1 MODERN ELECTRIC GENERATING STATIONS

1.1 How Power Is Generated

Virtually all the electric power in the United States today is generated by one of the methods depicted schematically in Fig. 1. 1. Approximately 90% of the electric power are generated by what is called the thermal-mechanical generation concept. In this concept, heat energy is converted into mechanical energy which powers an electric generator. Most of these power plants use the Rankine[1] cycle for conversion of heat energy to mechanical power.

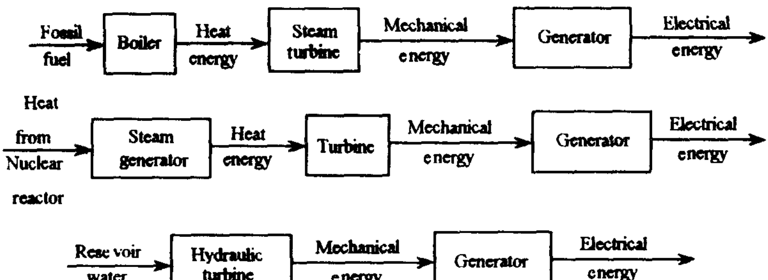


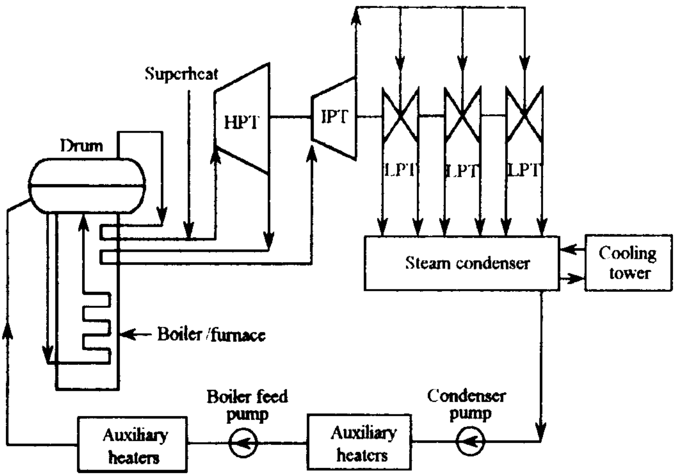
Figure 1. 1 Modern methods of electric energy production

Fossil-fuel plants represent the most common application of the thermal-mechanical concept. Coal, gas, or a petroleum fraction is mixed with air and injected into a boiler where combustion takes place. In most plants, heat from combustion is used to convert water to steam. This steam, in turn, flows through large pipes to a multistage turbine. In some plants fired by petroleum or gas, the combustion products flow directly to the turbine. As the steam or hot gas passes through the turbine, energy is extracted from the vapor to run the turbine. The turbine is mechanically connected to the generator, and it drives or rotates the generator, allowing the production of electrical energy.

1. 2 Steam Power Plants

The most widely used fossil systems burn coal or a heavy petroleum fraction to supply the thermal energy, and employ a steam turbine to power the electric generator. A typical heat cycle for a modern coal plant utilizing the Rankine cycle is shown schematically in Fig. 1. 2.

Coal has been, and for at the next decade or so will continue to be, the largest source of fuel for electrical generating stations in the United States. As early as 1925, coal generated 57% of this country's electrical power. Coal generated an average of 52% of the electrical power during the period from 1925 to 1970. Utilities burn about 65% of all the coal mined in the United States. In 1985 it is projected that coal will



Key:

HPT = high-pressure turbine

LPT = low-pressure turbine

IPT = intermediate-pressure turbine

Figure 1.2 Heat cycle for a coal-fired boiler

generate approximately 47% of the electrical power, and 875 million tons of coal will be consumed.

