SOLID FUEL BLENDING

Principles, Practices, and Problems

David A. Tillman • Dao N.B. Duong
N. Stanley Harding

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Butterworth-Heinemann is an imprint of Elsevier
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB UK
225 Wyman Street, Waltham, MA 02451 USA

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Library of Congress Cataloging-in-Publication Data
Tillman, David A.
Solid fuel blending : principles, practices, and problems / David A. Tillman, Dao Duong, N. Stanley Harding. – 1st ed.
p. cm.
Includes index.
ISBN 978-0-12-380932-2
1. Coal-fired power plants—Fuel. 2. Coal-fired power plants—Environmental aspects. 3. Coal—Combustion. 4. Biomass energy. 5. Waste products as fuel. I. Duong, Dao (Dao N.B.) II. Harding, N. S. III. Title.
TJ254.5.T55 2012
662.6'23–dc23 2011046946

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

For information on all Butterworth-Heinemann publications, visit our website at *www.books.elsevier.com*

Printed in the United States

12 13 14 15 16 10 9 8 7 6 5 4 3 2 1

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Dedication

To the friends and colleagues at DTE Energy, particularly Monroe Power Plant; at Foster Wheeler; and at EPRI who supported the development of many of the fuel blending concepts put forward in this book

Preface

Fuel blending with solid fuels is becoming an increasingly important process for electricity generation companies and installations, as well as for process industries that fire boilers and kilns to drive production of goods such as pulp and paper, expanded aggregates, and cement (and that periodically generate electricity in cogeneration applications). Many economic and environmental forces have combined to make fuel blending increasingly attractive. Blending low-sulfur/low-nitrogen subbituminous coals with traditional eastern and midwestern bituminous coals provides an inexpensive means for reducing airborne emissions and generating electricity. At the same time, maintaining a greater than 30% proportion of eastern or midwestern coal in the blend helps oxidize any mercury found in the coal. Oxidation of the mercury facilitates its capture in a fabric filter facility or an electrostatic precipitator.

Fuel blending can achieve a multiplicity of purposes. For example, it can be used to increase fuel reactivity, reduce fuel costs, address deposition or corrosion issues, reduce certain types of airborne emissions, address the capture of certain pollutants, and reduce the concentration of certain pollutants (e.g., chlorine, mercury, arsenic). Typically, fuel blending is thought of in terms of coal, but it also includes other materials from petroleum coke to biomass with coal or with another fuel type.

Blending without sufficient investigation and analysis can easily exacerbate problems such as slagging and fouling and corrosion. The behavior of inorganic constituents, and some organic constituents, is not necessarily linear with blends. Surprises—some favorable and many unfavorable—can occur with blending when insufficient data and analyses are used.

Blending techniques can also influence outcomes. Basic blending is done by the bucketful—a bucket of this and a bucket of that (or a slug of this and a slug of that). We have seen this approach at coal tipples, power plants, and pulp mills. In very carefully designed programs, bucket blending can work well. Transfer points can function as mixing stations and can facilitate relatively homogeneous blends. Frequently, however, this approach does not work, and the boiler "sees" a slug of this and a slug of that. Silos that rathole—that is, operate on a "first-in, first-out" basis—only make the problem worse. When metering conveyors are used, blending is more precise, and swings in fuel quality are basically eliminated. Metering conveyor systems can be elegant or basic, depending on the installation. With them, two-way blends are easily accomplished, and many can achieve three-way blends.

More and more blending involves weigh-belt feeders, metering conveyors, and positive controls leading to reproducible results. Such systems can again be

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simple or highly sophisticated, depending on the fuel yard and its design. These systems may involve sophisticated computer tracking and controls or may only consist of programmable logic controllers and dial-in controls. Variations appear to revolve around the extent to which automation replaces human activity in the fuel yard. The degree of sophistication also depends on how aggressive a plant is in controlling the blend and the outcome. Some plants are content to fire a single, constant blend of two or more fuels. Others vary the blend to respond to market conditions and the natural variability in such solid fuels as ranks of coal, biomass fuels, and numerous waste fuels.

The authors of this book have extensive experience in fuel blending. We have managed the fuels and combustion process for power plants and have consulted on fuels and combustion issues for utilities, process industries, and incinerators. Further, we have led research efforts in evaluating blends and blending processes for utilities and industries, EPRI, the U.S. Department of Energy, and numerous other organizations. These professional activities have led to the development of many observations and ideas that are presented here. This book reflects our collective experience with numerous organizations involved in the production and use of the vast array of solid fuels as well as our participation in professional societies and conferences dedicated to advancing the understanding of these materials and their utilization.

This book provides information on the issues of solid fuel blending and the principles, practices, and problems associated with it. Chapter 2 deals with the fundamentals of fuel blending, examining the blending of coal on coal, biomass on coal, petroleum coke on coal, and others. Chapter 3 looks at the blending of coals—the chemistry of blending, blending systems, and critical issues.

