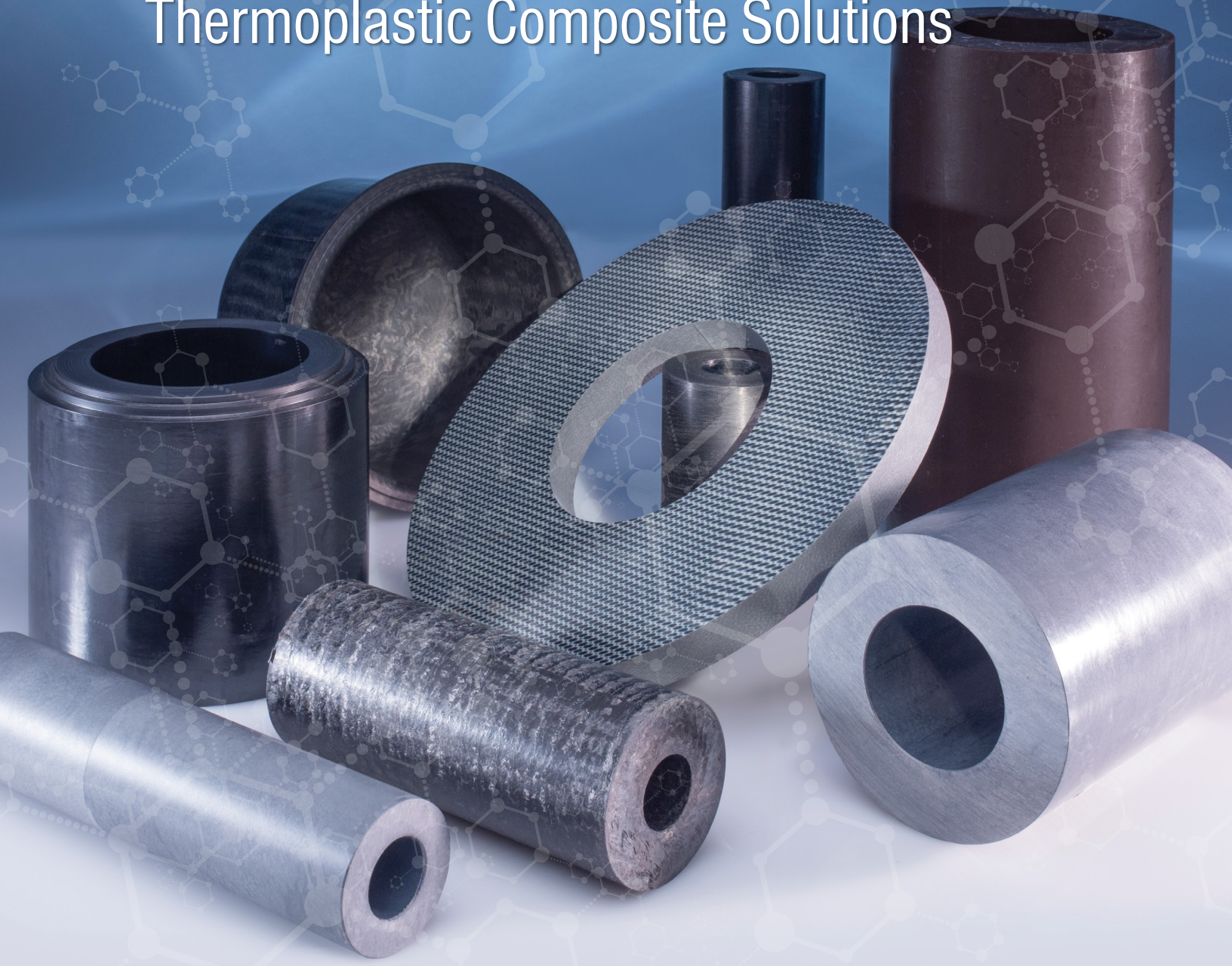




Thermoplastic Composite Solutions



The background of the entire image is a dark blue color. Overlaid on this background is a complex, light blue molecular structure. This structure consists of numerous interconnected hexagonal and pentagonal rings, with smaller circles representing atoms at the vertices of these rings. The structure is spread across the entire frame, with some areas being more dense than others.

