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Кафедра “Промышленная теплоэнергетика”

СБОРНИК ТЕКСТОВ

к практическим занятиям
по дисциплине **«Технический перевод»**
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Сборник текстов оригинальной научно-технической литературы на английском языке предназначен для студентов вузов, факультетов и специальностей направления «Энергетика», изучающих дисциплину «Технический перевод», а также может быть рекомендован аспирантам и инженерно-техническим работникам данных специальностей, самостоятельно изучающим английский язык.

Сборник содержит в основном неадаптированные и лишь в некоторых случаях сокращенные тексты из английской и американской литературы по теплоэнергетике, тепловым электростанциям и энергоменеджменту. В текстах встречаются грамматические явления и обороты, характерные для технической литературы на английском языке. Помимо текстов, книга содержит подстрочный комментарий, списки встречающихся сокращений и типичных устойчивых сочетаний, а также краткий словарь (с транскрипцией).

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INTRODUCTION

At the beginning of the nineteenth century, the stagecoach and the saddle horse were still the means of travel on land. Freight was transported on land in wagons drawn by horses or oxen.

On water barges were also drawn by horses. The water wheel had been in use for several centuries to drive flour mills and small manufacturing establishments. In agriculture man was still largely dependent upon his own physical strength and the work of his domestic animals. Later the steam engine was developed and applied to the operation of factories. This and the development of machine tools and machinery accelerated the industrial revolution and ultimately resulted in our modern industrial civilization which Is founded upon the low-cost mass production of goods that can be sold cheaply throughout the world.

The Newcomen[1] steam engine was invented in 1705 to pump water from the English coal mines. It was fairly well developed by 1720 and remained in extensive use for the 50 years. In 1763 a self-taught man the son of a Russian soldier Polzunov[2] worked out the project of the first universal steam engine. The construction of the engine involved great difficulties due to lack[2] of qualified assistants, lack of the necessary Instruments and in general lack of help and support, Polzunov had to do almost everything with his own hands.

Polzunov's engine had been working from August to November 10, 1766, when it was stopped and put out of operation because of a teak in the boiler. But, Polzunov did not live to see the results of his work. He died in poverty on May 27, 1766.

Later on in the course of the industrial revolution in England a number of inventors designed steam engines with a view to meeting the urgent demand for these machines.

A prominent place among these early inventors belongs to James Watt.[1] James Watt, an instrument maker at the University of Glasgow, while repairing a model of a Newcomen engine, noticed the large waste of energy due to alternately heating the steam cylinder with steam and cooling it with injection water.

He realized that this loss could be reduced by keeping the cylinder as hot as possible with insulation and using a separate condenser or water-cooled chamber which could be connected to the steam cylinder at the proper time by a valve. He patented the idea of the separate condenser in 1769. Subsequently, he closed the top of the steam cylinder with a cover or cylinder head. introduced steam alternately on both sides of the piston, and thus made the engine double acting. He invented a governor to -regulate the speed of the engine, a slide valve to control the admission, expansion, and exhaust of the steam, a pump to remove the air and condensate from the condenser, and, in fact, brought the steam engine to a fairly high state of development.

In 1882 Thomas Edison[3] started the Pearl Street Station[3] in New York for the purpose of supplying electricity to the users of the new incandescent lamp, thus laying the foundation for great central-station industry which now supplies the general public with electric light and power. Parsons patented a reaction turbine in 1884, and in 188& de Laval* was granted patents on an impulse turbine. By 1910 the steam turbine had replaced the reciprocating steam engine in the central-station industry. '

During the last decade, the gas turbine in the form of the turbojet and turboprop engines has replaced the reciprocating internal combustion engine in the military combat airplane and the faster and larger commercial aircraft. The gas turbine is also being used in such applications as electric power generation, natural gas transmission line pumping, and locomotives.

The recent development of the rocket threatens to revolutionize warfare with guided missiles and earth satellites. Since the rocket carries its own supply of oxygen for the burning of its fuel, it is capable of operating at altitudes where the earth's atmosphere is highly rarefied.

[1] Newcomen—Ньюкомен, Томас (1663—1729), английский изобретатель

[2] Polzunov — Ползунов Иван Иванович (1728-— 1766), выдающийся русский теплотехник, один из изобретателей универсального теплового двигателя

[3] **due to lack — из-за** недостатка.

