dependent; around 660 C for pure Al

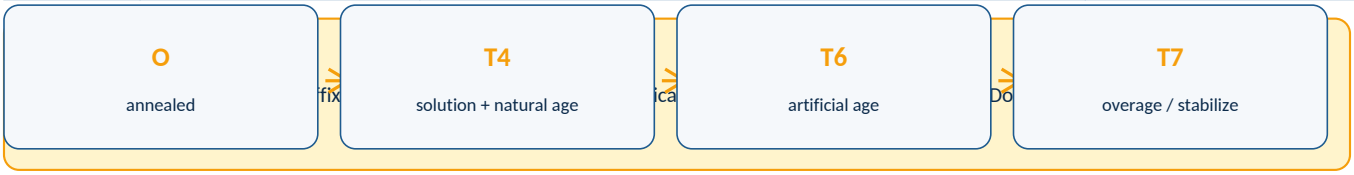
Welding / fire review

03 TEMPER DESIGNATIONS

Temper is part of the grade - never omit it

The same alloy can be soft and formable, naturally aged, artificially aged, strain hardened or stress relieved. Mechanical properties and process planning follow the full designation.

Code	Meaning	Design / manufacturing implication	Typical examples
F	As fabricated	Properties are not specially controlled by strain hardening or heat treatment	Extruded or cast condition where the product standard permits
O	Annealed	Lowest strength, highest ductility; useful for severe forming	5052-O sheet before deep forming
H1x	Strain hardened only	Strength rises and ductility falls with amount of cold work	H14, H18
H2x	Strain hardened + partially annealed	Intermediate strength/formability balance	H22, H24, H32-type product families
H3x	Strain hardened + stabilized	Used where thermal stability is controlled after cold work	Some 5xxx sheet tempers
T4	Solution heat treated + naturally aged	Good formability relative to T6; later aging may change dimensions/properties	6061-T4, selected automotive sheet
T5	Cooled from shaping process + artificially aged	Common for extrusions; press/quench history matters	6063-T5
T6	Solution heat treated + artificially aged	High strength; lower formability; welding can soften HAZ	6061-T6, 6082-T6
T7	Overaged / stabilized	Lower peak strength but improved stability or corrosion resistance in selected alloys	Selected 7xxx or elevated-temperature service



04 COMMON ALLOY SELECTION MATRIX

Choose the alloy from the dominant requirement

Ratings below are qualitative screening only. Verify mechanical properties, corrosion limits, temperature, weld filler, finish appearance and product availability for the exact temper and thickness.

Alloy / temper example	Strength	Forming	Welding	Corrosion	Finish / extrusion	Use and caution
1050 / 1100 - O or H	Low	Excellent	Good	Very good	Good appearance / conductivity	Deep drawing, reflectors, chemical/electrical parts; low structural strength
3003 - O/H14	Low-medium	Excellent	Good	Very good	Good sheet finish	General sheet metal, heat exchangers and formed enclosures
5052-H32	Medium	Very good	Very good	Very good	Good sheet finish	Reliable fabricated sheet choice; check bend radius by temper/thickness
5754-H22/H24	Medium	Very good	Very good	Very good	Good automotive finish	Formed and welded sheet; common in transport and general fabrication
5083-H111/H116/H321	Medium-high	Good	Very good	Excellent marine	Plate-oriented	Marine/welded structures; review high-temperature sensitization exposure
6061-T6	High	Limited for tight bends	Good with HAZ reduction	Good	Good machining / extrusion	Frames and machined parts; do not use base T6 strength through weld HAZ
6063-T5/T6	Medium	Extrusion-focused	Good	Good	Excellent extrusion / anodize	Architectural and visible profiles; lower structural strength than 6061/6082
6082-T6	High	Limited for tight bends	Good with HAZ reduction	Good	Structural extrusion	European structural profiles and machined parts
2024-T3 / 7075-T6	Very high	Limited	Generally poor for fusion welding	Moderate / controlled	Machining-focused	High-strength aerospace/tooling uses; corrosion and SCC controls required

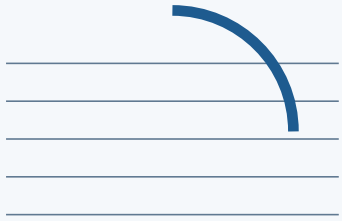
A WELDABLE ALLOY IS NOT A WELD-STRENGTH GUARANTEE

For precipitation-hardened 6xxx alloys, design strength near the weld may be controlled by the softened heat-affected zone. Use the governing code and qualified joint data.

