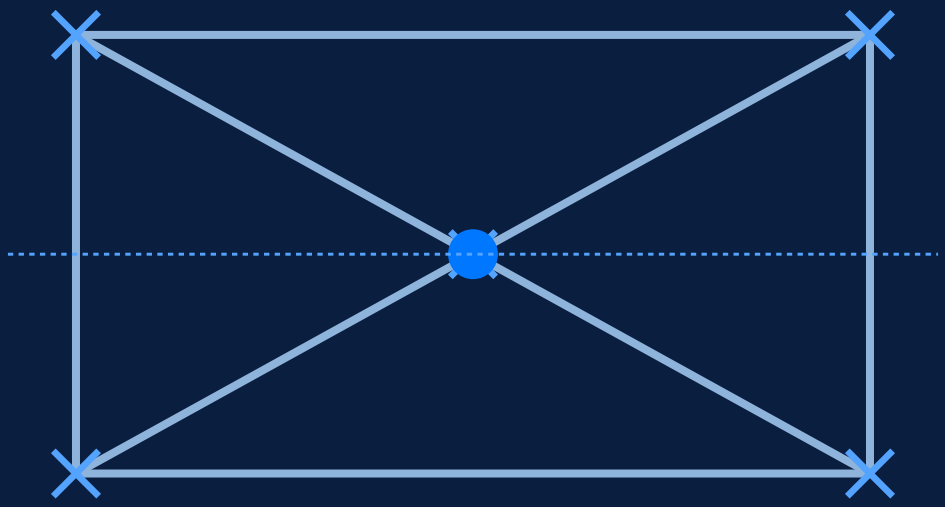
DESIGN FOR MANUFACTURING

WELDING DESIGN GUIDE FOR ALUMINUM STRUCTURES

Load paths | Joints | HAZ | Distortion | Inspection



LOAD PATH
continuous + verified

HEAT FLOW
controlled by WPS

ACCESS
designed before release

A practical DFM handbook for welded aluminum frames, enclosures and load-bearing assemblies

Prepared by BAOSONG

baosongprecision.com

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Conceptual engineering illustration - not a qualified design

00 Design logic and contents

Treat the weldment as a controlled system: code, design, procedure, fabrication and inspection must agree.

START HERE

This guide is a DFM reference, not a structural calculation, WPS, code interpretation or acceptance specification. A qualified engineer and welding organization must define the governing requirements.

Layer	Design question	Controlled output
1. Contract + code	What jurisdiction, service class and acceptance basis apply?	Named code edition, drawings, specification
2. Structural design	Where do loads, fatigue cycles and environmental actions travel?	Calculated joints, weld-affected allowables, details
3. Welding engineering	How will this exact material/joint/process be welded?	Qualified WPS/PQR and welder scope
4. Production	Can operators reach, fit, fixture, clean and sequence every joint?	Traveler, fixture plan, traceability
5. Verification	What is inspected, when, by whom and to what criteria?	ITP, reports and release record

Contents at a glance

Use the drawing-release checklist on page 17 before sending an RFQ. For early supplier input, visit BAOSONG Engineering Support.

01 Select the governing basis

A code name without edition, service category or acceptance level is incomplete.

Decision	Record on contract / drawing	Why it matters
Jurisdiction + owner requirements	Applicable legal and client specifications	May override shop defaults
Structural design basis	Material specification, design method, load combinations, fatigue category	Controls required strength and detailing
Welding code	For example, AWS D1.2/D1.2M:2026 when contractually applicable	Controls qualification, fabrication and inspection framework
Acceptance basis	Inspection method, extent, timing and acceptance criteria	A test method alone does not define pass/fail
Document hierarchy	Order of precedence for code, specification, drawing and WPS	Prevents conflicting instructions

CURRENT EDITION

AWS identifies D1.2/D1.2M:2026 as the current Structural Welding Code - Aluminum. Verify the edition adopted by the contract and local authority before release.

Two different design documents

The Aluminum Design Manual provides structural design rules and weld-affected strengths; AWS D1.2 provides the welding code framework. They are complementary, not interchangeable. See the Aluminum Association FAQ and AWS D1.2 page.

02 Alloy, temper and product form

Write the actual alloy, temper and product specification. 'Aluminum' is not enough for structural release.

