



## Frontier Metal Stamping

# Specification Master

Capabilities, tolerances and lead times across stamping, tooling, wire EDM, secondary operations, engineering review and inspection.

|   |                                             |                   |
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Figures are representative of the equipment and processes in place at the Frederick plant. Tighter tolerances are frequently achievable on specific features; send the print and we will tell you what holds. Frontier Metal Stamping is ISO 9001:2015 registered by PRI Certification, certificate 24360, and is an ITAR-registered manufacturer, DDTC registrant M28826.

# 1. Precision Metal Stamping & Forming

22 specifications

| CRITERIA                                             | SPECIFICATION                                                                                                                                                                                                                            | NOTES                                                                                                                                                                                               |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Burr Allowance (Post-Blank/Pierce)</b>            | 0.0005-0.003 in (0.0127-0.0762 mm)                                                                                                                                                                                                       | Typical as-stamped burr height; controlled via die clearance and punch condition. $\leq 10\%$ of material thickness typical. Lower burr achievable with fine clearances and post-process deburring. |
| <b>Coil Width (Servo Fed)</b>                        | 0.5-24 in (12.7-609.6 mm)                                                                                                                                                                                                                | Automated decoilers, straighteners, and servo roll feeders support continuous coil-fed production.                                                                                                  |
| <b>Common Materials</b>                              | Cold-rolled steel (CRS), HRPO, HSLA<br>Stainless steel (301, 304, 316)<br>Aluminum (5052, 6061)<br>Copper alloys (brass, phosphor bronze, beryllium copper)                                                                              | RoHS-compliant options supported; additional alloys available upon request.                                                                                                                         |
| <b>Core Stamping Operations</b>                      | Blanking<br>Piercing/punching<br>Bending<br>Lancing<br>Flanging<br>Hemming<br>Embossing<br>Coining                                                                                                                                       | Operations can be sequenced within progressive tooling to minimize secondary processing and increase throughput.                                                                                    |
| <b>Expedite Lead Time (Stocked Items)</b>            | 0-1 weeks                                                                                                                                                                                                                                | Same-day shipment available for stocked parts via inventory programs; otherwise expedited scheduling on request.                                                                                    |
| <b>Feature Tolerance (Critical Achievable)</b>       | -0.003-0.003 in (-0.076-0.076 mm)                                                                                                                                                                                                        | Tighter limits possible on select features (down to $\pm 0.001$ in / $\pm 0.025$ mm) using optimized tooling or secondary sizing.                                                                   |
| <b>Feature Tolerance (General)</b>                   | -0.005-0.005 in (-0.127-0.127 mm)                                                                                                                                                                                                        | Typical across most stamped features with well-designed tooling and in-process control.                                                                                                             |
| <b>Finishes Available via Managed Partners</b>       | Anodizing (sulfuric, hard-coat)<br>Chromate conversion coating<br>Electroless/electrolytic nickel<br>Gold plating<br>Chrome plating<br>Black oxide<br>Passivation, electropolishing<br>Industrial paint and powder coat<br>Heat treating | Finished parts supplied turnkey with certifications per print/spec.                                                                                                                                 |
| <b>First Article Lead Time after Tool Completion</b> | 1-2 weeks                                                                                                                                                                                                                                | Covers initial production run, inspection, and documentation package.                                                                                                                               |
| <b>In-Die Operations</b>                             | Tapping<br>Clinching<br>Selective hardware insertion<br>In-die sensing/vision (presence, misfeed, tonnage monitoring)                                                                                                                    | Integrating operations in-die reduces handling and improves positional accuracy for critical features; electronic monitoring improves process reliability.                                          |
| <b>Max Material Thickness (Coil Fed)</b>             | 0.01-0.25 in (0.254-6.35 mm)                                                                                                                                                                                                             | Typical working range; upper limit depends on alloy, feature density, and tool design.                                                                                                              |
| <b>New Tooling Lead Time</b>                         | 3-14 weeks                                                                                                                                                                                                                               | Includes tool design, build, and tryout; varies with complexity and station count.                                                                                                                  |
| <b>Practical Die/Part Envelope in Press</b>          | Min: 12L x 12W in (304.8L x 304.8W mm), Max: 48L x 24W in (1219.2L x 609.6W mm)                                                                                                                                                          | Approximate part/die size window that runs efficiently across the press fleet; confirm per part during DFM.                                                                                         |

