

EXPANDED PRODUCTS IN COMPOSITES



ForceMate®

ForceTec®

Flexmate®

TukLoc®

GromEx®

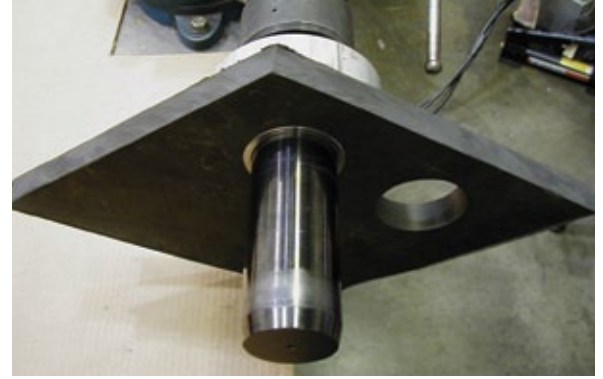


FATIGUE TECHNOLOGY

WHY USE FTI PRODUCTS IN COMPOSITES?

FTI product systems provide simple installations, design flexibility, and improved performance. They eliminate the risk and time associated with sealants, satellite holes, and other types of interference fit products. Each product is radially expanded from an initial clearance fit to lock it into the structure and provide uniform contact with the hole surface resulting in the following advantages over other assembly methods:

- Improved open hole compression strength.
- Faster product installation and joint assembly.
- Hole protection in areas where bare holes can wear or wallow.
- Reduced arcing and laminate damage caused by lightning strike.
- Improved electrical conductivity through fastened joints to grounding locations.
- Ease of repair.
- Better open-hole fatigue life.
- Higher installation reliability and repeatability.



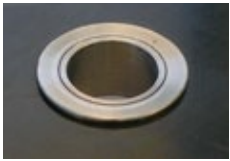
Optimal Performance in Bushed Joints

ForceMate®



FTI's proven ForceMate bushing installation process works well in composites providing a fast, consistent installation with superior performance to bonded and shrink fit bushings. The process uses a standard FTI puller unit with a different mandrel and nose cap, which are optimized for the unique properties of composite laminates.

ForceMate 2™

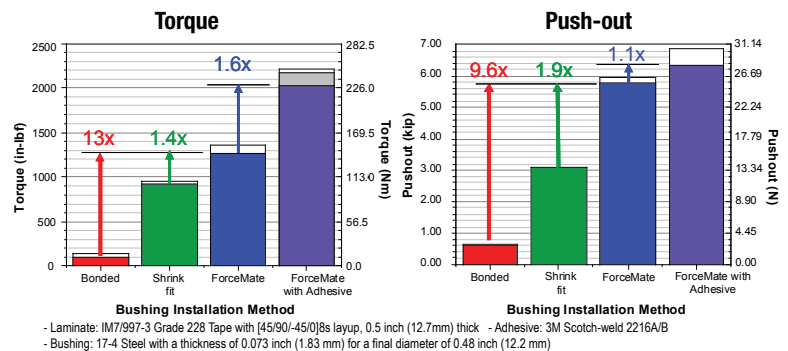


The ForceMate 2 process simultaneously installs two distinct components:
A classic ForceMate outer bushing
PLUS
A drawn-in inner wear liner or a nested bushing that props the hole and enhances retention.

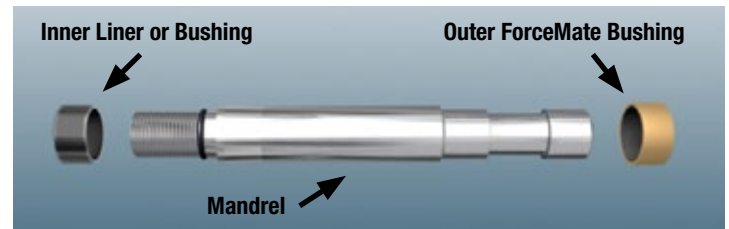
The ForceMate 2 process results in the following advantages:

- Increased interference for improved retention.
- Nested flanged or straight bushings install with one operation and reduce reaming steps.
- Provides a flange on both surfaces to protect composite faces and restrain edge effects under high loads.
- Enables the use of a wider range of bushing material combinations.
- Relative bushing configurations can be altered to optimize performance.

Comparison of Bushing Installation Methods



ForceMate 2 Installation Procedure



Place inner liner/bushing and outer ForceMate bushing onto mandrel.