Family / form	Design behavior to account for	DFM implication
5xxx wrought, non-heat-treatable	Strength derives partly from strain hardening; welding changes local temper	Use weld-affected properties; manage distortion and corrosion exposure
6xxx wrought, heat-treatable	HAZ softening can govern near the joint	Do not size from unwelded catalog tensile values
Sheet / plate	Rolling direction, thickness tolerance and edge condition matter	Plan blanks, seams, forming and joint preparation together
Extrusion	Section geometry, seam welds, straightness and temper matter	Keep torch access and heat balance visible in the profile concept
Castings	Porosity, chemistry and repair rules differ from wrought products	Confirm weldability and repair procedure before promising a welded joint

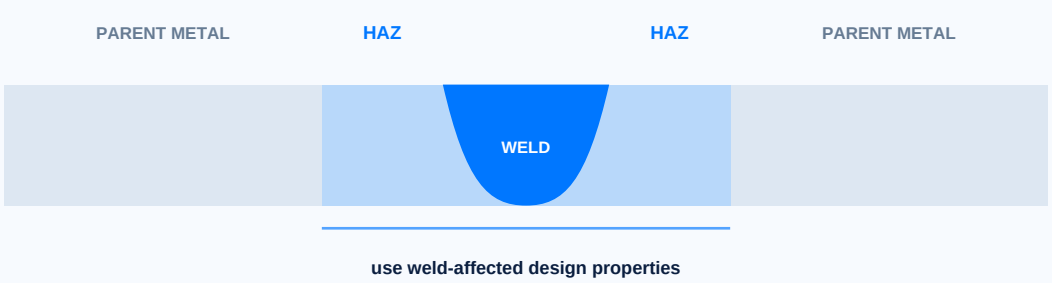
Filler metal is a design decision

- Select filler for base-alloy compatibility, cracking resistance, required properties, service temperature, corrosion exposure and final finish.
- AWS A5.10/A5.10M:2023 classifies bare aluminum and aluminum-alloy electrodes and rods; classification is not a universal selection chart.
- Record filler classification in the WPS and procurement controls; substitutions require welding-engineering review.

RELEASE GATE Base material and filler designations, temper, thickness range and traceability level must be frozen before procedure qualification or production.

03 Design for the heat-affected zone

The weakest structural location may sit beside a visually sound weld.



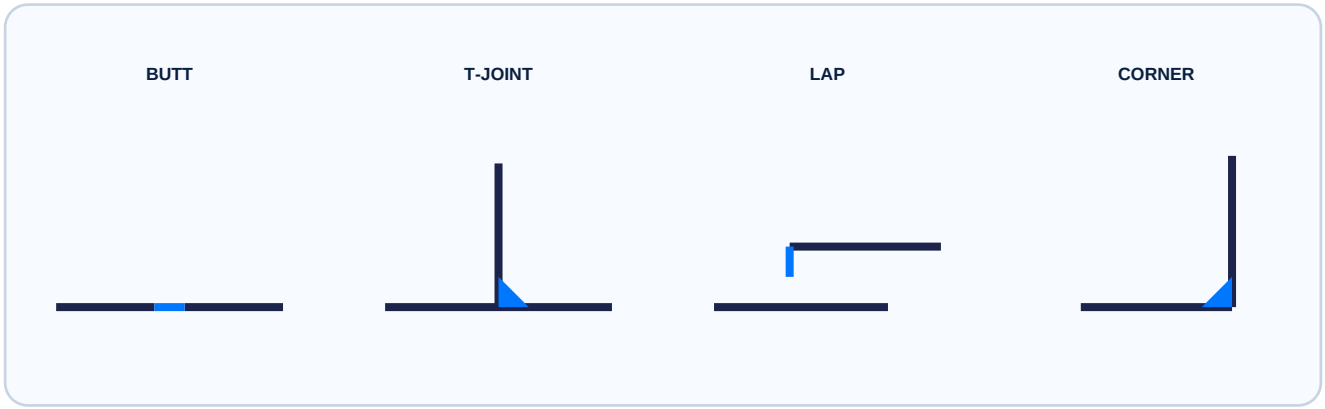
Zone	What changes	Design response
Weld metal	Composition and solidification are governed by base/filler combination and procedure	Use qualified procedure data and applicable code values
Fusion boundary	Geometric and metallurgical transition; discontinuities may concentrate here	Detail smooth load transfer and specify inspection
HAZ	Thermal cycle can reduce strength of hardened tempers	Use weld-affected allowable strengths and effective widths from the governing design standard
Parent metal	Retains specified properties away from the weld-affected region	Do not assume these values continue through the joint

COMMON ERROR

Checking the member with parent-metal properties and then adding a weld symbol does not complete the design. Recheck yielding, rupture, buckling and fatigue with the applicable welded properties.