[1] James Watt — Уатт, Джеме (173.6—1819). выдающийся английский изобретатель

[2] Thomas Edison —Эдисон, Томас Алва (1847— 19331), выдающийся американский электротехник, изобретатель, основатель крупных электротехнических предприятий и компаний

[3] Pearl Street Station — электростанция на Перл Стрит

[4] Parsons — Парсонс, Чарлз (1854—1931), английский инженер и предприниматель, изобретатель паровой реактивной турбины

THE STEAM POWER PLANT

The function of a steam power plant is to convert the energy in nuclear reactions or in coal, oil or gas into mechanical or electric energy 'through the expansion of steam from a high pressure to a low pressure in a suitable prime mover such as a turbine or engine, A noncondensing plant discharges the steam from the prime mover at an exhaust pressure equal to or greater than atmospheric pressure. A condensing plant exhausts from the prime mover into a condenser at a pressure less than atmospheric pressure.

In general, central-station plants are condensing plants since their sole output is electric energy and a reduction in the exhaust pressure at the prime mover decrease the amount of steam required to produce a given quantity of electric energy. Industrial plants are frequently noncondensing plants because large quantities of low-pressure steam are required for manufacturing operations. The power required for operation of a manufacturing plant may often be obtained as a by-product by generating steam at high pressure and expanding this steam in a prime mover to, the back pressure at which the steam is needed for manufacturing processes

The steam-generating unit consists of a furnace in which the fuel is burned, a boiler, superheater, and economizer, in which high-pressure steam is generated, and an air heater in which the toss of the energy due to combustion of the fuel is reduced to a minimum. The boiler is composed of a drum, in which a water level is maintained at about the mid-point so as to permit separation of the steam from the water, ap4 a bank of inclined tubes, connected to the drum in such a man' пег as to permit[1] water to circulate from the drum through the tubes and back to the drum. The hot products of combustion from the furnace flow across the boiler tubes and evaporate part of the water in the tubes. The furnace walls are composed of tubes which are also connected to the boiler drum to form very effective steam-generating surfaces. The steam which is separated from the water in the boiler drum then flows through a superheater which is in effect[2] a coil of tubing surrounded by the hot products of combustion. The temperature of the steam is increased in the superheater to perhaps 800° to 1100°F, at which temperature the high-pressure superheated steam flows through suitable piping to the turbine.

Since the gaseous products Of combustion leaving the boiler tube bank are at a relatively high temperature end their discharge to the chimney would resist in a large loss in energy, an economizer may he used to recover part of the energy in these gases. The economizer is a bank of tubes through which the boiler feedwater is pumped on its way to the boiler drum.

A reduction in gas temperature may be made by passing the products of combustion through an air heater which is a heat exchanger cooled by the air required for combustion. This air is supplied to the air heater at normal room temperature and may leave the air heater at 400° to 600° F, thus returning to the furnace energy that would otherwise be wasted up the chimney. The products of combustion are usually cooled in an air heater to an exit temperature of 275° to 400° F, after which they may be passed through a dust collector which will remove objectionable dust and thence through an induced-draft fan to the chimney. The function of the induced-draft fan is to pull the gases through the heat transfer surfaces of the boiler, superheater, economizer and air heater and to maintain a pressure in the furnace that is slightly less than atmospheric pressure. A forced-draft fan forces the combustion air to flow through the air heater, duct work, and burner into the furnace.

