PRECISION TUBING FOR AEROSPACE

Rethinking the Seamless Standard

A performance and economics case for laser-welded and drawn stainless tubing in aerospace and defense applications

WHITE PAPER

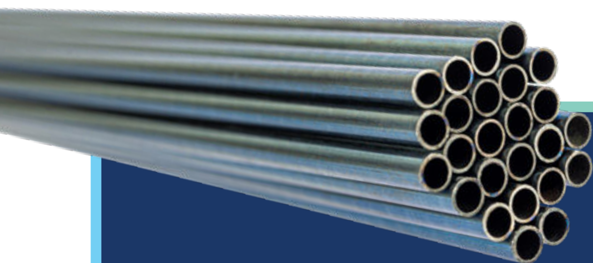
Executive Summary

Seamless stainless tubing has been the default specification in aerospace fluid and structural systems for decades—and not without reason.

Traditionally, the weld zone was the weakest point, and removing it reduced its risk altogether. But that logic was formed against an earlier generation of welded tubing.

Manufacturing advances have significantly changed the performance profile of welded tubing. Laser-welded and drawn stainless tubing, produced through a controlled cold-drawing and annealing sequence, performs equivalently to seamless tubing under the mechanical tests that matter most—making for lower costs, shorter lead times, and tighter dimensional consistency.

This paper makes the case for opening your specification to a better option—with process evidence, metallurgical mechanism, test data, and a qualification pathway to get there.



Key Findings

MECHANICAL EQUIVALENCE TO SEAMLESS—CONFIRMED BY FLARE TEST T-TEST ($P > 0.05$)

Mean flare load was statistically equivalent across laser welded and drawn, and seamless samples. No preferential weld-zone cracking. Failure modes and locations were consistent across both groups.

LOWER VARIANCE IN MECHANICAL PROPERTY DATA THAN TIG-WELDED TUBING

Head-to-head against TIG-welded tubing, the laser-welded and drawn product exceeded mean mechanical properties with a lower standard deviation across the lot—a direct result of process consistency built into every draw schedule.

LAYERED DEFECT ELIMINATION

100% ECT, progressive draw reductions, in-process mechanical testing, full lot traceability. Defects are eliminated through production. Inspection confirms what the process has already accomplished.

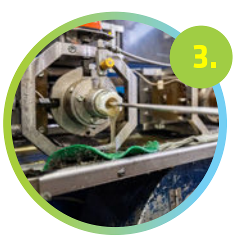
Five Manufacturing Steps That Eliminate Weld-Zone Risk

TIG-welded tubing earned the skepticism it received—inconsistent fusion, stress-concentrating bead geometry, heat-affected zones that altered grain structure, and surface conditions that resisted reliable inspection. Specifying seamless was a rational response to a real problem, and that logic locked into procurement specifications that are still in place today.

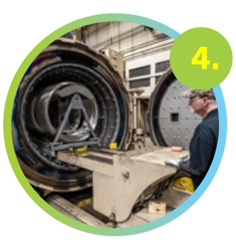
What changed is what "welded" means in production. Laser-welded and drawn stainless tubing now passes through five manufacturing steps, each specifically engineered to address the variables that made earlier welded tubing a liability.

Strip slitting controls the input. Stainless coil stock is slit to tight width tolerances because dimensional variation at this stage propagates forward—inconsistent strip width leads to inconsistent weld geometry, variable energy input at the laser, and a less predictable starting condition for drawing. Controlling the strip controls everything downstream.

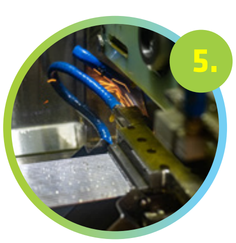
Laser welding produces a narrower, more consistent heat-affected zone than TIG—higher energy density, faster processing speeds, lower total heat input. The as-welded bead is still a microstructural discontinuity, but it's a controlled, geometrically predictable one. That distinction matters for what the drawing process can do with it.



Cold drawing is where the weld begins its transformation. As the tube passes through a die, compressive and tensile forces act on the weld zone and parent material simultaneously—the bead geometry irons out flat, and columnar weld grains elongate and begin to align with the parent metal flow. Each pass is both a defect-elimination step and a sizing step.