04 Load path and joint selection

Choose a joint geometry that transmits force directly, can be welded, and can be inspected.



Joint concept	Useful when	Watch for
Butt / groove	A near-continuous section and low eccentricity are required	Root condition, alignment, preparation, backing and inspection access
T-joint	A web, rib or attachment meets a face	Eccentric load, root/toe fatigue, access on one or both sides
Lap	Overlap helps assembly or thin material joining	Crevice, added weight, peel loading and finish entrapment
Corner	Frames, boxes and enclosures	Fit-up, burn-through risk, outside profile and finish blending

Prefer force flow over weld volume

- Align member centrelines and reaction paths where practical.
- Avoid forcing a small local weld to turn a global bending load.
- Provide transitions at brackets and attachments; show where welds start and stop.
- For fatigue service, detail the toe, root and termination as structural features - not cosmetic lines.

ENGINEER CHECK Joint type, length, effective throat, penetration, loading direction and redundancy must come from calculation and the governing code.

05 Fillet welds and effective transfer

A larger weld is not automatically stronger, cooler, straighter or more durable.

Drawing decision	What to define	Why
Weld location + side	Arrow/other side, all-around only when truly intended	Removes ambiguity and hidden access conflicts
Size basis	Calculated required size using the applicable code notation	Avoids arbitrary over-welding and excess heat
Length + pitch	Effective length; continuous or intermittent pattern	Controls load path, sealing, heat and corrosion behavior
Contour + finish	As-welded, flush, convex/concave only where function requires	Grinding can reduce throat or introduce notches
Termination	Exact start/stop and return treatment	Critical near edges, corners and fatigue hot spots

Continuous or intermittent?

Continuous may support	Intermittent may reduce	Engineering checks
Sealing, corrosion exclusion, uniform stiffness	Heat input, distortion, time and mass	Fatigue, local buckling, moisture traps, minimum effective length, code restrictions

NO UNIVERSAL SIZE

Do not copy a previous fillet size. Recalculate for material, temper, thickness, joint orientation, load, service and applicable weld-affected strength.

06 Groove joints, roots and backing

Groove preparation is procedure-specific geometry, not a generic drafting detail.

Variable	Design question	Release requirement
Joint penetration	Is partial or complete penetration structurally required?	State the required joint condition using the governing symbol system
Root access	Can the root be welded, cleaned, back-gouged and examined?	Show approach direction and any sequence constraint
Root opening + land	Can the qualified process hold the required penetration without collapse?	Dimension only from qualified procedure / fabricator review
Bevel geometry	Is preparation practical at the specified thickness and position?	Tie angle/radius to the qualified joint detail
Backing	Permanent, removable, integral or none? Compatible material?	Define removal, sealing, corrosion and inspection requirements
Alignment	How is mismatch limited and measured?	Drawing tolerance + fixture/inspection method

DESIGN REVIEW

Send a section view, not only a weld symbol. Include member thickness, root condition, side(s), access envelope, final contour and any prohibited backing.

Avoid hidden assumptions

A callout such as 'full weld' is not a defined penetration requirement. Use the contract's welding-symbol standard and name the joint condition unambiguously.

07 Access, position and sequencing

If the torch, filler, cleaning tool or inspector cannot reach the joint, the design is not production-ready.

Access envelope	Ask during CAD review	Typical design response
Torch + nozzle	Can the required work angle and travel angle be held along the whole seam?	Move the joint, open the section or split the assembly
Filler / wire	Is feeding stable at corners and near fixtures?	Add clearance and lead-in space
Cleaning	Can oxide/contamination be removed immediately before welding?	Provide open surfaces and a controlled cleaning sequence
Starts / stops	Can they be placed away from peak stress or blended per procedure?	Show run-on/off strategy when required
Inspection	Can visual, dimensional or specified NDT access the area?	Create sight lines, probe space or staged inspection

ASSEMBLY ORDER

Design subassemblies so enclosed joints are welded and inspected before closure. Do not rely on an operator improvising a sequence inside a finished box.

