FOSSIL FUEL HANDLING

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Summary

Fossil fuels used in large steam-generating units include solids, liquids, and gases. The most commonly used fuels in each of these categories are respectively coal, fuel oil, and natural gas. Natural gas is the most convenient with regard to handling as minimal storage or pretreatment is required prior to combustion. Oil is also fairly convenient to handle; it must however be pressurized and preheated to facilitate atomization prior to combustion. This requires some storage and auxiliary services. An advantage of both gas and oil is that they can be transported by pipeline directly from their source of supply or delivery. Coal, on the other hand, is not so conveniently transported and is usually delivered intermittently, resulting in a need for longer-term storage facilities. The coal itself, when utilized in large steam-generating units, must be pulverized to a fine powder to ensure rapid combustion while in suspension.

Coal pulverizing mills grind the coal by impact, crushing, or attrition. Various designs have been conceived to do this effectively without excessive wear on the grinding

elements. Vertical spindle mills make use of large rollers or balls running on a ring or race. Tube mills are large rotating cylinders containing small balls that tumble over one another. Pulverized coal from the mills is picked up by a stream of hot air, which dries the coal and transports it to the combustion zone. The performance and energy requirements of the mills vary with the type of coal and its moisture content. Once it has been pulverized, certain precautions are required to avoid premature or spontaneous ignition.

1. Liquid and Gaseous Fuel Handling

1.1. General Characteristics

Liquid fuels are generally considered to be derivatives of crude oil. There are however one or two exceptions. Oil emulsion such as "Orimulsion" is an emulsion of 70% bitumen and 30% water produced in Venezuela and has characteristics similar to that of heavy fuel oil. Coal–water slurries consisting of 70% pulverized coal and 30% water also handle and burn like heavy fuel oil. Fuel oils derived from crude oil are categorized from No. 1 (Kerosene) to No. 6 (Heavy Fuel Oil) with increasing viscosity. Generally the heavy residual fuel oil is the one mostly used in power plants. It has a high specific gravity approaching that of water and a high viscosity with a pour point of 18 °C. It contains some ash and usually has significant sulfur content. Gaseous fuels encompass natural gas, refinery gas, and coal gas. Although arising from diverse sources, all are relatively pure, clean-burning fuels. There is however some variation in calorific value depending upon the actual chemical constituents of the fuel. Natural gas, consisting mainly of methane or ethane with some heavier hydrocarbons, is widely used in power plants. Some natural gases contain other inert constituents that lower their overall calorific value. Generally sulfur compounds are removed to make gas suitable for small consumers as well.

1.2. Transport and Storage

Liquids and gases are conveniently transported by pipeline from the main point of delivery or production to the power plant. This may be a relatively short distance from a nearby harbor where they are delivered by tanker, or quite a long distance from an oil refinery or production well. If the distances are great, intermediate pumping stations are required to maintain the driving pressure in the system.

In gas pipelines some gas is drawn off and used in gas turbines that drive compressors in the main pipeline, thus conveniently eliminating the need for large external sources of pumping power. The pressure in gas pipelines is maintained at a high value, as much as 7 MPa, to increase the gas density and mass flow rate.

In oil pipelines carrying heavy fuel oil, the oil may have to be heated and maintained at an elevated temperature to reduce its viscosity and hence the pumping power required. Power from pumping is eventually dissipated as heat within the oil if the pipe is insulated. Therefore, if the flow rate is maintained, the temperature may not fall too much. Another way of reducing pumping requirements is to add some water to the oil. Under the proper conditions the lower viscosity water forms a thin annular layer adjacent to the pipe wall. The oil slides along this lower viscosity layer with less frictional loss.

Depending upon the continuity of production or frequency of delivery and reliability of transportation, some storage at site is required. For example, a gas-fired plant connected to a network of pipelines fed by a series of natural gas wells would not require on-site storage, but an oil-fired plant supplied with fuel oil by tanker from a foreign source would require extensive storage facilities. Fuel oil is conveniently stored in cylindrical storage tanks and natural gas in large water-seal tanks. With gas, some reserve storage may be made available within the supply pipeline by allowing the pressure to drop but this depends upon the length and size of the pipe and the pressure variation allowed.

