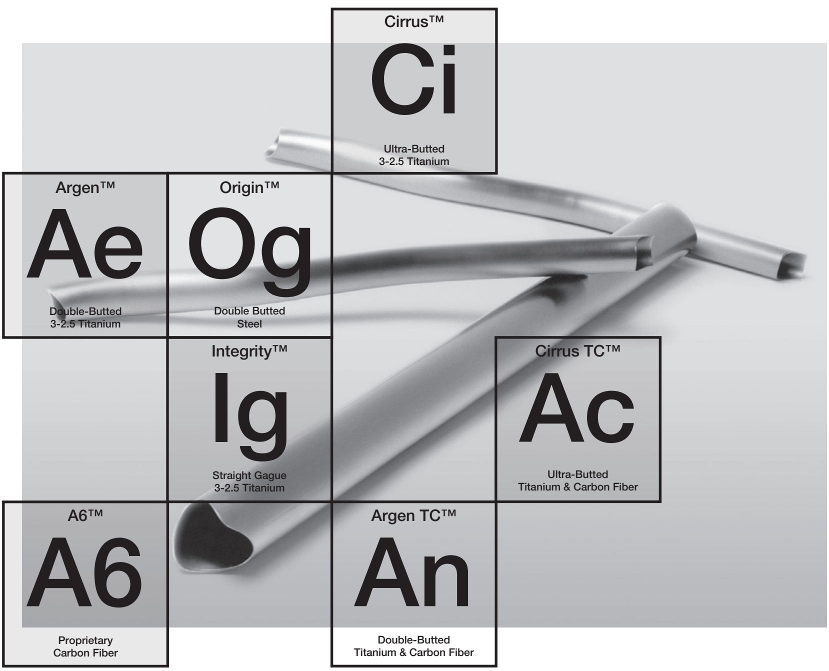
seven cycles

Seven's Titanium Technology & Manufacturing Methodology



Seven's approach to titanium bicycle manufacturing is as unique and innovative as each bike we build. Here's why…

Seven's Approach To Frame Building

At Seven, we utilize three essential elements—in addition to you—to create your ideal bike:

1. **Material choice:** Titanium—in this case.
2. **Customization:** Seven's unique Fit Methodology; applied through our Custom Kit™ and client interview.
3. **Seven Process Methodology™**: Our innovative approach to single-piece-flow manufacturing that ensures 100% individualization and quality assurance.

Any one or two of these ingredients can make a decent bike. However, only Seven employs all three with the sole purpose of building One Bike. Yours.™

Seven's development group has been building titanium frames for more than 20 years. In that time, Seven's influence on the titanium bike world has become well-known throughout the industry. We have built titanium bikes for the most famous racers in the world and have won multiple national and world championships.

We created this supplement to provide insight into how we design and manufacture titanium frames. We hope you find this interesting and informative!

Seven's Experience with Titanium: A Timeline

Seven's President and Founder, Rob Vandermark, has been designing titanium alloy frames longer than anyone else—for more than 25 years. This means that Seven's Development Team has more years of uninterrupted titanium alloy frame building experience than any other company on the planet.

Here is a brief history of Seven Cycles Development Team's titanium "firsts" and Seven's ongoing involvement in shaping the titanium bicycle industry.

Titanium Material Timeline

1987 First generation 3-2.5 titanium alloy mountain bikes: Seven's design team worked with Merlin Metalworks on the first ever titanium alloy mountain bikes.

1988 First oversized titanium tubing bikes. The first titanium bikes that ride like steel bikes—stiff drive trains with good vertical compliance.

1989 First S-bend chain stays and seat stays on mountain bikes—in titanium or any material.

1990 First double butted titanium road frames tested. These were true double butted titanium tubes that outperformed straight gauge tubes. This project worked so well that Greg LeMond bought frames for himself and his winning Tour de France Z Team—unprecedented. This model went into production in 1991.

1991 First "Size-Specific" titanium tube sets introduced. This required a deep understanding of material properties and relationships with the key titanium mills in the US.

1992 First bicycle-specific titanium tubing specifications developed with a primary US titanium supplier. Some of the specifications and design requirements actually exceeded aerospace and defense industry standards.

1993 Rob writes the landmark paper, "The Merlin Titanium Primer." This was the first comprehensive article about titanium in the bicycle industry. It has been used as a source in numerous articles including articles written by The Department of Energy and The Office of Science and Technical Information. The article was also published in its entirety in the periodical Cycling Science. Rob was asked to present at the Titanium Development Association on the material's use in the sports industry.

1994 First production butted titanium mountain bike.

1997 First "Rider-Specific" tube sets. Seven's design team takes titanium tube selection, properties, and manipulation to the next level.

1998 Seven writes the titanium primer for the 21st century in Seven's Technical Supplement.

1999 First World Championship won on a Seven titanium bike.

2000 Second World Championship won on the same titanium bike.

2001 Seven's design director speaks at MIT on engineering and titanium.

2002 Introduction of Ultrabutted™ tubing. This takes butting technology to its highest point to date. Ultrabutting allows for variable butting along the length of the tube. This provides for the lightest tube possible while maintaining optimum strength at all high stress areas.

2003 Seven's team wins the National Championship on a titanium bike—and then a total of 4 national titles beginning in 2003 through today.

2004 Seven brings all tube butting in house for the purposes of 100% quality control and continued butting innovation.

2007 Unique in-house fatigue testing system developed and implemented. Testing of titanium alloys and sources, innovative welding techniques, multiple finishing systems, and tube shapes ensues.

2008 Seven invests in a large radius tube bender, used to curve down tubes for suspension fork clearance, and top tubes for additional stand over clearance. The first 650B wheeled Sevens are designed, and our long awaited titanium seat post is brought to market.