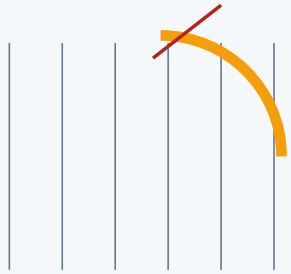
05 SHEET AND PLATE FABRICATION

Plan grain direction, temper, radius and surface protection together

Aluminum marks easily, springs back more than mild steel, conducts heat rapidly and may crack at tight bends in hard tempers. The actual lot and bend orientation should be trialed for demanding geometry.



BEND LINE PERPENDICULAR TO ROLLING DIRECTION



PARALLEL ORIENTATION MAY REQUIRE MORE RADIUS

Design factor	Lower-risk approach	Higher-risk condition / action
Bend orientation	Place difficult bend lines perpendicular to rolling direction where practical	Parallel bend lines can require larger radius; validate with supplier data
Temper	Use O, T4 or a suitable H temper for severe forming	T6 and hard H tempers need larger radius or alternate process
Cut edge	Deburr and place burr away from tensile surface	Laser/punch microcracks or sheared edges can initiate bend cracks
Springback	Prototype with production tooling and grain orientation	Small radii, high-strength temper and large included angles increase compensation
Surface protection	Use film, clean tools and controlled handling	Embedded steel particles and scratches become cosmetic/corrosion defects

3003 / 5052 SHEET

Usually the first screen for formed enclosures and brackets

FORMABILITY FIRST

6061-T6 SHEET

Useful when strength/machining dominate; tight bends can crack

STRENGTH FIRST

T4 THEN AGE

Can improve forming for heat-treatable alloys if process control permits

PROCESS ROUTE

NO UNIVERSAL R/T TABLE

Minimum inside radius depends on alloy, temper, thickness, grain direction, edge condition, bend method and acceptance criteria. Use published product data and representative trials, not a single generic ratio.

06 EXTRUSIONS, TUBES AND PROFILE DESIGN

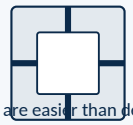
Design for metal flow, die strength, straightening and inspection

Extrusion can integrate features and reduce part count, but thin fins, deep pockets, large wall imbalance, tiny radii and asymmetric mass flow increase die cost, twist and dimensional variation.

BALANCED WALLS

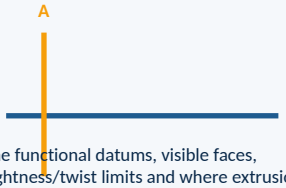
Keep wall thickness and mass distribution reasonably balanced. Heavy-to-thin transitions can distort and fill unevenly.

OPEN ACCESS



Open channels are easier than deep enclosed pockets. Hollow profiles need bridges/ports and show weld seams.

DATUM + APPEARANCE



Define functional datums, visible faces, straightness/twist limits and where extrusion die lines are acceptable.

Feature / issue	Design guidance	Procurement / inspection note
Wall thickness	Avoid abrupt heavy-to-thin changes and unsupported knife edges	State minimum wall and permitted local variation from product standard
Corners / radii	Use practical internal radii; sharp internal corners weaken die tongues	Show which radii are functional and which may be die-natural
Hollows	Control port-hole weld seams and pressure-tightness expectations	State whether seam location, leak testing or macro examination is required
Long profiles	Allow for straightness, twist, bow, cut squareness and thermal movement	Define inspection length, support condition and datum method
Machined extrusions	Leave machining stock and consider residual stress / section opening	Select stress-relieved temper where tight machining stability is needed
Visible anodized face	Keep die lines, handling marks and weld seams away from cosmetic areas	Approve finish sample and extrusion direction before production

EXTRUSION TOLERANCES ARE GEOMETRY-DEPENDENT

Profile tolerances depend on circumscribing circle, wall thickness, alloy, temper, profile class and measurement method. Use the selected ISO/ASTM/EN product standard - not a generic +/- value.

07 CUTTING, MACHINING, THREADS AND HARDWARE

Control heat, chip formation, bearing stress and embedded contamination

Aluminum cuts quickly but can gall, load tools, smear at edges and lose thread strength if the engagement and hardware strategy are copied from steel.

