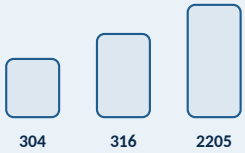
KINGSFORM METALWORKS

ENGINEERING TOOLKIT

STAINLESS STEEL GUIDE

Grade selection, corrosion resistance, fabrication, welding, finishing and procurement

GRADE SELECTION

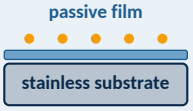


Match family and grade to corrosion, strength, forming, welding and appearance.

FABRICATION CONTROL

Control work hardening, springback, heat input, contamination and distortion.

SURFACE INTEGRITY



Specify finish, cleaning, pickling, passivation and acceptance separately.

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KFR-018	1.0	2026-07-18	English
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01 PURPOSE AND SELECTION WORKFLOW

Select the grade from the service environment backward

“Stainless” is not one material. Corrosion mechanism, fabrication route, surface condition and maintenance can change the correct grade.

CORE PRINCIPLE

Grade designation alone is incomplete. A released specification should define product form, governing standard, dimensions/tolerances, delivery condition, surface finish, weld condition, inspection certificate and any post-fabrication cleaning or passivation.

1 Environment

Chemistry, chlorides, temperature, wet/dry cycle, cleaning agents and deposits.

2 Failure mode

General corrosion, pitting, crevice, SCC, intergranular attack, erosion or galling.

3 Fabrication

Cutting, bending, deep draw, machining, welding, heat treatment and finishing.

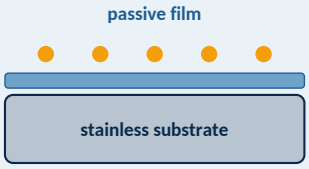
4 Function

Strength, stiffness, hygiene, magnetism, appearance, fatigue and life cycle.

5 Verification

MTC/PMI, weld procedure, finish sample, corrosion test and inspection plan.

WHY STAINLESS RESISTS CORROSION



The chromium-rich passive film forms spontaneously in suitable oxidizing environments and can repair after minor mechanical damage if the surface is clean and oxygen is available.

WHAT BREAKS THE PROTECTION

- Chloride concentration, deposits and crevices that locally starve the surface of oxygen.
- Heat tint, embedded carbon steel, scale, rough welds or contaminated abrasive media.
- Unsuitable temperature/chemical combination, residual tensile stress or stagnant geometry.
- Wrong product condition, wrong grade, or uncontrolled welding thermal cycle.

02 STAINLESS STEEL FAMILIES

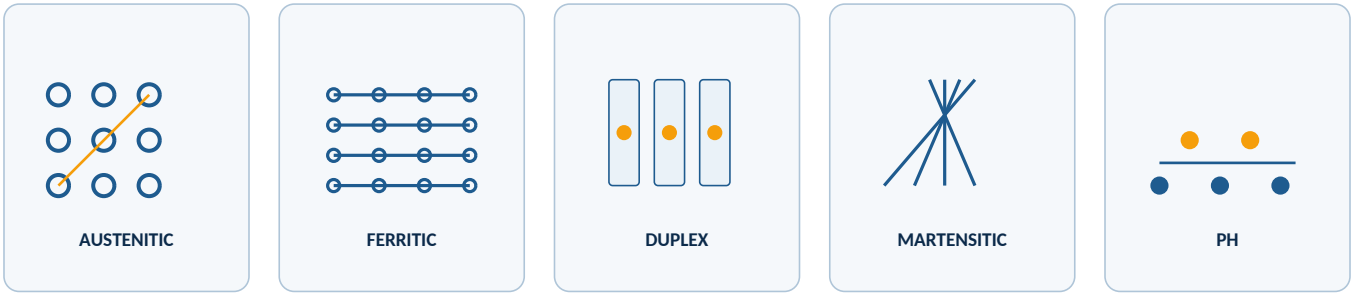
Start with metallurgy, then narrow to a grade

Each family offers a different balance of corrosion resistance, strength, toughness, magnetism, formability and weldability.