08 Fit-up, preparation and tolerance

Welding does not erase dimensional variation; it converts some of it into gap, mismatch, heat and distortion.

Control	Drawing / plan input	Production evidence
Cut length + squareness	Datum and pre-weld tolerance	Incoming or in-process dimensional record
Root / joint gap	Qualified range and measurement location	Fit-up check before welding
Mismatch	Maximum offset and reference surface	Gauge or dimensional report
Edge preparation	Machined/cut profile, burr and contamination condition	Visual verification before assembly
Surface cleanliness	Approved method and time-to-weld control	Traveler / process record where required
Fixture condition	Locators, clamps, tack plan and release point	First-article record and fixture maintenance

Tolerance stack sequence

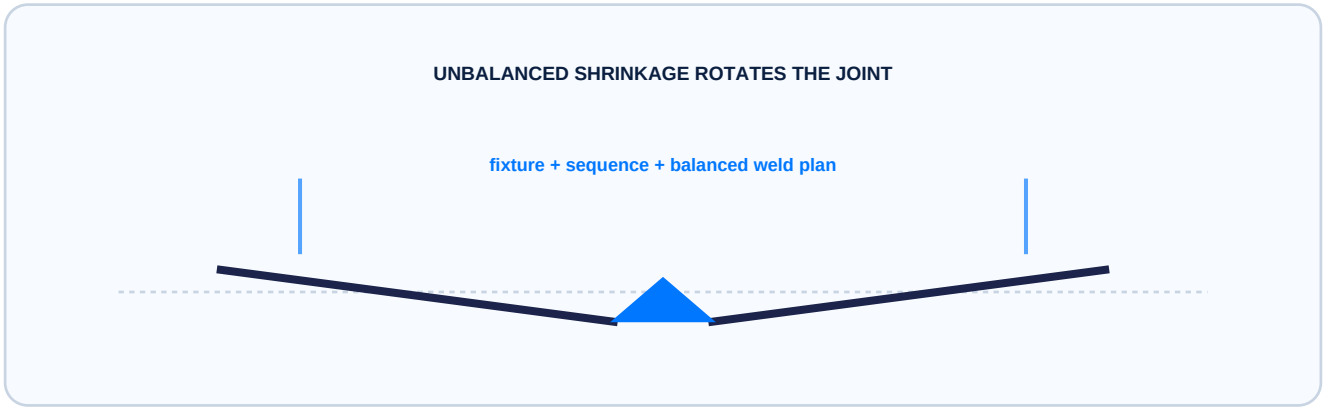
1 Parts	2 Fit-up	3 Weld shrinkage	4 Post-process
profile + cut + form variation	gap + mismatch + tack location	angular + longitudinal + transverse change	stress relief if allowed, machining, straightening, finish

DATUM RULE

Choose datums that survive welding and can be contacted in the fixture and inspection setup. Avoid dimensioning only from free edges that move with shrinkage.

09 Heat input, restraint and distortion

Distortion is a design variable. Manage it before adding tighter final tolerances.