| CRITERIA                                    | SPECIFICATION                                                                                                                                                                                           | NOTES                                                                                                                                  |
|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|
| <b>Press Bed Size (Max)</b>                 | 48L x 32W in (1219.2L x 812.8W mm)                                                                                                                                                                      | Maximum bed footprint used for tooling; usable window varies by press model, shut height, and feedline.                                |
| <b>Press Capacity</b>                       | 5-260 ton (44.5-2313 kN)                                                                                                                                                                                | Covers small precision features through heavy blanking/forming; press is selected to match part tonnage and die size.                  |
| <b>Production Scale</b>                     | Prototype (1-10 parts)<br>Short Run (11-500 parts)<br>Medium Run (501-10000 parts)<br>Mass Production (10001+ parts)                                                                                    | Programs scale from prototypes to sustained mass production; stocking and JIT releases available for steady demand.                    |
| <b>Prototype Lead Time</b>                  | 1-2 weeks                                                                                                                                                                                               | 3-10 days typical depending on method; expressed in weeks for consistency.                                                             |
| <b>Quality Controls and Documentation</b>   | ISO 9001:2015<br>First Article Inspection (FAI)<br>In-process inspection and press/tonnage monitoring<br>SPC with Cp/Cpk reporting<br>Material and finish certifications<br>PPAP available on request   | Lot traceability and documentation packages supplied per customer requirements.                                                        |
| <b>Repeat Order Lead Time</b>               | 1-3 weeks                                                                                                                                                                                               | Typical for standard finishes; plating/anodize may add time based on queue.                                                            |
| <b>Representative Presses and Feedlines</b> | Straight-side presses up to 260 ton<br>Servo press 220 ton<br>Gap-frame presses 50-260 ton<br>OBI presses 45 & 60 ton<br>Automated decoilers, straighteners, and servo roll feeders (up to 24 in width) | Tooling and press selection are matched to geometry, alloy, and target strokes-per-minute.                                             |
| <b>Stroke Rate</b>                          | 10-150 spm (10-150 spm)                                                                                                                                                                                 | Typical operating window across the press lineup; higher rates may be achievable on small parts in high-speed cells. Confirm per tool. |
| <b>Tool Steels and Coatings</b>             | Tool steels: D2, A2, S7, M2, M4, A11 (CPM 10V); carbide inserts where justified<br>Surface treatments/coatings: TiN, TiCN, AlCrN, nitriding                                                             | Selection based on alloy thickness/strength, feature density, and expected tool life; finalized during tool design.                    |

## 2. Tooling Design & Build

23 specifications

| CRITERIA                                                     | SPECIFICATION                                                                                                                                                              | NOTES                                                                                                                                    |
|--------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Achievable Tool Build Tolerance (EDM/Ground Features)</b> | -0.0002-0.0002 in (-0.005-0.005 mm)                                                                                                                                        | Typical on precision punch/die details and shut-offs using wire EDM, jig grinding, and controlled lapping.                               |
| <b>CMM Envelope (X x Y x Z)</b>                              | Min: 24L x 20W x 16H in (609.6L x 508W x 406.4H mm), Max: 40L x 28W x 24H in (1016L x 711.2W x 609.6H mm)                                                                  | Representative inspection volume across in-house Zeiss/Mitutoyo CMMs; full PPAP Level-3 dimensional reports available.                   |
| <b>CNC Machining Travel (X x Y x Z)</b>                      | Min: 16L x 20W x 16H in (406.4L x 508W x 406.4H mm), Max: 60L x 30W x 20H in (1524L x 762W x 508H mm)                                                                      | 3- to 5-axis vertical machining capacity for plates, inserts, and die shoes.                                                             |
| <b>Cycle Life Guarantee (Shots)</b>                          | 100000-5000000 shots                                                                                                                                                       | Life-of-tool programs with scheduled sharpening and insert replacement; life depends on alloy, thickness, and coating.                   |
| <b>Die/Mold Base Size Limit (Max)</b>                        | 58L x 36W in (1473L x 914W mm)                                                                                                                                             | Maximum base footprint routinely supported for progressive/transfer dies; confirm bolster pattern and shut height at quote.              |
| <b>Fixture Datum Repeatability</b>                           | -0.0005-0.0005 in (-0.0127-0.0127 mm)                                                                                                                                      | Modular 3-2-1 welding/machining fixtures with repeatable datums for fast changeovers.                                                    |
| <b>Grinding Feature Tolerance (Typical)</b>                  | -0.0002-0.0002 in (-0.005-0.005 mm)                                                                                                                                        | Flatness, parallelism, and size control on finished tool steel components.                                                               |
| <b>Hardening and Surface Treatments</b>                      | Vacuum heat treat<br>Cryogenic stabilization<br>Gas/ion nitriding<br>PVD coatings: TiN, TiCN, AlCrN<br>Black oxide (fixtures/components)<br>Polish/lap to mirror shut-offs | Treatments and coatings specified for wear life, galling resistance, and consistent break-edge.                                          |
| <b>Lead Time - Engineering Change / Tool Modification</b>    | 1-4 weeks                                                                                                                                                                  | Simple insert swaps faster; major re-cut/heat-treat on the longer end.                                                                   |
| <b>Lead Time - New Progressive Die (Design + Build)</b>      | 4-12 weeks                                                                                                                                                                 | Includes DFM, design, machining/EDM, assembly, tryout, and documentation; varies with station count and complexity.                      |
| <b>Lead Time - New Transfer Die (Design + Build)</b>         | 6-16 weeks                                                                                                                                                                 | Accounts for larger base, lifters/cams, and transfer tooling complexity.                                                                 |
| <b>Material Options for Inserts</b>                          | P20<br>H13<br>S7<br>D2<br>A2<br>M2<br>M3<br>A11<br>PM-M4<br>Tungsten carbide (select features)                                                                             | Tool-steel selection balances wear resistance, toughness, and cost for the target alloy and run rate.                                    |
| <b>Maximum Tool Weight</b>                                   | Up to 4000 lb (Up to 1814 kg)                                                                                                                                              | Representative crane/rigging capacity for die handling. Heavier tools may be accommodated with special arrangements—confirm per program. |
| <b>Post-Hardness Range (Typical)</b>                         | 52-62 HRC                                                                                                                                                                  | Representative hardness range for working inserts in D2/H13/S7; finalized per material and duty cycle.                                   |