2009 Our first commuter specific handlebar, the Tiberius Bar, is developed for the surging utility and commuter markets. We also begin fabrication of custom front and rear racks. Integrated seat post introduced as an option on Elium SLX, Elium SL, Mudhoney SLX, IMX SL and IMX 29 SL . The BB30 oversized bottom bracket option is made available.

2010 Interest in titanium utility bikes grows, Seven responds by creating the Traveler line of bikes.

2011 44mm head tubes are added to the list of frame options.

2012 1" road chain stays are implemented to increase stiffness even further.

Through these 25-plus years, Seven's design team has also tested titanium material from all parts of the globe including the U.K., Italy, Russia, Taiwan, and China. We have visited titanium fabrication companies on nearly every major cycling continent. We have evaluated every titanium alloy available—and some not available. We have worked, and continue to work, with all of the major—and some very small—titanium suppliers in the U.S.

Seven has invested more time and energy in developing standards, working with mills on process and certification, and testing, tracking, and managing the elements that impact tube quality and service life.

Seven's team applies our 25-plus years of technical knowledge to every frame we build.

Titanium Material Overview

Today, more than ever, there are hundreds of material variations, fabrication methods, and construction techniques available to bicycle builders. All of these options have a significant effect on a bicycle frame's ride characteristics, overall strength, long-term performance, and ultimately, your enjoyment of the sport.

A bicycle frame represents an ideal application for titanium tubing. The material's light weight, tunability, and durability—twice that of steel—allow the builder to impart a lively, plush ride to the frame, while maintaining excellent drivetrain efficiency and torsional stiffness. Working with titanium requires a great deal of expertise. Although titanium is not rare, it is expensive, primarily because processing the element is so costly.

Titanium Production

Titanium is available all over the world, although many people believe that the element titanium is extremely rare. Actually, it is the earth's fourth most abundant metallic element. Only aluminum, magnesium, and iron are more plentiful.

Nonetheless, titanium is never found in its pure form in the environment. Instead, the metal must be extracted from other compounds, such as rutile ore and ilmenite. This extraction process is difficult and expensive, and is one of the reasons why titanium, and therefore titanium tubing, is so costly.

The first step in the purification process is to create titanium sponge, named for its sponge-like appearance. Titanium dioxide—which also happens to be found in all kinds of white substances like paint, M&M candy prints, and donut fillings—is first mixed with coke; the mixture is then charged in a chlorinator. Titanium tetrachloride—or “tickle”—results when the ore reacts with the chlorine.

The tickle, a colorless liquid, is purified through fractional distillation then mixed with powdered magnesium. The brew is placed in a sealed container, void of oxygen and hydrogen, and heated up until the magnesium has reacted with the chlorine. This produces magnesium chloride and sought-after deposits of pure titanium, known as titanium sponge.

The sponge is compressed by enormous hydraulic presses into large pieces of titanium, referred to as compacts. The compacts are then TIG-welded together, end to end, to form a consumable electrode, weighing more than 25,000 lbs.

The pure titanium is alloyed at this stage, as well. 3Al-2.5V titanium, the material from which most titanium frames are manufactured, is created by adding 3% aluminum and 2.5% vanadium to the titanium.

The electrode, which is about one meter in diameter, is placed in a consumable electrode vacuum arc furnace to create a molten pool of titanium. Then, it is allowed to solidify in the furnace. The furnace has a copper lining for protection from the titanium, but because the copper lining of the furnace becomes attached to the titanium when frozen, it is removed along with the titanium. Using a large lathe, the copper is then separated from the ingot.

The titanium is now steps away from becoming tubing. But before it does, the ingot is reduced by an oversized forge. This forge is specifically designed for titanium, since titanium can’t be forged in the presence of oxygen. While in the forge, the ingot is continuously hammered and annealed. Annealing is the process of heating and cooling at a controlled rate, and is used for many purposes, including removing work hardening and embrittlement. The process is repeated until the ingot becomes a bar measuring approximately 8” in diameter, the proper size to fit through the hole of the impact extrusion machine. The impact extrusion machine (actually a combination of a forge and an extrusion machine) is used to make bar stock into tubing.

Manufacturing Titanium Tubing

The fabrication of titanium tubing requires special equipment and an oxygen-free environment. Depending upon how stringent the specifications for the tubing's size and weight, purity, straightness, molecular grain orientation, surface finish, and the presence or lack of surface defects, titanium tubing can cost nearly $70 per foot.

The 8" titanium bar that is created from hammering and annealing during the manufacture of titanium is at last fed into an impact extrusion machine. An enormous hydraulic cylinder drives the bar into one end of the machine to create an extremely hot tube, measuring approximately 45' in length. The tube is immediately immersed in a tub of hydrochloric acid to remove its superfluous outer layer.

The machine draws the oversized tubes down in size to create a tube hollow. But the tubing still isn't in a usable form. The tube hollow is shipped to a tubing mill, where the titanium is transformed into tubing. When the tube hollow arrives at the mill, it is weighed and inspected both visually and dimensionally. The hollow is also subjected to a chemical analysis to verify that the tube meets the mill's certification for purity requirements. Once the tube passes those tests, the hollow is cleaned and pickled (acid etched) to remove any oxidization or residual scale (also known as alpha case) and is ready for vacuum annealing.