Process	Key controls	Typical failure if missed
Laser / plasma	Alloy reflectivity, oxide/edge quality, gas, dross and heat distortion	Poor edge, recast, taper, discoloration or reduced bend performance
Sawing / routing	Sharp nonferrous tooling, support, lubrication and chip evacuation	Burrs, chatter, pickup and profile deformation
Milling / drilling	High-positive geometry, rigid setup, coolant/lubricant compatibility	Built-up edge, smeared hole, oversize feature or poor finish
Tapping	Correct tap style, generous chip clearance, lubricant and depth control	Galling, torn threads, trapped chips or broken tap
Threaded joint	Adequate engagement, insert/nutplate where service cycles are high	Stripped internal thread or embedment relaxation
Press / self-clinch hardware	Use aluminum-qualified hardware and sheet hardness/thickness window	Cracking, spin-out, low push-out or galvanic attack
Adhesive bonding	Clean/convert/prime as qualified; manage oxide regrowth and bondline	Low durability despite good initial lap-shear result

THREAD + HARDWARE DECISION

Direct tapped thread

Best for light duty and low service cycles when wall/engagement are sufficient.

Thread insert

Use for repeated assembly, repairability or higher pull-out demand.

Rivet nut / nutplate

Useful for thin wall and blind access; validate spin-out, installation and galvanic isolation.

Through-bolt + washer

Often most robust where rear access and bearing area are available.

KEEP STEEL DUST AWAY

Carbon-steel grinding dust and embedded iron can create staining and localized corrosion on aluminum. Separate tools/areas or clean and verify the surface before finishing.

08 WELDING AND HEAT-AFFECTED ZONES

Qualify the joint around alloy, temper, filler and service

The oxide film melts far above the aluminum substrate, hydrogen solubility changes sharply during solidification, and high thermal conductivity spreads heat rapidly. Cleanliness and procedure control are essential.

For heat-treated 6xxx material, the HAZ may control joint strength even when the weld bead looks acceptable.

Design / process factor	Engineering guidance	Failure mode controlled
Base alloy group	5xxx and 6xxx are common weldable families; 2xxx/7xxx need specific code approval	Hot cracking, low joint strength or corrosion
Filler selection	Choose from code/manufacturer compatibility data; consider strength, cracking, color match and temperature	Cracking, poor ductility, anodize mismatch or service degradation
Surface preparation	Remove oil, moisture and oxide with controlled clean tools shortly before welding	Porosity, lack of fusion and contamination
Heat input / travel	Use qualified parameters and manage interpass temperature	Excessive HAZ softening, distortion and burn-through
Joint restraint	Allow for high expansion; balance sequence and fixture without over-constraint	Angular distortion, residual stress and cracking
Back gouge / root	Define full penetration and inspection access where required	Incomplete penetration and trapped oxide
Postweld condition	Do not assume local T6 restoration by uncontrolled heating	Unknown strength, residual stress and dimensional change

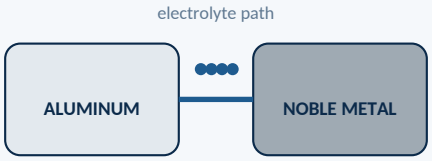
VISIBLE WELD QUALITY IS NOT STRUCTURAL QUALIFICATION

Specify the welding code, WPS/PQR, welder qualification, quality level, NDT and design allowables. Cosmetic smoothness alone does not demonstrate penetration or HAZ performance.

09 CORROSION AND GALVANIC DESIGN

The oxide film is helpful - but geometry and dissimilar metals still matter

Aluminum performs well in many atmospheres, yet chlorides, crevices, trapped alkaline cleaners, copper contamination and electrical contact with noble metals can drive rapid local attack.



A conductive electrolyte completes the galvanic cell. Aluminum usually becomes the anodic member against stainless steel, copper and many carbon materials.

Exposure / mechanism	Design control	Material / finish review
General atmosphere	Drain, ventilate, avoid dirt shelves and protect damaged finish	1xxx/3xxx/5xxx/6xxx often perform well with suitable finish
Marine / chloride	Avoid crevices, stagnant water and dissimilar-metal contact; washable geometry	5xxx marine grades or qualified protected 6xxx; verify product standard
Galvanic couple	Use insulating washers/sleeves, sealant, compatible coating and drainage	Small aluminum anode connected to large noble cathode is especially severe
Alkaline cleaner / concrete	Prevent prolonged contact and trapped wash solution	Coating or barrier may be required; define cleaning chemistry
High-Mg 5xxx at temperature	Review sensitization / intergranular corrosion risk for long exposure	Use approved temper/alloy for service temperature and marine duty
Copper / steel contamination	Separate tools, remove embedded particles and control runoff	Surface staining and localized pitting can follow contamination

ISOLATION MUST SURVIVE ASSEMBLY AND SERVICE

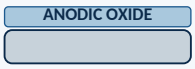
A nylon washer alone may not isolate a bolt shank, wet joint edge, damaged coating or conductive sealant. Review the complete current path and maintenance condition.