For more than 150 years, Greene, Tweed's customers have relied on the company's materials expertise and collaborative approach to the design and manufacture of elastomeric, thermoplastic, and thermoplastic composite solutions that deliver proven performance in extreme and demanding operating environments.

A global company with facilities across North America, Europe, and Asia, Greene, Tweed serves customers throughout a diverse range of markets, including energy, aerospace, defense, industrial, life sciences, and semiconductor.

Introduction

Greene, Tweed offers a proven line of high-performance thermoplastic composites for use in the most extreme upstream, midstream, downstream, petrochemical, and power generation applications.

Our thermoplastic composites keep rotating equipment functioning safely and reliably. We have designed solutions for temperatures ranging from cryogenic to 274°C (525°F) and for aggressive chemicals in all of our market segments. We engineer our thermoplastic composites to withstand high-abrasion and high-wear applications.

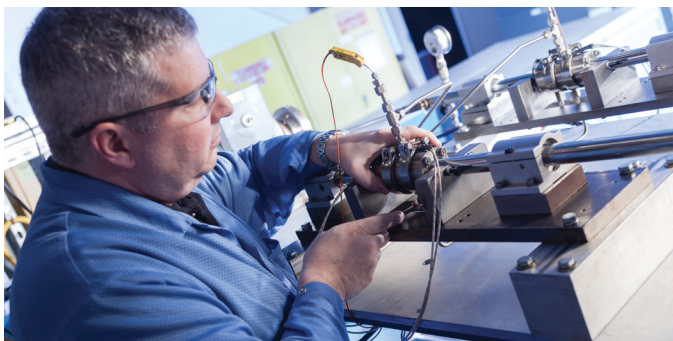
Greene, Tweed's containment shells and pressure vessels, made of thermoplastic composites, are high strength and impact- and thermal-shock-resistant while offering excellent corrosion resistance and dimensional stability.

Customers turn to Greene, Tweed for our thermoplastic composites materials expertise when they cannot afford downtime, lost production, damaged equipment, or health, safety, and environmental issues. We solve application challenges with our best-in-class materials. At Greene, Tweed, we understand the material's characteristics and properties, as well as how to process and manufacture finished parts from these materials.

Our applications engineering team has experience designing equipment at OEMs and service companies in the industries we serve. As such, Greene, Tweed's engineers understand the needs of the energy industry, as well as the failure modes of materials in a wide range of operating environments. We collaborate with our customers to select and provide the best material for the application to keep operations running safely and reliably, while providing needed technical support.

Materials Development

When customers require an alternative to a conventional material solution, they call on Greene, Tweed to recommend a composite to meet their needs.



Our Advanced Technology Group (ATG) pushes the boundaries of current materials technology to engineer new composites that enable future technology requirements. The ATG includes PhDs in diverse disciplines such as Materials Science, Polymer Science, Chemistry, Mechanical Engineering, and Coatings. We are careful and methodical in our development of new materials to ensure we deliver a consistent and quality product, anticipating the most demanding service conditions.

During early material development, Greene, Tweed materials scientists focus on combining the right ingredients in the right formulations to engineer improved performance, leveraging a long history of close collaboration with our customers and understanding their needs and challenges.

We run our materials through a gamut of application-specific performance tests, including chemical, physical, electrical, and mechanical static and dynamic tests, as well as full-scale customer-specific tests, pushing the boundaries well beyond service conditions to define reliable safety factors. When it comes to high-performance thermoplastic composites, our test results give customers peace of mind that our materials will keep their equipment safe and running longer with higher performance.

After testing, our scientists verify we can manufacture thermoplastic composites in production quantities while consistently achieving specifications to deliver best-in-class, quality materials to our customers.