Vacuum annealing is a critical step in the manufacture of titanium tubing for two important reasons:

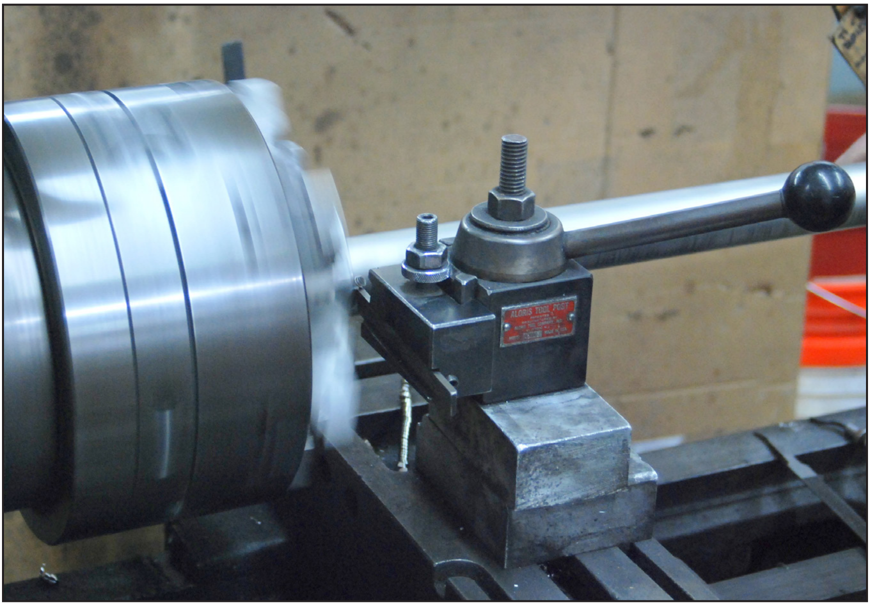
1. It lowers the strength of the tube to prepare it for the pilger mill (rocking). Titanium work hardens; thus, when the tube is run through the pilger mill, the tube's strength increases dramatically. As a result, the titanium becomes much harder and tougher and would damage the pilger were it not first vacuum annealed.
2. It makes the tube malleable (relieves stress) so that it can run through the pilger mill. This dramatically increases the tube's ductility without causing it to further lose strength. Were the tube not ductile, it would be very brittle and more likely to fail. It would also be much more difficult to machine and bend.

Since the stress reduction that occurs during annealing can also cause the tube to bend or bow, the tube is straightened before continuing through the process.

Pickled once again, the tube is then tested ultrasonically to detect any flaws—chemical or otherwise— that could create a problem during pilgering.

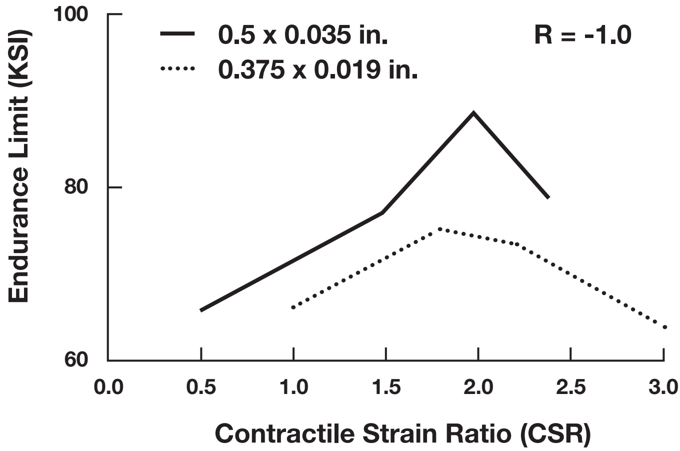
The pilger mill consists of an internal mandrel that supports the inside of the tube, and large rollers through which the tube rolls. During rocking, the hollow is squeezed, rolled, and hammered to reduce the diameter of the tube and make the tube wall thinner. The tube is actually pilgered several times. Some passes through the pilger mill focus on reducing the tube's diameter, while others emphasize reduction of the tube's wall thickness.

The repeated pilgering is performed as part of a sequence that also includes pickling, annealing, straightening, and ultrasonic testing, until the proper tube size and grain structure are achieved.



Grain structure is determined by the ratio of the rate at which the tube's diameter is reduced to the rate of reduction of the wall. Grain, or texture, is tested by measuring the contractile strain ratio (CSR) of the tube. A CSR from 1.7 to 1.9 promotes the highest fatigue strength possible, while maintaining excellent bending characteristics. A CSR above 2.0 improves bending, but decreases fatigue endurance dramatically. Since optimal CSR is controlled and determined at the mill, cold working (i.e., tapering or internal butting) the titanium tubing after it leaves the mill can detrimentally affect the endurance of the tube.

Grain structure can be detrimentally affected by cold working after the tubing has run through its final cold worked, stress-relieved (CWSR) cycle at the mill. For example, forcibly reducing a tube (as by swaging or tapering) after it has completed its final CWSR cycle rotates the molecules out of their radial orientation and lowers CSR. Reduction processes like these, often used to taper main tubes and chainstays, diminish the endurance limit of the tube.



Contractile strain ratio versus fatigue for 3/8 and 1/2 inch AMS 105 3-2.5 tubing. Note the sharp drop in fatige endurance as CSR approaches 2.0.

Once the optimal wall, diameter, and grain structure have been achieved, the tube is pickled again to remove any scale or debris from the pilgering process. A final anneal to accomplish a partial stress relief follows this step. The mill's goal is to achieve a delicate balance of ductility and strength; thus, this round of annealing slightly reduces the strength of the tube, while making it more workable for the end user.

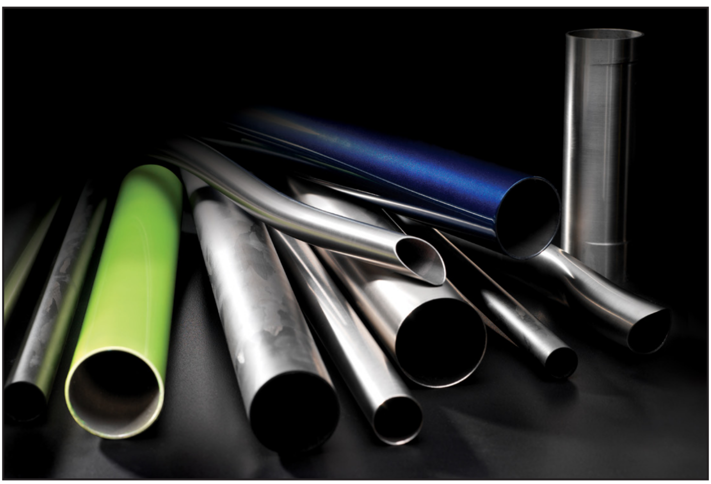
One last acid etching of both the inside and outside of the tube follows, since vacuum annealing can leave oxidation or alpha case. This final pickle also imparts a perfect finish. While this is not standard for sports grade titanium tubing, Seven specifically requests this final finish on its titanium tubing.

