Coal-Fired Steam Plants

An Online Continuing Education Course for Engineers

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Credit: 4 Hours / 4 PDH / 4 CPD

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Coal Fired Steam Plants

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Introduction

Coal fired power plants are an established source of electricity that provides vast quantities of inexpensive, reliable power. Generation from coal burning produces about 51% of the electricity generated in the U.S. In addition, known coal reserves are expected to last for centuries at the current rates of usage. See Figure 1 for a breakdown of electricity generation by fuel type.

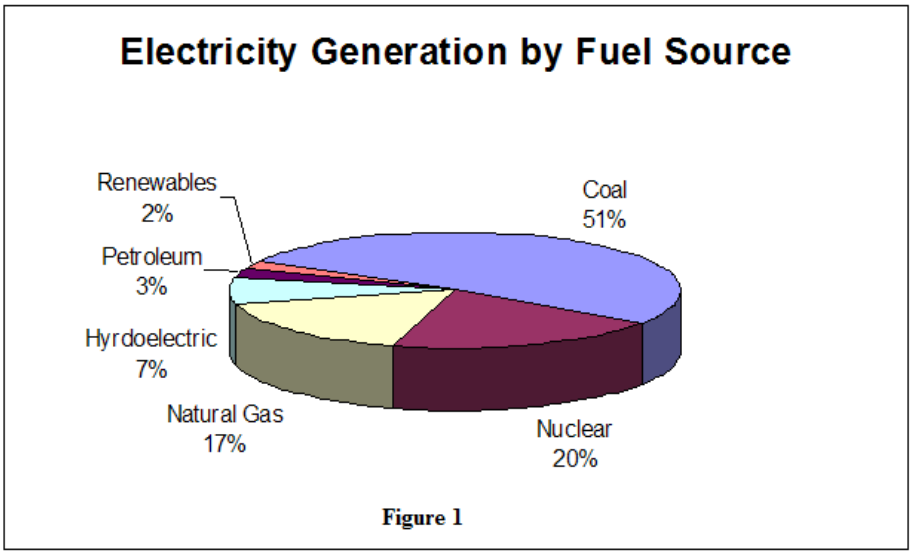

Figure 1

As you can see in Figure 1, coal is by far the most prevalent fuel source with nuclear fuel a distance second, followed closely by natural gas. It is expected that nuclear and natural gas will eventually surpass coal as the fuel of choice in the next 30 years.

Coal power is a rather simple process. In most coal fired power plants, chunks of coal are crushed into fine powder and are fed into a combustion unit where it is burned. Heat from the burning coal is used to generate steam that is used to spin one or more turbines to generate electricity.

Coal has played a major role in electrical production since the first power plants that were built in the United States in the 1880's. The earliest power plants used hand fed coal to heat a boiler and produce steam. This steam was used in *reciprocating steam engines* which turned generators to produce electricity. In 1884, the more efficient high speed *steam turbine* was developed which replaced the use of steam engines to generate electricity. In the 1920s, the pulverized coal firing was developed. This process brought advantages that included a higher combustion temperature, improved thermal efficiency and a lower requirement for excess air for combustion. In the 1940s, the cyclone furnace was developed. This new technology allowed the combustion of poorer grade of coal with less ash production and greater overall efficiency.

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Coal is pulverized into a fine powder stems because, if the coal is made fine enough, it will burn almost as easily and efficiently as a gas. The coal is crushed between balls or cylindrical rollers that move between two tracks or "races." The raw coal is then fed into the pulverizer along with air heated from the boiler. As the coal gets crushed by the rolling action, the hot air dries it and blows the usable fine coal powder out to be used as fuel. The powdered coal from the pulverizer is directly blown to a burner in the boiler. The burner mixes the powdered coal in the air suspension with additional pre-heated combustion air and forces it out of a nozzle. Under operating conditions, there is enough heat in the combustion zone to ignite all the incoming fuel.

Cyclone furnaces were developed after pulverized coal systems and require less processing of the coal fuel. They can burn poorer grade coals with higher moisture contents and ash contents. The crushed coal feed is either stored temporarily in bins or transported directly to the cyclone furnace. The furnace is basically a large cylinder jacketed with water pipes that absorb the some of the heat to make steam and protect the burner itself from melting down. A high powered fan blows the heated air and chunks of coal into one end of the cylinder. At the same time additional heated combustion air is injected along the curved surface of the cylinder causing the coal and air mixture to swirl in a centrifugal "cyclone" motion. The whirling of the air and coal enhances the burning.

Coal-fired technology has improved the heat rates of coal plants from over 138,000 BTU/kWh in the 1880's to less than 10,000 BTU/kWh today.

We will start this course with an overview of the coal industry followed by a detailed explanation of the components of a coal-fired steam plant and we will conclude with a look at the environmental issues associated with a coal-fired steam plant.

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Chapter 1

Coal as a Fuel Source

Coal is a fossil fuel formed from plant remains that were preserved by water and mud from biodegradation. Coal is a readily combustible black or brownish-black rock. It is composed primarily of carbon and hydrogen along with small quantities of other elements, notably sulfur. Coal is extracted from the ground by coal mining, either underground mining or open pit mining.

Coal is the largest source of fuel for the generation of electricity world-wide and is the larges
energy source in the U
the largest world-wi
emissions and it may
change and global w
dioxide emissions, cc
petroleum and about

Photo courtesy DOE

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Coal has been used as
of years; the Chinese n
10,000 years ago at the
Revolution led to the la
as the prime mover in i

the Industrial
from the water wheel

Coal is primarily used a
coal consumption is abo
production of electricity.

combustion. World
used for the

When coal is used for ele
with a boiler. The furnace heat converts boiler water to steam, which is then used to spin turbines which turn generators and create electricity. The thermodynamic efficiency of this process has been improved over time. Traditional steam turbines have topped out with some of the most advanced units reaching about 35% thermodynamic efficiency for the entire process, which means 65% of the coal energy is waste heat that is released into the surrounding environment. Older coal power plants are significantly less efficient and produce higher levels of waste heat.

Approximately 40% of the world electricity production uses coal. It is estimated that the total known coal deposits recoverable by current technologies might be sufficient for around 250-300 years' use at current consumption levels.

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