Annealing resets the microstructure. Recrystallization runs through the full cross-section—weld zone included—and the grain structure that emerges is determined by cold work strain and anneal parameters, as well as the original weld history. Laser welding is inherently free of many of the defects that are described.



Final sizing and 100% ECT establish the finished dimensions—OD, wall, ID, concentricity—and confirm the result. At this point, the weld is part of a tube that has been uniformly worked and thermally processed to parent metal equivalence.

The draw schedule is custom-engineered to each OD/wall combination—different dimensions require different reduction sequences to achieve full weld-zone homogenization. It results in a tube that has been worked and processed to parent metal equivalence across its full cross-section. The mechanical data confirms it.

A Quality Architecture Built on Defect Prevention

There are two models of quality in tube manufacturing. The first produces the tube, tests it, and accepts or rejects the result. The second engineers the process so that defects either aren't produced or are eliminated before they can propagate, and inspection confirms what the process has already accomplished.

For aerospace source approval programs, the difference between those two models shows up on audit day—in the escapes that cleared end-of-line inspection and in the documentation that can't reconstruct what actually happened.

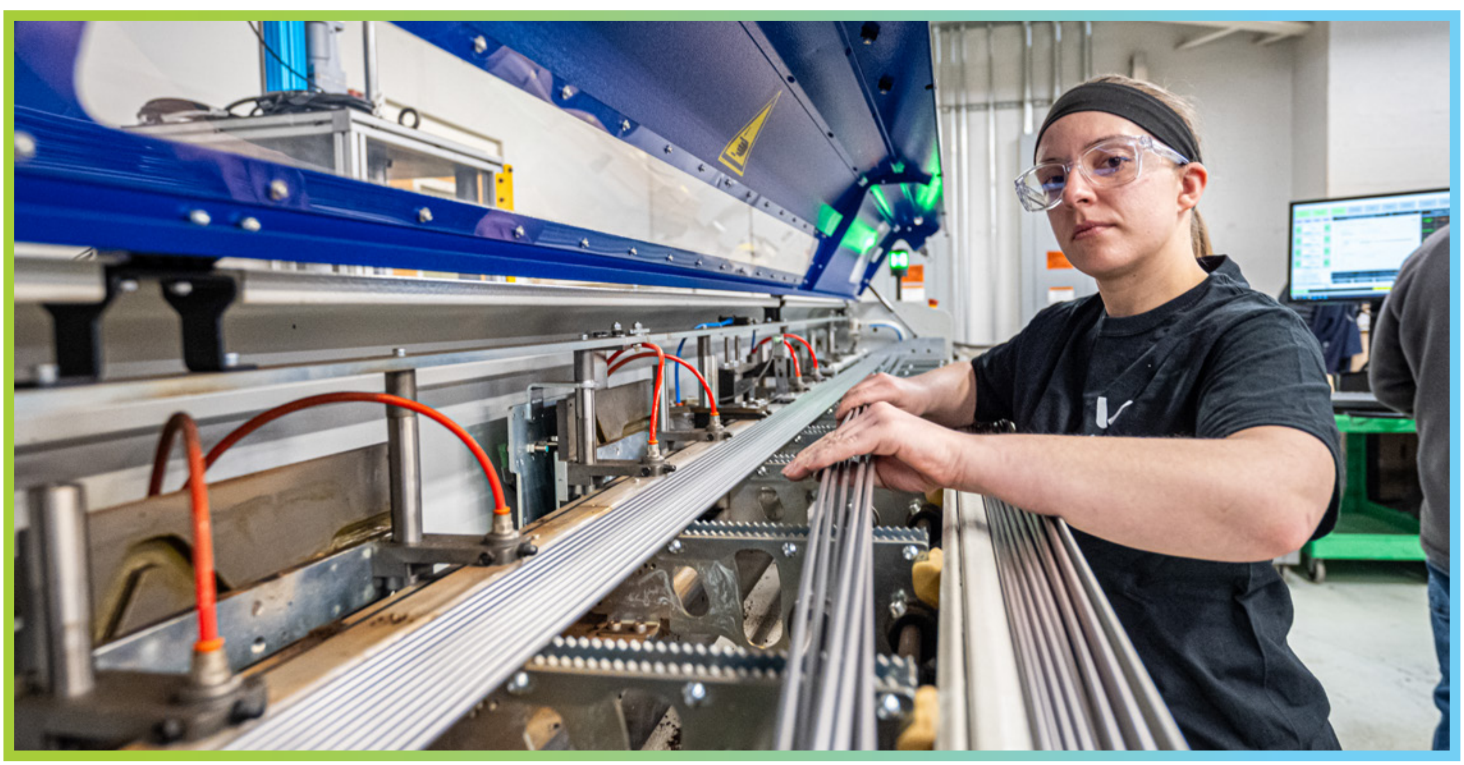
100% eddy current testing means testing every foot of every tube, rather than a sampled lot or a statistical batch. ECT is sensitive to surface-breaking and near-surface defects, including open seams and weld-zone irregularities. Nothing moves to the next process step without a clean signal.