Screw bushing retainer onto mandrel and place mandrel assembly into puller unit.

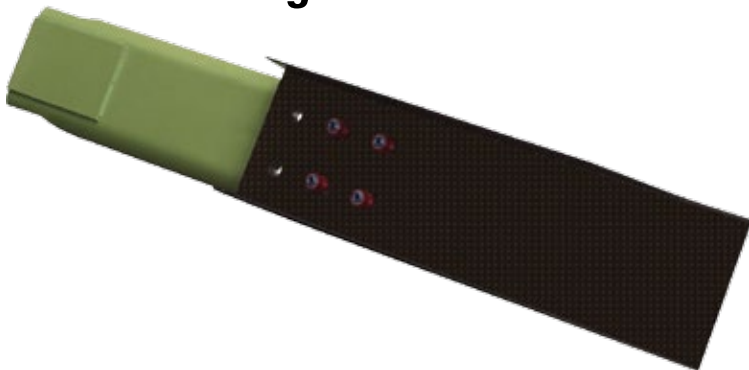


Slide mandrel assembly into hole. Activate puller unit.



Inner liner is held by elastic spring-back of outer ForceMate bushing.

Manufacturing Easement



Composite to Metal Fastening

The ForceMate bushing installation system facilitates one-up assembly of metal/composite hybrid structures, thereby reducing cycle times and labor costs.

- Installs bushings in the metal and composite at the same time with tailored relative expansion levels.
- Improves the fatigue life of the metal structure.
- Enables structures to be line-reamed without disassembly.
- Prevents burrs in parent material.
- Provides for simple rework if hole is drilled oversize or off position.
- Supports alignment tolerance.
- Accommodates thermal mis-match of materials.

Improved Electromagnetic Performance

FTI expanded products achieve excellent bonding and grounding or earthing performance because each product is radially expanded from a clearance fit starting hole to produce a final interference fit in the structure or component. Our highly repeatable process produces uniform contact with the hole surface without gaps or insulating sealant.

ForceLoc™ Blind Modular Fastening System

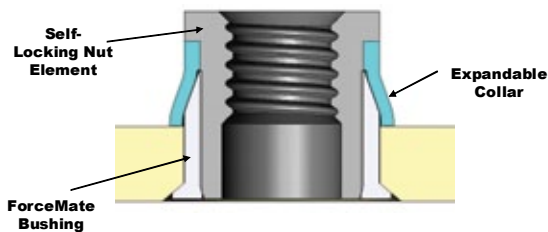


ForceLoc provides the user with a highly conductive, axial-load capable fastening system with many potential uses including:

- Electrical bonding stud.
- Threaded insert.
- Mounting for systems attachments (wire bundles, etc.).
- Blind nut.
- Electrically conductive repair.

ForceLoc is composed of three elements that become an integral nut or stud with a single pulling action from a standard FTI puller unit. The elements are adaptable to almost any need including the creation of a solid, threaded stud for equipment mounting. Please consult FTI for more information regarding options for your unique application.

ForceLoc's Basic Installation Methodology



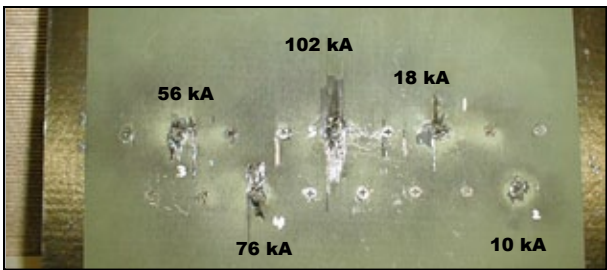
1. The ForceMate bushing is cold expanded into the structure.
2. The special mandrel continues through the bushing and draws the nut assembly into the bushing inside diameter with high interference. The expanded collar is simultaneously displaced radially over the conical end of the bushing, creating a permanent flange on the backside of the structure.

GromEx® Composite Panel Liners

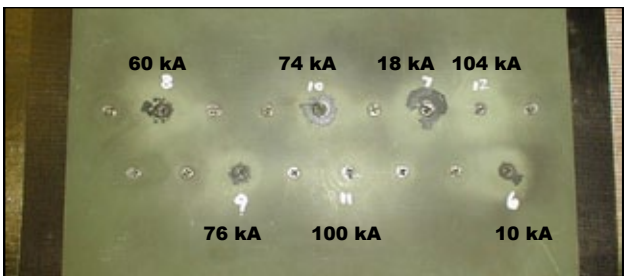


GromEx panel liners are used to protect composite panels from lightning strike damage and hole wear. They are suitable for use with any class of fit fastener and can be used to facilitate the installation of net fit fasteners in load transfer applications. GromEx is available in common fastener configurations including "T-shaped and 100° countersunk configurations.

