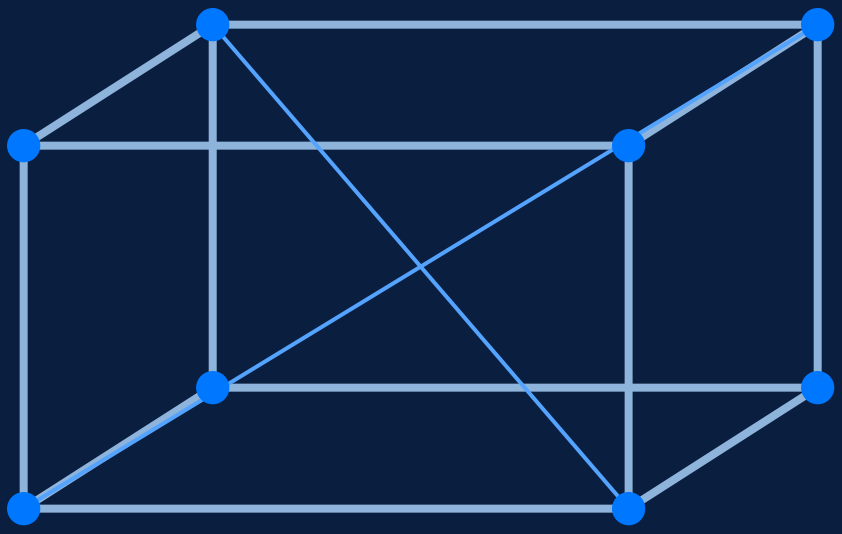
DESIGN FOR MANUFACTURING

FRAME & STRUCTURAL FABRICATION GUIDE

Architecture | Load paths | Joints | Datums | Inspection



STRUCTURE
function-led load path

PROCESS
fixture-led build plan

VERIFICATION
datum-led inspection

A practical engineering handbook for aluminum frames, machine bases, guards and structural assemblies

Prepared by BAOSONG

baosongprecision.com

Version 1.0 | September 2026 | Metric-first

Conceptual engineering illustration - not a qualified design

00 Frame design logic

A production-ready frame connects function, structural analysis, fabrication sequence and inspection datums.

SCOPE

This DFM guide supports aluminum frames, machine bases, guards and structural assemblies. It is not a structural calculation, welding procedure, legal compliance assessment or acceptance specification.

Layer	Question	Controlled output
Function	What must mount, move, align, protect or carry load?	Interface control document
Structure	How do static, dynamic, fatigue and environmental loads reach supports?	Qualified analysis and joint design
Fabrication	Can parts be cut, formed, fixtured, joined and released predictably?	Process route and fixture concept
Verification	Which datums and criteria demonstrate conformance?	Inspection plan and records

Engage BAOSONG Engineering Support while architecture and joint locations can still change.

01 Define the design basis

A frame cannot be optimized until loads, boundary conditions, life and failure consequences are explicit.

Input	Minimum definition	Design effect
Loads	Magnitude, direction, location, combinations and duty cycle	Member force, joint demand and deflection
Supports	Fixed, pinned, sliding, compliant or installation-preloaded	Reaction path and thermal restraint
Service	Temperature, corrosion, vibration, impact, transport and outdoor exposure	Material, finish, fatigue and drainage
Interfaces	Mounting faces, rails, doors, panels, actuators and cable routes	Datum scheme and local stiffness
Compliance	Jurisdiction, owner specification, code edition and documentation level	Analysis, qualification and acceptance framework

ALUMINUM BASIS

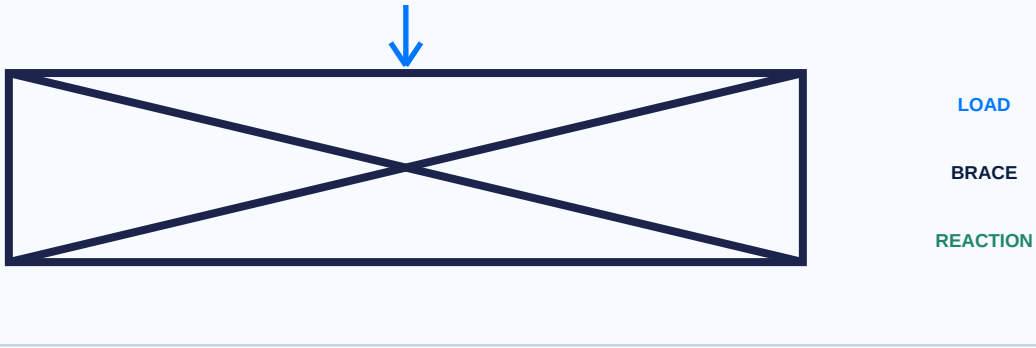
For structural aluminum, the Aluminum Design Manual and the contractually adopted welding code may both apply. Verify editions, jurisdiction and project requirements before release.

