Considerations for multi-fuel pellet fired boilers

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Detroit Stoker Company first developed grate systems for industrial facilities firing woodchips/ bark in 1947. Since that time Detroit Stoker has provided combustion equipment for a wide variety of renewable biomass fuels including bagasse, agricultural refuse fuels and urban refuse fuels.

For the past decade owners have been facing the reality of removing fossil fuels from their existing combustion systems, therefore Detroit Stoker has seen a notable increase in retrofitting existing coal fired boilers to utilize biomass and wood pellets as the primary fuel. To date, these facilities traditionally have no or limited access to a constant supply of biomass. Generally, these facilities are looking to maintain fuel flexibility and often elect to fire 100% pellets, 100% wood chip/ bagasse or co-fire a mixture of the two.

Retrofitting existing boilers from fossil fuels to traditional biomass fuels are often problematic. The original combustion system's performance design values are significantly different between coal and biomass. However, wood pellets, due to the higher calorific value and lower moisture, tends to make retrofitting easier. Yet, the range of biomass fuels other than wood pellets leads to difficulties for boiler designers to accommodate performance requirements.

Fuel Type	Moisture %	*LHV (MJ/kg)	Ash %	Chlorine %	Nitrogen %	Sulfur %
Wood Pellets	5-10	16,000-19,300	1.5	0.05	0.3	0.05
Bagasse	40-50	7,500-8,600	3-5	0.02-0.15	0.3-0.6	0.03-0.1

*Lower Heating Value

Table 1: Fuel Constituent for Bagasse & Pellets.

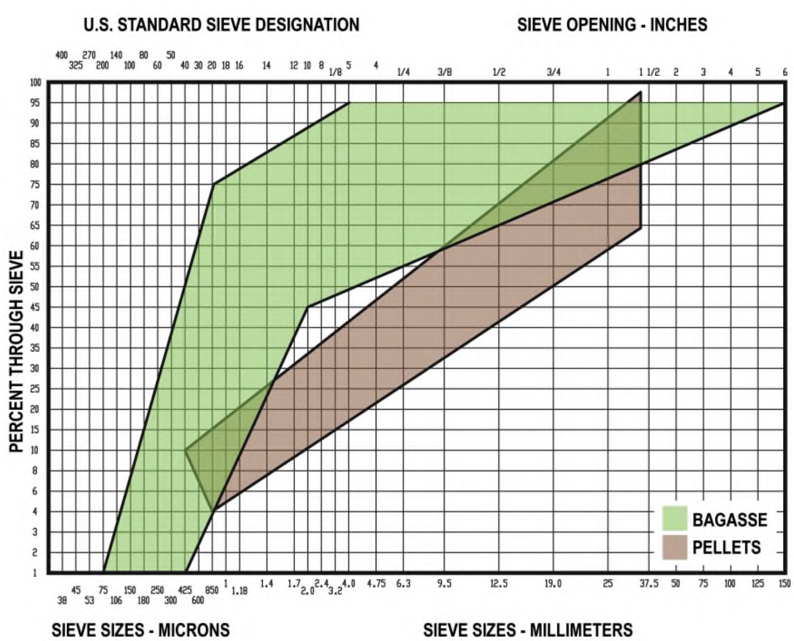

Figure 1: Bagasse & Pellet Recommended Sizing Curve.

Detroit Stoker continues to pursue new biomass projects specifically designed for wood pellets and alternative biomass fuels. Due to our experience with retrofit applications, we are better able to focus on technical recommendations for new pellet fired combustion systems.

Fuel

Refuse biomass fuels, such as bagasse, and pellets are two very different fuels which both present difficulties in handling and firing. Fortunately, Detroit Stoker has experience with both fuels. Bagasse and wood pellets have significantly different fuel constituents (Table 1) and sizing (Figure 1). Generally, switching a fuel from higher moisture (50%) to lower moisture (<10%) creates problems with fuel handling, combustion controls, and overheating of primary grate elements.