GromEx Panel Inserts Improve Lightning Strike Performance Over Glued-In or Swaged-In Grommets/Liners



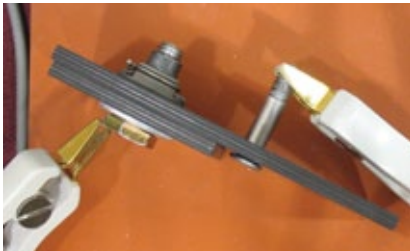
IM6/3501-6 carbon/epoxy panel with glued-in or swaged-in liners is damaged by 10kA strike on liner. Extensive damage noted at 102kA



Same panel material and dimensions as the first photo except GromEx cold expanded grommets were used and the strike was increased 10-fold to 100kA with significantly less damage.

Expanded Products Improve Joint Electrical Conductivity When Compared to a Standard Aerospace Nut and Bolt Combination

Fastener/electrode measurement



Copper plate measurement



Expanded Nut Plate, Blind Nut, and Bushing electrical conductivity comparison with a net fit, hex-nut NAS fastener.

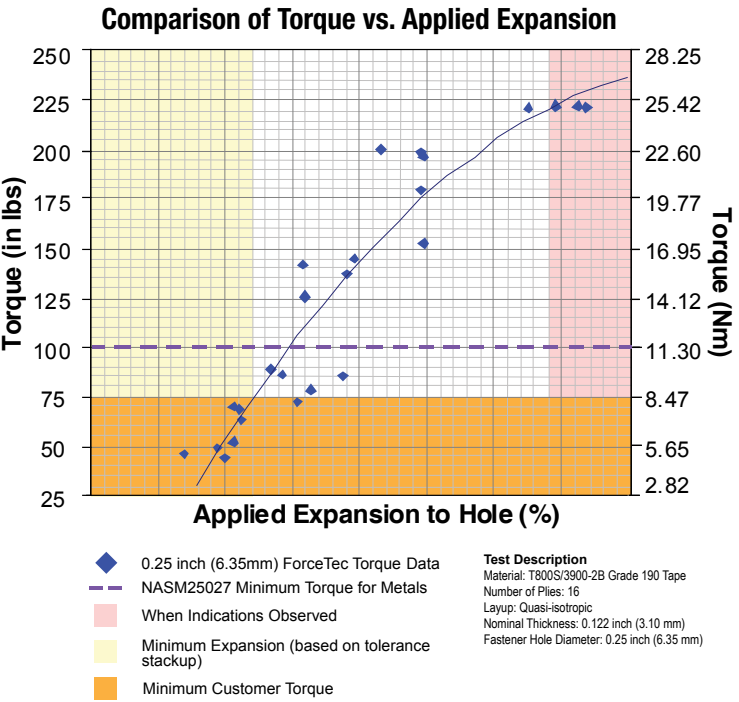
Fastener Type	Resistance, ohms	
	Without Copper Plate	With Copper Plate
	Fastener/electrode	
Baseline (Aerospace bolt only)	6.57	5.60
ForceTec, Ti, Class I Fit	0.0951	0.1184
ForceTec, Ti, Class II Fit	0.1102	0.1699
ForceTec, SS, Class I Fit	0.0848	0.1091
ForceTec, SS, Class II Fit	0.1325	0.1410
TukLoc, 304 SS	0.1172	0.1597
ForceMate, Steel	0.0955	0.1607

Laminate Integrity

FTI spent many years researching and developing installation process parameters for its expanded products in a variety of composites to ensure a safe, highly-repeatable process. Bushings and nut plate retainers were installed in a large number of materials and thicknesses to study the effect of applied expansion on laminate integrity.

