Overview of Renewable Densified Fuel, LLC Proprietary

Manufacturing Process

Renewable Densified Fuel, LLC (RDF) has developed a patent pending technology that produces a high Btu (10,000 Btu/LB), low ash sustainable biomass fuel. This fuel can be customized using a variety of biomass, agricultural and process byproducts to create a biomass fuel with specific characteristics for existing industrial and commercial boilers currently burning coal or biomass. This renewable biomass fuel was developed in consultation with boiler and grate manufacturers and has been targeted for use in industrial and large commercial or institutional solid fuel boiler applications that combust fuel at very high temperatures without changing existing infeed or handling systems. The renewable densified fuel produced from this application has a target value of 10,000 Btu/LB based on laboratory testing during the past two years of nearly 40 different mix designs using a variety of biomass "residuals" as well as pulp and paper mill residuals. The various mix designs developed for specific boiler applications have used a variety of “biomass” or renewable feedstocks such as urban wood waste, sawmill residuals, pulp mill and paper residues (pulp mill screenings/rejects, cardboard waste fiber) forest slash, agricultural residues such as corn stover, energy crops such as switch grass, as well as other biomass residuals (i.e. dust collection fines, sawdust, etc.) from flooring, molding, and other wood product industries.

The incoming biomass feedstocks can be combined in a variety of combinations however the feedstocks should be uniformly sized to ¾” minus. The average (incoming) target moisture content of feedstocks is approximately 10% which after processing typically produces a biomass fuel with less than 3% moisture and 2% ash depending on the biomass or residual feedstocks used to produce the densified fuel. In limited applications a small amount of the “biomass” feedstocks can be replaced with waxed cardboard and other "waste paper residuals" that could not be recycled or are "residuals" from paper sorting-recycling lines. Use of these items as feedstocks however increases fuel ash content which has been problematic in some boiler applications.

311 West Buffalo Street
New Buffalo, Michigan 49117
Toll Free: (877) 733-9033 Fax: (269) 469-5937

Added to the biomass feedstocks is a small amount of a Reconstituted Carbon Binder or RCB that is sourced as either recycled HDPE (No.2) or LDPE (No.4). These recycled products (i.e. retail bags, milk containers, liquid laundry containers, etc) are used for their high carbon and hydrogen makeup and relatively low melting points when producing this fuel. The result is a very durable fuel which provides a water resistant surface which is superior to other biomass fuels not using this technology with RCB. This allows for the densified fuel to be shipped via a variety of transport systems as well as being able to be delivered into boiler systems without any special handling requirements. This feature also allows for outside storage of this fuel for limited periods of time without any significant (Btu value) or physical degradation. The flexibility of this proprietary system allows for densified fuel to be formed into various configurations easily with a die change typically requiring 20 minutes or less to accommodate production of fuel to specific diameters and lengths and is some instances the ability to grind this fuel to 1" or ¾" in size (similar to coal). Unlike other biomass fuel systems this process produces a high Btu value, low ash renewable densified fuel to end users specifications (i.e. size, shape and density) in order to meet specific industrial or utility boiler applications. The ultimate fuel Mix Design for an assignment is in part based on utilization of available biomass or residual biomass feedstocks, shipping, storage and handling requirements which vary from geographic regions and from assignment to assignment. This is very different than producing smaller generic "pellet" fuel marketed primarily for residential use sold at the retail level. This fuel is not made for the residential market.

The typical diameter of the densified biomass fuel product using this proprietary process is between 1" – 1.25" (2.5 CM - 3.2 CM) and it is sized to various lengths. The fuel shown in Image 1 ranges from 1" – 3" (2.5 CM – 7.6 CM) in length and is 1" – 1.25" (2.5 CM – 3.2 CM) in diameter. The mix designs in this image include particle board mixes, agricultural residues, infested trees (i.e. beetle kill biomass) and urban wood wastes. Image 2 represents various 1" diameter (2.5 CM) mix designs using pulp and paper residuals, forest slash, "hard and soft wood" as well as a ¾" (1.9 CM) diameter fuel for a smaller boiler feed system. The use of recycled or post consumer HDPE or LDPE in the RCB was selected due to its ability to quickly dissolve into its components of carbon and hydrogen (within the Thermal Mixer) which allows for the RCB to infuse into the biomass quickly during the initial few seconds of the production cycle. During the final stages of the production cycle the temperature within the Thermal Mixer system reaches 300^0 F and the RCB displaces "residual moisture" contained within the biomass, agricultural residues, etc. (that evaporates during the cycle) prior to being discharged to the variable hydraulic press system to create a specific size or shape of densified fuel. The melt point and properties associated with the RCB was a key breakthrough when developing this densified biomass fuel technology. Use of the RCB eliminates crumbling, dusting and creates a product with superior handling, storage and combustion characteristics (very low emissions) when used in conjunction with coal fired systems or boilers using high moisture biomass (over 30% moisture content). In these applications the densified fuel is designed to deliver more effective, cleaner energy with less ash. When used in existing biomass fired boilers that use high moisture biomass or wood chips (as a primary fuel) co-firing of Renewable Densified Fuel at a rate of 25%-40% of the total biomass fuel improves boiler efficiency due to the lower total moisture content and promotes more effective and complete combustion when compared to the wet biomass which also reduces residual ash generation.