Greene, Tweed manages materials and technology development using the Stage Gate® process, which is founded on the discipline of idea generation derived from market needs. The stages include:

- Scope and feasibility, or the voice of the customer
- Screening tests and design of experiments
- Demonstration through internal tests, independent lab tests, and customer tests
- Pilot production
- Market launch

The Case for Thermoplastic Composites

Fiber-reinforced composites are engineered when a thermoplastic resin is used to bind and support the reinforcing fibers. Together, the thermoplastic resin and fibers act in synergy to become a material with properties that are superior to the individual constituents.

In centrifugal pumps, wear materials act as a buffer between rotating and stationary parts that are traditionally metallic in nature. To avoid galling and possible equipment seizure, dynamic metal clearances are set at a generous minimum as an industry standard. Non-metallic wear parts, such as those manufactured from Greene, Tweed's thermoplastic composites, enable smaller dynamic clearances. A smaller dynamic clearance has two distinct advantages. First, the reduced clearance restricts the recirculation of process media, thereby improving system efficiency. Second, the reduced clearance generates increased fluid pressure around the shaft, resulting in shaft stabilization and reduced system vibration.

Greene, Tweed's high-performance thermoplastic composites deliver wear and abrasion resistance in a variety of materials, temperature ranges, and operating pressures to meet different application requirements. The American Petroleum Institute (API) Standard 610 has included PEEK-based composites since its 9th edition as a viable alternative to metallic wear materials and acknowledges the significant benefits of these advanced materials.

In developing its line of high-performance thermoplastic composites, Greene, Tweed has focused on using the highest quality ingredients – such as PEEK or PFA combined with carbon fiber, Teflon® powder, or graphite – to deliver the best results for chemical resistance, high-temperature applications, high-wear and high-abrasion resistance, and low-thermal expansion.

High-performance thermoplastic composites are a logical choice for corrosive environments. They are lighter weight than metal alternatives and not prone to galling or seizing.

Customers upgrading to composite wear parts from metal wear parts in their rotating equipment have reported the following reliability improvements:

- Improved mean time between repair (MTBR) and routine maintenance tasks as well as reduced mean time to failure for wear rings, bearings, and bushings
- Minimized chance of catastrophic damage to expensive components, such as the shaft or impeller, as observed with traditional metallic wear parts
- Reduced vibration due to tighter clearance
- Improved reliability and efficiency of older equipment
- Reduced equipment life-cycle costs

Thermoplastic Vs Thermoset

Composites are created by bringing the matrix, or glue, into the carbon fiber tows and wetting them out, leading to full impregnation. This can be difficult for fiber in a bundle, weave, or braid, particularly if the polymer is highly viscous, as is the case with PEEK. As a result, composites are typically divided into two styles – thermoset and thermoplastic – which determine their method of creation.

Thermoset composites are polymers with monomers in liquid form, which makes it easy to impregnate the carbon fibers. A chemical reaction then bonds the monomer to create a polymer. The result is a three-dimensional web of molecules that stiffens the fibers. Once the shape sets, it is typically cured at high temperature. However, such a material offers low chemical resistance and wears away quickly.

Greene, Tweed engineers thermoplastic composites, which are highly reliable and extend MTBR. We work through our supply chain to obtain thermoplastic fiber, powder, and film to mix with the carbon fibers, which are seven microns in size, or 10 times smaller than a human hair, ensuring thorough distribution of the thermoplastic. When the mixture melts, the fibers are coated with the thermoplastic, which then cools and sets under pressure.

Thermoplastic-based composites offer naturally superior performance over thermoset composites:

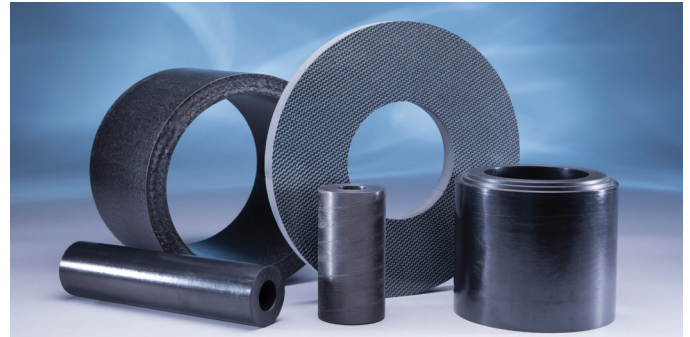
- Much higher chemical resistance
- Lower wear resistance and coefficient of friction
- Higher impact resistance and toughness
- Better damage tolerance, as they retain more strength after damage
- Higher service temperatures, particularly in wet environments, and steam resistance