U.S. policy is to move away from the use of petroleum for electric power generation. This de-emphasis on petroleum use for electric power generation will take years to have a substantial effect. Power generation by petroleum dropped slightly in 1974-1975 as a result of the original oil embargo, but in 1976 the use of petroleum rose to an all-time high of 556 million barrels for the generation of 320 billion kilowatt-hours. It has been estimated that completion of all the petroleum-fired generating units on order during the 1970s will result in a peak use of 900 million barrels of petroleum per year in the early 1980s. The use of petroleum for power generation should begin to decline thereafter.

As coal and nuclear plants assume a greater share of the base-loaded generation, oil plants will be increasingly used for peak or intermediate power production. However, it is expected that utilities will continue to use substantial amounts of petroleum well into the next century.

1.3 Introduction to Power Plant Systems and Components

The block diagram of Fig. 1.3 shows the major segments of a modern coal-fired power plant. After crushing and pulverizing, the coal is fed to the furnace, where it is burned.[2] In the flame region, much of the heat generated is transferred to boiler tubes which line the walls. The steam-water mixture formed in the boiler tubes proceeds to a steam drum, where the vapor and liquid are separated.[3] The liquid is returned to the boiler tubes and the vapor proceeds to a superheater. There the hot gases leaving the flame region superheat the saturated steam produced in the boiler section. The superheated steam proceeds to the turbine, where its thermal energy is converted to mechanical energy.[4]