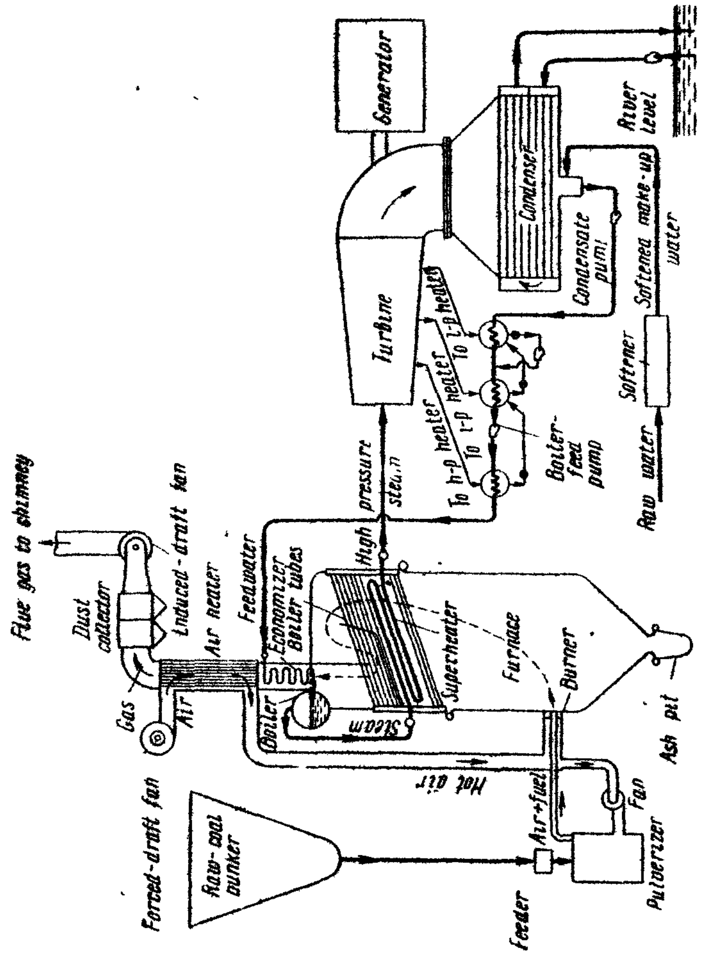

Fig. 1. Diagrammatic arrangement of a condensing steam power plant

Coal is delivered to the plant in railroad cars or barges which are unloaded by machinery. The coal may be placed in storage or may be crushed and elevated to the overhead raw-coal bunker in the boiler room.

The coal flows by gravity from the overhead bunker to the pulverizer or mill through a feeder which automatically maintains the correct amount of coal in the mill. In the mill the coal is ground to a fine dust. Some of the hot air from the air heater is forced through the mill to dry the coal and to pick up the finely pulverized particles arid carry them in suspension to the burner where they are mixed with the air required for their combustion and discharged into the furnace at high velocity to promote good combustion.

The high-pressure, high-temperature steam is expanded in a steam turbine which is generally connected to an electric generator. From 3 to 5 per cent of the output of the generator is needed to light the plant and to operate the many motors required for fans, pumps, etc., in the plant. The rest of the generator output is available for distribution outside the plant.

The condensed steam, which is normally at a temperature of 70° to 100° F, is pumped out of the condenser by means of a hot-well pump and is discharged through several feed-water heaters to a boiler feed pump that delivers the water to the economizer.

Most steam power plants of large size are now being built for operation at steam pressures of 1500 to 2400 psi, and in some plants pressure up to 5000 psi are being used. Steam temperatures of 1000° to 1100° F are in general use. Turbine-generator capacities of 250,000 kw (1 kilowatt = 1,34 horsepower) are common, and units of 500,000 kw are in operation. Steam-generating units capable of delivering 3,000,000 lb. of steam per hr are now in operation. Overall efficiency of the plant from raw coal supplied to electric energy delivered to the transmission line depends upon size, steam pressure, temperature, and other factors, and 40 per cent is now being realized on the basis of a full year of operation.

*** de Laval — Лаваль, Кард Густав Патрик де (l845-1913), шведский инженер и изобретатель**
[1] ... in such a manner as to permit...—...так, чтобы позволять…
* In effect — в сущности

THE INTERNAL-COMBUSTION-ENGINE POWER PLANT

The internal-combustion-engine power plant including essential auxiliaries is shown diagrammatically in Fig. 2. The fuel is burned directly in the cylinder of the engine or prime, mover, and the high pressure thus generated drives the piston downward and rotates a crankshaft.

Air is supplied to the engine through a silencer and cleaner, the function of which is to reduce noise and remove dust which would accelerate cylinder and piston wear if allowed to enter the cylinder.

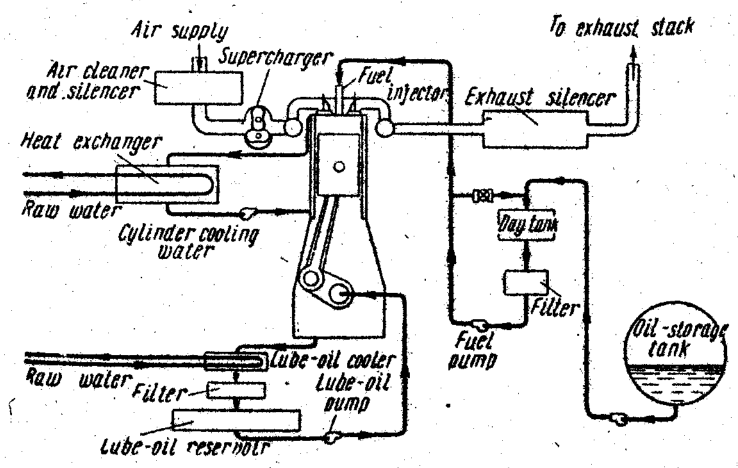

Fig. 2. The internal-combustion-engine power plant

A supercharger is installed in the air-intake system. The function of the supercharger is to increase the amount of air supplied to the cylinder by acting as an air pump. This in turn permits burning more fuel and obtaining more power from a given size of cylinder. An intake manifold is used to distribute the air equally from the supercharger to the various cylinders of multicylinder engine.