Materials Families

Greene, Tweed offers three families of thermoplastic composite materials: WR® (Wear Resistant) and AR® (Abrasion Resistant) materials, and Xycomp® containment shells and pressure vessels (structural parts).

Many of these materials are available in a variety of assemblies, finished parts, and stock shapes.

WR® Materials



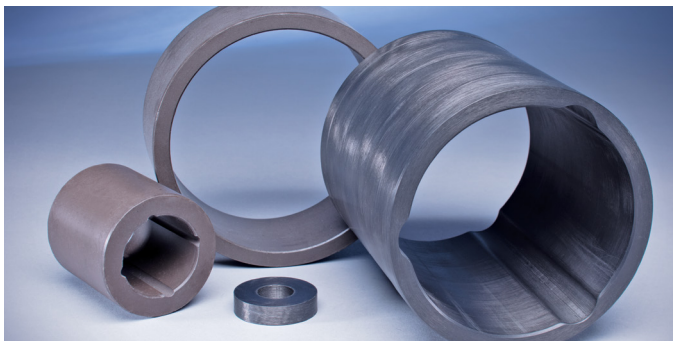
The WR® (Wear Resistant) line offers excellent wear and friction properties, along with superior non-galling and non-seizing performance. The WR® material portfolio enables extended MTBR and improved reliability.

Offering extended dry-run performance and exceptional chemical resistance, our WR® materials reduce running clearances by more than 50% in many cases. These reduced clearances minimize recirculation, which maximizes rotor stability (reducing vibration) and overall efficiency.

WR® materials operate in cryogenic temperatures up to 274°C (525°F). WR® materials are typically PEEK with carbon fibers, although our newest offering in the WR® line, WR® 650, is made of PFA with carbon fibers and provides the best overall performance in the portfolio.

WR® 300 is suitable for general wear resistance and often used for wear rings, bearings, and bushings. WR® 525 provides solutions for wear rings, bearings, and bushings in high-pressure, high-temperature (HPHT) stationary and rotating applications. Components manufactured from WR® 575, such as thrust pads and hydrodynamic bearings, are used in a variety of equipment, including pumps, turbines, and compressors. WR® 650 wear rings, bearings, and bushings provide extended dry-run capability and universal chemical compatibility in critical applications.

AR® Materials

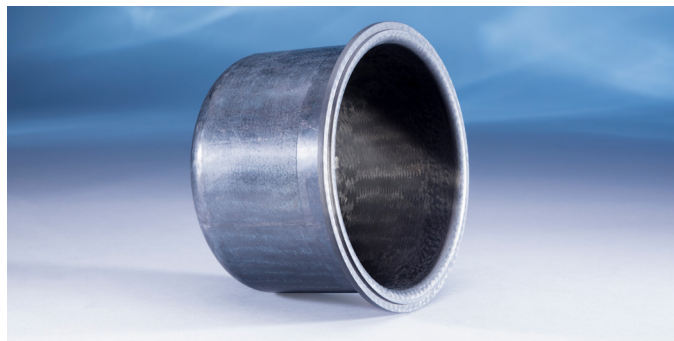


The AR® (Abrasion Resistant) line offers superior abrasion resistance and is less harsh to mating hardware compared to competing materials. The AR® line extends the service life of pumps and reduces downtime for pumps handling media-containing abrasives such as sand, coal ash, and other solids, which can wreak havoc in pumps.

Greene, Tweed's AR® family of materials can operate in subzero temperatures up to 121°C (250°F). The AR® 1 material is filled PTFE, while AR® HT is a blend of PTFE and PEEK.