Before the tubing can be boxed up and shipped out, it goes through a series of rigorous tests: eddy current or ultrasonic testing; visual and dimensional inspection; and a final quality control certification.

Titanium Quality

The quality and strength of titanium tubing varies just as it does for steel tubing, depending upon the source of the material. The key to tubing quality lies in processing, which plays a critical role in determining the structural integrity—and therefore the longevity—of the final product. During processing, three variables affect the final quality of a titanium tube: texture, also known as molecular grain orientation; interior and exterior surface finish; and the presence or lack of surface and chemical defects.

The tube's texture must be optimized to obtain the highest fatigue strength possible. Similarly, a smooth, defect-free surface also contributes to longer fatigue life.



Surface finish, both inside and outside, is directly affected by processing. Titanium is more notch-sensitive than steel. A defect-free surface makes a significant contribution to longer fatigue life. The inside diameter of most titanium bicycle tubing also plays an important role in promoting fatigue endurance; typically, the tube wall is so thin that both the outside and inside diameters undergo a cycle of relative compression and tension. The tension, or pulling, causes micro-cracking, which in turn can cause the tube or joint to fail. If the inside surface texture is much rougher than the outside, crack growth can begin on the inside.

Any **surface or chemical defect** will affect the tubing. The only way to avoid this is through rigorous quality-control procedures at the mill.

These factors, individually or in combination, greatly affect the longevity of a 3-2.5 seamless tube, and, in turn, the quality of the finished product.

Types of Titanium

In addition to unalloyed titanium, which is called commercially pure or CP, there are two alloys commonly used in the cycling industry today: 3AL-2.5V and 6AL-4V.

3AL-2.5V Alloy

3-2.5 titanium is an alloy consisting of 3% aluminum, 2.5% vanadium, and 94.5% pure titanium. The properties critical to bicycle tubing are best served by a high quality 3-2.5 seamless tube. Excellent fatigue life, property consistency, form-ability, and corrosion resistance are but a few of the reasons 3-2.5 is still the premier frame material.

In the U.S., bicycle frames are commonly manufactured using 3-2.5 certified to either an ASTM B-338 or a sports grade specification. ASTM B-338 meets all Aerospace Material Specifications for hydraulic tubing. Sports grade, certified according to a less stringent set of chemical and mechanical specifications, is typically less expensive.

Some builders may use surplus material or "scrap", which meets neither aerospace nor sports grade specifications. Certification is not available for scrap, making it impossible to determine whether the material is of inferior quality.

3-2.5 Tubing Comparison

In the U.S., the three most common grades of 3-2.5 titanium used in bikes are:

1. **3-2.5 AMS grade 105**, the same stuff you would find under the hood of a 747. This material must meet all AMS specifications (Aerospace Material Specifications, as issued by the Society of Automotive Engineers) for hydraulic tubing. Theoretically, buying AMS 105 tubing directly from the mill allows the designer an unlimited choice of diameters and wall thicknesses. In reality, there are large minimum order requirements and long lead times involved, and only a few of the largest titanium fabricators, such as Seven, can afford this luxury.

2. **3-2.5 "sports grade."** Sports grade tubing is marginally less expensive because it is subjected to fewer processing steps, which is supposed to cut costs. However, the cost savings to date have had a detrimental effect on material formability and surface texture, both inside and out.

3. **"Scrap" 3-2.5.** This is material which has not met either aerospace or sports grade specifications, or is simply a small amount of overrun from a mill run of aerospace or sports grade material. One of the problems in using scrap tubing is that there are no certifications or specifications, and thus no means for the buyer to determine whether any structural anomalies exist.

Seven's tubing constitutes a fourth category because our tubing is none of the above. Our specification varies from AMS grade 105 in that it has more stringent tolerances for straightness and surface texture. Seven's tubing also exceeds AMS specs for minimum ultimate tensile strength and minimum yield strength.

6AL-4V Alloy

An alloy of 6% aluminum, 4% vanadium, and 90% titanium, 6-4 titanium offers some very favorable raw material properties, which is why Seven uses it to fabricate dropouts and other frame parts. One of the properties that makes 6-4 an optimal material for dropouts is its toughness. But this toughness also makes it unattractive as a material from which to make tubing. Applying the techniques used to draw 3-2.5 tubing to 6-4 tubing costs much more and wears tooling very quickly. In addition, tube wall consistency, concentricity, and finish quality—both inside and outside—are limited. At the time of this printing, no U.S. mill offers seamless 6-4 tubing. However, some do offer 6-4 seamed, or welded, tubing.

Two major issues prevent Seven Cycles from favoring this method of tube manufacture. First, seamed tubing is fabricated by rolling 6-4 sheets into a tube shape while simultaneously welding the seam that is created in the rolling process. The result is a tube that has a welded seam—a potential failure point—along its length. This seam acts as both a hard point and a stress riser since the weld bead is thicker than the tube itself and the weld creates an inconsistency in the tube.

Second, 6-4 sheet is designed to be used as a sheet, not as a tube. If it is formed into a tube, its grain structure can lead to premature tube failure. Indeed, a 6-4 tube will fail through fatigue cycling (repeated flexing) before it should, and independent fatigue tests show that tubing made from 6-4 sheet does not have the fatigue life of a properly drawn 3-2.5 tube.