Hydraulic pressure testing is performed on finished tubes when required by the customer, providing direct structural confirmation for fluid system applications.

Full-lot traceability connects every finished tube to its material heat, draw schedule, anneal cycle, and inspection records. This is the same traceability architecture Viant runs for medical device manufacturing, where regulatory requirements make it non-negotiable—and it transfers directly to AS9100 aerospace source approval documentation.

The same quality system applies to custom OD/wall program. Custom work goes through the same architecture, with process parameters engineered to the specific requirement.

Over 200 million feet of laser-welded and drawn stainless tubing have been produced under this control architecture—a record of process stability that no qualification test program can replicate. It is the test program, run continuously over decades.



Weld-Zone Microstructure: From As-Welded Condition to Parent Metal Equivalence

Understanding what drawing and annealing do to a weld bead at the grain level is the difference between trusting the result and understanding why it's repeatable—and why it holds up across a full production lot.

The as-welded condition is what seamless specifications were written to avoid. Immediately after laser welding, the fusion zone contains columnar grains oriented perpendicular to the tube axis, with hardness elevated relative to the parent material and residual tensile stresses from the weld thermal cycle.

This is not the condition of the finished tube.

Cold drawing applies a complex stress state—compressive radially, tensile axially—to the weld zone and parent material simultaneously. The columnar grains, initially oriented transverse to the drawing direction, are broken down and elongated during cold working, then refined through recrystallization during subsequent annealing. The bead geometry is ironed flat and the localized residual tensile stress from welding is distributed uniformly around the circumference of the tube. With each successive pass, the weld zone becomes increasingly difficult to distinguish from the cold-worked parent material.

Annealing completes the transformation. Given sufficient cold-work reduction prior to annealing—and the draw schedule is engineered to ensure this for every OD/wall combination—the recrystallized grain structure throughout the weld zone is indistinguishable from that of the parent. Grain boundary character, grain size, and crystallographic texture are determined by cold-work strain and annealing parameters.