IMAGE 1: Four Mix Designs of One Inch Renewable Densified Fuel Sized to Various Lengths

In August 2007 a large scale boiler test was performed (following USEPA protocols) at Flambeau River Papers, LLC No. 6 Boiler in Park Falls, Wisconsin. The strategy at this facility was to replace supplemental coal being co-fired with hog fuel (biomass) used by the primary boiler. Densified fuel production began in Park Falls, Wisconsin in December 2008 after formal approval was granted by the Wisconsin Department of Natural Resources (WDNR) to FRP to use this renewable fuel in early December 2008. The second bi-annual emissions testing of No. 6 Boiler is scheduled for October 2009.

IMAGE 2: Examples of One Inch (2.5 CM) and ¾ Inch (1.9 CM) Diameter Renewable Densified Fuel Sized to a Nominal Length of 2" (5.1 CM)

A simple description of the process that produces this unique biomass fuel requires biomass feedstocks or other biomass residuals to be sized to ¾" minus and dried to the target moisture of near 10%. The biomass feedstocks are combined with the RCB in a combined feedstocks mixer. Several of these mixing systems are commercially available and are very effective for mixing these feedstocks (Ribbon mixers, agricultural feed mixers, etc). Several different biomass or residual biomass feedstocks can be mixed together at the same time (i.e. hard woods, softwoods, urban wood, pulp and paper residuals, agricultural residuals, etc) assuming a Mix Design exists using these biomass feedstocks. When making a fuel for a specific application multiple biomass and process residual feedstocks exhibit densities which will impact (slightly) pressure settings. Agricultural residues have much less density than woody biomass, however this proprietary densified fuel system can adjust for a wide range of biomass or process feedstock densities. This is important when producing a densified fuel for a specific user to maintain uniform handling, combustion characteristics and of course Btu value. The use of the RCB is impacted by all of these issues in order to maintain and create a high value fuel to insure good combustion properties. Therefore, appropriate design and planning for your project results in the ability to accommodate these factors easily and provides more flexibility as biomass supply markets change over time. Flexibility in feedstock supply and flexibility in mix designs is another feature of this process.

After the feedstocks are mixed together the feedstocks are conveyed (via belt, auger or with lighter feedstocks pneumatic conveyance systems) into a surge bin. The surge bin based on your facility design should be capable of holding an adequate supply of combined feedstocks (i.e. the project mix design) for constant infeed in to the patent pending Thermal Mixer.

Combined feedstocks are fed via an auger into the Thermal Mixer. The target temperature at the beginning stage within the Thermal Mixer is set to at least 275^0 F. Using PLC the combined feedstocks are transferred from the surge bin into the Thermal Mixer. The feed rate into the Thermal Mixer is based on the density of incoming feedstocks. The nominal throughput of the proprietary production system marketed in the United States is 3.5 to 4.0 tons per hour (TPH). Upon entering the Thermal Mixer the RCB is liquefied (in seconds) into its elemental components of carbon and hydrogen. The biomass and the RCB mix together for several seconds while the biomass continues to heat to between 275^0 – 300^0 F. During this stage of the process any residual moisture contained in the biomass evaporates and is replaced by the RCB. At the end of the cycle the RCB has infused the liquefied carbon and hydrogen into the biomass. The heated mixture exits the Thermal Mixer directly into the adjacent press tube. The variable hydraulic compaction system presses the heated mixture through the systems proprietary die. This die provides a specific compaction profile for the material mixed within the Thermal Mixer and can be changed easily and quickly (typically in 20 minutes) to provide multiple sizes of densified fuel to (potentially) multiple end users. Therefore, the fuel can be designed for stoker grate applications or suspension boilers (which requires the fuel to be pulverized prior to its introduction into the boiler) or for different size infeed systems for boilers at different locations.

The densified fuel exits the die at variable lengths and can be cut to a specific length prior to cooling. Typical diameters of densified fuel produced using this system range between ¾" to 2" and lengths range from 1.5 "to 4.0". Standard commercial conveying systems transport the still "hot" densified fuel (exit temperatures range between 250^0 - 300^0) to a "cooling station" using either a cooling conveyor or other similar commercial cooling systems. Image 3 illustrates the handling and storage system used for the densified fuel produced for FRP No. 6 Boiler. A font end (bucket) loader removes the fuel as needed from this bunker and delivers the densified fuel into the mills boiler along with other biomass.