Establishing Process Parameters

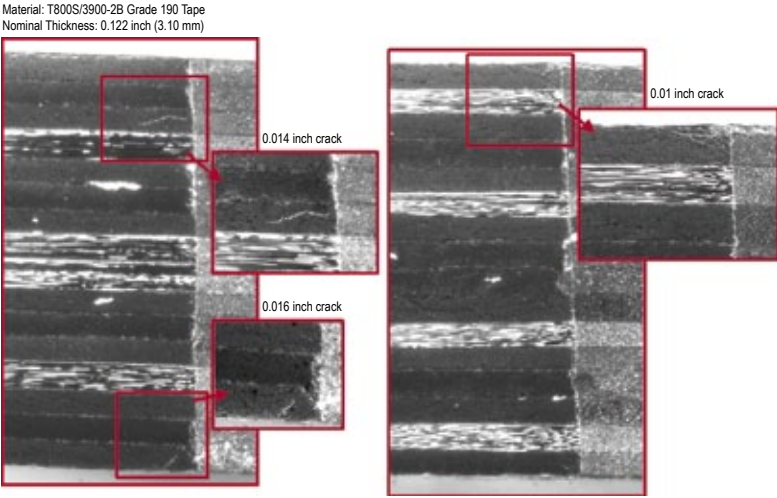
The chart below shows an example of ForceTec rivetless nut plate torque out values plotted against applied expansion for 0.25 inch (6.35 mm) titanium nut plates installed in a 0.12 inch (3.10 mm) carbon/epoxy tape, quasi-isotropic laminate. The process boundaries of nut plate overexpansion, minimum expansion based on tolerance stackup, and minimum acceptable customer torque are shaded in the chart. The minimum torque value for nut plates in metals per NASM25027 is included as a dashed line for reference. Studies such as this one are useful in establishing process parameters and design cutoffs for different materials and layups.



Extensive Characterization

To ensure that expanded product installation process parameters for composites meet current acceptable manufacturing standards, FTI performed extensive laminate characterization studies using standard NDI methods and micrographs. All FTI expanded product installations at the recommended process parameters showed no indications of damage when evaluated with standard NDI methods such as automated pulse-echo ultrasonic, automatic through-transmission ultrasonic, x-ray, and manual pulse-echo ultrasonic.

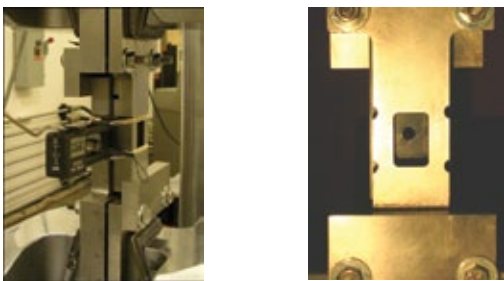
FTI also sectioned and microscopically examined the installed products and discovered some isolated microcracks in some holes (see photomicrographs below). However, the cracks did not extend around the hole and the surface ply cracks were much smaller than the drilling allowable. FTI found no detrimental impact during static and fatigue testing.



Today's aircraft require interference fit solutions to meet design parameters; FTI's products minimize the impact to laminate integrity and yield the highest performance.

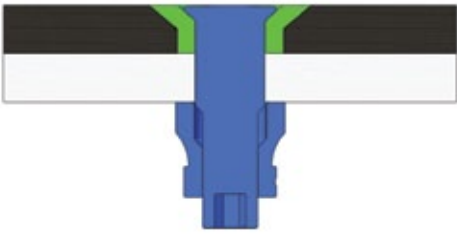
Mechanical Testing

Mechanical testing was performed to determine the effect of increasing the diameter of a hole and installing an expanded product. Testing showed that expanded products increased the open hole fatigue strength and open hole compression strength. Tension and bearing results were commensurate with the larger hole diameter and reduced net section.

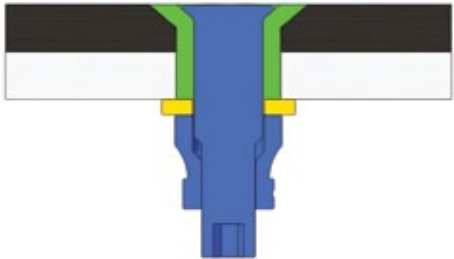


Open hole compression and open hole fatigue test setups

Many Composite Repair Solutions



ForceMate bushing used to resize damaged hole in laminate to nominal dimension.



ForceMate bushing used to restore the substructure and panel hole to nominal. A stepped bushing can be used to tailor expansion levels.

Expanded products can be used to repair damaged or discrepant composite structures or assemblies to:

- Re-size holes that were misdrilled during production so a nominal fastener can be used.
- Provide blind attachment in areas with restricted access for permanent or temporary laminate repairs.
- Re-size elongated holes damaged by in-service conditions.
- Replace disbonded studs.