Chapter 4 focuses on biomass cofiring with coal—the fundamentals of biomass cofiring, its chemistry, and associated systems. It also looks at specific case studies. Chapter 5 studies the aspects of waste fuel blending with coal—for example, tired-derived fuel, petroleum coke, and waste plastics and papers. Chapter 6 looks at the environmental aspects of fuel blending, and Chapter 7 considers various aspects of modeling associated with it. Chapter 8 focuses on the institutional aspects of fuel blending.

Acknowledgments

We have not performed our work alone or in a vacuum, and we have not written this book without significant help. Among those who have helped are Anthony Widenman, David Nordstrand, Michael F. Dunlap II, Joe Robinson, and many other present and former colleagues at DTE Energy. They have provided information, ideas, and comments concerning our efforts. Similarly, Mike Santucci and Jim Scavuzzo of ECG have provided ideas and information particularly on computer controls and various forms of modeling.

Rob Mudry of Air Flow Sciences provided significant information on both cold flow and computer modeling. Donald Kawecki of Research Cottrell—formerly of Foster Wheeler—helped with many discussions. Bruce and Sharon Falcone Miller of The Energy Institute of Pennsylvania State University contributed, as did Gareth Mitchell of PSU. Richard Monts provided photographs of coal trains, and Pentrex provided significant photography of both coal mining and coal trains in the Powder River Basin.

A special thanks goes to Melody Huang, a graduate student at Lehigh University, who helped substantially with literature searches. Many other individuals contributed support, ideas, and more. With their help, we offer this effort in evaluating the principles, processes, and consequences of blending solid fuels.

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Chapter 1

Introduction to Fuel Blending

1.1. OVERVIEW

The blending of two or more solid fuels involves combining the desired materials together in a careful, reproducible manner. This book deals with solid fuel blending that is controllable and reproducible; it focuses on systems where controlled conveyers, weigh belt feeders, and other means are used to provide a consistent feed to the combustion or gasification system. Blending, as discussed in this text, requires knowledge of what is being blended, why it is being blended, and the expected outcome of the blending process.

1.2. FUEL BLENDING FOR SOLID FUELS

Blending for solid fuels involves producing a reasonably homogeneous mixture of the two or more solids to be fired in a boiler. These solids may be coals of the same or similar ranks; coals of dissimilar ranks; coals with biomass fuels such as wood, wood waste, herbaceous crops, and crop wastes; fecal matter from animals; and industrial residues from the processing of biomass. Blends may also include coals and a range of industrial materials and residues, including petroleum cokes of one or another type, by-product aromatic carboxylic acid (BACA), coal wastes such as culm or gob, municipal solid waste-derived fuels (e.g., refuse-derived fuel, waste paper, waste plastics), tire-derived fuel, selected hazardous wastes, and many more. Blending is limited only by the ingenuity of the engineers and by the regulatory environment [1].

1.2.1. Blending System Considerations

From the perspective of fuel blending mechanical system fundamentals, we have these things to consider:

1. Where in the overall process scheme should blending occur?
2. What types of mechanical systems are available to accomplish blending?
3. What type of blending controls should exist?
4. What modifications must be made to plant equipment?

Following this discussion, the overall impacts or consequences of blending can be considered. It is important to note that the discussion here is an overview.

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To the extent that specific fuel blending influences these questions, more detail will be presented in subsequent chapters.

1.2.2. Where Blending Can Occur

Typically, blending occurs in the fuel yard of a utility power plant or industrial boiler; however, it can occur in an off-site fuel management facility with the blend being shipped to the power plant or industry. It can occur as part of the fuel handling process: in the feed system conveying fuel to the burners or other energy recovery and production systems (e.g., combustion or gasification systems). It can occur in the energy production equipment (e.g., the pulverized coal boiler) depending on the system design. In this case certain pulverizers are set up to handle one fuel, and others are set up to handle another fuel—the blend fuel(s).

Blending of different fuels depends on the fuels to be blended. At one extreme a utility or industry can purchase preblended fuel from a transloading facility or other similar operation. Many eastern tipples, such as Tanoma Coal Company, provide blends of fuel to their customers in order to meet specifications. When biomass cofiring was tested at the Shawville, Pennsylvania, generating station of (then) GPU Genco (now Reliant Energy), Tanoma Coal blended the woody biomass forms with the coal to meet the objectives of the blend process [2, 3]. When the Tennessee Valley Authority (TVA) tested firing up to 20% petroleum coke with coal at its Widows Creek Fossil Plant, the blend was prepared by the BRT facility in Kentucky and shipped on the river to the power plant. Other utilities and manufacturing industries have investigated this option as well [4–6].