With on-site storage of gaseous and particularly liquid fuels there is the risk of fire. The storage facilities are therefore located in a separate area with adequate spacing between storage tanks. Any liquid fuel tank must have bung walls around it to contain its total inventory should it rupture. Naturally, appropriate fire fighting facilities are required.

Liquid or gaseous fuel is piped to the plant from the storage facility. Gas is ultimately supplied to the spuds of the gas burners at a relatively low pressure of 60 kPa to 80 kPa. Oil, on the other hand, must be atomized at the burner to promote combustion. For effective atomization, the oil must be preheated to reduce its viscosity sufficiently and supplied to the burner at a pressure of about 2 MPa. This requires an extensive heating, pressurizing, and recirculation system to maintain proper flow from the storage facility and atomization at the burner. For example, No. 6 Fuel Oil requires temperatures of 38 °C for pumping and 93 °C for atomizing, so some preheating is usually required even in the supply line from the storage facility. To maintain the proper temperatures, surplus oil is recirculated so that there is adequate flow in the lines at all times.

1.3. Environmental Considerations

The transport of liquid and gaseous fuels by pipeline does not pose significant risks to the environment. Although leakage of gas and, especially, oil would be detrimental to the environment, pipelines are secure methods of transport with high reliability. They are also well protected against external corrosion and impact damage. Effective methods of internal inspection of pipelines for cracks and defects have been established so that any minor defects are likely to be identified before a major rupture could occur. Should a rupture or accident leading to sudden leakage occur, the rapid pressure drop would be sensed and the supply to the pipeline or flow in the pipeline arrested to minimize spillage.

When in storage at the plant, a large quantity is concentrated in a small area and the consequences of spillage, particularly of liquid fuel, are much greater. For protection against the spread of fire, a receiving well with bung walls to contain the fuel surrounds liquid fuel tanks. While it is important from a fire protection point of view to prevent it from spreading over the surface, it is also important from an environmental perspective to prevent it from seeping below the surface and contaminating the soil and groundwater. Impervious barriers, as shown in Figure 1, are therefore required below the storage tanks and extending under the receiving well and up into the bung walls to ensure no seepage even in the event of a rupture of a full tank.

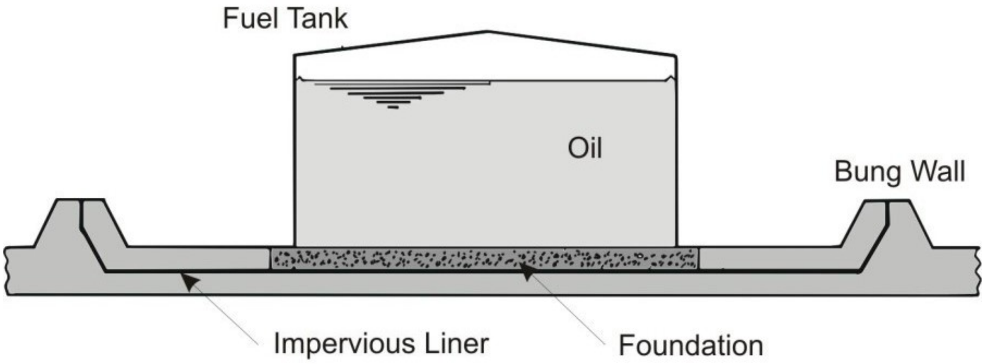

Figure 1. Spillage containment for liquid fuel tanks

2. Solid Fuel Handling

2.1. General Characteristics

Most solid fuel used in power plants is some form of coal, which is classified according to a ranking system. As coal is formed it goes through a process whereby moisture, volatile matter, and oxygen content progressively decrease while the percentage of carbon on a moisture and ash free basis increases. The lowest ranked coals are peat and lignite with high moisture and volatile contents but only 25% and 40% carbon respectively. Then there are sub-bituminous and bituminous coals, still with high volatile contents but with an increased carbon content of about 60%. Finally, there is anthracite, with very little volatile matter and a carbon content in excess of 90%. Coals contain significant amounts of ash made up of various non-combustible impurities, which ultimately have to be collected after the combustion process. A "proximate analysis" determines the amount of moisture, volatile matter, fixed carbon, and ash in a coal and hence indicates its ignition and combustion characteristics. An "ultimate analysis" determines the amounts of various elements such as carbon, hydrogen, nitrogen, sulfur, and oxygen in a coal and thereby allows prediction of the amounts of combustion products generated.