Family	Typical structure / examples	Strength and forming	Corrosion / welding	Use when...
Austenitic	304L, 316L; mostly non-magnetic in annealed condition	High ductility; strong work hardening; good deep draw	Broad weldability; chloride pitting/SCC still possible	Complex forming, hygiene, broad general fabrication
Ferritic	409, 430, 441; magnetic	Lower work hardening; moderate ductility; thickness and grain control matter	No nickel or low nickel; welding toughness and grain growth need control	Cost-sensitive mild corrosion, exhausts, appliance trim
Duplex	2205, lean duplex; magnetic mixed structure	Higher yield strength; greater springback; narrower forming window	Good chloride SCC resistance; weld heat balance is critical	Chloride service, weight reduction, high strength
Martensitic	410, 420; magnetic and hardenable	Heat-treatable; lower formability; hardness can be high	Corrosion below common austenitics; weld cracking risk	Wear, cutting edges, shafts and moderate corrosion
Precipitation hardening	17-4PH / 630; magnetic	High strength after aging; machining condition matters	Good general resistance but grade/condition specific	High strength, dimensional control, mechanical components

MAGNETISM IS NOT A RELIABLE GRADE TEST

Cold-worked austenitic stainless can become magnetic; ferritic, duplex, martensitic and precipitation-hardening grades are normally magnetic. Use documentation or PMI for grade verification.



03 GRADE SCREENING MATRIX

Compare grades by mechanism - not by a single “better” ranking

The table is a preliminary screen for common fabricated products. Confirm exact chemistry, properties and permitted product form in the governing standard and material certificate.

Grade / family	Relative corrosion screen	Strength level	Fabrication notes	Typical candidate uses
304L / austenitic	Good general atmospheric and hygienic service; limited in chlorides	Medium	Excellent forming and welding; work hardens	Indoor equipment, food-contact frames, general enclosures
316L / Mo-austenitic	Improved pitting and crevice resistance vs 304L; not “seawater proof”	Medium	Similar to 304L; higher alloy cost	Coastal atmosphere, washdown, pharmaceutical and marine hardware review
430 / ferritic	Mild atmospheric / indoor; weaker in aggressive chloride service	Medium-low	Magnetic; lower deep-draw margin than 304; weld detail matters	Appliance trim, decorative panels, mild environments
409 / stabilized ferritic	Designed for oxidation/exhaust duty, not decorative corrosion resistance	Medium-low	Heat-cycle capable; finish and discoloration expectations required	Automotive exhaust, hot gas shields
2205 / duplex	High chloride SCC resistance and higher pitting screen than 316L	High	High springback; weld heat input/interpass control essential	Chemical, coastal and process equipment after corrosion review
17-4PH / PH	Good general resistance; condition and environment specific	Very high	Heat treatment condition controls strength and size	Shafts, brackets, latches and high-strength machined parts

PREN IS A SCREENING INDEX - NOT A SERVICE GUARANTEE

A common screening form is PREN = %Cr + 3.3 x %Mo + 16 x %N. It can compare pitting resistance within suitable alloy families, but it does not capture surface finish, crevices, temperature, weld condition, contaminants or actual process chemistry.

04 CORROSION MECHANISMS

Identify the local condition that can defeat the passive film

Most unexpected stainless failures are localized: a crevice, deposit, weld oxide, chloride hotspot or stressed zone can govern the whole assembly.

PITTING

Localized attack often initiated by chlorides, contamination or surface defects.

CONTROL

Raise alloy pitting resistance; improve finish and cleaning; reduce chloride/temperature.

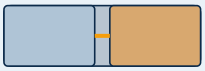
CREVICE

Shielded gaps under washers, gaskets, lap joints or deposits become chemically aggressive.