AR® 1 provides general abrasion resistance and is particularly suitable for vertical pumps, while AR® HT is suitable for high-temperature, abrasive-resistant applications, such as vertical water feed pumps in nuclear facilities.

Xycomp® Materials



Xycomp® materials deliver high strength, low weight, corrosion resistance, and dimensional stability, and may be used in HPHT applications up to 1,000 bar (14,500 psi) at 204°C (400°F) for continuous service conditions.

Xycomp® is ideally suited to replace metals or ceramics as containment shells/pressure vessels in magnetic drive pumps. Xycomp® eliminates eddy current losses for dramatic energy savings and reduced maintenance costs to keep pumps running longer and more efficiently. From improved chemical and impact resistance to excellent post-molding machinability, Xycomp® offers a wide range of benefits for challenging refining and petrochemical applications.

In Oil & Gas Upstream, the ability to x-ray through a Xycomp® pressure vessel enables accurate reservoir sampling while still containing pressure up to 1,000 bar (14,500 psi).

Quick Reference Guide

WR® 300

Material: PEEK reinforced with short, random carbon fibers

Temperature: Subzero/135°C (+275°F)

Application: General wear resistance

WR® 525

Material: PEEK reinforced with continuous hoop-wound carbon fibers

Temperature: Subzero/274°C (+525°F)

Application: HPHT stationary & rotating applications

WR® 575

Material: PEEK-reinforced woven carbon fiber

Temperature: Subzero/249°C (+480°F)

Application: Thruster pads for high-speed machinery

WR® 650

Material: Carbon fiber-filled PFA

Temperature: Cryogenic temperatures/260°C (+500°F)

Application: Extended dry run capability; almost universal chemical compatibility

AR® 1

Material: Filled PTFE

Temperature: Subzero/49°C (+120°F)

Application: General abrasive resistance

AR® HT

Material: Proprietary blend of PTFE and PEEK

Temperature: Subzero/121°C (+250°F)

Application: Higher temperature abrasive resistance

Xycomp®

Material: Carbon-fiber and PEEK composite

Temperature: Cryogenic temperatures/+250°C (482°F)

Application: Containment shells and pressure vessels

Markets

Greene, Tweed provides innovative composite materials and products for refineries, chemical plants, power generation facilities, and desalination plants.

Chemical and Hydrocarbon

In challenging environments, components must withstand aggressive media across a wide range of application parameters. With abrasive and/or corrosive liquids and slurries often leading to machinery failure and costly downtime, pump users require components that can help maintain consistent production capabilities. Our composite materials, used in most API 610 pump configurations, have performed successfully in demanding environments for more than a decade.

Power Generation

Fluids containing sand and other abrasives continue to be an issue for the power industry, creating expanded running clearances and reduced pump efficiency. Ultimately, equipment failure and unit shutdowns occur, lowering plant production. Greene, Tweed's composites last up to five times longer than traditional materials, while reducing downtimes and maintenance requirements.

Water and Wastewater

Enabling the collection, purification, and distribution of safe drinking water is a critical function of this industry's operations. Pump components must be thoroughly vetted to ensure they do not contaminate the water supply prior to being used in any drinking water application. Our composite materials have received WRAS (Water Regulations Advisory Scheme) approval and have been proven safe and effective for drinking water pumps.

Contact Greene, Tweed today to discuss how we can solve your challenges.