Increased Performance And Life In Nut Plate Joints

Whatever your application calls for –high shear load transfer, large float, frequent installation and removal, blind side access, sandwich panel structure – FTI fastening systems are the preferred solution. Each nut plate or blind nut protects the bore of the hole and provides mechanical load transfer for optimal performance and long life. It also provides electrical conductivity. Installation is simple, fast, and consistent without the risk and time constraints of additional countersunk rivet holes or adhesives. Replacement of a ForceTec nut element in the field or during repair is safe and straightforward.



ForceTec rivetless nut plates for use in composites are available in stainless steel and titanium in a variety of sizes and configurations including open style, domed, high float, and panel fastener configurations. The nut plates are dry film lubed for a mandrel only installation using a standard FTI puller unit with a mandrel, nose cap, and chuck assembly optimized for the special characteristics of composites.



Stainless Steel
(open and sealed)



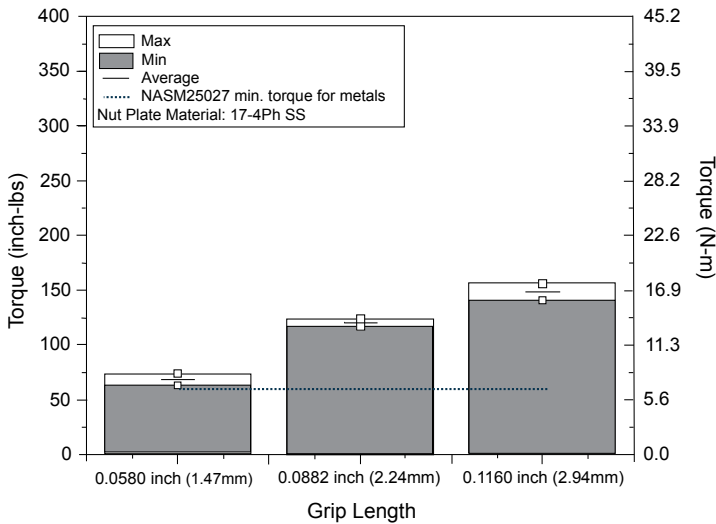
Titanium
(open and sealed)



Panel and Hi-Torque
Fasteners

Although FTI's installation system for ForceTec in composites uses a much lower expansion level than metals, the resulting torque out values are comparable, as the sample data below indicate. ForceTec is suitable for use in grip lengths as low as 0.06 inch (1.52 mm).

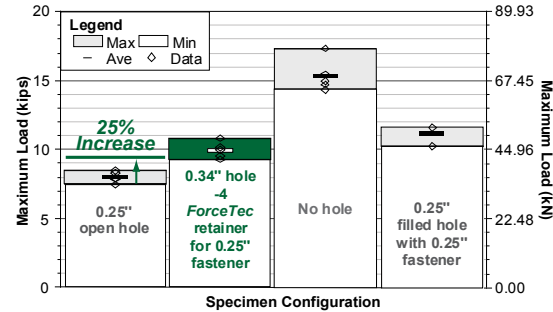
ForceTec Torque vs. Grip Length



Material: Carbon/Epoxy Tape, Thickness: 0.122 inch (3.1mm) Layout: [45/90/-45/0]2s
17-4 PH SS retainer installed in a .2996 inch (7.60mm) starting hole for a 3/16 inch (4.76mm) bolt.

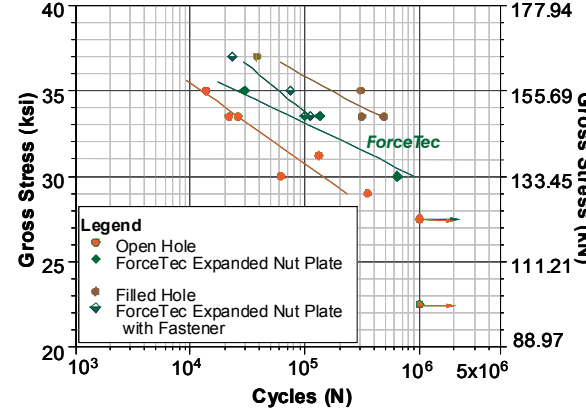
ForceTec retainers can be used to compensate for tolerance stackup in structural assembly and provide the hole filling strength advantages of a net or interference fit fastener without the access constraints or bolt removal challenges. The test data below are examples of how ForceTec performs in static compression and fatigue versus both open and filled holes.