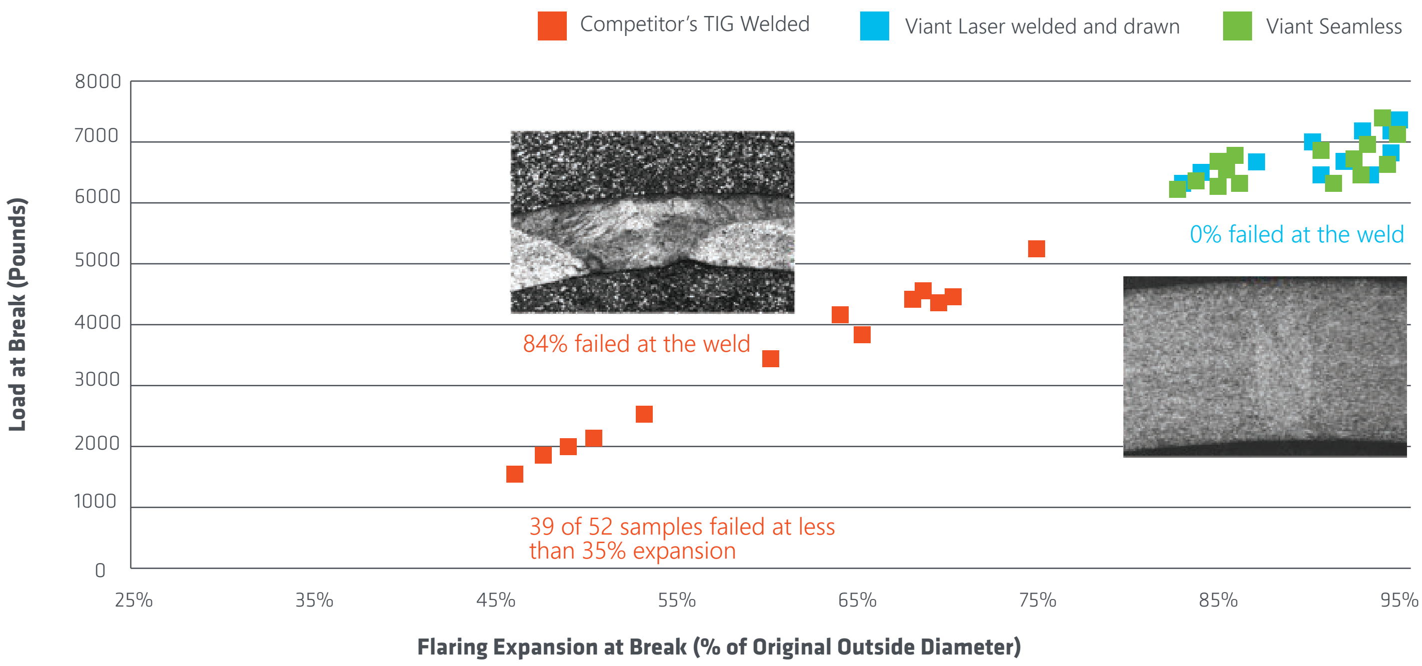
The TIG comparison matters here because it isolates the variable. TIG welding begins with greater variability in bead geometry, driven by electrode erosion and resulting changes in arc behavior. Drawing and annealing can reduce this variability, but when not fully homogenized, it can carry through as a wider distribution of finished mechanical properties.

Flare Test Results: Laser-Welded and Drawn vs. Seamless vs. TIG-Welded

Of the standard mechanical tests available, the flare test is one of the most revealing measures of weld quality. Tensile testing loads the weld and parent material in parallel—the stronger element carries the load, and in a well-drawn tube, that's the parent material.

The flare test puts them in series: the tube end is expanded over a conical mandrel, placing the fusion line in circumferential tension, and failure goes to whichever element is weaker. A weld zone that hasn't been fully homogenized shows up here. Flared tube ends are also a standard joining geometry in aerospace fluid systems, so performance in this test corresponds directly to performance in service.

Flare Testing of 304 Stainless Steel Tubes



METHODOLOGY

An instrumented flaring expansion test was conducted on 304 stainless steel tubing using an Instron tensile tester in compression mode. The method was aligned to ASTM A269 and ASTM A632 for stainless tubing flaring, and to the definitions and tubular annex in ASTM A370. All samples were 0.500 in. OD x 0.032 in. wall thickness and met ASTM A269 chemistry requirements for 304 stainless steel. Testing used a lubricated, hardened tool steel punch with a 30-degree included cone angle. Cone angle, crosshead rate, and first-fracture stop criteria were controlled. Load at fracture, OD diametral expansion response, fracture location, and fracture mode were recorded for laser-welded and drawn, seamless, and TIG-welded tube types. Statistical analysis used a two-sample t-test for means at the $\alpha = 0.05$ level.

LASER-WELDED AND DRAWN VS. SEAMLESS

The two tube forms were statistically equivalent at $\alpha = 0.05$ with no significant difference in mean flare load at break, and no preferential weld-zone cracking in the laser-welded and drawn samples. Failure modes and locations were consistent across both groups. For qualification purposes, a t-test against seamless controls at this threshold is the strongest statistical equivalence argument available—it's the same methodology used in material substitution of qualification across aerospace and defense programs.

LASER-WELDED AND DRAWN VS. TIG

Both tube forms completed the flare test, but the difference in load was substantial. Laser-welded and drawn tubing showed higher loads and lower variation across the lot—delivering tighter, more consistent performance from first sample to last. For programs managing qualification risk, that consistency means fewer marginal samples and a more predictable certification process. For programs managing qualification risk, that tighter variance means fewer marginal samples and a more predictable certification process.

