Advanced Torrefaction Systems, LLC

A Novel Approach to Torrefaction:

Use of an Oxidation Catalyst For Gas Treatment

Torrefaction is often considered the key to unlocking the potential of biomass for the production of solid-fuel energy on a large scale. Torrefaction is a thermo-chemical process that upgrades biomass to a high-quality solid fuel with characteristics similar to coal. The goal of torrefaction is to achieve a high-energy fuel that can be more effectively transported, stored and utilized at a power plant than conventional biomass.

Over the past decade or so, much attention has been given to research and development of the torrefaction process. Torrefaction technologies continue to emerge, but problems inherent to conventional torrefaction systems have hindered the development of commercial-scale torrefaction plants. One major concern is that the difficulty of handling the highly volatile gases created in the torrefaction process has led to fires and explosions in some demonstration-scale and commercial-scale plants.

This article discusses ATS TorreCat™ Technology, a new innovation that addresses some significant problems arising from the torrefaction process.

ATS TorreCat™ Technology (i) reduces safety concerns relating to fires and explosions both at plant level and (we believe) in storage and transportation of the finished product, (ii) optimizes energy efficiency and yields, and (iii) minimizes environmental impact arising from the process. In addition, ATS TorreCat™ Technology reduces capital and operating costs by eliminating equipment or steps otherwise necessary in conventional torrefaction systems.

Problems With Conventional Torrefaction Systems

- Heat for the process comes from traditional (thermal) combustion. Flue gases from traditional combustion cannot be used directly in the reactor or the cooler because the residual oxygen levels in those gases are too high and direct contact with the biomass would cause degradation of the final product and increase the possibility of fires and explosions. In addition, the inability to use flue gases directly makes the process less efficient and more capital intensive.

- In direct-contact reactors, torrefaction gases coming off the reactor are indirectly heated and returned back to the reactor as the heat source. These recirculated gases contain carbon monoxide (CO) and volatile organic compounds (VOCs), both of which are highly volatile and regulated pollutants. Recirculating the torrefaction gases increases the level of concentration of CO and VOCs in the reactor, increasing the possibility of fires and explosions.

- In indirect-contact reactors, unless an inert sweep gas is used, the level of concentration of CO and VOCs will be elevated, increasing the possibility of fires and explosions.

- Due to the complexity and/or inefficiency of utilizing the gas streams exiting the dryer and cooler, they are often vented to the atmosphere. Those gas streams contain stored heat and VOCs, and venting them results in emission of VOCs and wasting of the stored heat as well as the significant energy that could be gained from combusting those VOCs.

- VOCs continue to be generated (i) during transfer of the biomass from the reactor to the cooler and (ii) in the early (hotter) portion of the cooler. In addition, VOCs continue to diffuse out of the product in the later (colder) portion of the cooler. These VOCs are difficult to remove and become safety hazards in the cooler and in later storage and transportation of the final product.

- Inert gas (eg. nitrogen), which must be used to purge the whole torrefaction system to reduce the possibility of fires and explosions, must be purchased or generated on site at substantial cost.

- Thermal combustion produces nitrogen oxides (NO_x) which are regulated pollutants.

ATS TorreCat™ Technology

ATS TorreCat™ Technology uses an oxidation catalyst in a closed system to combust and destroy CO and VOCs produced in the torrefaction process. An oxidation catalyst is a substance, or a combination of substances, that accelerates the rate of a chemical reaction without being consumed by the reaction. Catalytic combustion is a reaction that occurs at temperatures 50% lower than traditional combustion. Because of this lower combustion temperature, essentially no NO_x is created. In addition,

an oxidation catalyst combusts CO and VOCs at very low-residual-oxygen levels (approximately 200 to 400 ppm). The output of the oxidation catalyst (catalyst flue gas) consists mainly of superheated steam and inert gases (carbon dioxide and nitrogen), all of which can be advantageously used throughout the process.

With ATS TorreCat™ Technology:

- Heat for the process comes from the flue gas exiting the oxidation catalyst. This low-residual-oxygen, inert catalyst flue gas can be used directly (in contact with the biomass) in the reactor and the cooler without causing appreciable degradation of the final product. This makes the process more efficient and less capital intensive.

- Using the inert catalyst flue gas as direct-contact heat source in the reactor minimizes the level of concentration of CO and VOCs in the reactor, decreasing the possibility of fires and explosions.