The steam leaving the high-pressure stage of the turbine is

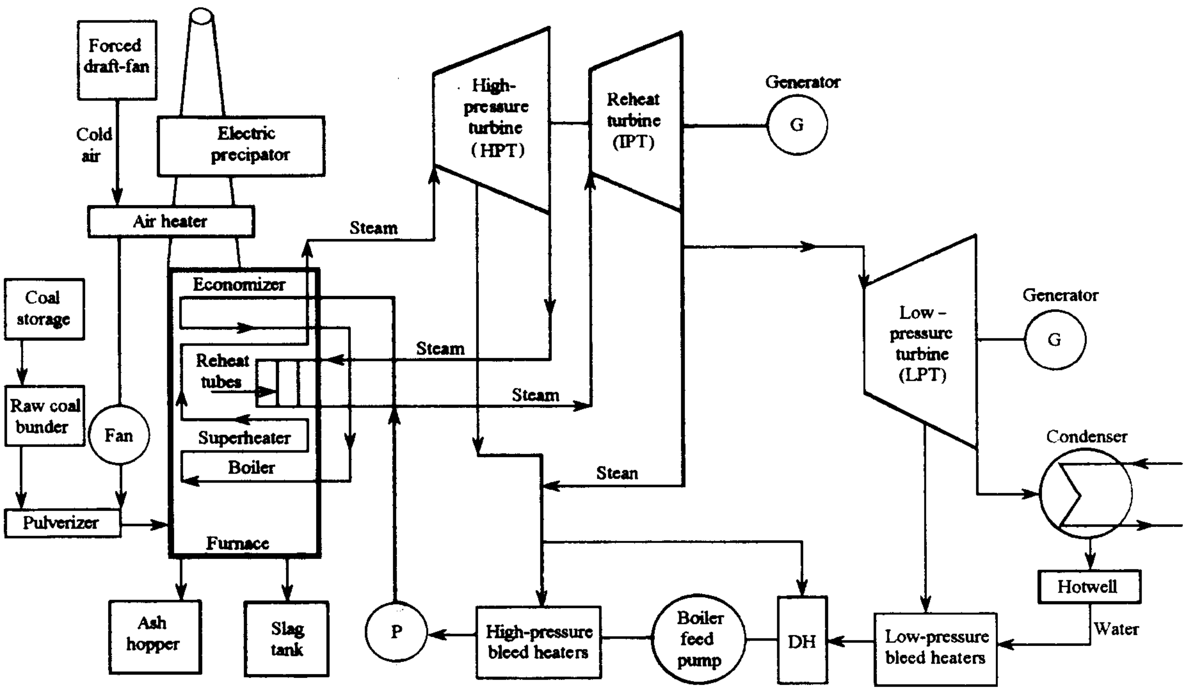


Figure 1. 3 Major components of a coal-fired power station

reheated in the furnace prior to being sent to the low-pressure sections of the turbine. The steam exiting from the low-pressure turbine proceeds to a condenser. The liquid from the condenser is reheated in regenerative feed-water heaters, using steam bled from the turbine, prior to being returned to the furnace.[5] The feed-water then proceeds to the furnace, where it is brought to near saturation in the economizer.[6] The gases leaving the economizer preheat the entering air and are then discharged through the stack. Particulates in the gas stream are removed by electrostatic precipitators prior to discharge. In newer plants, the exit gases are also scrubbed to remove SO_2.

The major factor in establishing the size of the power plant components is the required net power output. However, the design is significantly affected by the characteristics of the coal being burned, coal delivery methods, combustion technique selected, and constituents of the coal ash. The most significant coal characteristics are:

Moisture content

High heating value

Grindability index

Ash content

Ash fusion temperature

Sulfur content

These specific coal characteristics are far more meaningful in the design of the equipment and the station than is the rank of the coal being burned. Each specific coal characteristic can affect the design of certain plant equipment and components.

As an example, consider the effect of the moisture on power plant components. The general effect is to increase most boiler components sizes and to reduce boiler efficiency. A high moisture content will require a larger air heater. This, in turn, requires an increase in the temperature of the inlet air to the pulverizers since a greater volume of air is required to dry the coal in the pulverizer. This increases the initial primary air fan size and reduces the forced draft fan sizes. The burning of coal with a high moisture content results in a higher flue gas dew point, and raises the stack temperature needed to prevent corrosion. The net result of a high-moisture-content coal is to reduce the overall power plant efficiency.

The high heating value of the coal is another property that significantly affects plant design. The high heating value (HHV) establishes the rate at which coal is fed into the furnace (firing rate). Since the HHV can vary from 19,000 kJ/kg (8000 Btu[7]/lb[8]) to well over 28,500kJ/kg (12,000 Btu/lb) and since the firing rate for a given furnace or boiler output is inversely proportional to the HHV, it is easy to see that mass firing rates can vary by over 50%. Thus the HHV will affect the design of the boiler combustion zone, burners, pulverizers, coal feeders, silo storage requirements, coal-handling equipment, and the size of the active and inactive coal storage.