In recent years, some seamless 6-4 tubing has trickled into the bike industry from outside the U.S. However, it is only being offered as a few internally-butted tube lengths of limited sizes (as determined by tube diameter, wall thickness, and butting placement). These limited offerings are inadequate for modern high-end bike building, which requires a very wide variety of tubing to ensure optimum ride characteristics. In addition, external butting is preferred to internal butting for the reasons outlined in the Tube Butting Processes section of this document, under Manufacturing Overview.

One might argue that the strategic use of the limited 6-4 tube sizes available in combination with 3-2.5 tubes would create a better bike. But there is no weight advantage for bikes currently employing 6-4 tubes over the top-of-the-line 3-2.5 bikes available. And there is no appreciable stiffness or strength benefit either, since 6-4's higher bending stiffness is offset by its lower torsional stiffness, and the butting techniques employed in the 6-4 tubes currently available have a negative impact on fatigue strength. So 6-4 only adds expense.

CP: Pure Titanium

A small number of titanium frame builders incorporate Commercially Pure (CP) titanium into their frames. CP has, at best, half the strength of 3-2.5. A CP frame must be made heavier than an equivalent 3-2.5 frame in order to have comparable strength. Even most steels used in high quality frames have higher strength than CP. The overall quality of CP tubing is lower because it is typically used in low-cost applications—not bicycle building. CP is used mainly in industrial applications when corrosion resistance is most important.

Tough to Beat 3-2.5

Historically, aerospace and defense industries have driven materials technology, and 3-2.5 continues to be the Ti alloy of choice. At present, these industries are not clamoring for 6-4 tubing, which is why no U.S. mill is producing it. For there to one day be an ample supply of 6-4 tubing in a wide array of sizes and at a reasonable price, it will take the interest and purchasing power of an industry much bigger than the bike business. Though this may be on the horizon, there's no indication that it will happen any time soon.

In addition, an examination of some other high-tech industries that depend on high strength alloys like 3-2.5 and 6-4 reveals that none use 6-4 small diameter tubing, primarily for the reasons mentioned above. Consultation with titanium mills tells us that commercially available seamless 6-4 in a variety of sizes is not on the near horizon.

A Closer Look at Seven's Proprietary Tube Sets

Integrity™, Argen™, and Cirrus™: What are the key differences in these tube sets? And more important, how do they help achieve the design and performance objectives set forth for a particular frame model? Here we'll take a closer look at Seven's exclusive titanium tube sets and their integral relationship to our Axiom S, Axiom SL and Axiom SLX frame models.

From raw tubing to tube set

At Seven, we buy all of our titanium tubing mill-direct in roughly 35 different straight-gauge sizes, which are delivered to us in lengths averaging 15'. These tubes need to meet strict tolerances for fatigue strength, diameter, wall thickness, finish quality, straightness, and concentricity. Whether destined for Ultra-butting or remaining straight-gauge, a tube's long journey toward becoming part of a Seven tube set begins here.

Integrity™

The tubing that goes into Seven's straight-gauge Integrity takes the most direct route to becoming a tube set. Though each tube is carefully selected according to the performance needs and preferences of the individual rider, our Integrity requires the least amount of processing and manipulation, and is consequently less expensive. It also possesses maximum dent resistance and durability. On the flip side, however, it does not allow for as finely tuned ride characteristics, and results in a frame that is heavier than one made from butted tubing.

Argen™

The result of 15 years of tube butting research and development, our Argen tube set is a combination of single- and double-butted tubes designed to create the optimal balance of weight to performance. Though all Seven tube sets allow for custom tube selection for each individual rider's performance preferences, Argen is the most tune-able, as it offers the widest range of tube options and configurations.

Cirrus™

The ultrabutting process we developed to create our Cirrus tubing is our most technically sophisticated and yields our lightest tube set to date. Using proprietary butting technology, we shave weight wherever possible according to the particular stresses that occur over the length of the tube. With ultra light weight being its primary objective, Cirrus is not recommended for riders over 200 lbs or those who demand maximum frame stiffness.

Seven’s Titanium Tube Sets At-A-Glance

Tubing	Feature	Advantage	Benefit	Consideration
Integrity	Straight-gauge	Price; damage tolerence	Most affordable; most durable	Heavier; less tune-able characteristics
Argen	Double-butted	Light; best weight to performance; widest range of tube options	Most tune-able; optimized ride characteristics	Best all-around; No Compromise
Cirrus	Ultrabutted	Lightest; specifically engineered for light weight	Great for climbers & lighter riders; Light; compliant	Not for everyone; narrow range of ride characteristics; price

Titanium Manufacturing Overview

Tube Manipulation

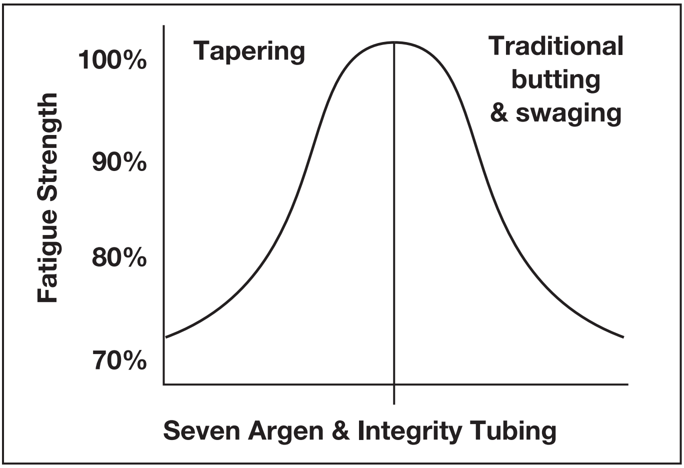
Tube Butting

A tube that is double butted, such as those found in Seven’s Argen™ tube set, has a thicker wall at its ends and is thinner in its midsection. The joints of a frame are its most highly stressed areas, and in a typical titanium or steel frame, possess lower mechanical properties—i.e., strength—than the unheated portions of the tubes. Thus, most failures occur at the frame’s joints. Butting efficiently strengthens the heat-affected zone at the joints without adding significant weight.