Purchasing preblended fuel has several advantages. No capital investment is required at the plant site. In reality the use of a blend is transparent to the power plant. The blend is handled like a single coal. This also requires little if any change in operations and maintenance practices. Purchasing preblended fuel, however, also has several disadvantages: The system is rigid, and the blend cannot be changed at the plant to respond to power plant needs or the consequences of in-seam variability of coal. If the blend is not desirable (e.g., if the blend causes slagging, fouling, or corrosion), the electricity generating plant or manufacturing facility must burn it in any event and probably must suffer a derate in the process. It may also experience elevated operations and maintenance costs in the process.

Probably the most common form of blending involves mixing two or more fuels in predetermined blends in the fuel yard. This can be accomplished in any number of ways, as will be discussed subsequently. This is the approach taken at the Monroe Power Plant of DTE Energy (Figure 1.1), the Limestone Generating Station of Texas Genco, and numerous other utilities and industries blending various types of coal of dissimilar rank. TVA took this approach testing blends of petroleum coke and coal at its Paradise Fossil Plant and blends

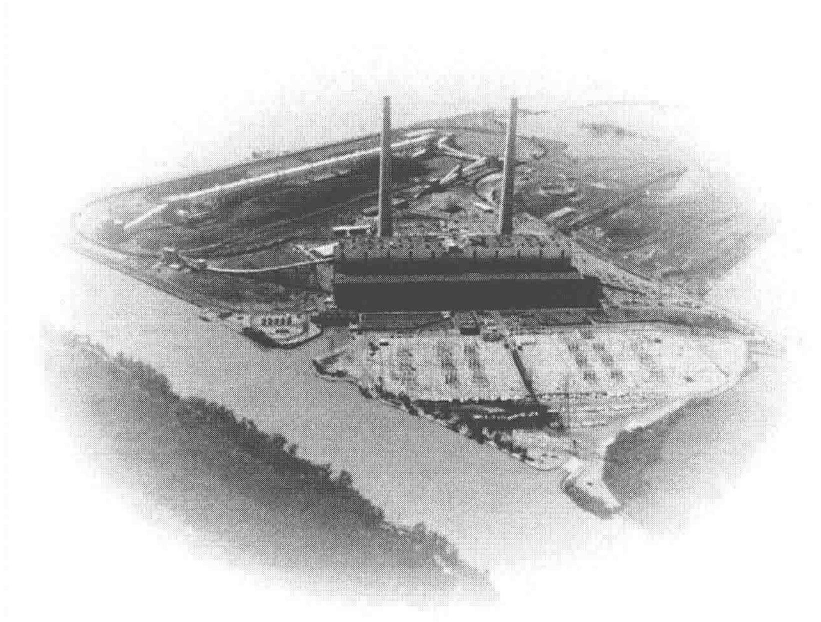

FIGURE 1.1 Aerial view of the Monroe Power Plant of DTE Energy. Note the coal yard at the back of the site. This coal yard contains the $400 million blending facility constructed such that three coals can be fed to the boiler in varying proportions to meet operational requirements. *Source: [10].*

of tire-derived fuel with sawdust and coal at its Allen Fossil Plant [3–5]. This approach was taken during the testing of petroleum coke and wood waste cofiring at the Bailly Generating Station of NiSources [7, 8]. This approach is limited to coal–coal blends, coal/petroleum coke blends, and cofiring with woody biomass, such as what was done at Plant Hammond of Southern Company [9], as well as at the Allen Fossil Plant and the Bailly Generating Station. This approach cannot be used with blends of coal and agricultural products such as switchgrass or corn stover.

The advantages of this approach include the ability to adjust the fuel blend to utilize varying properties of the fuel—both good and bad. Also, depending on the plant information and control system, the on-site blending can be used to minimize the risks associated with slagging, fouling, and deposition. Fuel characteristics leading to those conditions and fuel characteristics leading to unacceptable levels of pollution can be addressed by blending as well. The blending process can move the fuel characteristics away from the most severe conditions, depending on the fuels available.

This blending approach, however, has limitations. It can be very capital intensive—for example, the DTE Energy blending facility had a capital cost of $400 million [10]. Other facilities such as the Bailly Generating Station blending