| CRITERIA                                  | SPECIFICATION                                                                                                                               | NOTES                                                                                                                      |
|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| <b>Quality Controls and Documentation</b> | ISO 9001:2015<br>First Article/bench tryout reports<br>CMM inspection with full dimensional layouts<br>PPAP Level 3 documentation available | Traceable tool build records and inspection packages supplied on request.                                                  |
| <b>Simulated Press Stroke Capacity</b>    | 260 ton (2591 kN)                                                                                                                           | Press-capacity simulation used for tool design/validation and tryout correlation ( $\approx 1,600$ kN, about 180 US tons). |
| <b>Sinker EDM Travel (X x Y x Z)</b>      | Min: 8L x 12W x 10H in (203.2L x 304.8W x 254H mm), Max: 16L x 24W x 16H in (406.4L x 609.6W x 406.4H mm)                                   | Graphite/copper electrodes supported; burn strategies tuned for finish vs. MRR.                                            |
| <b>Software and File Formats</b>          | SolidWorks<br>AutoCAD<br>STEP (AP203/AP214)<br>IGES<br>Parasolid (x_t/x_b)<br>DXF/DWG<br>CAM for EDM/CNC (Mastercam/Esprit or equivalent)   | Native and neutral CAD supported; CAM outputs verified during NC and burn program reviews.                                 |
| <b>Surface Grinding Table Size (Max)</b>  | 24L x 12W in (609.6L x 304.8W mm)                                                                                                           | Magnetic chuck and precision fixtures used for parallelism and flatness on die components.                                 |
| <b>Turnaround - Emergency Repair</b>      | 0-1 weeks                                                                                                                                   | Same-day/overnight support available depending on scope and material availability.                                         |
| <b>Wire EDM Max Workpiece Thickness</b>   | 0.02-12 in (0.5-304.8 mm)                                                                                                                   | Range depends on machine, flushing strategy, and wire selection.                                                           |
| <b>Wire EDM Travel (X x Y x Z)</b>        | Min: 8L x 12W x 8H in (203.2L x 304.8W x 203.2H mm), Max: 16L x 24W x 16H in (406.4L x 609.6W x 406.4H mm)                                  | X/Y/Z mapped to width/length/height respectively for schema consistency.                                                   |
| <b>Wire EDM Wire Diameter</b>             | 0.01-0.01 in (0.254-0.254 mm)                                                                                                               | Fine wires for tight radii and micro-features; larger wires for faster roughing and long-taper cuts.                       |