The exhaust system consists of an exhaust manifold for collecting the discharge gases from each of the cylinders into a common exhaust line, an exhaust silencer or muffler for reducing noise, and the exhaust stack for disposing of the exhaust gases to the atmosphere without creating a public nuisance

The cooling system includes a pump for circulating water through the cylinder jackets and heads of each cylinder and a heat exchanger to remove the energy absorbed in the engine by the cooling water. The heat exchanger may be air-cooled as in the automobile radiator, or it may be water-cooled. Seldom is raw water fit to circulate directly through the jackets of an internal-combustion engine.

The lubricating oil may be passed through a cooler, fitter, and reservoir and is supplied to the engine under pressure by means of an oil pump, usually to a hollow crankshaft. The oil serves as a lubricant for the rubbing surfaces of the engine and also as a coolant.

The fuel system consists of a storage tank from which the fuel may be supplied to a small day tank or reservoir. The oil is filtered and pumped as needed to the fuel-injection system which is an integral part of the engine.

Since the fuel is burned directly in the cylinder of the prime mover, the internal-combustion-engine power plant is simpler and more compact than the steam power plant. It is seldom built in engine sizes of more than 4000 hp, whereas a 300,000-hp steam turbine is common. It is more efficient than a steam power plant of comparable size but not so efficient as large steam central-station plants, which moreover can burn a cheaper grade of fuel. Consequently, the internal-combustion engine is used primarily in the transportation field for driving automobiles, buses, trucks, tractors, locomotives, ships, and airplanes where a compact, light-weight, efficient power plant of relatively small size is necessary.

THE GAS-TURBINE POWER PLANT

Air is compressed in an axialflow compressor from atmospheric pressure to a pressure which is usually between the limits of 75 and 120 psi. The compressed air may then flow through a regenerator or heat exchanger in which the hot exhaust gas from the turbine is utilized to increase the temperature of the air, thereby recovering energy that would otherwise be lost to the atmosphere. Fuel is sprayed into the combustor in which it combines chemically with the oxygen in the air to produce a hot gas leaving the combustor at some temperature between 1200° and 1700° F. The pressure of the air decreases slightly between the compressor discharge and turbine inlet because of friction, but the increase in temperature in the regenerator and combustor results in more than doubling the volume. The hot gas then expands in the turbine in which it does enough work to drive the compressor as well as an electric generator or some other suitable machine. The exhaust gases leaving the turbine are cooled in the regenerator before being discharged to the atmosphere.

Where space and weight limitations are critical or fuel is cheap, the regenerator may be omitted with a substantial decrease in efficiency. The turboprop engine as applied to the airplane operates without a regenerator and with a geared propeller as the load. In the turbojet engine as applied to the airplane, the turbine develops only enough to drive the compressor and exhausts into a nozzle at a back pressure considerably in excess of atmospheric pressure. The rearward expansion of the exhaust gases from the nozzle at high velocity creates the thrust which propels the airplane.

THE NUCLEAR POWER PLANT

In the nuclear power plant energy is released in a reactor by nuclear fission. A coolant is pumped through the reactor to absorb and remove this energy and thereby prevent an excessive temperature in the reactor. In the more common types of nuclear power plants, the high-temperature coolant that leaves the reactor flows through a heat exchanger in which steam is generated.

Extensive provisions are made to protect the operating personnel and the general public from the hazards of radioactivity by the installation of radiation and containment shields which enclose all radioactive components of the system.

The heat exchanger serves as a steam boiler. The steam flows through a turbine and associated equipment that are identical in design and arrangement with similar equipment in a conventional steam power plant. In other words, the nuclear reactor, heat exchanger, and pump replace the fuel-burning equipment and the steam generator of the conventional steam power plant.