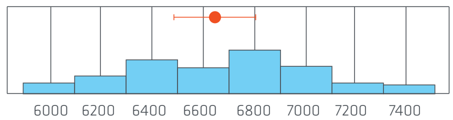
SUMMARY REPORT

2-Sample t Test for the Mean of Load at Break - W&D and Seamless

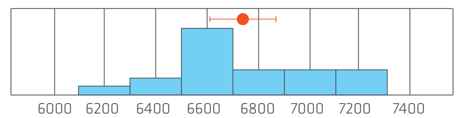
Distribution Of Data

Compare data and means of the samples

Load at Br_1



Load at Br_2



Do The Means Differ?

The mean of Load at Br_1 is not significantly different from the mean load at Br_2 (p>.05).

Individual Samples

Statistics	Load at Br_1	Load at Br_2
Sample size	20	20
Mean	66504	6742.9
95% CI	(6489, 6812)	(6612.9, 6872.9)
Standard deviation	344.42	277.68

Difference Bewtween Samples

Statistics	*Difference
Difference	-92,456
95% CI	(-293.09, 108.18)

*Diffence = Load at Br_1 - Load at Br_2

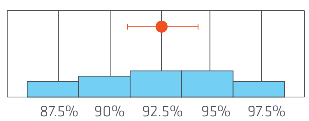
SUMMARY REPORT

2-Sample t Test for the Mean of Flaring Expansion - W&D and Seamless

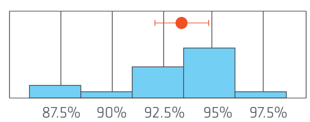
Distribution Of Data

Compare data and means of the samples

Flaring Ex_1



Flaring Ex_2



Do The Means Differ?

The mean of Flaring Ex_1 is not significantly different from the mean of flaring Ex_2 (p>.05).

Individual Samples

Statistics	Flaring Ex_1	Flaring Ex_2
Sample size	20	20
Mean	.92790	.93687
95% CI	(.9113, .9445)	(.92420, .94954)
Standard deviation	.035554	.027077

Difference Bewtween Samples

Statistics	*Difference
Difference	-.0089699
95% CI	(-.029257, .011317)

*Diffence = Load at Br_1 - Load at Br_2

Viant Laser Welded and Drawn

OD Flaring Expansion	Load at Break	Degrees from Weld
98.1%	7,162	95
95.8%	6,640	100
93.6%	6,623	10
93.6%	6,436	170
95.8%	6,698	90
93.9%	6,680	90
95.9%	7,138	160
93.4%	6,552	90
87.1%	6,190	60
87.7%	6,397	120
95.3%	7,021	95
90.3%	6,550	15
95.9%	6,710	150
95.6%	6,784	170
94.0%	6,580	95
95.0%	7,195	165
94.4%	6,589	10
93.2%	6,860	90
92.7%	7,031	5
92.5%	7,023	10

Viant Seamless

OD Flaring Expansion	Load at Break	Degrees from Weld
93.6%	6,352	N/A
94.9%	6,623	N/A
89.5%	6,073	N/A
97.4%	6,734	N/A
89.4%	6,311	N/A
89.4%	6,247	N/A
98.3%	7,058	N/A
95.6%	6,578	N/A
88.4%	6,337	N/A
95.5%	7,054	N/A
87.9%	6,367	N/A
93.1%	6,786	N/A
95.0%	6,853	N/A
88.9%	6,505	N/A
92.8%	6,785	N/A
93.0%	6,771	N/A
93.0%	6,903	N/A
86.7%	6,221	N/A
97.7%	7,304	N/A
95.8%	7,146	N/A

Competitor's TIG Welded

OD Flaring Expansion	Load at Break	Degrees from Weld
76.5%	5,238	35
67.4%	4,431	15
51.3%	2,140	0
69.2%	4,344	30
50.5%	2,050	0
68.4%	4,467	80
59.3%	3,346	0
63.7%	4,034	75
49.7%	1,890	0
52.7%	2,344	0
47.6%	1,610	0
65.4%	3,856	25
69.7%	4,368	120
39 samples <35%		

Performance-Based Specification Language and Qualification Pathway

Most programs that haven't qualified laser-welded and drawn tubing haven't done so because of performance concerns—the legacy spec simply predates the process. Moving to performance-based language is the path forward, and in most cases, it doesn't require re-engineering the program from the ground up.