## 3. Wire EDM

20 specifications

| CRITERIA                                                 | SPECIFICATION                                                                                                                                                                                                                                                | NOTES                                                                                                                    |
|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|
| <b>Applicable Workpiece Materials</b>                    | Tool steels (D2, A2, H13, S7, M2, PM grades)<br>Stainless steels (300/400 series, precipitation-hardening)<br>Tungsten carbide and carbide-tipped details<br>Titanium and nickel-based superalloys (Inconel/Hastelloy)<br>Copper, brass, and aluminum alloys | Any electrically conductive material can be cut; post-EDM surface may require polish or lap depending on application.    |
| <b>Automation and Work-Changer Options</b>               | Automatic wire threading (AWT) with re-thread on break<br>Submerged cutting with programmable flush<br>Tooling/palletization for repeatable setups<br>Program queue for unattended operation<br>In-process break detection and recovery                      | Supports lights-out cutting of long contours and multi-part nests.                                                       |
| <b>Dielectric Fluid Type</b>                             | Deionized water for wire EDM                                                                                                                                                                                                                                 | Water-based dielectric enables fine finish and efficient flushing; resistivity maintained via DI system.                 |
| <b>Dimensional Tolerance Capability (Fine Finish)</b>    | -0.0001-0.0001 in (-0.0025-0.0025 mm)                                                                                                                                                                                                                        | Achieved via multi-pass skim strategies and controlled offsets on critical details.                                      |
| <b>Dimensional Tolerance Capability (Typical)</b>        | -0.0002-0.0002 in (-0.005-0.005 mm)                                                                                                                                                                                                                          | Typical positional/size control on well-fixtured parts after thermal soak.                                               |
| <b>Inspection and Documentation</b>                      | CMM verification of critical profiles and datums<br>FAI/PPAP dimensional reports on request<br>Material and heat-treat certifications                                                                                                                        | Dimensional packages align with downstream tool assembly or part print requirements.                                     |
| <b>Kerf Width (Typical by Wire Size)</b>                 | 0.010 in wire → ~0.011-0.013 in kerf                                                                                                                                                                                                                         | Kerf depends on wire size, power settings, and dielectric condition; used for offset programming and clearance planning. |
| <b>Lead Time - Fine Detail Die Components</b>            | 2-4 weeks                                                                                                                                                                                                                                                    | Includes rough/skim passes, heat-treat coordination (if required), and inspection.                                       |
| <b>Lead Time - Prototype EDM Blanks</b>                  | 1-2 weeks                                                                                                                                                                                                                                                    | Simple profiles and insert details; dependent on material availability and finish requirements.                          |
| <b>Lead Time - Repeat Production EDM</b>                 | 1-2 weeks                                                                                                                                                                                                                                                    | Standard reorder of qualified parts or details with established programs and fixtures.                                   |
| <b>Maximum Workpiece Height (Submerged Cut)</b>          | 16 in (406.4 mm)                                                                                                                                                                                                                                             | Tall work supported with submerged cutting to stabilize flushing and heat removal.                                       |
| <b>Minimum Inside Corner Radius (with 0.010 In Wire)</b> | 0.006 in (0.152 mm)                                                                                                                                                                                                                                          | Approximate achievable inside radius equals half kerf; smaller radii achievable with finer wire at reduced removal rate. |
| <b>Production Scale</b>                                  | Prototype (1-10 parts)<br>Short Run (11-500 parts)<br>Medium Run (501-10000 parts)<br>Mass Production (10001+ parts)                                                                                                                                         | Unattended cutting and palletized setups enable efficient small-to-medium batches; large volumes evaluated case-by-case. |
| <b>Removal Rate</b>                                      | Metric: 20-300 mm <sup>2</sup> /min                                                                                                                                                                                                                          | Representative material removal area rate from skim-quality to aggressive roughing on medium-thickness steels.           |

| CRITERIA                                                               | SPECIFICATION                                                                                                                                           | NOTES                                                                                                                     |
|------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| <b>Start Hole Diameter (Pre-Drill/EDM Drill)</b>                       | 0.02-0.12 in (0.508-3.048 mm)                                                                                                                           | Hole size set by wire diameter and flushing requirements; micro-holes possible with dedicated EDM-drill.                  |
| <b>Surface Roughness Achievable (Ra)</b>                               | 8-125 $\mu$ in (0.2-3.2 $\mu$ m)                                                                                                                        | Roughing to finishing passes tailored to print; finest finishes used on shut-offs and sealing features.                   |
| <b>Taper Cut Capability at 4 In Height</b>                             | -15-15 deg (-15-15 deg)                                                                                                                                 | Programmable UV axes support compound tapers; angle limit scales with part thickness.                                     |
| <b>Tool Steels and Coatings (Mating Die Details)</b>                   | Tool steels: D2, A2, S7, H13, M2, M3, M4, A11; carbide inserts where justified<br>Surface treatments: TiN, TiCN, AlCrN, nitriding; polish/lap shut-offs | Selected to balance wear life and toughness for the stamped alloy and run rate.                                           |
| <b>Wire Diameter Range</b>                                             | 0.01-0.01 in (0.254-0.254 mm)                                                                                                                           | Fine wires enable tight inside radii and micro-features; larger wires increase removal rate on thick sections.            |
| <b>Wire EDM Travel (X <math>\times</math> Y <math>\times</math> Z)</b> | 16L x 24W x 16H in (406.4L x 609.6W x 406.4H mm)                                                                                                        | Representative X/Y/Z cutting envelope for die plates and insert details; verify part fixturing and flush access at quote. |

## 4. Secondary Operations & Value-Added Services

38 specifications

Deburring, tapping, hardware insertion, welding, assembly, kitting and packaging run in house at Frederick. Plating, anodizing, chromate conversion, black oxide, powder coat and paint are performed by managed finishing partners and are scheduled, inspected and warranted by Frontier as part of the job.