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Performance Recommendations and Combustor Design

Detroit Stoker Company is not a boiler or steam generator provider. Rather we are a provider of combustion equipment, having integral combustion air systems and fuel metering / distribution equipment. We work with a wide variety of boiler designers and providers throughout the world. By working with both international and regionally based boiler companies we have an extensive experience with fuels and their combustion characteristics. For the past 2 decades, it has become imperative that the main furnace be conservative in design to allow for staging of the combustion process to provide the best performance, consistent thermal input, emissions, and reduction of unburned carbon loss. This relates to the boiler/furnace being taller and having lower volumetric thermal release rates than in the past. Table 2 notes recommendations for design parameters for a modern biomass boiler. Figure 2 illustrates a typical biomass boiler fulfilling recommended design values.

Design Factors	Recommended Values
Grate Heat Release Rates	2.1 – 2.3 (MW/m^2, *LHV)
Volumetric Heat Release Rates	0.10 – 0.12 (MW/m^3, *LHV)
Furnace Residence Time	<3.0 (Seconds)

*Lower Heating Value

Table 2: Recommendations for Combustor Design Values.

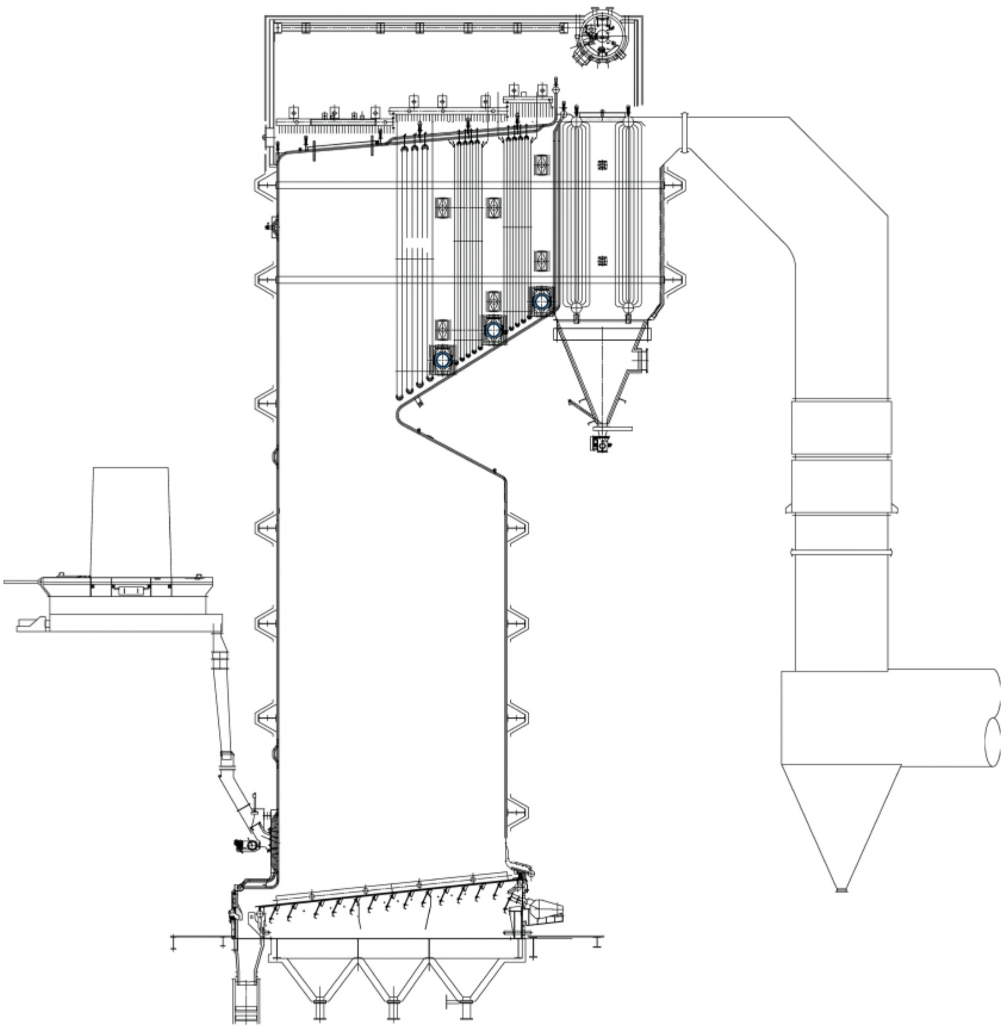

Figure 2: Configuration of a Modern Biomass Boiler.

In addition to design recommendations for the boiler. Detroit's water-cooled, vibrating conveying grate system, the HydroGrate, is the ideal choice for firing any combination of wood pellets and other biomass fuels. The HydroGrate stoker is a modular unit that utilizes an intermittent ash removal system. The grate surface vibrates intermittently at low amplitudes to move the ash/ fuel bed forward to discharge the ash off the front. The vibration of the grate is transmitted to the vibrating frame by an eccentric grate drive and supported by flex straps which isolate vibrations from the fixed frame and structural steel.

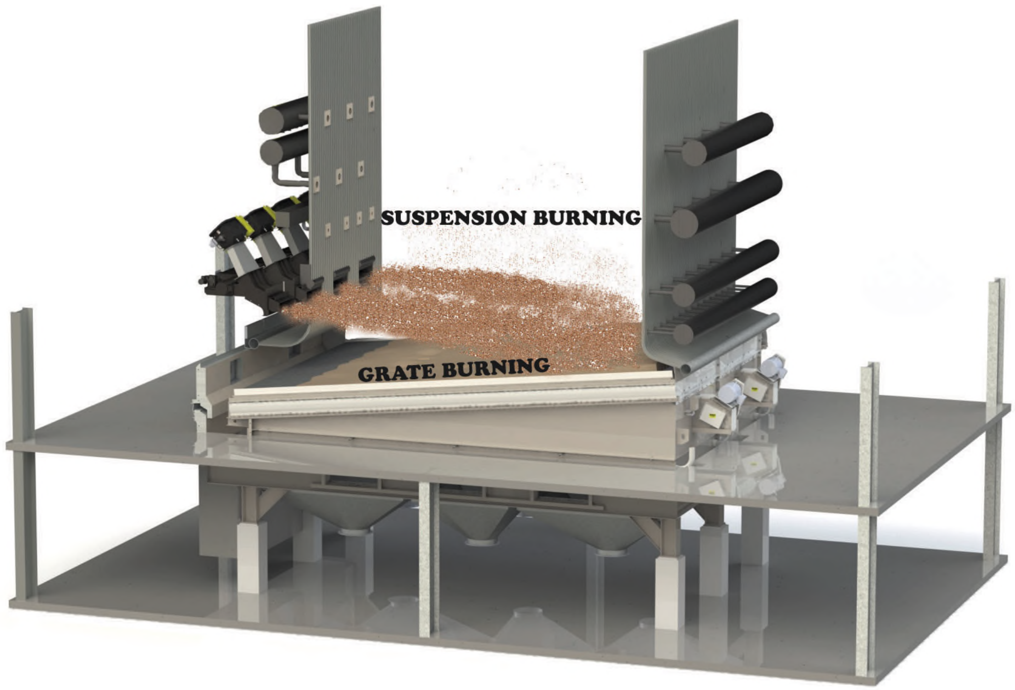

Figure 3: Detroit® Hydrograte Pellet Installation.