Do not hide boundary conditions

- Show attachment stiffness, bolt slip assumptions, base flatness and installation shims.
- Separate operating, maintenance, lifting, transport and accidental load cases.
- State allowable deflection and alignment drift at functional interfaces.

02 Build a direct load path

Use geometry to move forces to supports without unnecessary eccentricity, local bending or joint congestion.



Feature	Good intent	Failure to check
Primary rails / columns	Align with major forces and interface reactions	Global bending, buckling, vibration
Bracing	Create stable triangulation in required planes	Racking, torsion and connection flexibility
Cross-members	Support local equipment and distribute point loads	Local flange/wall crippling and deflection
Nodes	Bring member centrelines and force resultants together	Eccentric moments and weld concentration
Base / feet	Spread reactions into anchors or floor	Prying, plate bending and installation mismatch

TRACE IT

On one drawing view, trace every design load to a support. Any unexplained jump, offset or isolated bracket deserves a joint free-body check.

03 Choose material and product form

Use extrusions, plate, sheet, tube and machined nodes where their manufacturing strengths match the function.

Product form	Best use	DFM checks
Extrusion	Long members with integrated grooves, ribs or mounting features	Section availability/tooling, temper, straightness, cut and joining access
Tube / hollow profile	Efficient closed-section stiffness and clean frames	Wall access, vent/drain, end closure and internal finish
Plate	Gussets, bases, interfaces and high local load spreading	Flatness, cutting heat, edge preparation and mass
Sheet	Guards, trays, skins and shear panels	Bends, oil-canning, fastener pitch and removable access
Machined node	Accurate multi-member junction or bearing interface	Material utilization, tool access, tolerance transfer and cost

MATERIAL ID

Specify alloy, temper, product specification, thickness and traceability. Do not allow 'aluminum equivalent' substitutions without engineering review.

For profile-led architecture, coordinate custom aluminum extrusion with fabrication and machining requirements.

04 Size members for strength and stiffness

A frame can meet static strength and still fail functional alignment, vibration or local stability requirements.

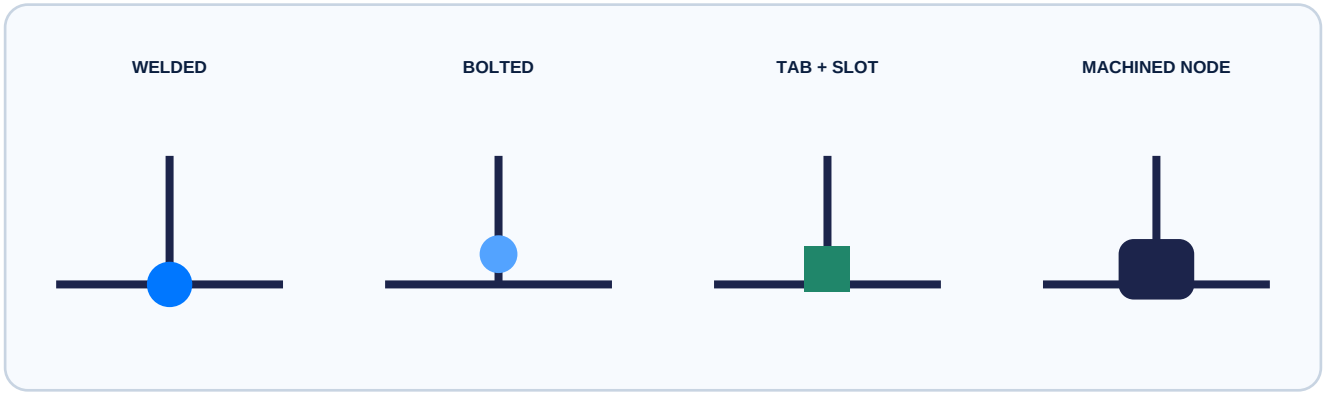
Check	Typical driver	Design response
Yield / rupture	Peak combined loads and weld-affected regions	Use applicable material and welded design values
Global buckling	Slender compression members and effective length	Brace, reduce unsupported length or increase section efficiency
Local buckling	Thin walls, concentrated loads and open sections	Add local support or select a more stable section
Deflection	Optics, rails, doors, seals and machining interfaces	Set interface-specific limits and include joint flexibility
Torsion	Offset loads and open sections	Close the load path or use efficient closed/boxed geometry
Dynamics	Motors, reciprocating masses and floor excitation	Check natural frequencies, damping and operating spectrum