| CRITERIA                                                   | SPECIFICATION                                                                                                                     | NOTES                                                                                                                       |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| <b>Anodize Thickness—Type II</b>                           | 0.0002-0.001 in (5-25 µm)                                                                                                         | Decorative/corrosion protection; clear or dyed with sealed pores.                                                           |
| <b>Anodize Thickness—Type III Hardcoat</b>                 | 0.001-0.004 in (25-100 µm)                                                                                                        | Wear-resistant coating for aluminum; color typically dark due to thickness.                                                 |
| <b>Assembly Services</b>                                   | Subassembly build and mechanical fastening<br>Adhesive bonding (per spec)<br>Functional checks (fit, torque, thread verification) | Work instructions and QC checkpoints documented per control plan.                                                           |
| <b>Black Oxide Conversion Layer</b>                        | 0.00002-0.00004 in (0.5-1 µm)                                                                                                     | Applied to ferrous parts for appearance and light corrosion resistance; usually oil sealed.                                 |
| <b>Chromate Conversion (Aluminum) Classes</b>              | Class 1A (maximum corrosion protection)<br>Class 3 (electrical conductivity/contact)                                              | Applied per MIL-DTL-5541 or equivalent; RoHS options available.                                                             |
| <b>Chrome Plating Thickness (Decorative or Functional)</b> | 0.0002-0.001 in (5-25 µm)                                                                                                         | Decorative thickness shown; heavy build functional chrome available on request.                                             |
| <b>Cleaning Methods</b>                                    | Aqueous wash with surfactant<br>Ultrasonic cleaning (small parts/fixtures)<br>Solvent wipe or vapor degrease (as specified)       | Method aligned to downstream welding or coating requirements.                                                               |
| <b>Cleanliness and FOD Controls</b>                        | Visual and wipe tests<br>Gravimetric residue checks (per request)<br>Particulate limits per VDA 19.1/ISO 16232 (when specified)   | Cleanliness criteria are documented in the control plan for critical applications.                                          |
| <b>Corrosion Resistance (Salt Spray Target)</b>            | 96-1000 h                                                                                                                         | Representative ASTM B117 performance window depending on finish system and pretreatment. Exact hours per print/coating TDS. |
| <b>Deburring Methods</b>                                   | Vibratory tumbling<br>Barrel tumbling<br>Mechanical/brush deburring<br>Hand deburring and edge break                              | Media and cycle time tuned to part geometry to protect critical surfaces.                                                   |
| <b>Edge Break Target after Deburr</b>                      | 0.003-0.01 in (0.0762-0.254 mm)                                                                                                   | Typical controlled edge radius to remove burrs without altering fit surfaces.                                               |
| <b>Electroless Nickel Thickness</b>                        | 0.0002-0.001 in (5-25 µm)                                                                                                         | Uniform deposition for complex geometries; phosphorus content per spec.                                                     |
| <b>Gold Plating Thickness</b>                              | 3-50 µin (0.08-1.27 µm)                                                                                                           | Contact and corrosion applications; underplate (Ni) as specified.                                                           |
| <b>Hardware Insertion Press Capacity</b>                   | 2-16 ton (17.8-142 kN)                                                                                                            | Supports self-clinching nuts, studs, standoffs, and similar hardware; sizing per manufacturer tables.                       |

| CRITERIA                                               | SPECIFICATION                                                                                                                                              | NOTES                                                                                                  |
|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| <b>Hardware Types</b>                                  | Self-clinching nuts, studs, standoffs<br>Swage and rivet fasteners<br>Threaded inserts (press-in, heat-set for plastics in fixtures)                       | Torque-out and push-out verification available on request.                                             |
| <b>Inventory and Delivery Programs</b>                 | Kanban and Min/Max<br>Vendor-managed inventory<br>JIT releases<br>Drop shipments                                                                           | Schedules synchronized to customer demand; stocking levels agreed in advance.                          |
| <b>Kitting, Packaging, and Labeling</b>                | Custom kitting with part segregation<br>ESD-safe packaging when specified<br>Barcoding/labeling to PO and revision<br>Protective wraps, trays, and dunnage | Packaging designed to protect surface finish and simplify line-side use.                               |
| <b>Lead Time - Hardware Insertion and Tapping</b>      | 0-1 weeks                                                                                                                                                  | Often completed within the stamping cell or as a short secondary step.                                 |
| <b>Lead Time - Kitting and Packaging</b>               | 0-1 weeks                                                                                                                                                  | Standard cartons and labels stocked; custom packaging on request.                                      |
| <b>Lead Time - Plating/Anodize</b>                     | 1-3 weeks                                                                                                                                                  | Timing varies by finish type, cert requirements, and lot size.                                         |
| <b>Lead Time - Powder Coat</b>                         | 1-2 weeks                                                                                                                                                  | Includes pretreatment, coating, cure, and inspection; color match may add time.                        |
| <b>Lead Time - Welding and Subassembly</b>             | 1-2 weeks                                                                                                                                                  | Depends on fixture complexity, inspection scope, and volume.                                           |
| <b>MIG Welding Material Thickness</b>                  | 0.04-0.375 in (1-9.5 mm)                                                                                                                                   | Typical sheet and plate range for fillet and butt joints; thicker sections on request with joint prep. |
| <b>Passivation Standards (Stainless)</b>               | ASTM A967 (nitric or citric)<br>AMS 2700                                                                                                                   | Method selected by alloy and downstream finish requirements.                                           |
| <b>Powder Coat Adhesion Tests</b>                      | ASTM D3359 cross-hatch (4B-5B typical)<br>MEK double rubs (per TDS)<br>ASTM D3363 pencil hardness (per spec)                                               | Adhesion verified per customer-specified method; substrate prep and cure are key drivers.              |
| <b>Powder Coat Colors and Gloss</b>                    | RAL or Federal Standard references<br>Custom colors to supplied chip<br>Gloss, semi-gloss, matte                                                           | Color and gloss matched to target; batch certification available.                                      |
| <b>Powder Coat Cure Dwell Time</b>                     | 0.17-0.33 weeks                                                                                                                                            | Approximately 10-20 minutes at temperature; expressed in weeks for schema consistency.                 |
| <b>Powder Coat Cure Temperature</b>                    | 350-400 °F (176-204 °C)                                                                                                                                    | Typical metal temperature window; actual schedule per coating manufacturer TDS.                        |
| <b>Powder Coat Film Thickness</b>                      | 1.5-4 mil (38-102 µm)                                                                                                                                      | Measured via comb or DFT gauge; thickness depends on coating system and environment class.             |
| <b>Production Scale</b>                                | Prototype (1-10 parts)<br>Short Run (11-500 parts)<br>Medium Run (501-10000 parts)<br>Mass Production (10001+ parts)                                       | Secondary operations scale with demand; bundled with stamping for flow and shorter lead time.          |
| <b>Resistance Spot Welding Stack Thickness (Steel)</b> | 0.01-0.125 in (0.25-3.18 mm)                                                                                                                               | Range assumes typical carbon steels; aluminum spot welding on request with dedicated electrodes.       |
| <b>Resistance Weld Nugget Diameter (Typical)</b>       | 0.08-0.25 in (2-6.4 mm)                                                                                                                                    | Actual nugget size validated by peel tests and destructive checks per print.                           |