New Words and Expressions

air fan 风机

air heater 空气预热器

ash [æʃ] n. 灰

ash fusion temperature 灰熔点温度

ash hopper 灰斗

boiler ['bɔilə] n. 锅炉

burner ['bə:nə] n. 喷燃器 燃烧器

coal ash 煤灰

coal feeder 给煤机

coal plant 燃煤电厂

coal-fired power plant 燃煤电厂

coal-handling equipment 输煤设备

condensate pump 凝结水泵

combustion [kəm'bʌstʃən] n. 燃烧

combustion technique 燃烧技术

combustion zone 燃烧区

condensate [kən'denseit] n. 凝结水

condenser [kənden'sə] n. 凝汽器

content ['kɔntent]n. 成分 含量

convert [kɔn'və:t] vt. 转换 变换

cooling tower 冷却水塔

crush [krʌʃ] v. 破碎 压碎

cycle ['saikl] n. vt. vi. 循环

deaerate ['di:'eiəreit] vt. vi. 除去空气 除去氧气

dew [dju:] n. 露 露水

dew point 露点

draft [dra:ft] n. 通风

drum [drʌm] n. 锅筒 汽包

economizer [i:'kɔnəmaizə] n. 省煤器

efficiency [i'fiʃənsi] n. 效率

electric generator 发电机

electrostatic [i'lektrou'stætik] a. 静电的

electrostatic precipitator 静电除尘器

embargo[em'ba:gou] v. n. 禁止进(出)口 禁运

fan [fæn] n. 风机

feed pump 给水泵

feed-water 给水

firing rate 燃烧率；燃烧速度

flame [fleim] n. 火焰；火苗

flue [flu:] n. 烟道

flue gas 烟道气

forced draft 送风；强制通风

forced-draft fan 送风机

fossil ['fɔsil] a. 化石的

fossil-fuel 矿物燃料

furnace ['fə:nis] n. 炉膛

fusion ['fju:ʒən] n. 熔化 熔融

generator ['dʒenəreitə] n. 发电机 发生器

grindability [graində'biliti] n. 可磨性 可磨度

grindability index 可磨系数

heater ['hi:tə] n. 加热器

HHV (high heating value) 高位发热值

hopper ['hɔpə] n. 漏斗

index ['indeks] n. 系数

kilowatt ['kiləwɔt] n. 千瓦（特）

kilowatt-hour 千瓦小时

mechanical energy 机械能

mixture ['mikstʃə] n. 混合；混合物

moisture ['mɔistʃə] n. 湿度；水分

moisture content 水分

multistage ['mʌlti'steidʒ] a. 多级的

nuclear ['nju:kliə] a. 原子核的

nuclear plant 核电厂

nuclear reactor 核反应堆

power plant 发电厂

precipitator [pri'sipiteitə] n. 除尘器

preheat ['pri:'hi:t] v. 预热

pressure['preʃə] n. 压力

primary air fan 一次风机

property ['prɔpəti] n. 性质 特性 性能

pulverize ['pʌlvəraiz] v. 磨碎；磨成粉状

pulverizer ['pʌlvəraizə] n. 磨煤机

pump [pʌmp] n. 泵 水泵

Rankine cycle 朗肯循环

raw [rɔ:] a.原状的 自然的

raw water 原水；

reactor [ri'æktə] n. 反应堆

regenerative ['ridʒenəreitiv] a.

回热(式)的 再生(式)的

regenerative feed-water heater 回热式给水加热器

reheat[ˈriːˈhiːt] vt. 再热；重新加热

reheater [ˈriːhiːtə] n. 再热器

reservoir [ˈrezəvwaː] n. 水库；蓄水池 水箱 油箱

reservoir water 库容水；水箱水

saturate[ˈsætʃəreit] vt. 使饱和

saturated steam 饱和蒸汽

saturation [sætʃəˈreiʃən] n. 饱和 饱和状态

scrub [skrʌb] v. 清洗 洗涤

separate [ˈsepəreit] v. 分离

silo [ˈsailou] n. 贮仓 筒仓

slag [slæg] n. 煤渣 炉渣

stack [stæk] n. 烟囱

steam [stiːm] n. 水蒸气；蒸汽

steam drum 汽包 锅筒

steam generator 蒸汽发生器

steam turbine 汽轮机

steam-water mixture 汽水混合物

sulfur[ˈsʌlfə] n. 硫 硫黄

sulfur content 硫分

superheat [sjuːpəˈhiːt] vt. 过(度加)热

superheated steam 过热蒸汽

superheater [sjuːpəˈhiːtə] n. 过热器

tower [ˈtauə] n. 塔

turbine [ˈtəːbin] n. 叶轮机 汽轮机

vapor[ˈveipə] n. 气 蒸气

virtually [ˈvəːtjuəli] ad. 几乎

Key Words Explanation

1. **crush**: To press something with great force so as to destroy its natural shape or condition.
   破碎：以很大的压力作用于某物从而破坏其原有的形状或状态。
2. **pulverize**: To press or crush something until it becomes fine powder.
   粉碎：将某物压碎或破碎成为细粉末状。

3. **grind** ：To crush something into small pieces or a powder by pressing between hard surfaces.

研磨：通过坚硬表面之间的挤压使某物破碎或使之成为粉末。

4. **gas** ：A state of matter in which the molecules move freely，thereby causing the matter to expand indefinitely ，the total volume of any vessel in which it is contained.