MODEL REALITY

Include joint compliance, equipment mass, panel contribution only when justified, support flexibility and realistic installation constraints.

05 Select a connection architecture

Choose joints by load transfer, serviceability, assembly sequence, access and lifecycle - not appearance alone.



Connection	Advantages	Tradeoffs
Welded	Continuous load transfer, permanent assembly, compact envelope	Heat-affected properties, distortion, access and inspection
Bolted	Replaceable, field-assembled, low heat input	Hole bearing, slip, preload, access, loosening and galvanic isolation
Tab-and-slot + weld	Self-location and repeatable fit-up	Slot clearance, tolerance stack and visible witness features
Machined node	Accurate multi-axis interface and smooth load transition	Machining cost, material yield and joining sequence
Adhesive / hybrid	Distributed load and dissimilar-material isolation in suitable services	Surface preparation, cure, temperature, durability and validation

JOINT OWNER

A structural engineer must define joint demand and capacity. The fabrication drawing must then make that joint accessible, buildable and inspectable.

06 Design gussets, brackets and nodes

Reinforcement should spread load gradually instead of moving the hot spot to a stiffer edge.

Detail	Risk pattern	Better intent
Square-ended gusset	Abrupt stiffness and weld termination in peak stress	Taper or shape load transfer; verify fatigue category
Single-sided bracket	Eccentricity twists the member wall	Balance the load path or check local torsion and wall bending
Large pad on thin wall	Heat, restraint and local distortion	Spread load with compatible thickness transition and planned sequence
Intersecting gussets	Weld congestion and inaccessible roots	Offset, stage or redesign the node for access
Base plate + column	Prying, local plate bending and anchor mismatch	Coordinate plate stiffness, welds, anchors, grout/shims and installation tolerances

Detail review

- Show the force introduction area, not only the attachment outline.
- Move weld starts/stops away from fatigue hot spots where the code permits.
- Preserve tool, torch, fastener and inspection access around the node.
- Check drainage and finishing around double layers and closed corners.

CALCULATE A visually larger gusset can increase local stiffness and stress concentration. Verify the complete node, including parent material, HAZ, fasteners and supporting wall.

07 Plan welding as part of the structure

Weld type, length and sequence affect strength, distortion, fatigue, corrosion and final geometry.

Design item	Drawing / specification input	Production control
Joint condition	Weld symbol, side, length, size/penetration and termination	Qualified WPS and joint detail
Access	Torch, filler, cleaning, starts/stops and inspection envelope	Assembly and fixture sequence
Heat balance	Joint volume, symmetry and member thickness transition	Weld sequence and essential variables
HAZ	Weld-affected structural properties and effective region	Material/WPS traceability
Acceptance	Method, extent, stage and criteria	Inspection and repair records

COMPANION GUIDE

Use the BAOSONG Welding Design Guide for Aluminum Structures for detailed HAZ, joint, distortion and inspection decisions. Do not copy universal weld sizes or process parameters.

Manufacturing links: Welding | Metal Fabrication | Quality.

08 Design fixtures and datums together

A stable setup locates functionally important interfaces while allowing predictable assembly and shrinkage.