| CRITERIA                                 | SPECIFICATION                                                                                                                            | NOTES                                                                                   |
|------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| <b>Surface Pretreatments</b>             | Iron phosphate (steel)<br>Zinc phosphate (corrosion class upgrade)<br>Chromate conversion (aluminum)<br>Media blast for adhesion profile | Pretreatment selected for environment rating and adhesion durability.                   |
| <b>Tapping Methods</b>                   | Cut tapping<br>Roll forming (thread forming)<br>In-die tapping (select parts)                                                            | Method selected by material, thickness, and thread engagement requirements.             |
| <b>Threading Range (Tapping/Forming)</b> | #4-40 through 1/2-13 (UNC/UNF)<br>M3 through M12 (metric coarse/fine)                                                                    | Cut tapping and roll forming supported; holes prepared per class-of-fit.                |
| <b>TIG Welding Material Thickness</b>    | 0.02-0.25 in (0.5-6.35 mm)                                                                                                               | Used where heat input control and cosmetic beads are critical.                          |
| <b>Weldable Materials</b>                | Cold-rolled steel (CRS), HRPO, HSLA<br>Stainless steel (301, 304, 316)<br>Aluminum (5052, 6061)                                          | Filler selection and precleaning per alloy; weld procedures tailored to joint geometry. |
| <b>Welding Processes</b>                 | GMAW (MIG), manual and robotic<br>GTAW (TIG), manual<br>Resistance spot welding                                                          | Process selection depends on alloy, thickness, joint design, and production rate.       |

## 5. Engineering Reviews & Prototyping

18 specifications

| CRITERIA                                              | SPECIFICATION                                                                                                                                                                                                                                                                                                                                                                                                                                                            | NOTES                                                                                                                          |
|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <b>Bend Radius Guidelines</b>                         | CRS: inside radius $\approx 1.0\times$ material thickness<br>Stainless: inside radius $\approx 1.0\text{--}1.5\times$ thickness<br>Aluminum: inside radius $\approx 0.8\text{--}1.0\times$ thickness                                                                                                                                                                                                                                                                     | Guidelines for early design; final radii are validated via coupon trials and springback compensation.                          |
| <b>CNC Machined Prototype Tolerance (Typical)</b>     | -0.003-0.003 in (-0.076-0.076 mm)                                                                                                                                                                                                                                                                                                                                                                                                                                        | Critical features on machined prototypes can reach $\pm 0.001$ in with appropriate fixturing and toolpaths.                    |
| <b>Common Prototype Materials</b>                     | Cold-rolled steel (CRS), HRPO, HSLA<br>Stainless steel (301, 304, 316)<br>Aluminum (5052-H32, 6061-T6)<br>Copper alloys (brass, phosphor bronze, beryllium copper)<br>Tooling board, ABS/PLA (for fixtures and masters)                                                                                                                                                                                                                                                  | Material selection mirrors production intent; plastics and boards used for fixtures and master patterns.                       |
| <b>DFM Scope and Deliverables</b>                     | Tolerance and stack-up analysis with datum scheme recommendations<br>Formability review: bend radii, grain direction, reliefs, springback planning<br>Process selection and cost drivers (progressive vs. stage vs. secondary ops)<br>Material recommendation and thickness review<br>Risk assessment and control plan inputs (FMEA-light, CTQ identification)<br>Gauge/inspection plan and sampling strategy<br>Actionable design edits and updated CAD when authorized | Structured review artifacts are issued as a brief report or red-lined CAD/drawing package to speed decisions.                  |
| <b>Formed Flange Length Tolerance (Typical)</b>       | -0.015-0.015 in (-0.381-0.381 mm)                                                                                                                                                                                                                                                                                                                                                                                                                                        | Dependent on bend radius, material, and method; improved with gauged stop features.                                            |
| <b>Formed Prototype Bend Angle Tolerance</b>          | -1-1 deg (-1-1 deg)                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Applies to simple press-brake or hand-form bends; tighter control requires hard tooling or secondary sizing.                   |
| <b>Inspection and Documentation</b>                   | FAI reports with ballooned drawings<br>CMM or comparator spot-checks on critical features<br>Material/finish certifications as applicable<br>PPAP documentation available on request                                                                                                                                                                                                                                                                                     | Inspection scope scales with risk and program phase; critical features verified before design freeze.                          |
| <b>Laser Cutting Tolerance (Typical)</b>              | -0.01-0.01 in (-0.254-0.254 mm)                                                                                                                                                                                                                                                                                                                                                                                                                                          | Typical profile tolerance band; features $\geq 0.060$ in allow tighter control (down to $\pm 0.005$ in) depending on geometry. |
| <b>Lead Time - DFM Review</b>                         | 0-1 weeks                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Simple prints can be turned in days; complex assemblies may require additional time for stack-ups and process routing.         |
| <b>Lead Time - Prototype Blanks (Laser/EDM)</b>       | 1-2 weeks                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Depends on material availability, feature density, and finishing requirements.                                                 |
| <b>Lead Time - Soft Tooling / Hand Form Prototype</b> | 2-4 weeks                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Includes fixture/gage prints, setup, and first-article evaluation.                                                             |