CONTROL

Eliminate or seal crevices; drain; use continuous hygienic welds where required.

GALVANIC



Electrical contact between dissimilar metals plus electrolyte can attack the less noble material.

CONTROL

Isolate metals; control area ratio; coat the less noble member; provide drainage.

CHLORIDE SCC

Cracking requires susceptible alloy, tensile stress and a critical chloride-temperature condition.

CONTROL

Reduce stress/temperature/chlorides; select duplex or other resistant alloy after review.

INTERGRANULAR

Sensitization or unsuitable thermal history can reduce grain-boundary corrosion resistance.

CONTROL

Use low-carbon/stabilized grades; qualify welding and heat treatment; test where specified.

ROUGING / TEA STAIN

Surface discoloration or rust-like staining may occur without deep structural attack.

CONTROL

Remove iron contamination; improve rinse/dry/maintenance; confirm finish and environment.

05 ENVIRONMENT SELECTION

Use the harshest local condition, not the average atmosphere

A sheltered crevice, heated chloride droplet or cleaning chemical can be more severe than the surrounding environment.

Service condition	304L	316L	430 / 409	2205	Design action
Dry indoor / controlled atmosphere	Usually suitable	Suitable; often unnecessary premium	430 often viable; 409 only where appearance is secondary	Usually unnecessary	Define appearance, cleaning and contamination controls
Outdoor urban / rain-washed	Often suitable with finish/maintenance review	Higher margin	430 depends on exposure and finish	High margin	Avoid sheltered dirt traps and mixed-metal runoff
Food / pharma washdown	Common candidate	Preferred where chlorides/chemicals justify	Usually limited by hygiene/cleaning requirements	Possible after process review	Specify finish, weld smoothness, cleaning chemistry and validation
Coastal salt atmosphere	Risk increases with shelter and deposits	Common starting point, not automatic guarantee	Generally weak candidate	Higher margin	Use exposure testing or corrosion specialist for critical service
Seawater immersion / splash	Generally poor candidate	Pitting/crevice risk remains significant	Not suitable	Candidate only after detailed review	Crevice design, cathodic effects, biofouling and alloy verification
Hot chloride / concentrated cleaner	SCC and pitting risk	Still vulnerable	Depends on chemistry; often unsuitable	Improved SCC resistance but not universal	Require chemistry/temperature data and corrosion test evidence
High-temperature exhaust	Oxidation limits grade-specific	Possible but cost may be high	409/441 often considered	Not normally selected for this reason	Define peak/cycle temperature and condensate chemistry

SELECTION RED FLAGS

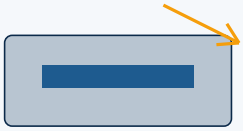
Do not approve a grade from a generic “marine”, “food grade”, “acid resistant” or “stainless” label. Obtain chloride level, pH, temperature, oxidizing/reducing condition, wet time, deposits, cleaning chemicals, maintenance access and expected life.

06 DESIGN FOR CORROSION RESISTANCE

Geometry can improve or destroy the grade margin

Drainage, access, smooth transitions and isolation often deliver more reliability than a small alloy upgrade applied to a poor detail.

DRAINAGE



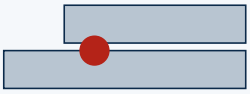
BAD

horizontal pocket traps chloride-rich liquid.

GOOD

slope, drain and rinse access prevent concentration.

CREVICES



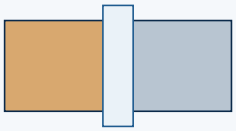
BAD

unsealed lap joint or washer gap remains wet.

GOOD

eliminate gap, seal completely, or make it cleanable.

MIXED METALS



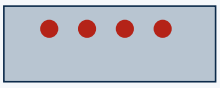
BAD

stainless fastener on large wet aluminum area without isolation.

GOOD

isolate, coat appropriately and control area ratio.

CONTAMINATION



BAD

carbon-steel brush or shared grinding dust embeds iron.