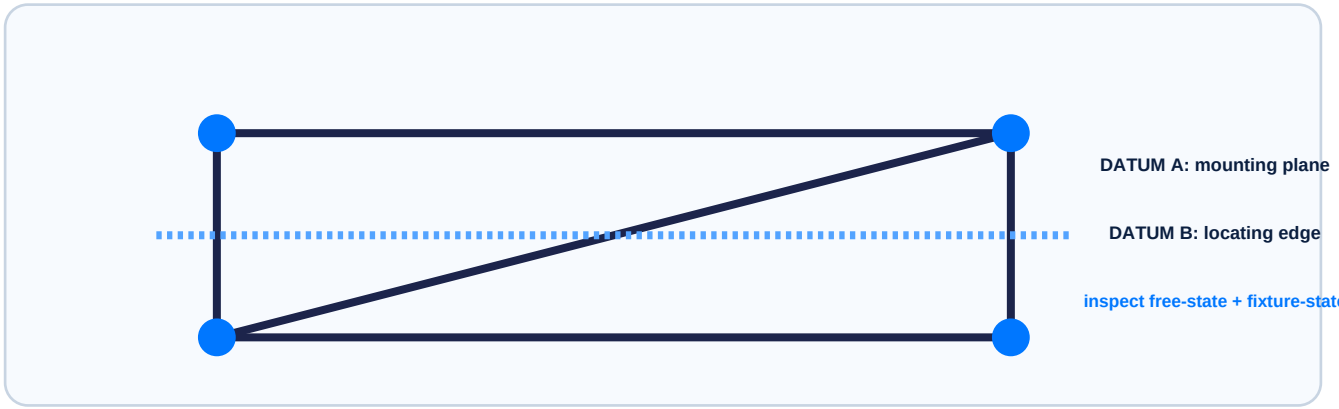


Lever	Useful action	Caution
Joint design	Minimize required weld volume while satisfying structural demand	Never reduce weld demand without recalculation
Layout	Place welds near the neutral axis; use symmetry where practical	Symmetry in CAD may not equal thermal symmetry
Sequence	Balance sides, use planned skip/back-step logic if qualified	Sequence belongs in production instructions
Fixture	Locate from functional datums and permit predictable shrinkage	Over-restraint can raise residual stress or cracking risk
Allowance	Leave stock for critical post-weld machining	Confirm cleanup remains after worst-case movement
Verification	Measure first article at defined release and temperature conditions	Do not inspect while fixture force hides distortion

PROCESS CONTROL Preheat, interpass temperature, current, voltage, travel speed and heat input are WPS variables. Never place generic values on a drawing without welding-engineering approval.

10 Frames and thin-wall structures

Define geometry in the condition that matters: free, restrained, installed or machined.



Requirement	Define explicitly	Measurement note
Overall size	Datum origin and basic member envelope	State temperature and free/restrained condition when relevant
Squareness	Referenced edges/planes and evaluation method	Diagonal difference is a check, not always the specification
Flatness	Functional mounting plane and zone	Avoid averaging across weld crowns or temporary clamps
Twist	Section stations and reference coordinate system	Long frames need multiple sections
Hole pattern	True position to functional datums after welding/machining	Define whether holes are pre- or post-weld
Interface loads	Mounting points, supports and installation constraint	Model realistic boundary conditions

THIN WALL

Local burn-through risk, panel oil-canning and heat concentration rise as wall thickness falls. Design access, backing strategy and heat balance with the fabricator before freezing the section.

11 Thickness transitions and terminations

Abrupt stiffness changes attract stress, heat imbalance and distortion.

Detail	Risk	Better design intent
Thin member into thick block	Thick side acts as heat sink; thin edge overheats	Use a qualified transition, accessible joint and balanced preparation
Bracket ending in a stressed panel	Weld termination and bracket tip become a local hot spot	Taper/shape the attachment and move the termination from peak stress
Intersecting seams	Multiple thermal cycles and difficult inspection	Separate intersections where design/code permit; define sequence
Tube closure	Hidden root, trapped contamination, inaccessible inspection	Use staged assembly, vent/drain logic and clear closure detail
Machined boss on thin skin	High restraint and post-weld position drift	Use a load-spreading interface and machine functional features later

Design review prompts

- Does the load enter gradually, or at a sharp attachment end?
- Can the qualified process accommodate both thicknesses in the specified position?
- Will one member constrain shrinkage of the other?
- Can the joint be inspected before it becomes hidden?
- Is local reinforcement increasing stiffness so abruptly that fatigue moves next door?

CALCULATION

A transition that looks smoother still needs structural verification, including local stress, weld-affected strength, buckling and fatigue where applicable.

12 Fatigue and cyclic service

Fatigue performance depends on detail category, stress range and weld geometry - not only static capacity.

Risk driver	Design action	Verification
Weld toe or root in peak stress	Redirect load; reduce secondary bending; choose the joint side deliberately	Applicable fatigue category and stress-range calculation
Abrupt attachment termination	Taper or extend load transfer away from the hot spot	Detail-specific category; no assumed benefit without basis
Start/stop or repair in critical zone	Relocate or control with qualified procedure	Inspection and repair record
Grinding / blending	Specify only if structurally required and procedurally controlled	Minimum remaining throat, surface condition and inspection
Vibration + resonance	Separate excitation from natural frequency and provide damping/support	Dynamic analysis or test under realistic boundary conditions

SERVICE DATA Give the engineer load spectra, cycle count, stress ratio, temperature, corrosion exposure and consequences of failure. 'Dynamic' is not a usable fatigue requirement.

13 Corrosion, drainage and galvanic isolation

The weld, crevice, fastener and finish form one exposure system.