气体：分子在自由运动的物质状态，因而促成物质无限制膨胀以占据容纳它的任何容器的整个体积。

5. **vapor**：A gas which is at a temperature and can therefore be liquefied by a suitable increase in pressure.

蒸汽：处在其临界温度之下并且因此适当增加压力就可以液化的气体。

6. **steam** ：Water in the vapor state ；formed when specific latent heat of vaporization is supplied to water at boiling point.

水蒸气：蒸发状态的水；将蒸发比潜热供给沸点下的水时形成的。

7. **burn** ：To be on fire or produce flames.

燃烧：处于着火状态或有火苗出现。

8. **combustion**：Chemical union of oxygen with gas accompanied by the evolution of light and rapid production of heat (exothermic).

燃烧：氧与气体的化学结合，此过程伴随着光的释放，并迅速产生热量(放热)。

9. **fire**：(Material that is in) the state of burning that produces flames which send out heat and light ，and might produce smoke.

火（物质处于)燃烧状态,伴有发光、发热的火苗,并会有烟雾产生。

10. **flame** ：A region in which chemical interaction between gases occurs，accompanied by the evolution of light and heat.

火焰：发生气体之间相互化学反应的区域，伴有光和热的释放。

Notes

1. Rankine

   朗肯,William John Macquorn Rankine ,苏格兰人,以 1854 年提出朗肯循环概念而著名。

2. After crushing and pulverizing , the coal is fed to the furnace , where it is burned.

   句中,where 引出 furnace 的非限定性定语从句, it 指 the coal ,全句可译为"燃煤经过破碎和研磨以后,被送入炉膛进行燃烧。"

3. The steam-water mixture formed in the boiler tubes proceeds to a steam drum , where the vapor and liquid are separated.

   句中 vapor 指 steam,liquid 指 water,where 引出 steam drum 的非限定性定语从句,全句可译为"锅炉炉管中所形成的汽水混合物进入汽包,并在其中进行汽水分离。"

4. The superheated steam proceeds to the turbine, where its thermal energy is converted to mechanical energy.

   句中 where 引出 turbine 的非限定性定语从句,该句可译为"过热蒸汽进入汽轮机后,其热能被转化为机械能。"

5. The liquid from the condenser is reheated in regenerative feed-water heaters, using steam bled from the turbine, prior to being returned to the furnace.

   句中 liquid 指凝气器的凝结水,该句可译为"凝汽器的凝结水在返回炉膛之前，在再生式给水加热器中利用汽轮机的抽汽进行再热。"

6. The feed-water then proceeds to the furnace , where it is brought to near saturation in the economizer.

句中 feed-water 指凝结水离开凝气器后而称为给水，where 引出 furnace 的非限定性定语从句，该句可译为"给水然后进入炉膛，在省煤器中被加热至接近饱和状态。"

7. Btu

英制热量单位，为 British thermal unit 的缩写，1Btu 等于 252cal。

8. lb

英磅，为 pound 的缩写，1lb 等于 0.454kg。

2 FUEL HANDLING AND PREPARATION FOR BURNING

2. 1 Coal Handling Systems

The coal-handling systems at a large modern power plant unload the coal, handle it in the yard, and prepare the coal for burning in the furnace. Figure 2. 1 is a block diagram which shows the major steps in the coal handling operation at a power plant. Since most coal plants burn pulverized coal, this section focuses on the preparation of pulverized coal.

Rail shipment of coal accounts for nearly three-fourths of the coal delivered to U. S. power plants. Unit trains supply the coal for large power plants. Shipments of 10,000 tons or more are quickly unloaded by rapid-discharge bottom railroad cars. A 100 -ton load of coal can be discharged from a hopper car in 20 seconds.