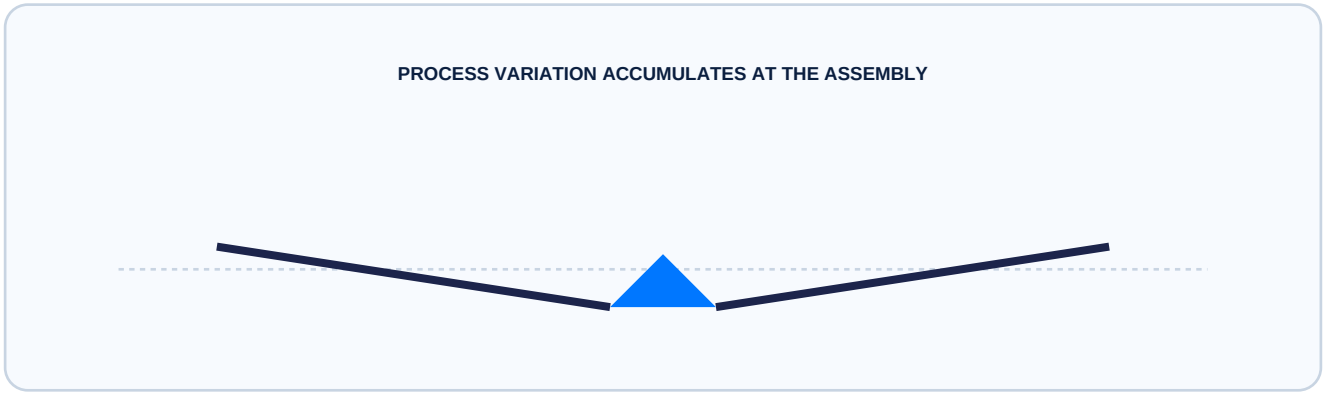
Fixture principle	Design intent	Avoid
3-2-1 location	Constrain necessary degrees of freedom from functional datums	Redundant locators fighting part variation
Clamp near support	Close the force loop without bending slender members	Pulling a warped part into apparent compliance
Accessible joints	Keep clamps clear of welding, cleaning and inspection	Moving clamps mid-seam without a plan
Shrinkage path	Permit or compensate predictable movement	Over-restraint that raises stress or cracking risk
Repeatable release	Define tack sequence, weld stage and unclamp condition	Inspecting only while fixture force hides distortion

FIRST ARTICLE

Record locator scheme, tack condition, weld sequence, release order and free-state geometry. Use the evidence to tune the process before serial production.

09 Control tolerance and distortion

Separate part tolerance, fit-up variation, joining distortion, post-process change and final acceptance.



Stage	Specify / measure	Reason
Incoming components	Cut length, squareness, form and feature location	Controls fit-up before joining
Fixture / tack	Gap, mismatch, diagonal and datum seating	Prevents hidden preload
Post-join free state	Overall size, flatness, twist and interface position	Reveals process distortion
Post-machining	Functional faces, bores, holes and threads	Verifies recovered geometry
After finish	Masking, coating build, appearance and final fit	Captures the delivered condition

GENERAL TOLERANCE

ISO 13920:2023 provides four general-tolerance classes for welded constructions. The drawing must state the selected class or individual tolerances; choose by function, not habit.

10 Plan post-fabrication machining

Machine precision interfaces after the operations that move them, with enough stock and a stable datum strategy.

Feature	Routing decision	Key requirement
Mounting plane	Machine after joining if frame distortion affects function	Define free/restrained setup and final flatness
Rail pads	Machine together where coplanarity is critical	Common setup and accessible tool path
Coaxial bores	Finish in one setup or controlled transfer	Datum and alignment method
Hole pattern	Drill/ream after welding if positional accuracy is tight	Final feature position to frame datums
Threads	Protect or produce after finish as needed	Class, depth, coating allowance and cleanliness
Datum targets	Create robust pads/bores that survive finishing	Measurement repeatability and handling protection

STOCK CHECK Machining allowance must cover worst-case distortion, profile tolerance, fixture seating and setup error without thinning a structural wall below design minimum.

Coordinate the frame route with BAOSONG CNC Machining before freezing access and allowance.

11 Design bolted and modular frames

Modularity helps shipping, service and scaling only when interfaces locate, clamp and carry load deliberately.

Interface feature	Function	DFM question
Locating pin / pilot	Controls repeatable position independently of clamp force	Can it assemble without binding across tolerance and temperature?
Bolts	Provide clamp and/or shear transfer per joint design	Is installation access, torque/preload method and locking defined?
Slotted hole	Allows adjustment or thermal movement	Which direction, final lock condition and edge distance?
Splice plate	Transfers force between modules	Are bearing, slip, prying and fatigue checked?
Shim / grout	Compensates installation surface variation	Is thickness range, material and retention controlled?
Electrical bond / isolation	Controls grounding or galvanic path	Is the required state explicit after coating?