There are four reliability concerns that typically drive seamless preference. Each has a direct technical response, supported by data that can be included in a source approval package.

PRESSURE INTEGRITY

Pressure testing to proof and burst is standard on all production. Flare test data confirms that the fusion line is not prone to failure under hoop stress loading, similar to the loading condition in hydrostatic pressure testing. For applications requiring cyclic pressure fatigue data, testing can be scoped and executed on a program-specific basis.

FATIGUE PERFORMANCE

Surface and subsurface discontinuities act as fatigue initiation sites. The draw-and-anneal sequence reduces these features through deformation and recrystallization. Post-weld ECT provides full-length process monitoring, and additional inspection can be performed at the customer's request. S–N data on laser-welded and drawn product is available, and program-specific fatigue testing can be added for fracture-critical applications.

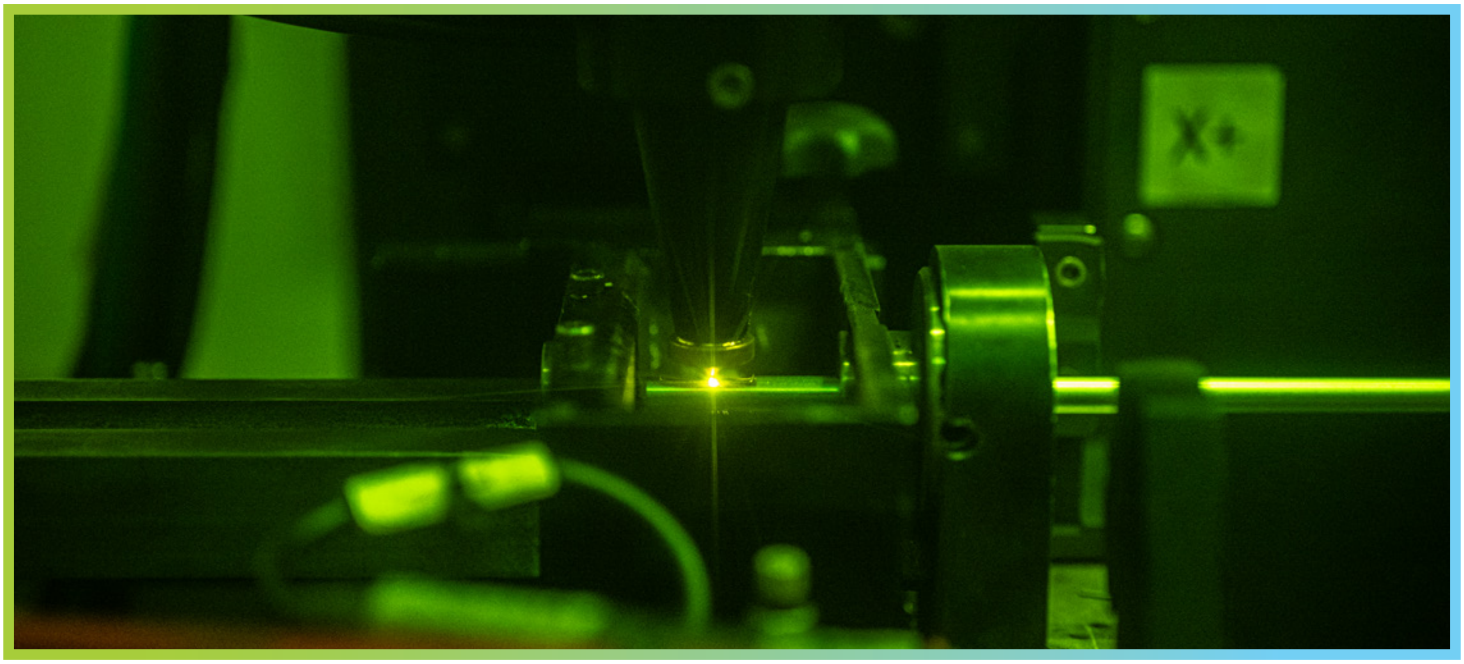
THERMAL STABILITY

Final annealing produces a solution-annealed condition through the full cross-section—sensitization is not present in the finished product. For sustained elevated- temperature applications, alloy selection follows the same logic as seamless specification: 321, 347, or other stabilized grades produced in custom dimensions under the same quality system.