CHAPTER I

BURNING EQUIPMENT

There are two general methods of firing fuel commonly employed: 1) on stationary grates, or 2) on stokers. Also coal may be pulverized to the consistency of 70 per cent through a 200-mesh screen and burned in suspension. The types of solid fuel encountered in various parts of the world and the general conditions under which they must be burned are so variable that it is impossible to design one type of grate or stoker that is exactly suited to all fuels. The problem becomes one rather of suiting the equipment to the type of fuel to be handled.

To a certain extent, the design of the furnace must be considered coincidentally with the selection of fuel-burning equipment, so that satisfactory ignition and heat release may be ensured. The choice of equipment for a given set of conditions is limited, and, although any stoker will burn any fuel only one design as a rule will give satisfactory results. Coals may be broadly classified as follows:

Group 1. This group includes the anthracites and semi-anthracites which should be burned without agitation of the fuel bed.

A fuel of this class is satisfactorily burned on travelling-grate or chain-grate stokers, on which the coal is fed in a comparatively thin, uniform layer. As combustion progresses, the ash covers the surface of the stoker and acts as a protective blanket, the fuel being supplied with combustion air as it travels toward the ashpit.

Group 2. This group includes the bituminous coals of the caking type which require agitation of the fuel bed to break up the mass of coke as it forms as well as to resist the tendency of this fuel to fuse into a mat, or cake, that resists the passage of air and retards the process of combustion. Underfeed stokers of the multiple-retort type are designed to burn coals of this class, for the plungers have a characteristic forward and upward motion. By breaking up the surface of the fuel bed, more air passages are created, with a tendency to increase combustion rate. A few coals of this class have a low ash-fusion temperature with a resulting tendency to fuse and jam the operating parts of the stoker. These coals, particularly if high in sulphur, should be avoided as stoker fuels.

Group 3. This group includes midwestern coals and most of the western bituminous coals. These do not tend to soften but form masses of coke, they require no agitation of the fuel bed and are burned to best advantage on chain-grate stokers.

Group 4. This group consists of most of subbituminous coals and lignite’s which do not fuse when heated and do not require agitation. They have a tendency to disintegrate or slack on the grate as well as drift and sift through if disturbed. They have a tendency to avalanche on inclined grates and are most satisfactorily burned on chain- or travelling-grate stokers.

FURNACES

A furnace is a fairly gas-tight and well-insulated space, in which gas, oil, pulverized coat, of the combustible gases from solid-fuel beds may be burned with a minimum amount of excess air and with reasonably complete combustion. Near the exit from the furnace at which place most of the fuel has been burned, the furnace gases will consist of inert gases such as CO_2, N_3 and H_2O vapor, together with some O_2 and some combustible gases such as CO, H_2, hydrocarbons, and particles of free carbon (soot). If combustion is to be complete, the combustible gases must be brought into intimate contact with the residual oxygen in a furnace atmosphere composed principally of inert gases. Also, the oxygen must be kept to a minimum if the loss due to heating the excess air from room temperature to chimney-gas temperature is to be low. Consequently, the major function of the furnace is to provide space in which the fuel may be burned with a minimum amount of excess air and with a minimum loss due to the escape of unburned fuel.

The design of a satisfactory furnace is based upon the "three T's of combustion": temperature, turbulence, and time.

For each particular fossil fuel, there is a minimum temperature, known as the ignition temperature, below which the combustion of that fuel in the correct amount of air will not take place.

The ignition temperature of a fuel in air as reported by various investigators depends somewhat upon the methods used to determine it and, for some common gases, is as follows:

Hydrogen (H_2)	1075—1095° F
Carbon monoxide (CO)	1190—1215° F
Methane (CH_4)	1200—1380° F
Ethane (C_2H_6)	1070-1165° F

If the combustible gases are cooled below the ignition temperature, they will not burn, regardless of the amount of oxygen present. A furnace must therefore be large enough and be maintained at a high enough temperature to permit the combustible gases to burn before they are cooled below the ignition temperature. In other words, the relatively cool heat-transfer surfaces must be so located that they do not cool the furnace gases below the ignition temperature until after combustion is reasonably complete[1].

Turbulence is essential if combustion is to be complete in a furnace of economical size[2]. Violent mixing of oxygen with the combustible gases in a furnace increases the rate of combustion, shortens the flame, reduces the required furnace volume, and decreases the chance that combustible gases will escape from the furnace without coming into contact with the oxygen necessary for their combustion. The amount of excess oxygen or air required for combustion is decreased by effective mixing. Turbulence is obtained, in the case of oil, gas, and powdered coal, by using burners which introduce the fuel-air mixture into the furnace with a violent whirling action. High-velocity steam or air jets and mixing arches may be used to increase the turbulence in furnaces fired with coal on stokers.