Exposure detail	Failure mechanism	Design response
Lap / sealed cavity	Electrolyte trapped behind an incomplete seal	Choose intentional full seal or open drainage; avoid ambiguous partial sealing
Tube / box section	Condensation or wash fluid accumulates	Provide drain/vent paths that remain open after finish
Stainless or copper contact	Galvanic couple in conductive moisture	Isolate metals, control fasteners and specify compatible sealants
Coating break at weld	Uneven coverage, spatter or difficult pretreatment	Define cleanup and finish access; qualify masking and sealing
Outdoor / marine service	Chloride and crevice exposure amplify detail sensitivity	Specify alloy, filler and coating as a validated system
Closed volume during welding/finish	Pressure, contamination or chemical entrapment	Engineer vents and process-safe drainage; never weld a sealed contaminated volume

FINISH REVIEW

Anodizing, conversion coating, powder coating and wet paint have different edge, crevice, masking and appearance constraints. Review the welded assembly with BAOSONG Surface Finishing before release.

14 Post-weld machining and finishing

Place final precision after the process that moves the part - and preserve enough stock to recover it.

Feature	Recommended planning question	Drawing note
Mounting face	Must it be flat relative to the welded frame in free or installed condition?	Final datum, flatness, setup state and surface finish
Bearing / bore pair	Must axes be concentric after welding?	Machine in one setup where practical; define coaxiality/position
Hole pattern	Can welded distortion move pre-drilled holes out of position?	Identify post-weld features and datum references
Thread	Will coating or heat affect fit?	Class, depth, masking/chasing rule and inspection timing
Cosmetic face	Will weld/HAZ show through anodize or brushing?	Approved appearance standard and witness sample
Sealing interface	Can porosity or distortion compromise leakage?	Machining allowance plus leak-test stage and medium

Process chain

1 Cut/form	2 Fit/tack	3 Weld	4 Stabilize/inspect	5 Machine	6 Finish + final
leave stock	protect datums	qualified WPS	release fixture; measure	one datum strategy	mask, inspect, pack

Coordinate welded fabrication, CNC machining and surface finishing as one routing rather than separate supplier assumptions.

15 WPS, qualification and production controls

The drawing defines design intent; the qualified welding system defines how it is produced.

Control item	Minimum question	Evidence
WPS / PQR	Does qualification cover process, material group, thickness, joint and position?	Approved WPS and supporting qualification record
Welder qualification	Is the operator qualified within the required range?	Current qualification record; continuity where applicable
Filler + shielding	Are classification, lot, storage and gas controlled?	Certificates, issue/storage record
Base material	Is alloy/temper traceability matched to the design?	Material certificate and identification transfer
Preparation + cleaning	Are dedicated tools, contamination control and time sequence defined?	Work instruction / traveler
Parameters	Are essential variables recorded and within WPS range?	Machine record or production log as required
Repairs	Who may authorize; what procedure and reinspection apply?	Repair disposition and closed inspection record

INTERNATIONAL WORK

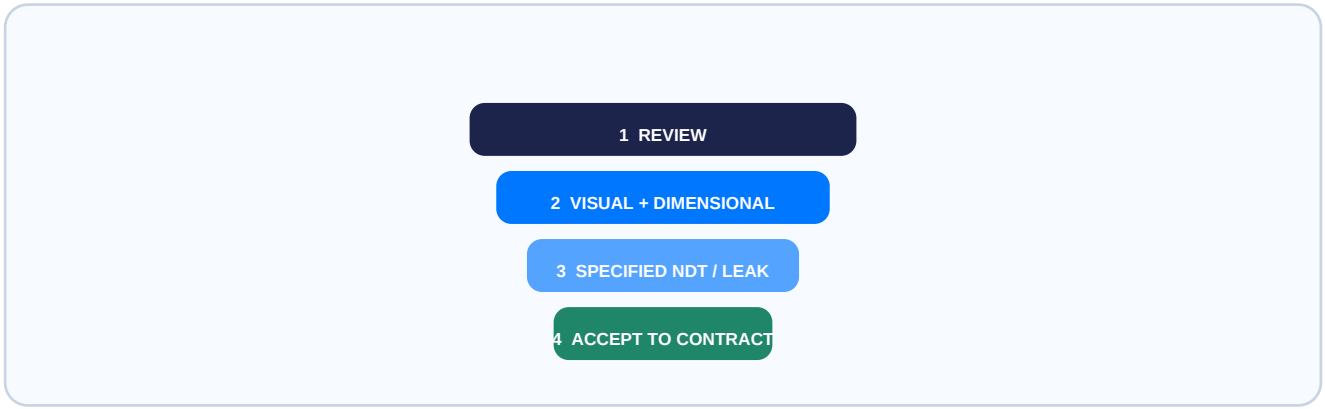
ISO 15614-2:2025 addresses welding procedure tests for arc welding of aluminum alloys. ISO 9606-2:2004 remains current as of its 2023 confirmation, while a replacement is under development. Use only standards adopted by the contract.