The grate surface is constructed of water-cooled tubing which circulates deaerated boiler quality water through a multi-pass grid helping maintain low component temperatures. This cooling effectively increases the longevity of the grate surface reducing maintenance costs. The cooling grid tubes are also covered by cast elements to reduce any abrasion to add additional service life. The cooled surface can fire a wide range of fuels and fuel moistures, ranging from low moistures of 5% up to higher moistures of 60% due to the fact primary combustion air is set for combustion and not to maintain grate temperature.

To assist in the drying of high moisture fuel the Detroit® HydroGrate is capable of handling up to 371°C (700° F) primary air. When firing low moisture fuel, such as pellets, primary air temperature should be lowered to delay moisture evaporation. Primary air enters below the grate surface in three (3) zones per module. Zone dampers provide flow control to each zone independently allowing control to drying of high moisture fuels, combustion control, and ash cooling through orifices located on the grate surface. The HydroGrate stoker with modular construction is shipped shop assembled and ready for installation. Biomass units are designed to provide an additional level of combustion air to provide flexibility in operation and performance. Earlier units often were designed with limited capacity secondary air systems, typically 35 – 40% of the total combustion air. Newer units are designed with 50 – 60% capacity of secondary air to increase the flexibility of fuels fired. Additionally, extra rows of secondary air have been added higher in the furnace to increase control of the combustion and provide operators more tools for reducing emissions and flue gas temperatures. This secondary air system in the most useful tool to provide control of emissions and combustion control for a varying range of fuels.

The HydroGrate stoker is a modular unit that utilizes an intermittent ash removal system and is the ideal choice for firing any combination of wood pellets and other biomass fuels.

These systems provide turbulence and mixing of suspended fuel particles, staged air nozzles are used to lower both thermal NOx & CO. Special attention must be given when designing secondary air systems for European folded boilers as the rear wall arrangement and wide range of fuels require specific arrangements in order to be effective. Air nozzles are interlaced on the front and rear walls on the furnace with a maximum of five (5) levels. Nozzle layouts, diameters, and pressures are optimized for specific fuel characteristics and should be reexamined in the event of a major fuel change.