Seven’s ultra-butted Cirrus™ tube set takes butting to a whole new level. It’s similar to a double-butted tube in that the wall thickness at the ends of the tube is greater; however, the wall thickness will vary extensively over the tube length according to the complex stresses the tube will undergo at various points. Seven’s Cirrus™ tube set makes possible the lightest bikes available.

Tube Butting Processes

Traditionally, tubing has been butted internally. Using an internal mandrel, material is displaced from the center of the tube to make the tube thinner in that area. The mandrel must then be drawn out of the tube, past the thick sections, so the tube must be limited in its thickness differentials. Internally butted tubing has some advantages, such as its usefulness in lugged construction. However, internally butted tubes typically are limited to a 40 percent thickness differential to allow the mandrel to be removed. Therefore, there are fewer tube sizes from which to choose, and the variation in thickness may not be ideal. Externally butted tubes suffer from no such differential limitations.



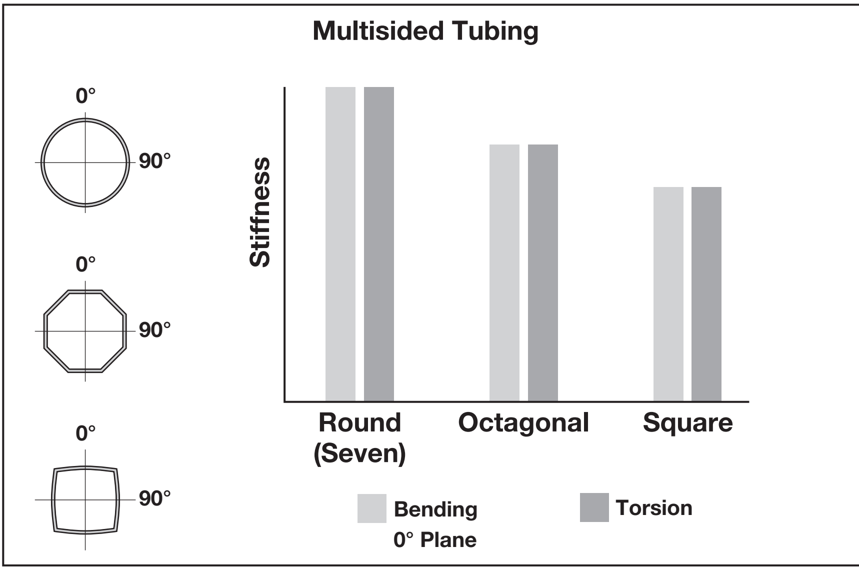
In addition, the properties of an internally butted titanium tube are affected by the excessive manipulation that occurs when using a mandrel. Although cold working can increase strength, too much cold working after the tube mill's final annealing and stress relieving cycles can detrimentally change the texture of the tubing. The tubing's CSR (Contractile Strain Ratio) increases—beyond its optimal rate—resulting in poor fatigue characteristics.

External butting is a superior method for tube reinforcement, and, generally speaking, produces a lighter tube with equal strength, or a stronger tube with lighter weight, than an internally butted one. There are two key advantages to externally butted titanium tubing—one metallurgical, the other, mechanical.

Metallurgically, drawing titanium tubing at the mill determines its crystallographic texture, or grain orientation. And grain orientation affects yield strength, ductility, and fatigue strength. The mill controls the grain texture with a lengthy process of rocking and heat treatments. The control of these steps creates an optimized fatigue life and ductility. The tube leaves the mill with the best possible combination of properties. Therefore, when titanium tubing is cold worked by tapering or internal butting—whether by the mill or by secondary vendors—the tube's properties will be compromised.

Mechanically, in pure engineering terms, an externally butted tube is a more efficient use of material. For a given tube's weight, an externally butted tube will be stiffer; for a given stiffness, the tube will be lighter. In addition, internal butting can hide scratches or notching due to mandrel movement. Surface scratches create stress risers that can lead to premature failure. Externally butted titanium avoids these problems.

Using proprietary processes that do not affect the tubing's grain structure or internal surface, Seven creates externally butted titanium tubing that maintains its fatigue strength and ductility. These processes allow for every possible permutation of tube diameter and wall thickness, in addition to an optimum strength-to-weight ratio, and create no surface defects or scratches.

