Materials from Conversion of Coal for Power Production: Practical Working Definitions

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ABSTRACT

The terminology of the solid materials that result from the conversion of coal, primarily for power production, has gradually changed, resulting in a variety of common terms being used interchangeably and frequently incorrectly. A large volume of materials produced by power plants consuming coal are referred to as coal combustion by-products (CCBs), or more recently as coal combustion products (CCPs), by those in the power industry, the ash marketing industry, and most users of these materials. These same materials are frequently termed coal combustion wastes (CCWs) by regulators, citizen groups, and others. The authors will refer to these materials as CCBs in this document. The solids included in these categories are fly ash, bottom ash, boiler slag, and flue gas desulfurization (FGD) material. Immediately, it must be pointed out that FGD material is a by-product of removal of sulfur gases at these power plants and not related to the combustion process.

Additional inconsistencies in terminology and definitions can be found in the common usage of many of these terms to refer to solid materials produced from advanced combustion systems such as fluidized-bed combustion (FBC) and solid materials produced from blended fuels. These inconsistencies can provided misleading inferences related to the utilization of CCBs. This paper discusses terminology and definitions related to CCBs from formal sources such as EPA (U.S. Environmental Protection Agency) and ASTM (American Society for Testing and Materials) and from common usage.

BASIC TERMS AND BACKGROUND

A discussion of the terms and definitions used formally and informally in the CCB industry warrants some background discussion. Fossil fuels inherently contain inorganic components either as part of that fuel or as impurities. In conversion of fossil fuels to energy or other products such as syngas, there are inorganic components that remain as a solid residue. This substance is ash by definition: “the earthy or mineral residue that remains after combustible substances (as coal) have been thoroughly burned (dictionary)”. Of course, ash is also defined as “something that symbolizes grief, repentance, or humiliation” which may also have relevance to the CCB industry

when reviewing the struggles of the industry in gaining acceptance of CCBs as useful, valuable materials.

The authors agree that the term “ash” is most frequently used within the CCB industry to refer to “fly ash” because fly ash is historically the most commonly marketed CCB and is a high-volume residue. The marketing of fly ash began in 1946[1] following the development and installation of pulverized fuel boilers during World War II. Interestingly, some of these pulverized fuel boilers, now called pc (pulverized coal, definitely not politically correct) units, have been upgraded and retrofitted and are still being operated, well past their expected lifetimes. There are several configurations for commonly used pc furnaces that can impact ash formation, but the primary advantage of pc combustion is the very fine nature of the fly ash produced. In general, pc combustion results in approximately 65%–85% fly ash and the remainder a coarser bottom ash (dry-bottom boiler) or boiler slag (wet-bottom boiler). Cyclone combustion uses coarsely pulverized coal (95% −¼ in.) and produces much higher percentages of bottom ash (up to 75%–90%, depending on coal type) and smaller amounts of fly ash. Stoker-fired units do not require the same level of coal grinding (e.g., −¾ in.) because the coal generally stays in the hot zone for an extended period of time, allowing complete combustion of larger coal particles.

Fly ash can be defined as the fine ash that is carried out of the boiler with the flue gases. Almost all of these are particles, except for the smallest size fraction, and are usually collected by either an electrostatic precipitator (ESP) or a fabric filter (baghouse). **Bottom ash** can be defined as the ash that falls to the bottom of the furnace and is removed as nonmolten particles or clinkers. **Boiler slag** can be defined as the molten inorganic material from the coal that drains to the bottom of cyclone-type or other wet-bottom furnaces and discharges into a water-filled pit where it is cooled and removed as glassy particles that can resemble sand.

Fly ash, bottom ash, boiler slag, and FGD material were included in EPA’s August 2, 1993, final regulatory decision stating that effective September 2, 1993, these materials are not regulated as hazardous wastes under Subtitle C and officially placing them under Subtitle D as solid wastes under the jurisdiction of individual states.[2] Note that EPA still calls them solid “wastes,” primarily because the Resource Conservation and Recovery Act (RCRA) regulates wastes. Because approximately 70% of these materials are still being placed in permanent disposal in the United States, the term waste is applicable. The term waste as used here more appropriately refers to the missed opportunity from disposal of these materials, and it is in that area that the CCB industry needs to focus. However, the debate over terminology remains a part of the effort required to take full advantage of the opportunities for utilizing CCBs.