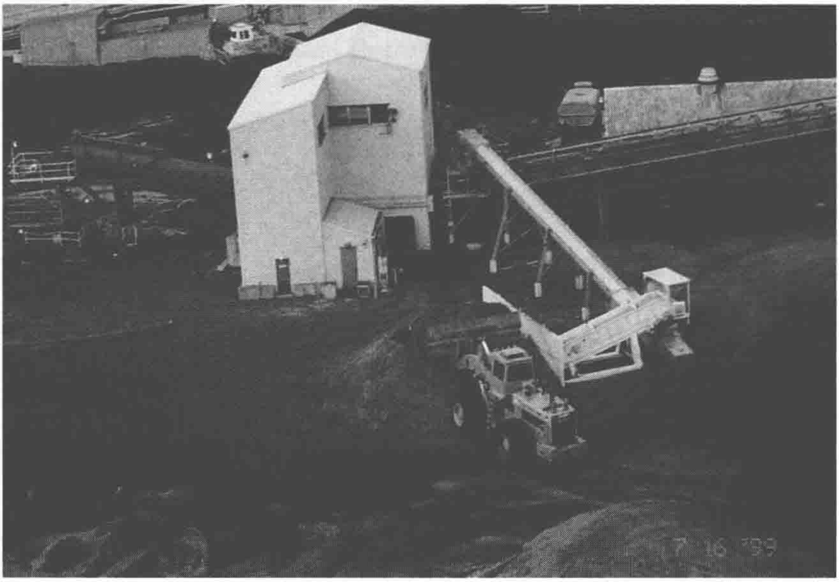

FIGURE 1.2 The on-site blending facility constructed at Bailly Generating Station for testing purposes. Note that this is a labor-intensive system. *Source: [7].*

system, shown in Figure 1.2, cost only $1.2 million. However, the Bailly blending system is more labor intensive, requiring two additional operating persons just to run the blending system [3, 7]. Maintenance must be vigorously pursued in order to preserve the accuracy and consistency of the blending; otherwise, it is not effective. This is discussed more extensively in Chapters 2 and 3. At the extreme is bucket blending—using two front-end loaders to build piles of the blends. This can result in blends that are "a slug of this and a slug of that," and these blends do not maximize the desired benefits of good blending.

On-site blending introduces another potential problem: preferential grinding or pulverization in the mills. When introducing two coals to a mill, the pulverizer will grind the softer (higher-HGI) coal more completely than the harder coal. For example, Monroe Power Plant was using a blend of 70% Powder River Basin (PRB)/30% Central Appalachian (CA) bituminous coal. Tests showed that the >50 mesh cut of the pulverized material was 70% CA bituminous coal [10]. The >200 mesh, >400 mesh, and residual products were where the PRB coal was concentrated. This preferential grinding—preparing the softer, more easily pulverized coal more thoroughly than the harder coal—is a common experience in blending operations. This is discussed more extensively in Chapter 3.

A third approach to blending is blending in the furnace or boiler itself. The various fuels are prepared separately and introduced into the boiler separately.

This has been used with dissimilar coals such as PRB subbituminous coal and lignite at the Limestone Generating Station. It is the preferred method for cofiring biomass with coal in pulverized coal boilers and is required when cofiring agricultural products such as switchgrass with coal, as has been demonstrated at Plant Gadsden of Southern Company, Ottumwa Generating Station of Alliant Energy, and Blount St. Station of Madison Gas & Electric [3].

Agricultural materials, such as switchgrass, do not lend themselves to blending with coal in the coal yard. This approach has been in existence for a long time and has been used in stoker firing as well as pulverized coal (PC) firing [11]. Detroit Stoker developed a fuel feeding system with a paddle wheel for coal stoker firing and a windswept spout for wood waste firing—simultaneously—in the large stoker-fired boilers of the pulp and paper industry [11].

This approach is also being used by Foster Wheeler in the design and construction of two 300-MWe circulating fluidized bed (CFB) boilers being supplied to Dominion Energy. These boilers will be fired with up to 20% wood waste and 80% coal. The mixing of wood waste with coal will occur in the CFB itself, not in the fuel yard. This approach was used in one cyclone installation: the Allen generating station of Northern States Power. Dry, finely divided sawdust from the adjacent Andersen Windows plant was fired in the secondary air plenum of 3 of the 12 cyclone barrels in a manner similar to the means for firing natural gas in cyclone boilers.

There are distinct advantages to this form of blending. If two coals are blended using this approach in a PC boiler, then the pulverizers can be set to the individual coals being fired. If biomass is being fired with coal, then the coal delivery system is not impacted. If wet coal is received and a derate is to be taken, the addition of the biomass can minimize that derate, depending on the specific design. It should be noted, however, that this blending approach is more suited to tangentially fired PC boilers than wall-fired boilers. Tangentially fired PC boilers have a single fireball, whereas wall-fired boilers have distinct flames from each burner; there is less mixing of the fuel and flame in such installations. A disadvantage of this approach is that some of the chemistry benefits of blending are not achieved with in-furnace blending.

Therefore, numerous locations can be used for blending different fuels being fired in a single boiler. Choice of the optimal location depends on the fuels being burned, the firing method, and the approach of the electric utility or process industry.

1.3. OBJECTIVES FOR BLENDING

Blending is designed to meet certain overall objectives: economic, environmental, and technical. The economic objectives are always tied to producing the useful energy product at the lowest cost. This may be process steam, where cost is expressed in $ per 10^3 lb of useful steam; electricity, where cost is

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