| CRITERIA                                          | SPECIFICATION                                                                                                                                                                                             | NOTES                                                                                                          |
|---------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|
| <b>Production Scale</b>                           | Prototype (1-10 parts)<br>Short Run (11-500 parts)<br>Medium Run (501-10000 parts)<br>Mass Production (10001+ parts)                                                                                      | Pilot lots can bridge from prototypes to production while process capability is validated.                     |
| <b>Prototype Blank Envelope (Laser/Waterjet)</b>  | Min: 1L x 1W in (25.4L x 25.4W mm),<br>Max: 96L x 48W in (2438.4L x 1219.2W mm)                                                                                                                           | Larger blanks may be split into nested segments and re-located with tooling pins.                              |
| <b>Prototype Material Thickness (Flat Blanks)</b> | 0.01-0.25 in (0.254-6.35 mm)                                                                                                                                                                              | Typical working range for laser/waterjet/EDM prototypes aligned to production stamping gauges.                 |
| <b>Prototype Methods</b>                          | Laser-cut sheet blanks<br>Wire EDM blanks and fine features<br>CNC-machined prototypes<br>Soft/prototype dies and hand-forming<br>3D-printed check gages/fixtures<br>Press brake forming for simple bends | Method is selected to balance speed, fidelity to production, and cost per iteration.                           |
| <b>Supported File Formats</b>                     | SolidWorks<br>STEP (AP203/AP214)<br>IGES<br>Parasolid (x_t/x_b)<br>DXF/DWG<br>PDF for drawings                                                                                                            | Native and neutral CAD accepted; drawings with defined GD&T expedite DFM and inspection.                       |
| <b>Trial Finishes (As Requested)</b>              | Deburr/vibratory tumble<br>Passivation (stainless)<br>Anodize or chromate conversion (aluminum)<br>Black oxide (carbon steels)<br>Powder coat or wet paint (appearance/protection)                        | Prototype finishes simulate production surfaces for functional and cosmetic evaluation.                        |
| <b>Waterjet Cutting Tolerance (Typical)</b>       | -0.02-0.02 in (-0.508-0.508 mm)                                                                                                                                                                           | Useful for thicker blanks or heat-affected-zone avoidance; edge taper minimized via quality setting and speed. |