FGD material, also included in EPA’s 1993 ruling, can be defined as material derived from a variety of processes used to control sulfur emissions from boiler stacks. These systems include wet scrubbers, spray-dry scrubbers, sorbent injectors, and a combined sulfur oxide (SO_x) and nitrogen oxide (NO_x) process.

It is possible that the CCB industry would not have developed the way it has if it were not for EPA’s emission regulations. Emission regulations first mandated reduction of particulate matter released to the atmosphere by utilities, which required utilities to install collection devices for fly

ash. At present, every operating U.S. utility-owned coal-fired unit is believed to have particulate control equipment in place. Later emission regulations significant to CCB production mandated limits on SO_x emissions. As a result, utilities using high-sulfur coal could change coal sources, which resulted in a different by-product character, or scrub the flue gas using sorbents to remove the SO_x gases. The result of FGD was high volumes of spent FGD sorbent material. There is a wide range of FGD technologies, thus FGD materials have broadly varied characteristics, but most contain high concentrations of calcium and sulfur.

Utilities are currently responding to regulation placing limits on NO_x emissions, which also impacts the character of ash by-products. Issues related to air toxic emissions, including mercury and CO_2 emissions, are currently under technical and regulatory scrutiny. Regulations that limit utility emissions further are expected to have additional impacts on by-product quantity, quality, and characteristics. Changes in CCB characteristics require an associated evaluation of technical issues related to CCB performance in conventional utilization applications and perhaps development of new markets.

THE ISSUES

The solid materials that result from the use of fossil fuel in power production, whether referred to as wastes or by-products, vary with the type of fuel used, the conversion system, the emission controls applied to the system, the solid collection system, and specific operating conditions. This variation leads to the point of this paper: What are reasonable working definitions of these materials?

Examining these variables provides some insight into the issues surrounding the development of good working definitions. The fuel type alone has resulted in differences of opinion on what qualifies as a CCB. Since oil and gas result in very small amounts of nonconverted materials or by-products, it is assumed that the greatest concern is with CCBs from coal use. Further, the scenario is limited to fly ash generated at coal-fired power plants. If one is a potential user of this fly ash without any knowledge of the power or CCB industries, one would logically assume that fly ash then is a by-product of only coal. That seems simple, and one would assume that fly ash would be fly ash, unless one is aware that there are different types of coal that result in fly ashes with very different characteristics and that these coals can be, and with more frequency are, blended, adding another variable to the fly ash produced. Additionally, coal-fired power plants do not only blend different coal types, many power producers blend coal with other “fuels.” These fuels may include natural gas, fuel oil, biomass, waste wood, waste tires, petroleum coke and other industrial wastes, depending on what is cost-effective or valuable in reducing emissions. These added fuels can be blended in varying amounts. While the by-product may still have the bulk physical appearance of “fly ash,” is it really fly ash in the common usage of the term? Does the amount of noncoal fuel impact the definition? If so, what is the limit beyond which the fly ash is no longer a CCB? EPA includes fly ash, bottom ash, boiler slag, and FGD material from systems that use a minimum of 51% coal as fuel, but EPA does not refer to these materials as either CCBs or CCPs. ASTM has one definition of fly ash that states it must be produced “solely” from the combustion of coal and a second definition for CCPs that indicates these materials must be from fuels that are “primarily” coal.

Basic questions are raised as the variables related to CCB production/collection are described. These basic questions of definition need to be addressed by the CCB industry. Scientifically and legally sound definitions are needed. With time, some of the confusion caused by variables in CCB production/collection will likely be reduced by development of a set of reliable performance data. The use of performance standards rather than prescriptive standards will also alleviate some of the questions about terms and definitions, and the authors support the development and use of performance standards. The authors encourage discussion within the industry. Caution in clearly identifying CCBs is also encouraged. Simply identifying a material as pc fly ash sets it apart from FBC fly ash, waste-to-energy (WTE) fly ash, or other fly ashes that are being moved into the marketplace. Individuals in contact with users and potential users of these materials are encouraged to know what they are discussing and use cautious descriptions to facilitate responsible utilization. The authors support a proposed effort by ASTM E 50.03 to develop a standard guide to terms and definitions for CCBs, but this effort will be most successful if a broad range of groups and individuals participate in the development.

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