10 SURFACE FINISH AND APPEARANCE

Specify pretreatment, finish, cosmetic class and masking as one package

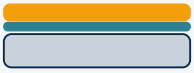
Alloy, temper, extrusion die lines, weld filler, grinding and heat tint can remain visible after anodizing. A color name without a process and approved sample is incomplete.

ANODIZING



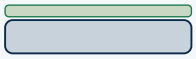
Integral oxide layer for corrosion, wear or appearance. Thickness class, sealing, color, alloy and pretreatment must be specified.

CONVERSION + PAINT



Conversion pretreatment improves corrosion resistance and coating adhesion. Powder/liquid film and cure must suit the alloy and service.

CHEMICAL / MECHANICAL



Bright dip, brushing, bead blast, polishing or etching change texture and can amplify lot-to-lot visual variation.

Requirement	What to specify	Why it matters
Appearance zone	A/B/C cosmetic faces, viewing distance, lighting and permitted marks	Prevents applying premium finish criteria to hidden surfaces
Anodize	Type/class, thickness, color, sealing, gloss and approved limit sample	Alloy and welds can color differently; coating changes dimensions
Powder / paint	Pretreatment, resin, color standard, gloss, texture, thickness and cure	Adhesion and corrosion depend on pretreatment as much as topcoat
Masking	Threads, bores, electrical contacts, bond areas and grounding points	Avoids assembly interference and loss of conductivity
Rack / contact marks	Permitted location and maximum visual impact	Anodizing and coating need electrical/mechanical contact
Edge / cavity coverage	Drainage, venting and access for cleaning/rinse	Trapped chemicals cause stains, corrosion and coating defects
Repair	Approved touch-up method and visibility limit	Local repair may not match anodize color or performance

APPROVE A REAL PROCESS SAMPLE

For visible aluminum, approve alloy + temper + mill route + pretreatment + finish on representative geometry. Flat color chips do not predict welds, extrusion seams, grain or rack marks.

11 PROCUREMENT, CERTIFICATION AND INSPECTION

Buy the exact product condition that was designed

Purchase orders should prevent silent changes in temper, mill route, surface, extrusion class, weld seam, heat treatment, finish and traceability.

Purchase-order field	Minimum definition	Verification method
Standard / alloy / temper	Full product standard and designation including suffixes	MTC / certificate against PO
Product form	Sheet, plate, extrusion, drawn tube, bar, forging or casting	Marking and physical inspection
Dimensions / tolerances	Thickness, width, profile/tube dimensions, straightness, twist and cut length	Calibrated measurement to standard method
Surface condition	Mill finish, film, anodize-ready, visible face, permitted scratches/die lines	Approved sample and incoming visual standard
Mechanical properties	Applicable thickness/size range and test direction	MTC tensile/hardness; retest when contract requires
Temper verification	Heat-treatment route and stress-relieved suffix where required	Hardness/conductivity correlation or approved laboratory test
Weld / pressure requirement	Extrusion seam status, leak test, NDT or weld quality level	Inspection report and traceable procedure
Finish	Pretreatment, thickness, color, sealing/cure, masking and rack location	Coating/anodize inspection report
Traceability	Heat/lot, piece marking, remnant control and certificate retention	Trace audit from certificate to part

PRACTICAL INSPECTION TOOLBOX

- **MTC review** — alloy / temper / lot
- **Hardness** — process consistency
- **Conductivity** — selected heat-treatable alloys
- **XRF / OES** — chemistry screening
- **CMM / gauges** — dimensions / twist / flatness
- **Finish tests** — thickness / seal / adhesion

PMI HAS LIMITS

Handheld XRF can separate many alloy families but does not prove temper, mechanical properties, heat treatment or all light elements with equal reliability. Use the correct method for the decision.

12 COMMON FAILURES AND CORRECTIVE ACTIONS

Trace the defect back through material, process and finish

A visible crack, stain or soft weld zone often begins with an omitted temper, wrong bend orientation, contaminated surface, unqualified filler or incomplete galvanic isolation.