SERVICE STATE

Specify whether tolerances and alignment apply before or after final bolt tightening, leveling, shimming and equipment installation.

12 Integrate panels, guards and routing

Secondary systems can stiffen, preload or distort the primary frame - or block access needed to build it.

System	Integration questions	Release output
Sheet panels	Structural shear panel or removable cover? Thermal expansion? Oil-canning?	Attachment pitch, edge condition, isolation and flatness intent
Doors / hinges	Sag, seal compression and adjustment range?	Hinge datum, latch envelope and final gap plan
Cable / hose	Minimum bend, moving envelope, service access and abrasion?	Routing zones, clips and protected pass-throughs
Machine guarding	Required standard, impact/containment, visibility and interlock?	Compliance specification and interface drawing
Drain / vent	Where do liquids, condensate and trapped air move?	Slope, low-point drains and finish-safe vents
Lifting points	Which assembled condition and centre of gravity?	Engineer-approved lift plan and marked interfaces

SEQUENCE

Install hidden clips, nuts, cable trays and internal weldments before closing skins - but protect them from weld heat, debris and finishing processes.

13 Design for fatigue, vibration and transport

Dynamic service often makes connection stiffness and detail geometry more important than member static stress.

Driver	Design action	Evidence
Repeated equipment load	Map stress range at members, HAZ, weld toes/roots and fastener holes	Applicable fatigue calculation
Motor / process excitation	Separate natural frequencies; manage stiffness, mass and damping	Modal / harmonic analysis or test
Transport shock	Define orientation, restraint, lifting and acceleration cases	Transport load case and packaging validation
Loose panels / hardware	Control preload, locking and contact interfaces	Assembly instruction and audit
Attachment termination	Use gradual load transfer and locate away from peak stress	Detail category and inspection requirement

INPUT QUALITY

Provide frequency spectrum, cycles, acceleration, damping assumptions, operating states and consequences of failure. 'Vibration resistant' is not a testable requirement.

14 Control corrosion and finishing

Drainage, dissimilar metals, crevices and coating access belong in the frame architecture.

Risk	Design control	Finish / inspection note
Trapped electrolyte	Open drainage or intentional full seal; avoid ambiguous partial seams	Confirm drains remain open after coating
Closed tube volume	Engineer safe vents and process drainage	Never heat or weld an unsafe sealed contaminated volume
Dissimilar fastener	Isolate galvanic couples in wet service	Validate washers, sleeves, sealant and coating system
Crevice / overlap	Provide access for pretreatment and drying	Define acceptable seam and seal condition
Coating build	Protect precision interfaces and thread fits	Masking drawing and witness sample
Handling damage	Provide lifting/packing points away from cosmetic faces	Final appearance and packaging inspection

SYSTEM REVIEW

Select alloy, filler, fastener, sealant and finish as one exposure system. Review with BAOSONG Surface Finishing before release.

15 Build the manufacturing route

Sequence operations around access, movement and verification gates rather than departmental convenience.

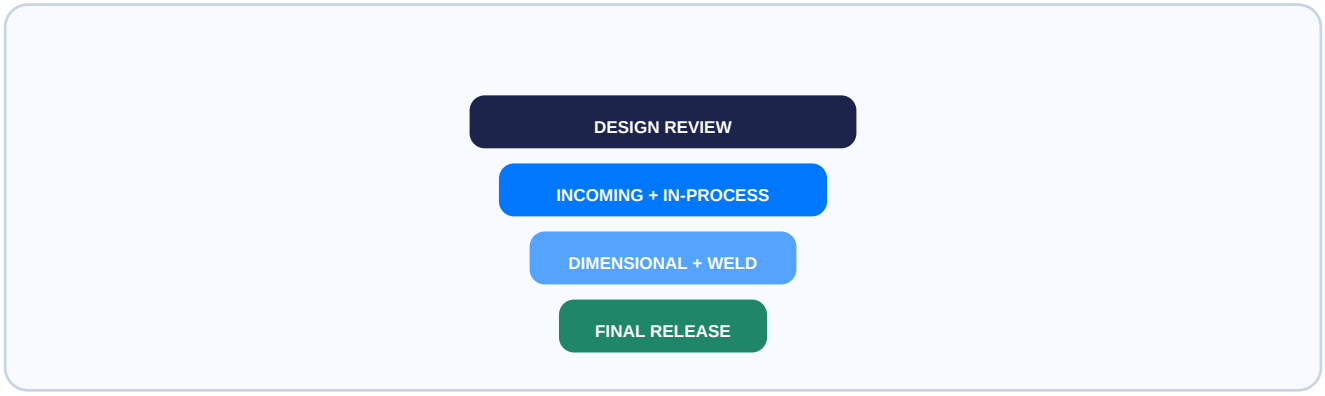
Gate	Release question	Typical record
Material	Correct alloy/temper/form and certificates?	Receiving record + identification
Components	Cut, formed and machined details within pre-join tolerance?	In-process dimensional report
Fit-up	Datums seated, gaps/mismatch controlled, fixture approved?	Fit-up / first-article check
Join	Qualified process, sequence and personnel?	Traveler, WPS and traceability
Recovery	Straightening allowed? Enough stock for machining?	Disposition + machining report
Finish / final	Coating, dimensions, welds and documentation accepted?	Final inspection + release pack