During the mining of coal some rock may be included, adding to its ash content, and during transport and storage rain may add surface moisture to the coal. For ease of transport, coal is partially crushed to eliminate large lumps and therefore facilitate handling. In the process fine particles are produced, leading to a possible dust nuisance in certain locations. The fine particles also lead to rapid oxidation when exposed to the atmosphere. This generates heat that may ultimately initiate spontaneous combustion of the coal.

Another problem with coal handling occurs in cold climates: the freezing of the free moisture that prevents the coal from flowing properly, particularly when being reclaimed from outdoor storage facilities.

2.2. Transport and Storage

Solid fuel is usually transported to the power plant by ship, train, or conveyor belt depending upon the distance from the mine. Appropriate unloading facilities are required to handle deliveries by ship or train. With ships the coal has to be scooped from within the holds by a special unloading gantry, whereas with trains the individual cars can be simply inverted by a tipper if not of the bottom opening hopper type. Conveyer belts carry the coal from the unloading facility to the storage site.

Depending upon the frequency of delivery or continuity of production if supplied directly from a single mine, some storage at the power plant is required. Since the coal can, in most instances, be stored on open ground the storage site can be extensive and cater for seasonal variations in coal supply. Whatever the size of storage facility, provision must be made to stack the coal and to reclaim it as required for combustion in the plant. Generally the deposition and reclamation of the coal within the storage facility should be cycled so that coal is stored for as short a time as possible. If, however, the coal is to be stored for an extended period, precautions must be taken to prevent fires arising from spontaneous combustion. Good compaction of the coal in thin enough layers to prevent segregation of the coarse and fine particles is effective in minimizing diffusion and percolation of air within the coal.

Large-scale material handling equipment is required to move the coal from the storage facility to the plant. Conveyer belts carry the coal up the inside of inclined ducts to the hoppers in the top of the boiler house. These hoppers have a storage capacity of several hours so as not to jeopardize the operation of the boiler in the event of a breakdown in the coal conveying system.

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Bibliography

Black and Veatch. (1996). *Power Plant Engineering* (eds L.F. Drbal, P.G. Boston, K.L. Westra and R.B. Erikson), 858 pp. New York, Chapman & Hall. [Covers all main aspects of thermal power plants including fuel combustion. Separate topics by specialist authors]

British Electricity International. (1991). *Modern Power Station Practice: Volume B, Boilers and Ancillary Plan*, 184 pp. Oxford, Pergamon. [Comprehensive text directed towards design and operational aspects of fossil fuel fired boilers.]

Singer J.G. (ed.) (1991). *Combustion Fossil Power*, 1042 pp. Windsor, Conn.: Combustion Engineering ABB. [Specialized text on boiler plant technology. In depth treatment of fossil fuels and combustion.]

Stultz S.C. and Kitto J.B. (eds.) (1992). *Steam: Its Generation and Use*, 947 pp. Barberton, Ohio: Babcock and Wilcox. [Specialized text on boiler plant technology. Leading text on steam generation including combustion of fuels.]

Biographical Sketch

Robin Chaplin obtained a B.Sc. and M.Sc. in mechanical engineering from the University of Cape Town. Between these two periods of study he spent two years gaining experience in the operation and maintenance of coal fired power plants in South Africa. He subsequently spent a further year gaining experience on research and prototype nuclear reactors in South Africa and the United Kingdom, and obtained an M.Sc. in nuclear engineering from Imperial College, London University. On returning and taking up a position in the head office of Eskom he spent some twelve years there, initially in project management and then as head of steam turbine specialists. During this period he was involved with the construction of the Ruacana Hydro Power Station in Namibia and Koeberg Nuclear Power Station in South Africa, being responsible for the underground mechanical equipment and civil structures and for the mechanical balance-of-plant equipment at the respective plants. Continuing his interests in power plant modeling and simulation, he obtained a Ph.D. in mechanical engineering from Queen's University in Canada. He was subsequently appointed as Chair in Power Plant Engineering at the University of New Brunswick, where he teaches thermodynamics and fluid mechanics and specialized courses in nuclear and power plant engineering in the Department of Chemical Engineering. An important function is involvement in the plant operator and shift supervisor training programs at Point Lepreau Nuclear Generating Station. This includes the development of material and teaching of courses in both nuclear and non-nuclear aspects of the program.