Open Hole Compression Testing to ASTM D6484



Specimen Description:
Material: Carbon/Epoxy Tape, Thickness: 0.122 inch (3.10mm)
Layup: [45/90/-45/0]2s, Fastener Hole Dia. 0.25 inch (6.35mm)

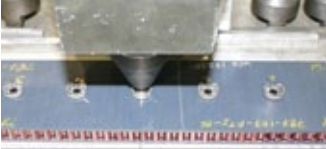
Zero Load Transfer Fatigue Testing



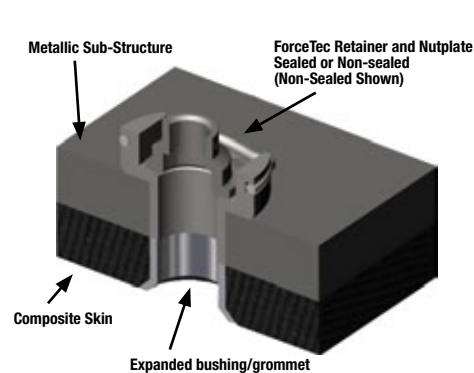
Specimen Description:
Material: Carbon/Epoxy Tape, Thickness: 0.122 inch (3.10mm) Layout: [45/90/-45/0]2s, Fastener Hole Dia. 0.25 inch (6.35mm)
Test Description:
R-Ratio: -1.0, Frequency: 3Hz, Environment: Ambient lab air
Note: Arrow on data point indicates no failure

Blind Nuts, Sandwich Panels, and Other Special Applications

FTI manufactures expanded nut systems for almost any application including honeycomb core panels and blind nut installations. Please call us for guidance with your design.



Example Of Composite Skin Attachment To Metal Substructure



Post Assembly Installation Procedure

1. Locate the components of the assembly and secure or clamp the joint using undersized holes and temporary fasteners.
2. Ream the starting hole without de-stacking the components.
3. Place the ForceMate bushing (or ForceTec retainer) into the metal portion of the joint.
4. Place the bushing into the composite member of the joint.
5. Pull the expansion mandrel through the two bushings to individually radially expand them into each component of the stack-up.
6. Ream if necessary to achieve final hole tolerance.

Pre-Assembly Installation Procedure

- Installation of the bushing prior to assembly of the stack-up makes it easier to control the engagement (hole fill) of the bushing through the bore of the hole for maximum fatigue life improvement. A thick wall bushing can be used to compensate for a large mismatch of the hole locations with no drop-off in fatigue life.

FTI designs and manufactures a full range of cold expansion products for the aerospace industry. These products are specifically engineered to achieve aircraft production and cost initiatives; meet design goals, production rates and aircraft performance objectives; and provide life-cycle cost savings.

Here are some of FTI's other innovative products:



Split Sleeve Cold Expansion™

Fatigue Life Enhancement of Holes in Metal Structures

- Enhances structural fatigue life
- Increases the durability and damage tolerance of holes
- One-sided operation
- Over 40 years proven service



ForceTec® LITE

Rivetless Nut Plate For Automated Assembly of Aluminum Substructure

- One step installation
- Reduce life cycle costs
- Engineered for high volume applications
- Zero waste stream
- Factory-sealed: No sealant required after installation



TukLoc®

Blind Fastening System

- Easy hole preparation
- No additional sealants required
- Rapid installation
- Highly reliable process



Flexmate®

Advanced Aerospace Fitting

- Fatigue life improvement
- Simple one-piece design
- Minimum envelope
- Minimum weight
- Excellent sealing and electrical conductivity



FTI's world headquarters and manufacturing plant is located just 5 minutes from the Sea-Tac International Airport and 10 minutes from downtown Seattle, Washington.

FTI SERVICES

Fatigue Technology is the world leader in cold expansion technology. We have pioneered this science since 1969 and have advanced the cold expansion process to develop cost savings ideas for production simplification, manufacturing and maintenance time-saving, and improved aircraft structural performance. We offer our customers a full range of services to support their applications.

THESE SERVICES INCLUDE:

- On-site product support
- Technical training
- Engineering/design support
- Product and materials testing
- Research and development services
- Field repairs and upgrades

(Please contact us to discuss your current application.)

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