- Gas streams exiting the dryer, reactor and cooler are recycled to the oxidation catalyst, utilizing the stored heat and energy (via combustion of the CO and VOCs) contained in those gas streams. This significantly reduces environmental impact and allows for the highest level of process and heat integration, optimizing energy efficiency and yields.

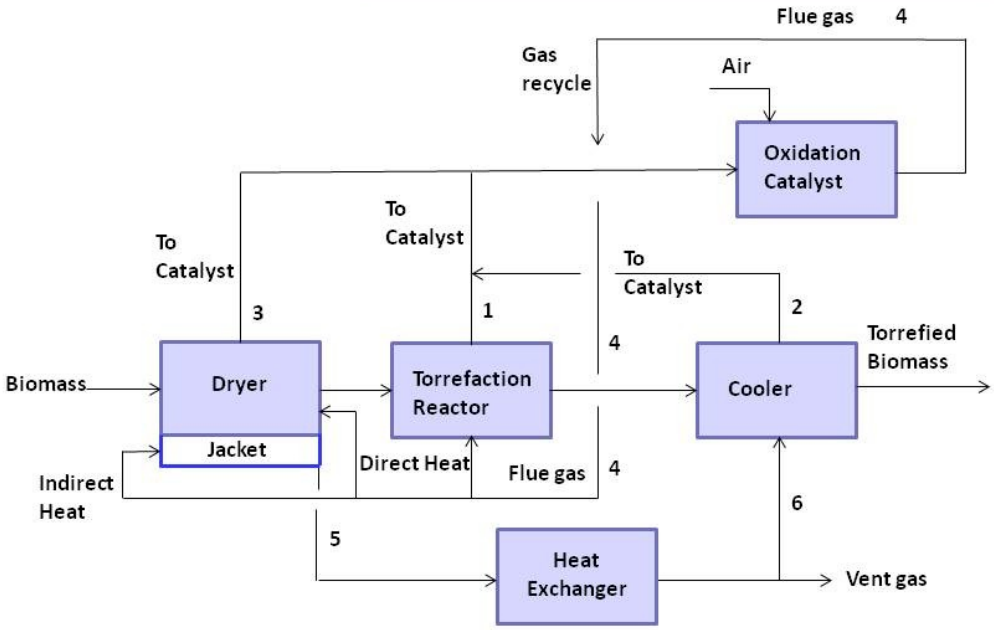
- The inert catalyst flue gas is used to both directly and indirectly heat the biomass in the dryer. The portion of the flue gas used as indirect heat does not directly contact the biomass and therefore remains uncontaminated and inert. It is cooled as its heat is used in the jacket section of the dryer, further cooled in the heat exchanger via ambient air, and it is then used as the cooling medium in the cooler.

- The cooled inert catalyst flue gas directly contacts the hot, torrefied biomass in the cooler causing residual VOCs to be “stripped” away. This results in increased safety in the cooler and safer storage and transportation of the final product.

- The inert catalyst flue gas can be used to purge the whole torrefaction system to reduce the possibility of fires and explosions, thereby eliminating the need to otherwise purchase or generate inert gas.

- If desired, the reactor and the cooler can be integrated into one unit, resulting in reduced capital and operating costs and in simpler, more efficient heat integration.

FLOWCHART OF ATS TORRECAT™ TECHNOLOGY



The above Flowchart provides an example configuration of a torrefaction system using ATS TorreCat™ Technology.

With reference to the Flowchart, gas streams exiting the Torrefaction Reactor (1), Cooler (2) and Dryer (3) are combusted in the Oxidation Catalyst. Inert gases (carbon dioxide and nitrogen) and superheated steam comprise the flue gas (4) exiting the Oxidation Catalyst. A portion of this flue gas (4) is sent to the Torrefaction Reactor to provide direct heat for torrefaction. Another portion of this flue gas (4) is sent to the Dryer to provide both direct and indirect (through the Jacket) heat for drying. The portion of flue gas (4) that provides indirect heat through the Jacket does not come into contact with the biomass and therefore remains uncontaminated and inert. It is partially cooled as its heat is used in the Jacket. This partially-cooled, inert gas (5) then passes through the Heat Exchanger where it is further cooled. This cooled gas (6) is then sent to the Cooler where it is used as the medium to cool the hot, torrefied biomass coming from the Torrefaction Reactor. This cooled gas (6) also sweeps away VOCs from the Cooler and is then recycled back to the Oxidation Catalyst.

Advanced Torrefaction Systems, LLC believes that ATS TorreCat™ Technology is an important key to the development of viable, commercial-scale torrefaction plants.

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