BENDING BEHAVIOR

Concentricity and wall uniformity in laser-welded and drawn tubing meet or exceed seamless tolerances, a direct function of starting from uniform strip stock rather than a pierced billet. Weld zone ductility, confirmed by flare testing, supports tight-radius bending without preferential failure at the weld bead.

A qualification program typically involves dimensional verification, verification of mechanical properties per the applicable ASTM standard, flare or flange testing per ASTM A1016, ECT certification review, and proof pressure testing for fluid applications. These requirements are defined by the customer specification, and supporting data is generated accordingly as part of the qualification process.



Design & Specification Guidance

Recommended callouts for aerospace procurement and qualification:

Specification Item	Details
Base Specification	ASTM A269 or ASTM A632 for austenitic stainless steel welded & seamless tubing; supplement with ASTM A1016 general requirements as applicable.
Material & Condition	304/316/321/347 series, solution annealed after final cold work unless otherwise specified.
Manufacturing Route	Laser seam welded from slit strip with multipass cold drawing, weld bead ironing and intermediate solution anneals.
NDT	100% in process eddy current per ASTM E426 (austenitic/titanium tubing) and air under water pressure test per ASTM A269, ASTM A632 or ASTM A1016 as required.
Mechanical Acceptance	In process flare and flatten test combined with final tensile testing per ASTM A269, ASTM A632 or ASTM A1016.
Dimensional	OD, wall thickness, length, straightness, concentricity, ovality tolerances; surface finish per print.
Corrosion	ASTM A262 intergranular corrosion testing practice A/E.

Dimensional Consistency, Coil Form, and Supply Chain Economics

The mechanical data establishes that laser-welded and drawn tubing has the structural integrity of seamless tubing. The dimensional, logistics, and supply chain advantages are the program economics case—and they compound across a full production lifecycle.

CONCENTRICITY AND WALL UNIFORMITY

Seamless tubing is produced by piercing and hot-rolling or extrusion processes that introduce wall eccentricity that downstream operations reduce but don't fully correct. Laser-welded and drawn tubing starts from a precision-slit flat strip with uniform thickness across its width. The wall distribution around the circumference reflects that starting uniformity, with less variation within the tolerance band. For precision machining of tube ends, swaging, and tight-clearance assembly, this translates to fewer dimensional exceptions and tighter process capability on downstream operations.