GOOD

dedicated tooling, clean storage and verified final cleaning.

DETAIL REVIEW QUESTIONS

Can every wetted surface drain and dry? Can deposits be removed? Is a crevice intentionally sealed or intentionally open? Is the stainless shielded from oxygen? Can cleaning reach the back side of welds and fasteners? Are mixed metals electrically and chemically compatible?

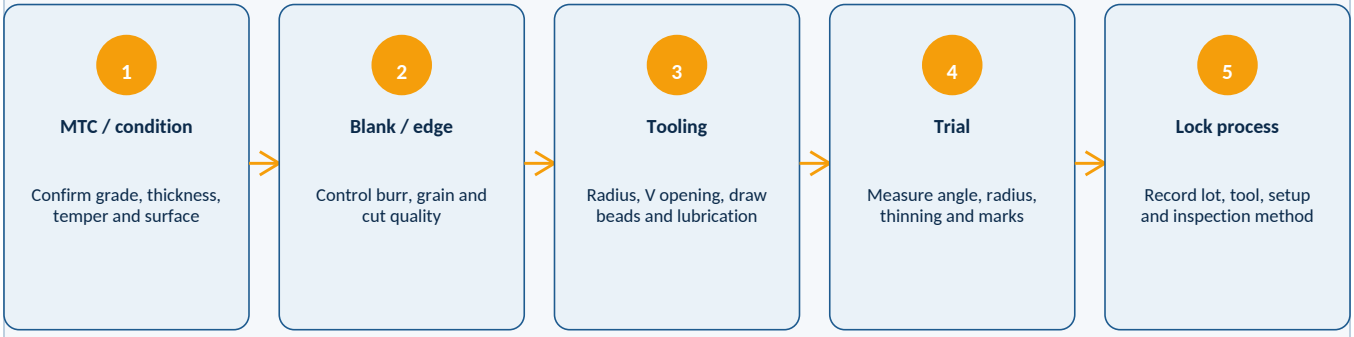
07 FORMING AND BENDING

Expect work hardening, springback and surface marking

Use trial bends and supplier capability data. A universal minimum bend radius is unsafe because grade, temper, thickness, grain direction, edge quality, tooling and cosmetic limits all interact.

Factor	Austenitic 304L/316L	Ferritic 430/409	Duplex 2205	Design response
Work hardening	High	Low to medium	Medium-high	Allow forming force, intermediate anneal only if process permits, avoid repeated correction
Springback	Medium-high	Medium	High	Prototype and compensate tooling/angle; control material condition
Deep drawing	Good	Grade/thickness dependent	Limited vs austenitic	Use drawing-quality product and validated blank/lubrication
Edge cracking risk	Rises with shear damage and tight radius	Sensitive to grain and edge quality	Rises with tight radius/high strain	Deburr, improve cut edge, enlarge radius, orient bend
Surface marking	High visibility on polished finishes	High visibility	High visibility	Use clean protective films, polished tools and dedicated handling

FORMING VALIDATION LOOP



BEND NOTE FOR DRAWINGS

State material grade and product condition, nominal thickness, inside radius where functionally important, bend angle, datum scheme, grain/rolling direction when required, visible-surface protection and acceptable springback/shape tolerance.

08 CUTTING AND MACHINING

Preserve corrosion resistance while controlling heat and contamination

Stainless has lower thermal conductivity than carbon steel and many grades work harden. Heat, rubbing and contaminated tools can degrade both dimensional control and surface integrity.