IMAGE 3: Outside Fuel Storage Bunker for Renewable Densified Fuel for No. 6 Boiler at Flambeau River Papers, LLC Park Falls, Wisconsin

After WDNR approval this new plant began producing densified fuel for the mills boiler system using a proprietary mix design developed for Flambeau River Papers, LLC based on their feedstock profile. Image 4 is a view of the renewable fuel bunker and the front end loader removing fuel for delivery into the infeed system at No. 6 Boiler. Image 5 is the south end of the densified fuel plant and renewable storage bunker taken in January 2009. Image 6 and Image 7 illustrates how the densified fuel is introduced into existing No.6 Boiler biomass feed system – no changes in the boilers handling or infeed systems. Densified fuel is removed from the outside fuel bunker via a front end loader (See Image 4) and then directly into the existing infeed system that contains bark, biomass and Renewable Densified Fuel.

The densified biomass fuel used in this boiler was targeted to replace coal that was co-fired with the existing ground biomass with average moisture content (seasonally adjusted average) of approximately 42%. The densified biomass fuel was designed to combust like coal without changing fuel storage or boiler infeed systems and significantly reduced the boilers carbon footprint as well as total sulfur emissions without adversely impacting routine system operations.

IMAGE 4: Front End Loader Retrieving Renewable Densified Fuel from Bunker at Flambeau Rivers Papers. LLC Park Falls, Wisconsin May 2009

As mentioned previously, emissions tests were performed under normal operating conditions at Flambeau River Papers No. 6 Boiler during the mills required bi-annual compliance testing. This boiler historically used up to 50 tons per day (TPD) of coal (winter months) co-fired with 450-500 tons per day of biomass, with the biomass having a moisture content ranging between 35%-45%. The objective in this application at the paper mill was to illustrate the use of this densified biomass fuel to replace the coal co-fired with biomass in the No.6 Boiler. Testing indicated that sulfur emissions were drastically reduced and other regulated emissions also improved. The use of the densified biomass fuel also displaced an estimated 15,000– 20,000 tons per year (TPY) of carbon previously attributed to coal used at this installation. The carbon footprint of the mill was reduced significantly while beneficially reusing onsite biomass fines and process residuals generated from the mill. The change over from coal to Renewable Densified Fuel also improves the ash quality making the ash produced by No. 6 Boiler available for evaluations in other beneficial use options.

.

IMAGE 5: View of Densified Fuel Plant and Renewable Fuel Bunker (right of building) for No. 6 Boiler Fuel January 2009

IMAGE 6: Renewable Densified Fuel Comingled with Bark and Biomass at No. 6 Boiler Park Falls, Wisconsin

IMAGE 7: Close up View of Distribution of Renewable Densified Fuel Comingled with Bark and Biomass at Flambeau River Papers, LLC Park Falls, Wisconsin

The No.6 Boiler shown in IMAGE 8 is permitted by the WDNR at 249,000,000 Btu/hour and produces over 160,000 pounds per hour of high temperature, high pressure "process" steam for use in the paper mill and generates 5 MW of electricity, also used by the paper mill. A portion of the densified fuel used for the 2007 boiler tests used pulp mill rejects or "knots" to illustrate beneficial reuse of pulp mill residuals (at 30% of the total mix design for the densified fuel).

The mix design for the FRP No. 6 Boiler will continue to use reclaimed fines from the mills biomass grinding/hogging operations and knots generated from the pulp mill. A fines recovery system was installed as part of this project to provide biomass residuals to the onsite densified fuel plant and also reduces potential fugitive emissions from the boilers biomass handling systems.

IMAGE 8: A view of Flambeau Rivers Papers, LLC No. 6 Boiler from the Densified Fuel Production (North end of wood yard) Plant Park Falls, Wisconsin

This patent pending technology is unique in the way multiple biomass feedstocks are combined to produce a high Btu value, low ash renewable biomass fuel. Over time feedstock supplies as well as pricing may fluctuate and this technology is adaptable and produces a sustainable fuel that can use existing infeed or fuel handing systems at most boilers and power plants. The fuel is very durable, resistant to moisture and precipitation, and can be shipped via dump trucks, live bottom trailers, in Gaylord containers, super sacks, by rail or barge with minimal physical or BTU degradation. It is a simple renewable alternative to use either as a supplemental fuel in existing high moisture biomass boilers or as a replacement for carbon based fuels in existing coal fired systems. This is an example of “green” made easy.