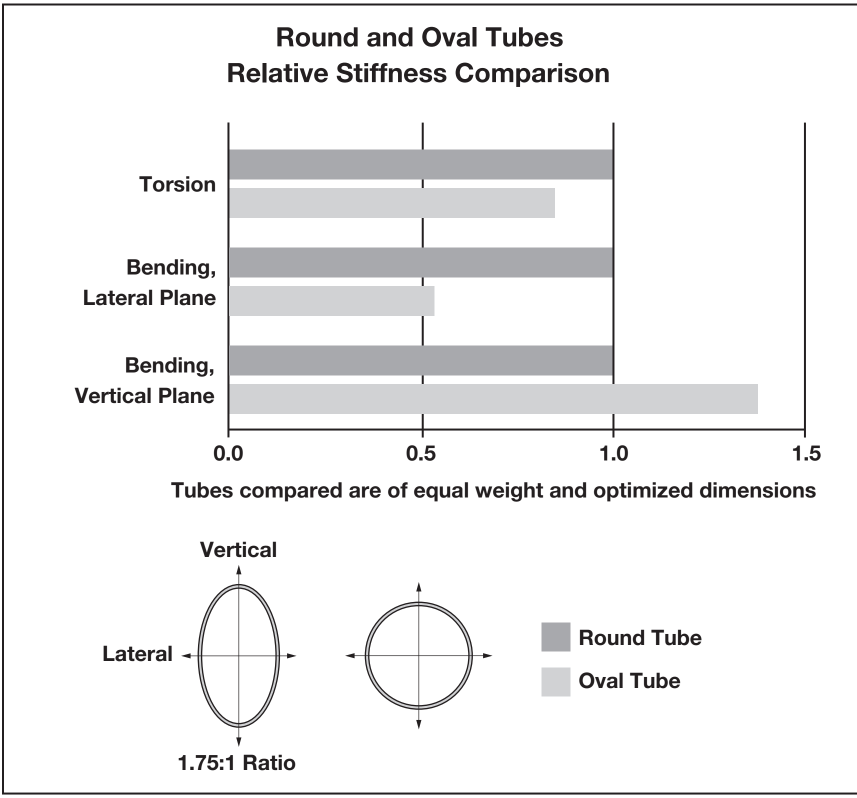


Shaped Tubing

Odd tube shapes (ovals, so-called geometrically enhanced tubes, squares, six-sided tubes, etc.) are becoming more and more common these days. At first glance, these shapes appear to enhance the performance of the bike. Unfortunately, in most cases, performance is actually compromised.

Stiffness: A round tube is the optimal shape to achieve a balance of all bending and torsional stresses a bike undergoes. Odd shaped tubes always compromise torsional stiffness, and bending stiffness is always compromised in at least one plane. Overall, round tubes are stiffer for a given weight. Although oval tubes may be stiffer in the major plane, they are more flexible in the minor axis. In addition, oval tubes suffer most from a lack of torsional stiffness.

Grain Structure: Grain structure is what provides the strength and toughness of a material. The mill draws the tube in a specific way so that the resulting grain structure is optimized for strength and fatigue endurance. Thus, if the shape of the tube is changed, the tube's grain structure is also changed. As a result, the tubes' strength and durability are compromised.



Notch Sensitivity: Most shaped tubes are formed by a mandrel. However, a mandrel causes internal scoring. Internal score marks are stress risers that can potentially lead to failure. So while round tubes may not be the latest fashion, they are reliable, durable, and result in bikes with optimize weight to performance that last for the long haul.

To be clear, there are occasions when a shaped tube is useful. However, it's important to look at the underlying purpose of a shaped tube, since some aspect of performance is almost always compromised as a result using a non-round tube. The information below provides strengths and weaknesses for the three main categories of shaped tubes.

Shape	Example	Performance Strength	Performance Weakness
Shapes that effect the mechanical properties of the tube: stiffness, compliance, etc.	Tapered or multisided tubes	Aesthetics (subjective) Marketing differentiation	A constant diameter, butted tube will be lighter for a specified stiffness
Shapes that facilitate the use of common and popular components	Seven's S-bend chain stays	This allows for the use of a large diameter, stiff tube and reasonable tire and chain ring clearance	Too much shaping reduces performance; see above

Surface Treatments

Anodizing

A small number of manufactures offer anodizing as a way of decorating the surface of titanium frames (or components). Basically, the process creates a dense, colorful film of titanium oxide, which adheres to the frame's surface. Ironically, this is the same type of oxidation that any skilled titanium welder will prevent at all costs, because it will cause the weld joint to become extremely brittle. This is why Seven's expert welders bathe both the inside and outside of a titanium frame's weld joints in an inert gas, thereby protecting the molten metal from the high levels of nitrogen and oxygen that naturally occur in the environment.

The titanium oxide film created by anodizing is, thus, extremely brittle, so the frame's surface cannot flex as it would during normal use. Cracks form through the anodized shell, which will eventually propagate into the tube wall, ultimately causing frame failure.

Seven strongly advises against anodizing titanium. Hence, we will void the lifetime warranty on any Seven frame that has been anodized.

Shot Peening

Shot peening is a process of firing thousands of small spherical "shot" at a surface. It literally peens the surface of the material, reworking it to put it under compressive stress.

In theory, the failure point for most structures that undergo fatigue cycling, such as a bicycle frame, is its outermost surface. The natural tension of the surface can lead to crack induced failure. Correctly applied, shot peening creates localized compression of the tubing surface, thereby reducing the likelihood of crack initiation.

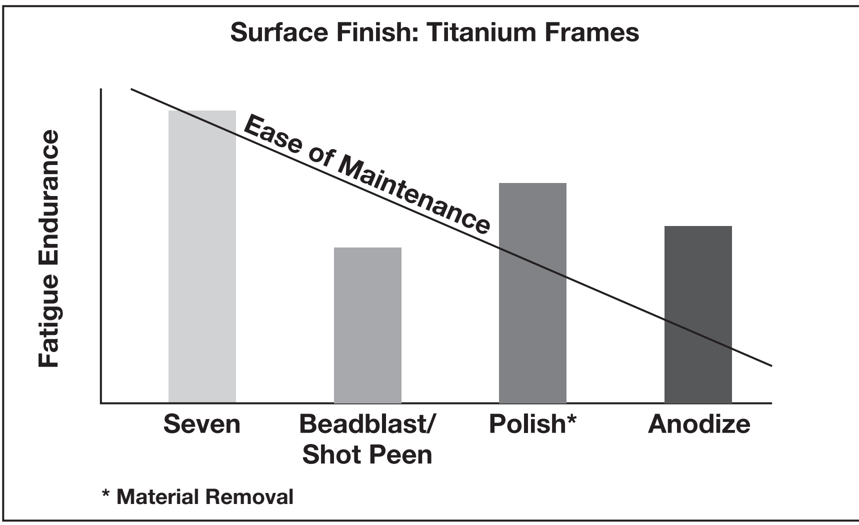
However, it is extremely difficult to properly shot peen an intricate, welded, small diameter tubular structure, such as a bike frame. The difficulty arises from the trajectory of the shot. To be effective as a means of increasing fatigue life, the shot's trajectory is best applied at approximately a 90-degree angle to the material's surface. Unfortunately, a frame's tube diameter is small enough that much of the shot is hitting the surface at 60 degrees or even less. At this angle, the shot is skimming the surface, instead of peening it. This skimming does not benefit the surface structure.