Some western surface-mined coal and some eastern coal from Pennsylvania[1], West Virginia[2], and Ohio[3] is shipped by barge. Barge shipment of coal accounts for approximately 10% of the coal used by U. S. utilities. The barges used to ship coal are generally not self-unloading, except for a few barges on the Great Lakes[4]. The power plant must therefor

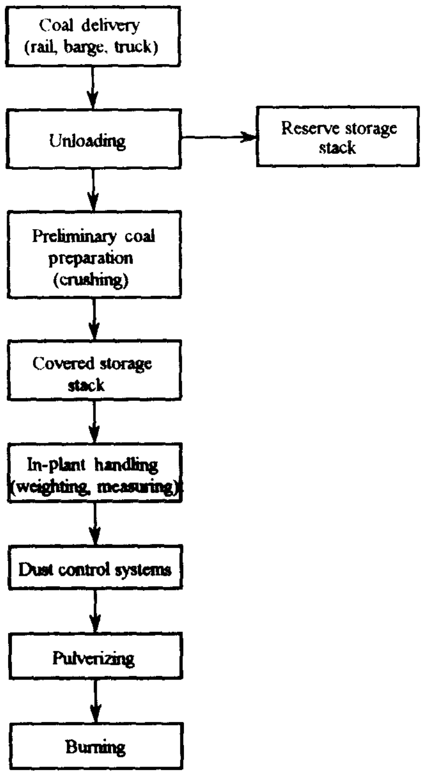


Figure 2. 1 Coal-handling systems

have its own equipment for unloading barge coal. A typical unloader consists of a tower housing a trolly boom with a clamshell bucket. The bucket swings over the barge to load and dumps the coal in hoppers on shore.

The remainder of the coal used by utilities is shipped by either truck or overland conveyer. Overland conveyers are used where power plants are located near large mines.

Coal stored at a power plant may be placed in either active storage or reserve storage. The active storage supplies the normal power operation while the reserve storage pile is kept for emergencies and delays in regular shipment. Current utility practice is to keep large inactive reserves, up to 500,000 tons, to ensure a reliable fuel supply for 60 to 90 days of plant operation.

Since reserve storage piles are usually outdoors, frozen coal is a problem often faced by power plants in the north during the winter months. Surface moisture on the coal causes the coal particles to freeze together. The difficulties caused depend on the coal particle size. Large chunks of coal have weaker ice bonds than small fine particles because the surface-to-volume ratio is much lower. Severe winter weather conditions can cause entire train loads or reserve stacks of coal to freeze together solid.

There are three methods of dealing with frozen coal: heat, mechanical devices, and freeze-control agents (FCAs). The heating operation is performed in an enclosed thawing shed that is heated by steam, electric, or gas heaters. This method is becoming increasingly expensive. Alternatively, mechanical devices can be used to shake, crush, or vibrate in order to break up the coal-ice mass. Freeze-control agents act as antifreeze to weaken the crystalline structure of the ice bond.

The most widely used FCA is ethylene glycol. It is applied at a few pints per ton of coal when the coal is loaded into the car or silo. Ethylene glycol has proved highly successful as a freeze-control agent.

Coal in active storage is generally kept under cover to protect it from moisture and freezing. Large concrete bunkers immediately adjacent to the boiler plant are usually used. In some cases, both the active and inactive storage is under cover. This is particularly true for western coal, much of which is subbituminous, as it tends to produce large quantities of small particles, known as fines.[5] With these coals, dust and moisture can become serious problems, making closed storage attractive.[6] Large concrete silos are often used for this purpose. The silos are normally kept under a slight negative pressure to minimize dust problems.

2.2 Handling Equipment

Very large quantities of coal are handled daily at modern stations. A 600-Mwe[7] unit, at full power operation, handles and burns approximately 300 tons of coal per hour, or 7200 ton of coal per day. Some of the coal delivery and receiving systems must be designed to handle up to 4000 tons of coal per hour.

One of the major tasks is building the active and reserve "stacks" of coal. Although there are a number of techniques