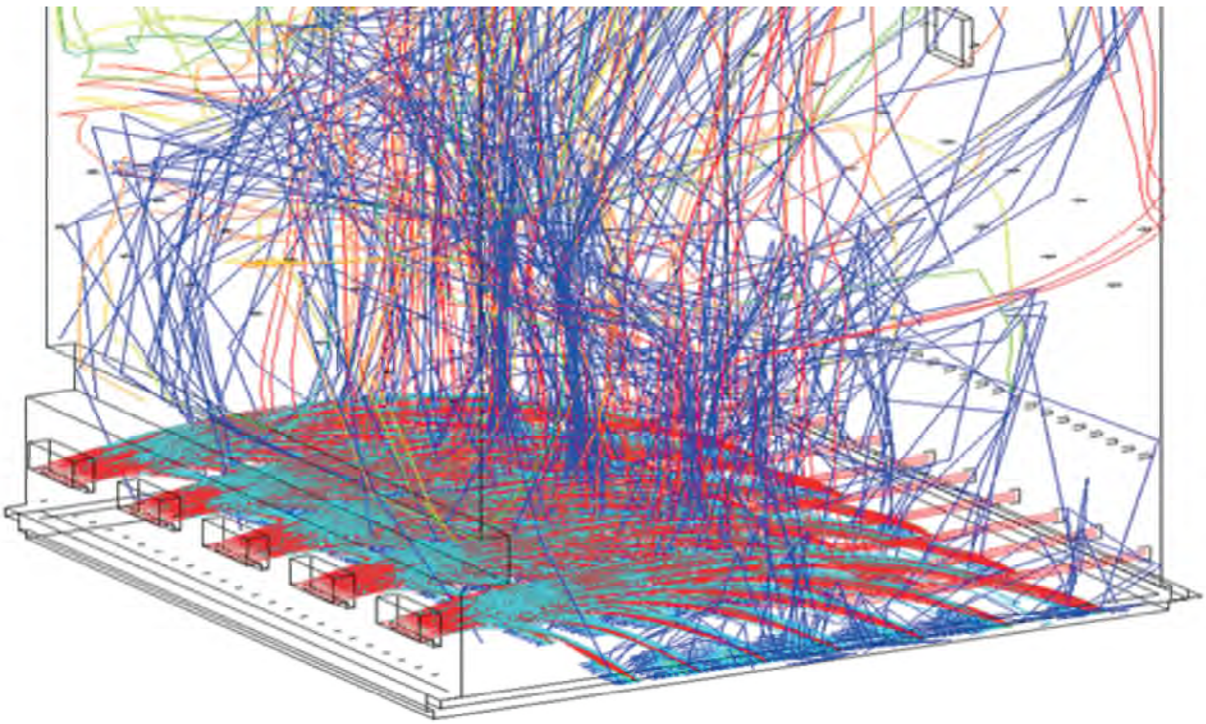

Figure 4: Properly adjusted combustion air showing mixing of particles.

It is imperative that fuel types be examined before selecting the source of preheated air or use of ambient combustion air. Low moisture fuels, such as pellets, require relatively low temperature preheated air or ambient air. This can be sourced from a properly sized tubular air heater or a steam coil air heater.

Tubular air heaters have limited control over the outlet air temperature as these are sized to achieve a target temperature at specific steam loads. Tubular air heaters are practical for facilities firing consistent low moisture fuels as the output cannot be easily adjusted. However, fuel sources which vary in moisture and type require flexibility when controlling the preheated air temperatures. Steam coil and water coil air heaters provide this flexibility. Outlet air temperatures can be controlled by adjusting steam or water flow through the tubes allowing temperatures to be increased to expedite moisture evaporation for high moisture fuels and to lower temperatures to reduce thermal NOx for drier fuels.

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Fuel Metering and Distributon

Despite combustion design, establishing the best possible fuel metering and distribution is imperative to the operability of a solid fuel boiler. The Detroit® Bagasse Triple Drum Feeder and Detroit® Pellet Metering Feeder are two equipment systems engineered to handle these difficulties. The Detroit® Bagasse Triple Drum Feeder, shown in figure 5, supplies fuel to the furnace at a closely controlled and uniform rate. The feeder consists of two (2) metering drums which control the flow of the refuse biomass fuel and one (1) carding drum to sort material into a consistent and uniform fuel flow. Bagasse is then distributed evenly into the furnace via a Detroit® Air Swept Distributor Spout.

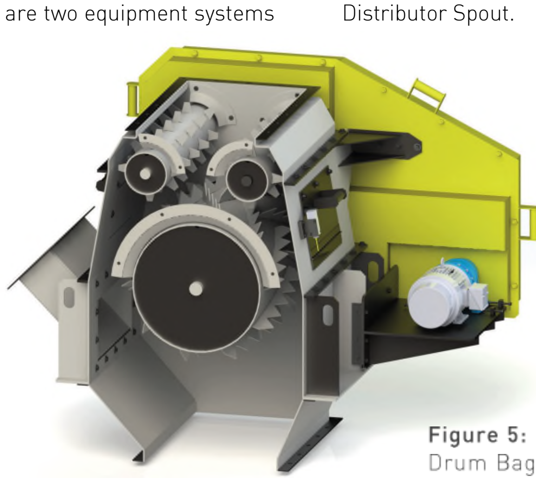

Figure 5: Detroit® Triple Drum Bagasse Feeder.

Wood pellet's free flowing characteristics present many unique challenges when attempting to handle the fuel by traditional means. Screw metering bins are typically used with woody biomass fuel; however, these systems are ineffective at consistently feeding pellets into the furnace. Screw conveyor design allows pellets to slug feed, resulting in an unstable surging effect within the furnace. Furnaces utilizing screw conveyors as the primary pellet metering devices experience uneven fuel distribution and erratic fuel flow swings. Detroit's research and development into chute design and distribution using conventionally designed rotary valves showed pellets will bias one side of a chute if not metered correctly. This bias causes fuel piling on the grate surface resulting in overheating grate equipment.