QUALITY SYSTEM

ISO 3834-2:2021 defines comprehensive quality requirements for fusion welding in workshops and field installation. Apply it only when selected by the contract or quality plan.

16 Inspection and first-article validation

Inspect what matters to function, at the stage when it is visible and measurable.



Verification	Define before RFQ	Do not assume
Dimensional	Datums, state, temperature, method and report format	A fixture-held measurement represents free state
Weld visual	Timing, access, method and acceptance criteria	Visual testing proves internal soundness
Specified NDT	Method, extent, technique, personnel and acceptance	A method name is a pass/fail limit
Coating	Pretreatment, color/gloss, thickness zones and masking	Cosmetic acceptance is self-evident
Functional	Interface mockup, door/rail motion, load or leak test	A dimensional report replaces function
Documentation	Certificates, WPS records, FAI, photos and packaging release	Records can be reconstructed after shipment

VISUAL TESTING

ISO 17637:2016 covers visual testing of fusion-welded joints and can also apply before welding. Acceptance still comes from the governing contract/code.

17 Drawing and RFQ release checklist

Give suppliers a controlled package that separates structural intent, fabrication controls and final acceptance.

Gate	Required input
Model + drawings	3D CAD, controlled 2D PDF, revision and order of precedence
Design basis	Application, loads, supports, duty, environment, code/edition and engineer approval
Materials	Alloy, temper, form, specifications, certificates and substitutions policy
Connections	Calculated joint requirements, weld/fastener details, access and assembly sequence
Datums + tolerance	Pre-join and final requirements; free/restrained/installed state
Process	WPS/qualification expectations, straightening limits, machining and finish routing
Inspection	Methods, extent, timing, criteria, FAI and document package
Commercial	Quantities, forecast, target schedule, shipping modules and delivery location

QUOTE CLARITY

Ask suppliers to list deviations, assumptions, tooling/fixture charges, sample plan and recurring versus non-recurring cost separately.

Cost levers that preserve function

- Use repeated cut lengths, joint families and common interface plates.
- Relax nonfunctional cosmetic or geometric requirements by zone.
- Choose shipping modules before fixtures and hole patterns are frozen.
- Move precision to a small number of post-fabrication datum features.

18 References and BAOSONG contact

Check the edition adopted by the contract. Standards and customer requirements can change.

Reference	Guide use	Link
Aluminum Design Manual 2020	Structural design rules for aluminum members and connections	Official page
AWS D1.2/D1.2M:2026	Structural Welding Code - Aluminum	Official page
ISO 13920:2023	General tolerances for welded constructions	Official page
ISO 3834-2:2021	Comprehensive fusion-welding quality requirements	Official page
ISO 17637:2016	Visual testing of fusion-welded joints	Official page
ASME Y14.5-2018 (R2024)	Dimensioning and tolerancing language	Official page

USE LIMITATION	Educational DFM guidance only. It does not replace a qualified structural engineer, welding engineer, approved drawings, applicable law/code, qualified procedures or contract acceptance criteria.

REQUEST A REVIEW	Send CAD, drawings, loads/service, materials, quantities, finish, inspection plan and schedule.
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