## 6. Inspection & Quality Control

25 specifications

| CRITERIA                                                   | SPECIFICATION                                                                                                                                                                 | NOTES                                                                                                                      |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| <b>Bore Gage Diameter Range</b>                            | 0.125-6 in (3.175-152.4 mm)                                                                                                                                                   | Two-point and three-point systems used; masters traceable to NIST.                                                         |
| <b>CMM Envelope (X x Y x Z)</b>                            | Min: 16L x 16W x 16H in (406.4L x 406.4W x 406.4H mm), Max: 40L x 28W x 24H in (1016L x 711.2W x 609.6H mm)                                                                   | Represents inspection volume across in-house CMMs; larger parts can be sectionally verified or fixtured.                   |
| <b>CMM Measurement Uncertainty (Typical)</b>               | 0.00003-0.00009 in (0.0008-0.0023 mm)                                                                                                                                         | Applies to well-fixtured parts after thermal soak; complex geometries may require feature-specific uncertainty statements. |
| <b>CMM Table—Max Part Weight</b>                           | 0-40 lb (0-18 kg)                                                                                                                                                             | Heavier parts may be supported with special fixturing or alternative measurement methods.                                  |
| <b>Data Outputs and Formats</b>                            | PDF inspection reports<br>CSV/Excel data tables<br>Native CMM exports (e.g., PC-DMIS, MCOSMOS)<br>QIF or DMIS exchange when supported<br>Image markups from vision/comparator | File naming and lot traceability match customer PO and drawing revisions.                                                  |
| <b>Environmental Control—Relative Humidity</b>             | 35-55 %RH                                                                                                                                                                     | Humidity maintained to protect gages and ensure stable measurement conditions.                                             |
| <b>Environmental Control—Temperature</b>                   | 66-70 °F (19-21 °C)                                                                                                                                                           | Parts are temperature-stabilized prior to high-accuracy CMM measurement.                                                   |
| <b>Gage R&amp;R Target (%GRR of Tolerance)</b>             | 0-10 %                                                                                                                                                                        | Aim ≤10% for critical characteristics; investigate at 10–30% per MSA guidance. Pricing for related studies is negotiable.  |
| <b>Hand Metrology Ranges</b>                               | Calipers: 0–12 in (0–300 mm)<br>Micrometers: 0–6 in (0–150 mm), outside/inside<br>Height gages: 0–24 in (0–600 mm)                                                            | Used for rapid checks and lot verification; calibrated to internal schedule.                                               |
| <b>Inspection Methods</b>                                  | Incoming inspection<br>In-process inspection<br>Final inspection<br>First Article Inspection (FAI)<br>PPAP dimensional and capability studies                                 | Scope is defined by control plan and risk; critical-to-quality features receive heightened sampling.                       |
| <b>Lead Time - Capability Study (E.G., 30 Piece)</b>       | 1-2 weeks                                                                                                                                                                     | Includes study plan, data collection, and Cp/Cpk report. Pricing negotiable for capability studies.                        |
| <b>Lead Time - FAI Dimensional Package</b>                 | 1-2 weeks                                                                                                                                                                     | Includes ballooned drawing, full measurements, and certificates.                                                           |
| <b>Lead Time - PPAP Level 3 (Dimensional + Capability)</b> | 1-3 weeks                                                                                                                                                                     | Timing depends on sample size, capability studies, and supplier docs (material/finish certs).                              |
| <b>Lead Time - Routine Lot Inspection Report</b>           | 0-1 weeks                                                                                                                                                                     | Typical for standard lots; expedite available when coordinated at PO.                                                      |
| <b>Optical Comparator Magnification</b>                    | 30-300 x                                                                                                                                                                      | Typical lens set; select magnification to balance field of view and feature resolution.                                    |
| <b>Optical Comparator Stage Travel (X x Y)</b>             | Min: 6L x 6W in (152.4L x 152.4W mm), Max: 12L x 18W in (304.8L x 457.2W mm)                                                                                                  | Suitable for profiles, thread forms, and edge locations; overlays and DXF comparison available.                            |

| CRITERIA                                         | SPECIFICATION                                                                                                                | NOTES                                                                                                                                    |
|--------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Pin Gage Coverage</b>                         | 0.011-0.75 in (0.279-19.05 mm)                                                                                               | Class ZZ/plus-minus sets maintained; certificates available upon request.                                                                |
| <b>Production Scale</b>                          | Prototype (1-10 parts)<br>Short Run (11-500 parts)<br>Medium Run (501-10000 parts)<br>Mass Production (10001+ parts)         | Inspection scales from prototype FAIs to full production PPAP and ongoing SPC monitoring.                                                |
| <b>Quality System and Frameworks</b>             | ISO 9001:2015 registered<br>AS9102 FAI forms supported<br>AIAG PPAP (Level 1-3) supported<br>MSA (Gage R&R) and SPC per AIAG | Certificates and documentation packages provided per program requirements.                                                               |
| <b>Sampling Plans and AQL</b>                    | ANSI/ASQ Z1.4<br>C=0 (zero acceptance) plans when specified<br>100% inspection for safety/critical features                  | Plans selected by risk and defect history; tightened/normal/reduced switching rules applied as needed; sampling/AQL applied as required. |
| <b>SPC Metrics and Charts</b>                    | X-R and X-S charts<br>Individuals-Moving Range (I-MR)<br>Cp/Cpk and Pp/Ppk indices<br>Run charts and histograms              | Live data collection on critical features; capability indices included in reports when requested; SPC depth applied as required.         |
| <b>Surface Roughness Measurement (Ra)</b>        | 0.01-125 µin (0.000254-3.175 µm)                                                                                             | Contact stylus profilometer used for functional and cosmetic surface validation.                                                         |
| <b>Thread Gage Coverage</b>                      | UNC/UNF/UNEF<br>Metric coarse/fine<br>NPT/NPTF                                                                               | Go/No-Go plug and ring gages with current calibration certificates.                                                                      |
| <b>Vision Field of View (per Frame)</b>          | Min: 0.4L x 0.5W in (10.16L x 12.7W mm), Max: 1.5L x 2W in (38.1L x 50.8W mm)                                                | Small FOV supports fine features at high resolution; larger FOV speeds general dimensional checks.                                       |
| <b>Vision System Resolution (Edge Detection)</b> | 0.00003-0.00009 in (0.0008-0.0023 mm)                                                                                        | Resolution depends on lens, lighting, and field of view; verified by gage blocks and glass scales.                                       |