Southeastern Regional Biomass Energy Program

Fluidized Bed Combustion and Gasification: A Guide for Biomass Waste Generators

Administered For
The United States
Department of Energy

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1.0 INTRODUCTION

Due to the rising cost and, at times, unreliable supply of conventional fuels such as coal, oil, and natural gas, many institutions, businesses, and manufacturers have been forced to evaluate the use of alternative fuel sources. One of the most attractive of these alternatives is biomass fuels. Due to the unique characteristics of biomass fuels, i.e. composition, reactivity, combustion characteristics, and emission potential, fluidized beds have been demonstrated to be a very attractive concept for utilizing them for energy production by either combustion or gasification processes.

This manual provides guidelines for the design and application of FBC and FBG systems for burning and gasifying biomass fuels. It is divided into three sections. Section 1 contains a description of FBC and FBG designs and applications. Section 2 provides information for the non technical biomass generator and/or decision maker. Section 3 provides detailed technical information for the designer and engineer responsible for evaluating the technical merits of an FBC or FBG facility. Appendix A provides a list of biomass fueled fluidized bed facilities. Appendix B contains responses to the survey of vendors offering fluidized bed units capable of utilizing biomass fuels. Appendix C gives a list of vendors who provide equipment that would be used in the preparation of biomass fuels. Appendix D provides addresses for federal and state environmental offices in the southeast.

1.0.1 Biomass Fuels

The term biomass covers an extremely broad spectrum of materials. Sources of biomass fuels include waste from manufacturing, agriculture, forestry, pulp and paper plants, residential waste, and landfills. Specifically these fuels can include: whole tree wood chips, sawmill waste wood, bark, prunings, straw, nut shells, hay, some manufacturing wastes, municipal solid wastes, refuse derived fuel, and sewage sludge.

Biomass materials can differ significantly from conventional fuels in areas such as heating value, fuel moisture, and ash chemistry. Each of these properties can influence the design and operation of a combustion or gasification unit. However, despite their range in values, the actual fuel heating value of biomass is reasonably consistent when compared on an ash and moisture free basis.

Most biomass fuels can be obtained for almost nothing or some suppliers may even pay for the disposal of their waste. As a result, biomass fuels can be much lower in cost than conventional fuels. The economics are particularly attractive when the biomass fuel can be used near the same facility where it was produced. This application can improve the economics of the fuel burning unit while reducing or eliminating the overall waste disposal.

Fluidized bed technology, utilizing biomass as a fuel source, falls into two distinct methodologies. Biomass can be used as a source of energy directly through combustion for providing heat energy - fluidized bed combustion (FBC), or indirectly by gasification and then using the resulting gas as the source of energy - fluidized bed gasification (FBG). FBCs are described in Section 1.1 and FBGs are described in Section 1.2.

The FBC systems as offered by the major boiler vendors, have been commercially available for over 10 years in this country and for longer abroad. Biomass fuels have been successfully fired on many of these units. Currently there are over 580 FBC units in operation or planned for operation. Of these, over 110 will be firing or co-firing some form of biomass fuel. Commercial warranties and guarantees are offered on all these units and, in most cases, these are competitive or better than those on conventional technologies for burning biomass. Appendix A contains a listing of the biomass FBC installations.

The worldwide experience base with fluidized bed combustion of alternate fuels has grown significantly since the early 1980s, with over 60 started after 1982. Alternate fuels are burned in both dedicated FBC boilers and in coal-fired FBC boilers converted to cofire alternate fuels. The experience base confirms that FBC technology is ideal for recovering energy from a wide range of alternate fuels derived from municipal, commercial, industrial, and agricultural wastes and for disposing of the portions of the wastes that can't be recycled. [1]

The fluidized bed gasification systems offered do not have the experience base of the FBC units. Most of the experience is in Europe. Although the designs are similar and performance comparable, the lack of demand for the low Btu gas produced by biomass gasifiers has thus far limited the commercial applications and the vendor aggressiveness in developing a product. Further, the lag in the development of a gas turbine using this gas has slowed the combined cycle applications development.

The FBG designs have been demonstrated on vendors bench and pilot scale facilities and are expected to perform similarly on commercial scale facilities. Competitive commercial warranties and guarantees are offered by the vendors indicating a degree of confidence. Further, these systems have been demonstrated in other parts of the world.

1.0.2 Fluidized Bed Fundamentals

The fluidization process begins with a bed of solid granular particles, such as sand or limestone, suspended by an upward flow of air or gas. As the velocity of the gas stream is increased, the individual particles begin to be suspended. At this point the minimum fluidizing velocity is achieved. As the air or gas flow is increased the bed material becomes highly agitated and begins to flow and mix freely. Bubbles, similar to those in a briskly boiling fluid, pass through the bed and the surface of the solids is diffused and no longer well defined. The bed material is said to be "fluidized" because it has the appearance and some of the properties of a boiling fluid. Continuing to increase air or gas flow results in increased entrainment of the bed particles.

Although each fluidized bed design has distinctly different design features, a common feature of each concept is the presence of the combustion or gasification chamber. Here the fuel and bed material are kept in suspension and circulation by the upward current of air and flue gas. The air is distributed uniformly into the bed via a perforated grid plate or a system of nozzles. To initiate combustion or gasification in the fluidized material, the bed temperature is elevated by using a startup fuel such as gas or oil, to a temperature capable of supporting combustion/gasification of the primary fuel. Figure 1.0-1 shows the fundamental concept of a fluidized bed.