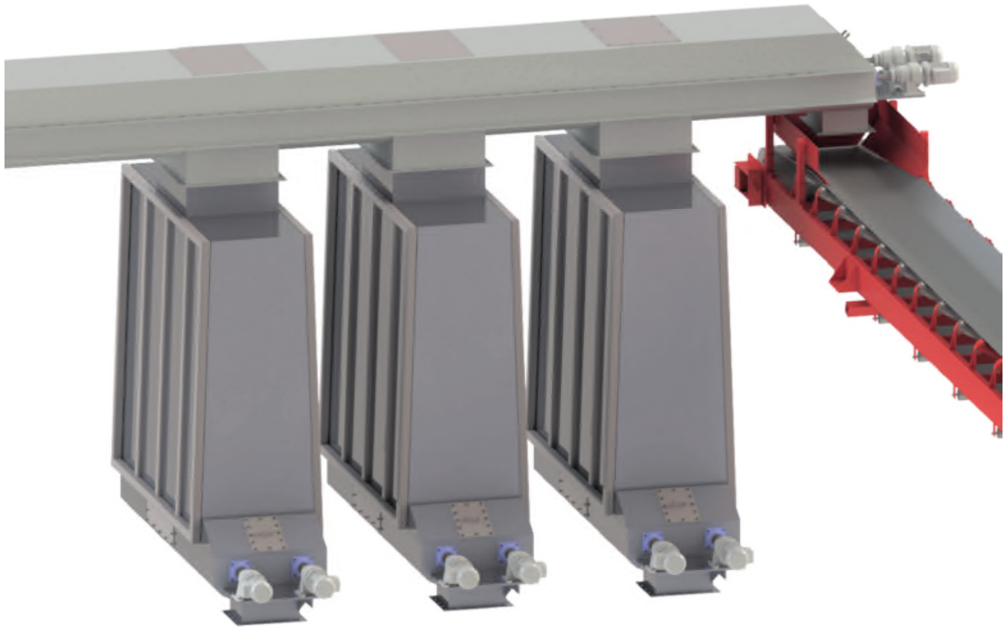

Figure 6: Typical Biomass Screw Metering Bin.

Unrestricted large vertical drops in pellet chute work after metering bins cause uncontrollable fuel distribution often resulting in piling on the rear wall of furnaces. Screw conveyors used as the primary pellet fuel feed equipment also allow ambient tramp air to enter the furnace due to the lack of a seal between ambient fuel feed systems and the negative furnace draft.

Infiltration of ambient tramp air before the measurement of flue gas O_2 concentration relates to an erroneous reading of actual O_2 concentrations used for combustion control. Therefore, to reduce O_2 concentrations the combustion air(s) have to be reduced. Also, the additional amount of tramp air infiltration increases volume of flue gas and therefore pressure drops through a steam generator combustor, often leading to a performance reduction of air pollution control systems and the induced draft fan. Excess O_2 entering through the fuel stream allows early combustion of dry fuel such as wood pellets, causing over heating side walls and fuel feed equipment. This ultimately leads to a decrease in equipment service life and increased maintenance.

Detroit Stoker has completed extensive research and development to establish a solution for successful commercial firing of wood pellets using the Detroit® Pellet Metering Feeder to provide a consistent fuel flow into the furnace and eliminate tramp air entering through the fuel feed system. Similar to a rotary valve, the feeder seals the ambient upstream fuel supply and downstream furnace differential pressure using a mechanical seal.