Tel: +1.281.765.4500

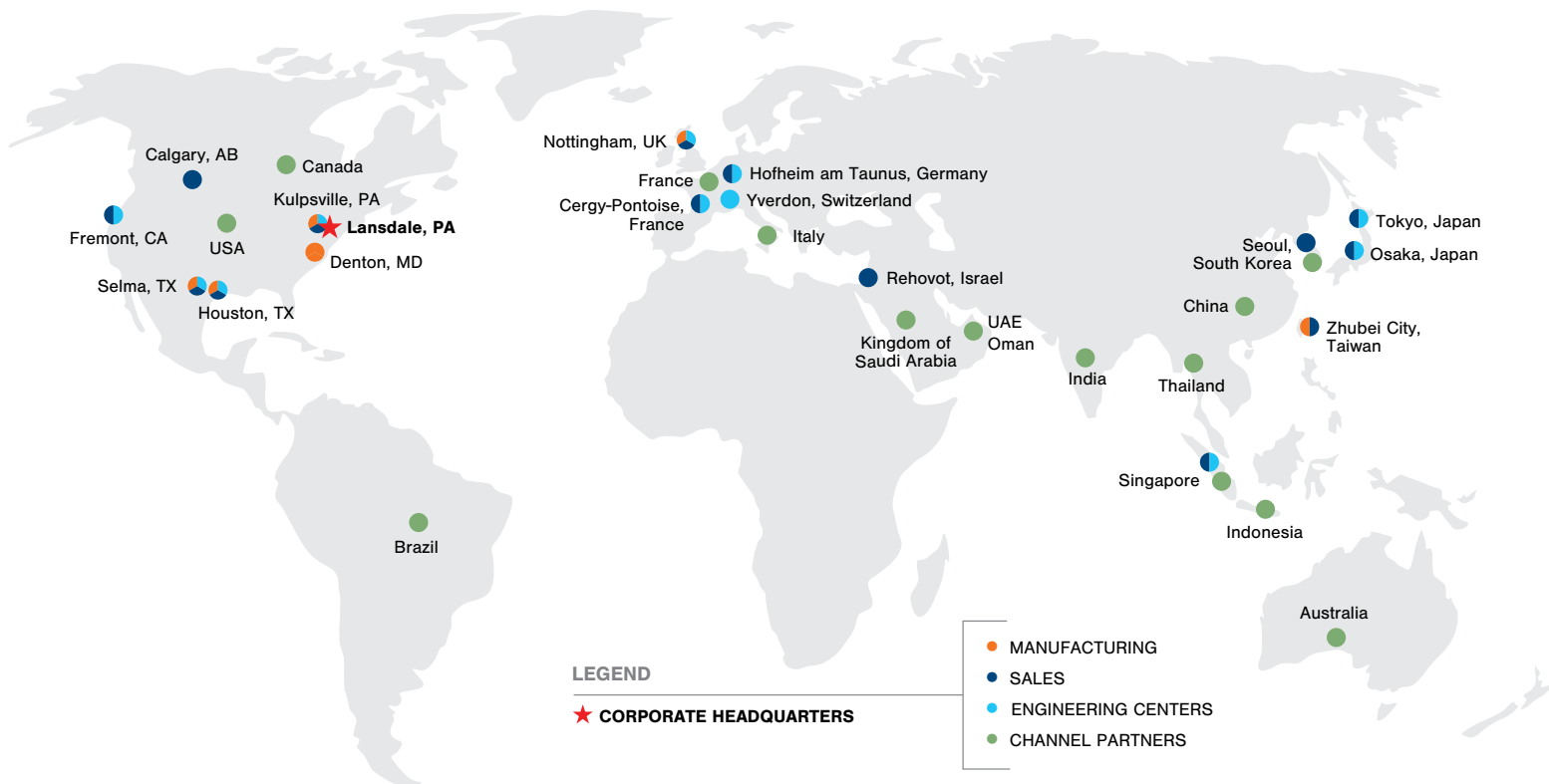
Fax: +1.281.821.2696

www.gtweed.com

Where We Play

Global Presence, Local Service.

With more than 1,600 employees across 11 countries, Greene, Tweed offers material, design, engineering, and manufacturing expertise worldwide, collaborating with customers to meet their critical challenges through the development of custom-designed, leading-edge components.



Contact Us

Greene, Tweed
Houston, TX, USA

Tel: +1.281.765.4500
Fax: +1.281.821.2696

Statements and recommendations in this publication are based on our experience and knowledge of typical applications of this product and shall not constitute a guarantee of performance nor modify or alter our standard warranty applicable to such products.
© 2019, Greene Tweed all rights reserved. All trademarks are property of their respective owners.

1/19-GT BR-US-EN-013

www.gtweed.com