Observed problem	Likely contributors	Corrective action
Bend cracks	Hard temper, tight radius, bend parallel to grain, damaged edge or wrong alloy	Verify lot/temper; improve edge; rotate bend; increase radius; trial production material
Weld porosity	Moisture, oil, oxide, contaminated wire or poor gas coverage	Quarantine; clean with controlled method; check filler storage and gas; requalify parameters
Low weld-zone strength	HAZ softening in 6xxx, wrong design allowable or excessive heat input	Use code HAZ properties; redesign joint; control heat; qualify WPS
Hot cracking	Incompatible alloy/filler, joint dilution, restraint or poor bead shape	Review base/filler compatibility; change joint and sequence; qualified repair
Anodize color mismatch	Different alloys/tempers, weld filler, grain, die seam or grinding pattern	Segregate lots; use approved sample; control filler and cosmetic zone
Powder peels / blisters	Poor cleaning/conversion, trapped rinse, under-cure or contamination	Rework pretreatment; improve drainage; verify cure and coating compatibility
White corrosion / pitting	Chloride, crevice, alkaline cleaner, galvanic contact or wet packaging	Remove source; isolate metals; improve drainage/finish; dry packaging
Threads strip or seize	Insufficient engagement, soft wall, galling, over-torque or coating buildup	Use insert/nutplate; revise torque; lubricate as approved; mask or gauge after finish
Extrusion twists after machining	Residual stress, asymmetric stock removal, weak setup or wrong temper	Use stress-relieved temper; rough/finish sequence; symmetric machining and support

REPAIR CAN CHANGE THE SYSTEM

Local heating, weld repair, grinding, re-anodizing, thread chasing and chemical stripping can alter temper, dimensions, residual stress, appearance and traceability. Approve repair before shipment.

13 DESIGN RELEASE CHECKLIST AND REFERENCES

Release alloy, temper, fabrication and finish together

Use this checklist across design, procurement, fabrication, welding, finishing and quality. Delete only items proven not applicable.

- [ ] 1. Governing product standard, alloy, temper and suffix are specified.
- [ ] 2. Product form and mill route match the design data used.
- [ ] 3. Strength, stiffness, buckling, fatigue and temperature needs are defined.
- [ ] 4. Corrosion exposure and dissimilar-metal contacts are reviewed.
- [ ] 5. Sheet grain direction and cosmetic face are shown where relevant.
- [ ] 6. Bend radius, edge condition, temper and springback are validated.
- [ ] 7. Extrusion walls, hollows, radii and mass balance are die-feasible.
- [ ] 8. Extrusion seam, straightness, twist and visible-face limits are stated.
- [ ] 9. Machining stock and stress-relieved temper are considered.
- [ ] 10. Threads / inserts / hardware meet pull-out, torque and service-cycle needs.
- [ ] 11. Steel-particle contamination controls are included.
- [ ] 12. Welding code, WPS, filler and cleanliness controls are defined.
- [ ] 13. HAZ properties, heat input and distortion are included in design.
- [ ] 14. Weld quality level, NDT and final inspection stage are specified.
- [ ] 15. Galvanic isolation covers bolt, edge, electrolyte and maintenance paths.
- [ ] 16. Drainage and cleaning access prevent crevice and alkaline attack.
- [ ] 17. Finish system and pretreatment match environment and appearance.
- [ ] 18. Anodize / coating thickness and dimensional buildup are allowed.
- [ ] 19. Masking, rack points, electrical contacts and bond areas are defined.
- [ ] 20. Approved representative finish sample is available for cosmetic work.
- [ ] 21. MTC, lot traceability and marking match project risk.
- [ ] 22. Temper verification method is defined where mix-up risk exists.
- [ ] 23. Packaging prevents moisture, scratching and dissimilar-metal contact.
- [ ] 24. Deviations, repairs and substitutions require written approval.

CORE REFERENCES - STATUS CHECKED 18 JULY 2026

- ISO 209:2024 + Amd 1:2026 - wrought aluminum chemical composition.
- ISO 6361-1:2011; 6361-2/-3/-4:2014; 6361-5:2011 - sheet, strip and plate.
- ISO 6362-1/-2/-3/-4/-5/-7:2022 and ISO 6362-6:2025 - extrusions/tubes.
- ASTM B209/B209M-21a - aluminum sheet and plate (revision work active).
- ASTM B221/B221M-21 - extruded bars, rods, wire, profiles and tubes.
- ASTM B210/B210M-26 - drawn seamless tubes; B308/B308M-20 - 6061-T6 profiles.
- ISO 7599:2018 - decorative/protective anodic oxidation specification.
- ASTM B580-25 - anodic oxide coatings; ASTM B921-08(2023) - non-hex Cr conversion.
- ISO 10042:2018 - quality levels for arc-welded aluminum joints.
- ISO 15614-2:2025 - welding procedure qualification for aluminum.
- ISO 9606-2:2004 - welder qualification for aluminum fusion welding.
- AWS D1.2/D1.2M:2014 remains the published code while the 2026 update is pending.

Use licensed standards and the project contract as the controlling source. Official publishers: iso.org, astm.org and aws.org.