Process	Strength	Primary risks	Controls before release
Fiber laser	Fast, accurate sheet/profile cutting	Heat tint, dross, nitrogen/oxygen edge chemistry, small-feature distortion	Specify edge quality, gas choice, burr limit, post-cleaning and feature-to-edge rules
Plasma	Productive for thicker plate	Wide HAZ, oxide scale, taper and rough edge	Allow machining/grinding; remove scale; verify corrosion-critical edges
Waterjet	Low thermal effect	Taper, striation, abrasive embedment and wet contamination	Specify cut class, rinse/dry, remove embedded media where critical
Sawing	Good for bar/tube	Smearing, burr, blade contamination and heat	Dedicated blade/coolant, stable feed, deburr and clean
Machining	Excellent precision	Work hardening, built-up edge, galling, tool wear	Rigid setup, sharp tooling, positive feed, coolant and avoid dwelling
Grinding / finishing	Flexible edge/weld finishing	Cross-contamination, overheating, inconsistent grain	Dedicated stainless abrasives, controlled direction, heat-tint removal and visual sample

DO

Use dedicated clean tooling; maintain positive feed; remove burrs without overheating; clean lubricants and marking compounds; protect visible surfaces; define final edge condition.

DO NOT

Let a dull tool rub; use carbon-steel wire brushes; accept blue/brown heat tint on corrosion-critical areas; mix abrasive media; leave chloride-bearing coolant or fingerprints trapped.

Relative machining attention generally increases from ferritic to austenitic and duplex grades; confirm with the material supplier and machining trial.

09 WELDING STAINLESS STEEL

Control metallurgy, heat tint, shielding and distortion

A visually acceptable weld can still have reduced corrosion resistance. Define weld procedure, filler, shielding, purge, interpass limit, post-weld cleaning and acceptance together.

1
BASE METAL
Confirm grade, thickness, product condition and traceability.

2
WPS / FILLER
Select qualified process and compatible filler; address dissimilar joints.

3
FIT-UP
Clean joint; control gap, tack quality and access for purge/cleaning.

4
HEAT CONTROL
Manage current, travel speed, sequence, interpass and distortion.

5
POST-WELD
Remove heat tint/scale as specified; rinse, passivate and inspect.

Topic	Austenitic	Ferritic	Duplex	Release requirement
Hot cracking / solidification	Filler and ferrite balance matter	Usually lower hot-cracking tendency	Composition/thermal cycle critical	Use qualified WPS and approved consumable
Grain / phase control	Avoid excessive heat and sensitization	Grain growth and toughness can govern	Maintain austenite-ferrite balance; avoid intermetallics	Control heat input, interpass and purge
Distortion	High thermal expansion; lower conductivity	Lower expansion than austenitic	High strength and springback	Fixture, sequence, balanced weld and final datum plan
Backside oxidation	Root oxide can reduce corrosion	Still harmful	Especially important in corrosion service	Define purge quality and root acceptance
Post-weld surface	Remove tint/scale where corrosion/appearance requires	Clean and restore surface	Strict cleaning may be required	Specify pickling/passivation/mechanical finish and verification

HEAT TINT IS A PROCESS SIGNAL

Light straw brown purple blue grey/black

Color alone is not an acceptance specification. Relate it to service, cleaning method and verified corrosion performance.

10 SURFACE FINISH AND PASSIVATION

Specify appearance, roughness and chemical cleanliness separately

Mill finish names, mechanical polish, Ra value, directional grain and passivation are different requirements. One does not automatically guarantee the others.

Surface / treatment	What it controls	Typical risks	Specify...
2B / mill finish	Flat-rolled baseline finish	Lot-to-lot appearance and protective-film marks	Product standard, side(s), film and cosmetic zone
BA / bright annealed	High reflectivity from process route	Distortion visibility, scratches and weld mismatch	Gloss/appearance sample, handling and weld finishing
No. 4 / directional polish	Linear appearance and moderate roughness	Grain mismatch, blend marks and corner inconsistency	Abrasive sequence, direction, sample and allowable repair
Bead blasted	Uniform matte texture	Embedded media, uneven density and cleanability	Media type, cleanliness, pressure, masking and sample
Pickling	Removes scale/heat tint and metal-depleted oxide layer	Over-pickling, trapped acid, inconsistent appearance	Chemistry/process, rinse, neutralization and acceptance
Passivation	Chemical treatment to enhance passive-film formation after cleaning	Cannot remove heavy scale or fix bad design	Applicable specification, method and verification test
Electropolishing	Controlled anodic removal, smoothing and brightening	Dimensional change, edge rounding and fixture marks	Stock removal, current density/process, Ra/appearance and test

POST-FABRICATION SURFACE RESTORATION

1 **Degrease**
Remove oil, adhesive, marker and shop soil.