COIL FORM AVAILABILITY

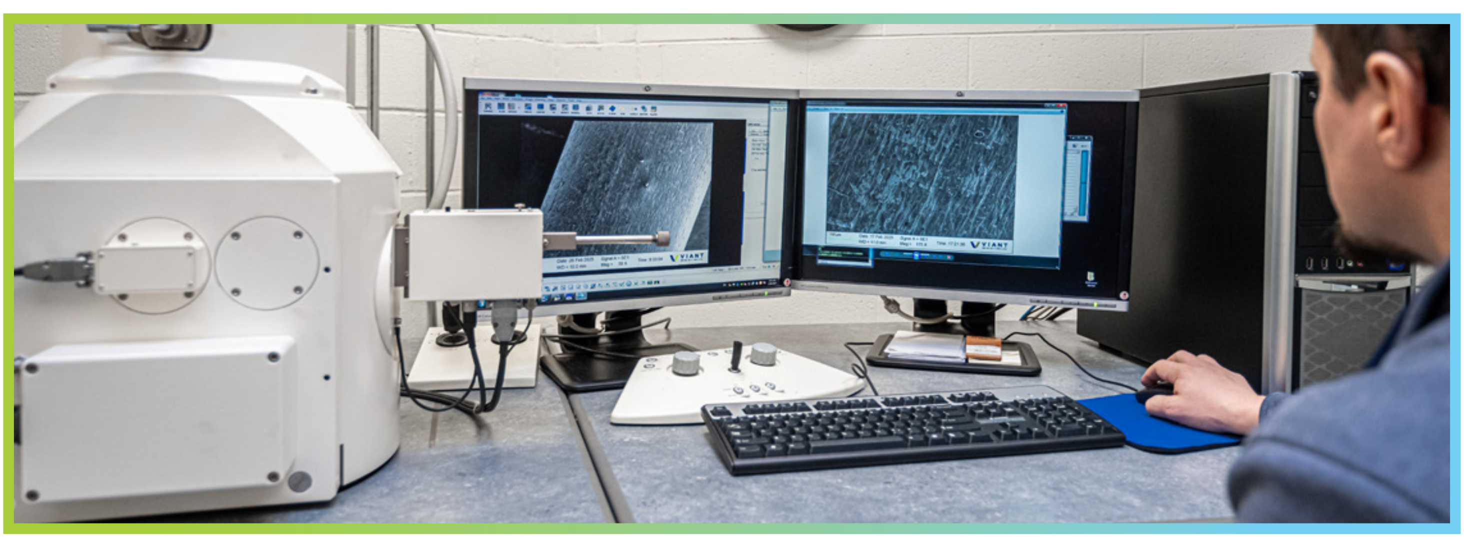
Seamless tubing is routinely drawn in coil by Viant and others in aerospace sizes. Laser-welded and drawn tubing can be produced in coil form. For fluid and instrumentation systems, coil form means fewer joints, fewer joint qualifications, and longer continuous runs—all of which reduce installation complexity and failure risk.

SUPPLY CHAIN RESPONSIVENESS

Viant offers welded and drawn or seamless in aerospace alloys according to the customer's specification. The offer of laser welded and drawn offers a lower cost alternative to seamless with improved dimensional control on wall thickness. The laser welded and drawn process isn't more or less responsive for short-run or quick-turns than seamless. For programs with evolving specifications during development, faster response to revision compresses the schedule and reduces the cost of design iteration. For production programs, a more flexible supply base reduces single-source exposure and improves on-demand delivery performance.

UNIT ECONOMICS

Lower raw material input per foot, continuous coil production efficiency, and a more distributed supply base combine to produce lower unit cost at equivalent or better dimensional performance. This is not a cost reduction that requires a performance trade off—it is supported by the same qualification data as seamless.



Viant Precision Tubing: Eight Decades of Process Engineering for Mission-Critical Applications

Viant's Collegeville facility has been producing precision tubing since 1940—through nuclear work in the 1960s, stainless coil drawing in the 1980s, and the transition to full laser weld-and-draw production by the mid-2000s. The company has operated under several names across that arc—Uniform Tubes, UTI, Accellent, Lake Region, Integer, and now Viant—but the facility, the process knowledge, and the engineering team have been continuous. The engineers who developed stainless coil drawing in the 1980s trained the engineers who built out the laser weld-and-draw process in the 2000s. Eight decades of accumulated process knowledge are embedded in the way the facility operates.

All production at Collegeville is made to customer order and spec, whether that's custom OD/wall combinations, specific alloy grades, tight-tolerance programs with property requirements outside standard ASTM tables, or draw schedules engineered to hit mechanical performance targets. The draw schedule, anneal cycle, and inspection protocol are engineered to the specification. Two metallurgists on staff, an on-site lab with SEM/EDS capability, in-house die and tooling manufacture, AS9100 and ISO 13485 registration—when a specification gets difficult, the engineering infrastructure is already in place. And when a program requirement changes during development—metallurgists, process engineers, and application engineers who know the process are the ones responding to it.

References

- *ASTM A269 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service.*
- *ASTM A370 — Standard Test Methods and Definitions for Mechanical Testing of Steel Products (includes tubular annex).*
- *ASTM A632 — Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing (Small-Diameter) for General Service.*
- *ASTM E426 — Standard Practice for Electromagnetic (Eddy-Current) Examination of Seamless and Welded Tubular Products, Austenitic Stainless Steel and Titanium.*
- *ASTM E309 — Standard Practice for Eddy-Current Examination of Steel Tubular Products Using Magnetic Saturation.*
- *ISO 17643 — Non-destructive testing of welds — Eddy current testing of welds by complex-plane analysis.*
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