The main drawback to shot peening as a titanium surface treatment is in the durability and maintenance of the finish. If it becomes scratched or worn-looking—as is likely from normal use—it can't easily be restored. By contrast, the satin finish applied to Seven titanium frames can be maintained simply with the use of a little ScotchBrite™ (Very fine AA) and a light application of a wax-based furniture polish.

Polishing

The highly polished finish offered on some frames is created using an abrasive process that smoothes the surface by removing material. It's difficult to control the amount of material that is removed—particularly around the frame's joints. This material reduction will make the joints weaker, which could lead to frame failure.

A polished finish is also more difficult to care for long-term than a satin finish. A small scratch on a satin finish can easily be removed using Scotchbrite™, so its elegance is easy to maintain for the life of the frame.



Welding Techniques

Proper welding technique is one of the most important steps in the construction of a titanium frame, since titanium has a tendency to alloy with anything it touches. Fortunately, this is only a problem when it is in its molten state during the welding process (over 1700 degrees C).

Oxygen, nitrogen, and hydrocarbons are the three most damaging elements to a molten titanium weld bead. If any of these substances enters and mixes with a titanium weld bead, the fatigue life and structural integrity of the joint is greatly compromised.

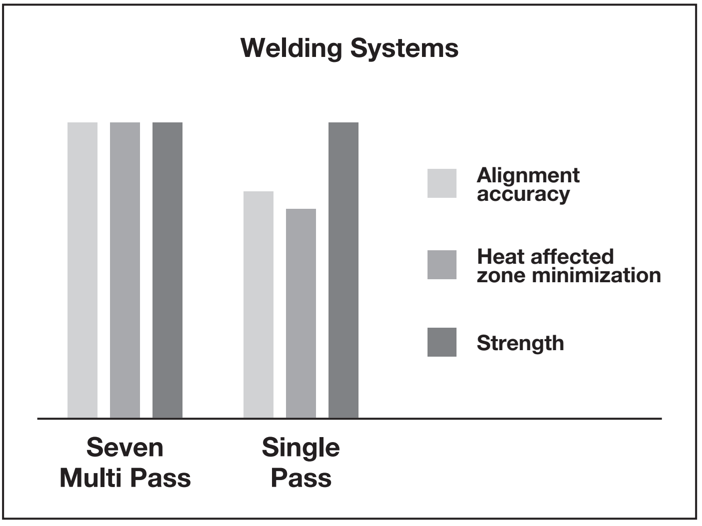
Therefore, Seven Cycles uses a proprietary TIG welding process to build our titanium frames. Specially modified TIG welding torches, lenses, and cups ensure that the welded joint has the highest possible level of strength and purity. We have also specially modified our welding machines to optimize weld strength in all of our frames.

Since even fingerprint oils (hydrocarbons) will dramatically degrade a weld joint's fatigue life, we prepare and clean each tube prior to welding. Our machinists wear cotton gloves during the welding preparation stages, even before any welding is performed, and welders also wear cotton gloves while welding and handling any frame to keep the tubes from becoming contaminated.

To keep airborne contaminants out of the weld area during welding, we bathe both the inside and outside of the frame's joints in a completely inert gas, thereby protecting the molten metal from the high levels of nitrogen and oxygen that naturally occur in the environment. A positive pressure purge system creates a purely inert atmosphere inside the frame. Outside, the modified TIG torch produces a bath of inert gas to shield the bead from possible contamination. The inert gas maintains the titanium's purity, and does not react with the metal.

Individuals who weld titanium must have very steady hands to avoid both flaws and contamination in the weld zone. Even something as simple as inappropriate weld wire movement can actually create vortices that stir up nitrogen and oxygen and allow them into the molten TIG bead, thereby compromising the joint's strength.

To minimize heat distortion and optimize bead penetration, Seven uses various weld wire sizes and bead sizes, depending on the joint and tube selection. Heat distortion must be minimized because it can create problems with frame alignment that affect the bike's handling and tracking during riding. Nonetheless, we still perform five frame alignment checks throughout the welding process to maintain precise alignment. If a slight alignment adjustment is necessary, the welding steps can be modified to bring the frame back into alignment.



Finishing

A titanium frame spends almost a day in final finishing. Cleaning the entire frame to remove any oil or residue left over from final machining is the first order of business. Next, we brush the frame with a nylon wheel to bring the raw titanium to its glossy, natural luster. Seven's titanium frames are not polished, so no material is removed from the tubes' surface. Because we use only the highest quality tubing to build our frames, the tubes have no surface scratches or imperfections that would make it necessary to polish, paint, bead blast, or otherwise alter the frame.

To enhance the frame's finish, we simply touch it up with Scotch Brite™, a 3M product that might remind you of—but isn't—the pot scrubber in your kitchen sink. Grade A, or very fine, gives us the best results. Once the frame has been wheeled and buffed, it's ready for decals, which are specially designed to adhere to titanium. As a final touch, we spray the entire frame, head tube to dropout, with a generous application of light wax; this helps to keep fingerprint oils, chain lube, and other greasy substances from leaving marks on the frame.

Then, we install the remaining bits of hardware, including water bottle mounts, a laser-cut stainless steel head badge, and a seat top. The finishing touch is a laminated, wallet-size frame card that we affix to the frame. It lists the frame's geometry and serial number, and is signed by all the individuals who built it to signify that the frame is indeed one of a kind.

What's Next?

We hope this booklet provides insight into how Seven has become well-known in the industry by applying our 25-plus years of titanium technology—in conjunction with our Custom Kit™ and manufacturing systems—to build One Bike. Yours.™

We hope we can build the next Seven for you.

How Do I Order A Seven Or Find Out More?

To find our more about Seven, or to find your local authorized Seven retailer, contact us:

- T: 617-923-7774
- E: info@sevencycles.com
- W: www.sevencycles.com

We look forward to hearing from you.

seven cycles

One Bike. Yours.™