2 **Descale / pickle**
Remove heat tint and oxide where required.

3 **Rinse / neutralize**
Prevent chemical carryover and staining.

4 **Passivate**
Apply specified treatment after clean surface is achieved.

5 **Verify / protect**
Test, inspect, dry and package without recontamination.

11 PRODUCT FORM AND PROCUREMENT

A grade name is not a purchase specification

Flat product, bar, pipe, mechanical tube, pressure tube and castings can have different chemistry limits, properties, tolerances, test requirements and supply conditions.

PLATE / SHEET / STRIP

Flat-rolled standard, grade, thickness tolerance, finish, edge, flatness, protective film, grain direction.

BAR / SHAPE

Bar standard, hot/cold finish, size tolerance, straightness, condition, surface defect limit and machining allowance.

MECHANICAL TUBE

Mechanical tubing standard, shape, OD/section, wall, weld condition, finish, corner radius, twist/straightness.

PIPE / PRESSURE TUBE

Pressure/service standard, schedule or OD x wall, seamless/welded, heat treatment, NDE/hydro and ends.

FASTENERS

Fastener standard, property class/grade, thread tolerance, surface condition, galling control and certification.

CAST / FORGED PART

Product standard, grade, heat treatment, mechanical tests, NDE, repair welding and machining datum.

Purchase-order field	Minimum definition
Material identity	Governing standard + grade/designation + product form
Dimensions	Nominal size, tolerance standard/class, straightness/flatness, edge/corner condition
Delivery condition	Annealed, cold-worked, solution annealed, aged, stabilized or other condition
Surface	Mill finish / polish / blasting / pickling / passivation; side, direction, sample and protective film
Weld condition	Seam condition, bead removal, annealing, purge/root, cosmetic weld blend as applicable
Testing and certification	Heat/lot traceability, inspection certificate, PMI, mechanical/corrosion/NDE tests if required
Packaging	Interleaf, film, dry pack, VCI suitability, no carbon-steel contact, label and traceability

CROSS-STANDARD WARNING

AISI/SAE type numbers, UNS numbers, EN grade names and ISO designations are not automatically interchangeable. Confirm chemistry, mechanical properties, product form and supplementary requirements before accepting a local equivalent.

12 INSPECTION AND FAILURE PREVENTION

Verify identity, fabrication quality and surface condition

Inspection must reproduce the contract requirement. A handheld alloy reading, visual weld check or salt-spray result alone cannot prove fitness for every corrosion service.

Verification	What it can confirm	Limit / caution
MTC / heat trace	Specified chemistry/properties and lot identity	Only works if traceability is maintained through cutting and fabrication
PMI (XRF/OES)	Alloy family and selected elements	XRF may not measure carbon; method/grade discrimination must be defined
Visual / dimensional	Finish, weld shape, distortion, size and workmanship	Needs lighting, sample, datum and measurable acceptance criteria
Ferrite / phase check	Weld or duplex phase indicator where specified	Instrument calibration and procedure are grade/process specific
Free-iron / passivation tests	Surface contamination or treatment effectiveness under specified method	Pass/fail depends on selected standard and service requirement
PT / NDT	Surface-breaking discontinuities and weld quality	Does not establish corrosion resistance by itself
Corrosion testing	Specific susceptibility or comparative resistance	Test medium and specimen condition must represent the service