Detroit has performed application testing to establish consistent and accurate pellet distribution over the grate surface. The feeder is capable of metering pellets at a variable rate of 1,360 kg/hr (3,000 lb/hr) up to 10,900 kg/hr (24,000 lb/hr) while eliminating slugging effects seen with screw conveyors and conventional rotary type feeders. The feeder is designed to operate with a constant head of material and to be mounted in close proximity to a Detroit® Air Swept Distributor or Detroit® Air Swept Pellet Distributor. The Detroit® Pellet Metering Feeder can be supplied as ATEX certified if the application requires.

Both the Detroit® Air Swept Distributor and Detroit® Pellet Distributor spread fuel onto the grate surface by nozzles of low-pressure air. A rotary air damper fluctuates air pressure spreading fuel evenly from front to rear. The Pellet

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To combust biomass the evaporation of moisture must first occur followed by the vaporization of hydrocarbon compounds and gas vapor ignition with combustion.

Distributor takes into consideration the flow characteristics of pellets and has been redesigned to handle the extreme temperatures of low moisture pellet firing.

The significant differences in fuel characteristics between bagasse and pellets create several challenges when co-firing or fuel switching. To combust biomass the evaporation of moisture must first occur followed by the vaporization of hydrocarbon compounds and gas vapor ignition with combustion. Low moisture fuels begin vaporization and ignition sooner as there is very little water to evaporate, generally igniting and combusting in suspension before the fuel has reached the grate surface. During fuel distribution large particles with high terminal velocities deposit on the grate, which require more time to dry and devolatilize. As the particles dry and devolatilize the size and density decreases, this decrease in mass causes the particle to be reintroduced into the fired combustion zone as fractioning occurs. Pellets on the other hand, have much lower terminal velocities with greater surface areas which often combust in suspension leaving very little ash bed if distributed with oxygen rich ambient air.

To prevent this premature combustion flue gas recirculation (FGR) is used to distribute pellets into the furnace. FGR uses low O_2 flue gas to prevent combustion by preventing oxygen from reacting with carbon, delaying the combustion process. Traditionally FGR has been used as a NOx control strategy, when used for distribution air the low O_2 gases can provide a level of reduction in both NOx and CO by reducing excess oxygen in the boiler front wall area. Delaying combustion protects distribution equipment from excessive heat and allows an ash bed to form on the grate surface when firing low moisture fuels such as pellets.

Detroit Stoker has been committed to serving the biomass industry for over 75 years. As pellets become a viable choice for an alternative fuel source, Detroit has developed a complete combustion system capable of effectively handling and firing such a challenging fuel. Detroit's versatile combustion systems support industrial facilities in the process of working towards sustainable operations in both new installations and retrofits of existing equipment.

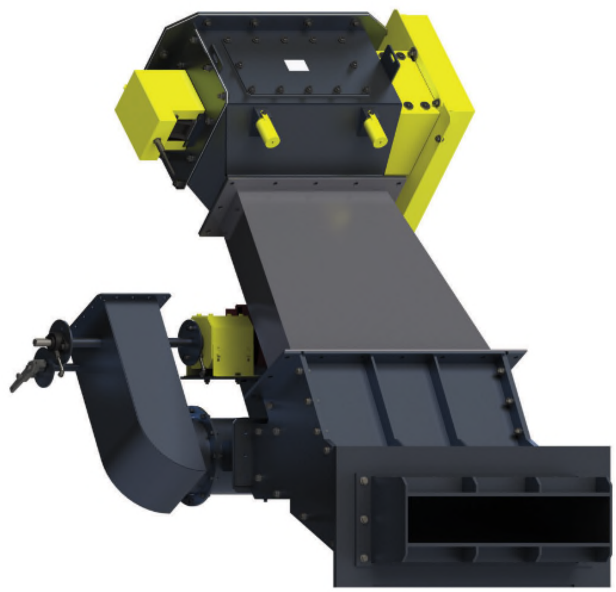

Figure 7: Detroit® Pellet Metering Feeder and Detroit® Pellet Distributor.

Figure 8: Detroit® Pellet Metering Feeder Now Available.