Supplier package

BAOSONG Welding and Metal Fabrication can be included in an RFQ routing with engineering, machining and finishing requirements.

16 Inspection and acceptance

Inspection method, extent, timing and acceptance criteria are four separate decisions.



Method	Finds / verifies	Does not establish by itself
Visual testing (VT)	Surface condition, profile, alignment and visible imperfections	Internal soundness or acceptance limit
Dimensional inspection	Geometry against defined datums and state	Weld integrity
Penetrant testing (PT)	Surface-breaking discontinuities on suitable non-porous surfaces	Subsurface discontinuities or accept/reject criteria
Radiographic / ultrasonic	Selected internal conditions when technique is suitable	Fitness for service without specified acceptance basis
Leak testing	Leak tightness for the stated medium, pressure and dwell	Structural strength or fatigue life
Destructive tests / coupons	Procedure or production evidence when specified	Every production location

QUALITY LEVELS

ISO 10042 quality levels describe production quality for arc-welded aluminum imperfections; they are not a stand-alone fitness-for-purpose decision. ISO 3452-1 defines PT principles but not acceptance criteria.

17 Drawing release and RFQ checklist

Freeze interfaces, responsibilities and verification before requesting a production quote.

Gate	Release evidence
Design basis	Code/edition, jurisdiction, load cases, service and fatigue duty named
Material	Alloy, temper, product standard, thickness and traceability defined
Joint intent	Joint sections, weld symbols, size/length/side and termination defined
HAZ design	Weld-affected allowables used in strength, buckling and fatigue checks
Access	Torch, cleaning, fixture and inspection envelopes reviewed
Tolerance	Pre-weld, in-process and final dimensions separated; datum state defined
Procedure	Required WPS/PQR and welder qualification framework stated
Inspection	Method, extent, timing, acceptance and record format stated
Post-process	Machining allowance, straightening limits, finish and masking defined
Deliverables	Certificates, reports, samples, FAI and packaging listed

REQUEST A MANUFACTURING REVIEW	Include 3D CAD, controlled 2D drawing, quantities, target schedule, application, loads/service, code basis, finish and inspection plan.
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18 References and use limitation

Check the contractually adopted edition. Standards and project requirements can change.

Reference	Guide use	Link
AWS D1.2/D1.2M:2026	Structural Welding Code - Aluminum; design, fabrication, qualification and inspection framework	Official AWS page
Aluminum Design Manual 2020	Structural design rules including welded / weld-affected provisions	Official Aluminum Association page
AWS A5.10/A5.10M:2023	Classification of bare aluminum and aluminum-alloy welding electrodes and rods	AWS A5 committee page
ISO 15614-2:2025	Welding procedure qualification by test for arc welding of aluminum and its alloys	Official ISO page
ISO 9606-2:2004	Welder qualification for fusion welding of aluminum; confirmed current in 2023	Official ISO page
ISO 17637:2016	Visual testing of fusion-welded joints	Official ISO page
ISO 10042:2018	Quality levels for imperfections in arc-welded aluminum joints	Official ISO page
ISO 3452-1:2021	General principles for penetrant testing; not acceptance criteria	Official ISO page
Aluminum Association standards	Material designation and industry standards portal	Official standards page

USE LIMITATION

This guide is educational DFM guidance. It does not replace a licensed/qualified structural engineer, welding engineer, approved drawings, qualified WPS/PQR, welder qualification, inspection plan, applicable law, governing code or the project contract.

BAOSONG resources: Welding | Metal Fabrication | Engineering Support | Quality | Contact

Document control

Version	Date	Language	Prepared for
1.0	September 2026	English	BAOSONG technical marketing / DFM review