Observed problem	Likely contributors	Corrective action
Rust spots after delivery	Embedded iron, carbon-steel dust, chloride residue, wet packaging	Identify source; clean/pickle/passivate as approved; segregate tools and packaging
Weld zone corrodes first	Heat tint, poor purge, crevice, wrong filler or thermal cycle	Review WPS, root shielding, oxide removal, detail and grade
Cracks during forming	Tight radius, damaged edge, wrong condition, grain direction, repeated correction	Verify MTC; improve edge/radius/tooling; trial and lock process
Galling / seized threads	High contact pressure, similar stainless pair, dry assembly, rough finish	Use suitable lubricant/coating/material pair; control torque and thread finish

13 DESIGN RELEASE CHECKLIST AND REFERENCES

Release the material, process and verification plan together

The checklist is intentionally cross-functional: design, procurement, fabrication, quality and end-use conditions must agree.

- [ ] 1. Service chemistry, temperature, chlorides and wet/dry cycle are documented.
- [ ] 2. Dominant corrosion mechanism and critical locations are identified.
- [ ] 3. Grade and family selection are justified against alternatives.
- [ ] 4. Governing material/product standard and edition are stated.
- [ ] 5. Product form and delivery/heat-treatment condition are stated.
- [ ] 6. Dimensions, tolerances, flatness/straightness and edge condition are defined.
- [ ] 7. Surface finish, direction, cosmetic zones and comparison sample are defined.
- [ ] 8. Crevices, drainage, deposits and cleaning access have been reviewed.
- [ ] 9. Dissimilar-metal contacts and area ratio are controlled.
- [ ] 10. Carbon-steel contamination controls are included in the process plan.
- [ ] 11. Cutting process, burr/HAZ limits and post-cut cleaning are defined.
- [ ] 12. Forming radius, grain direction, springback and visible-surface protection are validated.
- [ ] 13. Welding code/WPS, filler, shielding, purge and interpass controls are specified.
- [ ] 14. Weld quality level, dimensional datum and distortion plan are agreed.
- [ ] 15. Heat tint/scale removal requirement is explicit.
- [ ] 16. Pickling, passivation or electropolishing method is specified where required.
- [ ] 17. Rinse, drying and recontamination controls are included.
- [ ] 18. MTC, heat/lot traceability and marking method are defined.
- [ ] 19. PMI method and limitations are addressed where grade mix-up risk exists.
- [ ] 20. NDT, corrosion tests and passivation verification are contractually defined.
- [ ] 21. Thread galling and stainless fastener assembly controls are included.
- [ ] 22. Packaging prevents scratching, moisture retention and carbon-steel contact.
- [ ] 23. Prototype or service exposure validation is planned for uncertain environments.
- [ ] 24. Supplier deviations require written engineering approval before manufacture.

CORE REFERENCES - STATUS CHECKED 18 JULY 2026

- ISO 15510:2014 - Stainless steels - Chemical composition.
- ASTM A240/A240M-26 - Stainless plate, sheet and strip.
- ASTM A276/A276M-25 - Stainless steel bars and shapes.
- ASTM A554-26 - Welded stainless steel mechanical tubing.
- ASTM A269/A269M-25 and A312/A312M-25 - tubing / pipe applications.
- ASTM A380/A380M-25 - Cleaning, descaling, pickling and passivation.
- ASTM A967/A967M-25 - Chemical passivation treatments.
- ASTM A262-15(2021) / ISO 3651-2:1998 - intergranular corrosion tests.
- ISO 5817:2023 - weld imperfection quality levels.
- ISO 3834-2:2021 - comprehensive fusion-welding quality requirements.
- AWS D1.6/D1.6M:2017 AMD1 - structural welding code, stainless steel.
- Outokumpu Handbook of Stainless Steel and welding/corrosion guides.

Use licensed standards and the customer contract as the controlling source. Reference pages: iso.org, astm.org, aws.org and outokumpu.com.