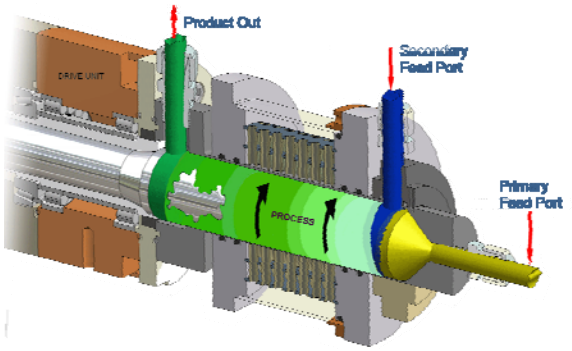
The STT® System



About Four Rivers BioEnergy

At Four Rivers BioEnergy Company, Inc., we have pioneered a break-through system for the manufacturing of chemicals, pharmaceuticals and energy products. Named STT® after its spinning tube-in-tube design, the system's unique two-dimensional flowing film format produces significant time and cost savings over traditional production methods. The STT® advantage lies in avoiding the problems and inefficiencies which are present in most conventional manufacturing processes. With its broad applicability and flexibility, STT® technology allows us to accelerate the rates of chemical reactions by up to three orders of magnitude, increase conversions and yields, control the quality of chemical processes in real-time, and lower costs. Additionally we can dramatically decrease the time required for manufacturing scale-up.

We have successfully applied the STT® system to the manufacturing of biodiesel at bench and pilot scale from a variety of different feedstocks. Working with our government partners at the United States Environmental Protection Agency (USEPA) as well as our academic collaborators, we are now applying the STT® system to the manufacturing of a number of commercially important chemicals and can advantageously impact the economics of green chemistry.

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Our patented STT® approach provides simple and effective solutions to many of the manufacturing issues related to the production of chemicals, pharmaceuticals, and energy products caused by intense competition, intellectual property issues and government regulation.

The key is STT®'s two-dimensional flowing film approach that improves manufacturing efficiencies and enhances cost savings as well as providing novel and unique formulation methodologies. Advantages of STT® relative to conventional mixing methods include:

- **Rapid and Uniform Mixing** - The high shear flow that is responsible for the mixing within STT® is much more energetic than that achievable in a conventional volume-based mixer, resulting in mixing at the molecular level. This more vigorous type of mixing leads to faster reaction processes and higher yields. In addition, the flowing format results in less waste due to production failures. The system can process gases, liquids, and viscous solids, and is suitable for mixed-phase reactions. Use of our STT® system can also reduce solvent and catalyst requirements lowering production costs.

- **Precise Temperature Control** – The two dimensional format of STT® enables precise temperature control. This differs from a conventional, three dimensional environment of a volume-based system where considerable temperature variations between one part of the mixing vessel and another may exist due to distance from the heating source. Precise temperature control increases yield and leads to better product quality control and less likelihood of batch loss.

- **Broad Range of Uses** - STT®, in modified configurations, has a number of commercially important uses. STT® can be used to control the size or morphology of chemical crystals, to optimally combine different types of chemical substances, and to produce uniform particle coatings. It can also be used to formulate very high potency drugs for which it is necessary to uniformly mix a small amount of the active pharmaceutical ingredient with a relatively large amount of excipient. Each of these processes serves an important role in the formulation of specialty chemical and pharmaceutical products. In addition, STT® technology has demonstrated an ability to improve the yield of bioproducts from tissue culture systems, and is also capable of producing customized micro-composite materials for electronics applications. Four Rivers is installing the STT® technology to manufacture biodiesel. This variety of capabilities cannot be found in any one conventional mixing system.

The STT® System

- **Scalability** – STT® is highly scalable because important reaction parameters of STT® that affect rate of mixing and heat transfer, such as the flow rate and the gap between the rotor and stator, are not altered by increasing the size of the system. Thus, the transition of the chemical process from pilot scale to production scale systems is seamless. We have demonstrated the scale-up of a pharmaceutically-relevant chemistry from research bench to pilot plant levels in a single day.

- **Customizability** - The STT® flowing film format approach permits an unprecedented level of control of reactions, resulting in the more efficient and less costly manufacture of products. The operating parameters of STT® can be adjusted to match those of the process being run, including matching the STT® reactor's mixing speed with the reaction rate, controlling the stoichiometry of the reaction through the proper introduction of reactants, adjusting the flow pattern of reactants in STT® with the reaction mechanism, setting residence time in STT® with the reaction time, and balancing the heat transfer characteristics of STT® with the reaction isotherm.

- **Dynamic Monitoring** - STT® allows for the progress of the chemical reaction to be monitored continuously and in real time. If a problem occurs, a process can be halted and the problem corrected with a minimal loss of valuable reagents. In contrast, conventional volume-based systems require a significant degree of additional effort, expenditure and complexity to attain and maintain a continuous oversight of reactions. As such, a production problem generally leads to a loss of most or all of the reagents since they are all combined at one time.

- **Unique Approach** – STT® incorporates a novel and unique approach to the production of chemicals, pharmaceuticals, food products, materials used for electronic applications, wastewater treatment and energy products. Our STT® process and unique spinning-tube-in-tube design is covered by 15 issued patents and several pending patent applications. Where appropriate, patents have been filed throughout the world.

- **Size** – Our commercial scale STT®'s are small in size but can produce the same amount of product as a much larger conventional reactor. This process intensification is possible due to the increase in reaction rates that we achieve from the intense shear generated in the reactor. For example, biodiesel transesterification can be done in less than 1 second in the STT® system.

A commercial size STT® reactor capable of producing over 13 million gallons per year of biodiesel from various feedstocks.

STT® achieves these advantages by inducing a physical phenomenon that is conceptually ideal for the mixing of reactants called Couette flow. We induce Couette flow by mixing reactants in a narrow annular gap between a stationary stator and a quickly rotating, concentrically positioned internal rotor so that the reactants move as a coherent thin film. We are the first company that has been able to practically apply Couette flow to manufacturing.

Until the advent of STT®, Couette flow was not suited to manufacturing applications because it often generates tiny radial whirlpools called Taylor vortices that disrupt the mixing process. The Taylor vortices create boundaries between the different materials entering the system and hinder their interaction. Thus, for example, if a red and a white liquid were introduced into a standard Couette mixer with its Taylor vortices, the thin film created would resemble a Barber pole. We have developed STT® to induce Couette flow without the production of disruptive Taylor vortices by modifying conditions relating to circumferential rotor speeds, the smoothness of the rotor and stator surfaces, and the size of the annular gap.