During operation, fuel and sorbent are continuously fed into the unit. The bed will primarily consist of fuel ash, sand or lime, and sulfated sorbent (if needed). Unburned fuel will normally make up less than one percent of the bed. The bed material becomes an isothermal reactor with heat transfer from the bed material to boiler tube surface and to the fresh fuel and air. The turbulent mixing of air and fuel at temperatures above the ignition point of the fuel causes combustion/gasification to occur without the need for conventional burners.

Due to their unique design, FBC and FBG units can be fired with many types of fuels including the lower-grade coals, refuse derived fuels, coal-cleaning wastes, peat, biomass, and other hard-to-burn fuels. FBCs can also accommodate cofiring waste fuels in units designed for coal or other solid fuels with relative ease. As a result, FBC and FBG units are currently being used throughout the world to make use of, while disposing of, a wide range of solid waste fuels, including municipal and industrial solid wastes and sludges, agricultural wastes, and coal mining or cleaning wastes. [2]

If the fuel contains sulfur, a sorbent, such as limestone or dolomite, will be used as the bed material in order to capture the SO_2 released during combustion. For fuels with little or no sulfur, sand or another similar inert material can be used. The combustor temperature of FBC and FBG units is generally maintained in a range from 1450°F to 1650°F. These lower temperatures for FBC are required for optimum sulfur capture, i.e., the reaction of sulfur dioxide with calcined limestone. Even

Fluidized Bed Concept

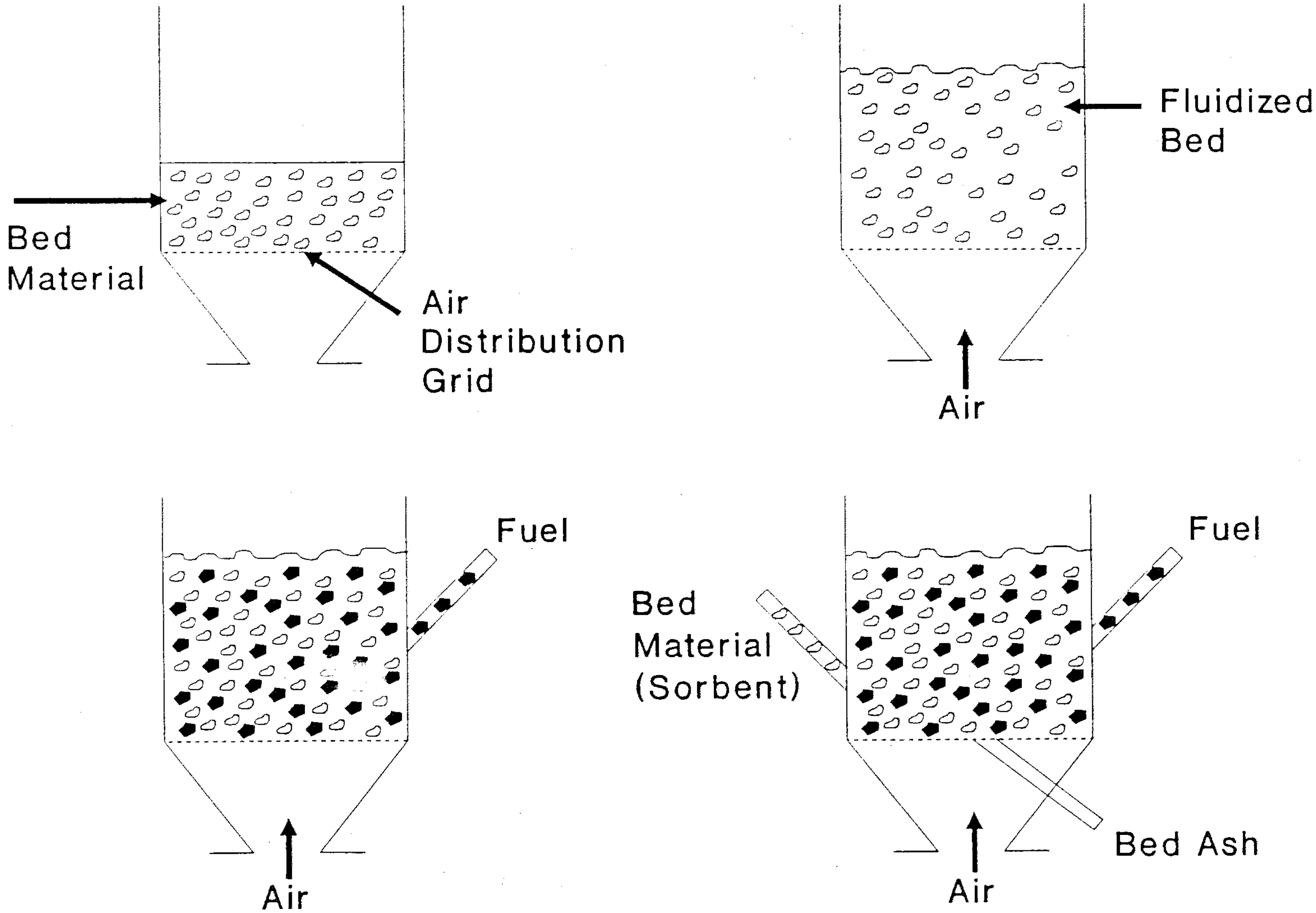

Figure 1.0-1

without a sulfur capture requirement, this temperature range is typically used since it allows the process to operate below the ash fusion temperature of most fuels. This lower operating temperature reduces slagging, fouling, and related corrosion from low melting point sodium, potassium, and sulfur compounds. Therefore FBCs and FBGs do not experience those problems to the extent they are commonly experienced on conventional units. Also, the biomass fuels tend to be very reactive and are efficiently combusted at low temperatures; therefore, nitrogen oxides (NO_x) emissions are significantly reduced by substantially eliminating thermal NO_x.