Since combustion is not instantaneous, time must be provided for the oxygen to find and react with the combustible gases in the furnace. In burning fuels such as gas, oil, or pulverized coal, the incoming fuel-air mixture must be heated above the ignition temperature by radiation from the flame or hot walls of the furnace. Since gaseous fuels are composed of molecules, they burn very rapidly when thoroughly mixed with oxygen at a temperature above the ignition temperature. However, the individual particles of pulverized coal or atomized oil are very large in comparison with the size of molecules, and many molecules of oxygen are necessary to burn one particle of coal or droplet of oil. Time is required for the oxygen molecules to diffuse through the blanket of inert products of combustion which surround a partially burned particle of fuel and to react with the unburned fuel. Consequently, oil and pulverized coal burn with a longer flame than gaseous fuels.

The required furnace volume is dependent, therefore, upon the kind of fuel burned, the method of burning the fuel, the quantity of excess air in the furnace, and the effectiveness of furnace turbulence. The shape of the furnace depends upon the kind of fuel burned, the equipment employed to burn the fuel, and the type of boiler used to absorb the energy if the fuel is burned for steam generation.

Industrial furnaces in which the objective is to create and maintain a region at a high temperature and the furnaces of small steam boilers are constructed of fire brick, a brick that has been developed to withstand high temperatures without softening, to resist the erosive effects of furnace atmospheres and particles of ash, and to resist spalling when subjected to fluctuating temperatures. Low vertical walls may be constructed of fire brick in the conventional manner. High walls which are subject to considerable expansion, may be tied to and sectionally supported by an external steel frame.

When a boiler furnace is operated at high capacity, the temperature may be high enough to melt or fuse the ash which is carried in suspension by the furnace gases. Molten ash will chemically attack and erode the fire brick with which it comes into contact. Also, if the ash particles are not cooled below the temperature at which they are plastic or sticky before they are carried into the convection tube banks of the boiler, they will adhere to these surfaces, obstruct the gas passages, and force a shutdown of the unit[1]. Moreover, the function of a boiler is to generate steam, and the most effective heat-transfer surface is that which can "see" the high-temperature flame and absorb radiant energy. The rate of heat absorption expressed in Btu per hour per square foot of projected wall area may be from 1000 to 10,000 times as great as the heat-transfer rate in the boiler surface with which the products of combustion are in contact last before being discharged up the chimney. Consequently, the walls of furnaces for large steam boilers are constructed of boiler tubes.

[1] **until after combustion is reasonably complete —** до тех пор, пока сжигание не завершено
[2] **If combustion is to be complete in a furnace of economical size—-** когда должна быть обеспечена полнота сжигания в топках экономичных размеров

CYCLONE FURNACE (CRUSHED COAL)

The cyclone furnace is a water-cooled horizontal cylinder (5 to 10 ft in diameter) into which coal is introduced.

As the coal moves from front to rear, combustion air is introduced tangentially at high velocity and about 35-in water gage pressure. This causes a whirling or centrifugal action, with the solid fuel particles moving to the periphery of the combustion chamber where their movement is retarded by molten slag that covers its walls. Although the finer fuel particles burn in suspension, the cyclone method of combustion is primarily a surface-burning process. The solid fuel particles in the liquid ash coating on the walls are scrubbed by the incoming air stream, providing intimate coal and air mixing. Combustion in the cyclone furnace is complete and has practically no carbon loss.

The cyclone furnace is water-cooled as an adjunct to the boiler circulation system. It is attached to the steam generating unit, which may have either of two types of secondary furnaces: 1) the water screen type, in which a water screen of tubes divides the furnace into lower and upper sections; and 2) the open furnace type. In the water screen furnace, the fly-ash loading of the flue gases will be about 10 per cent of the total ash fired. In the open furnace, the loading will be about 15 per cent. This refuse may be collected and returned for reinjection.

Some stations find the cyclone furnace advantageous and there are definite sales trends in its favour. As it is not necessary to pulverize the coal, a considerable saving is obtained in both initial investment and also in operating expense.

This furnace has been proved to be suitable for a wide range of coals and for firing gas or oil either in combination with coal or as stand-by or substitute fuel. The cyclone furnace is also capable of burning waste or by-product fuels such as wood, chars, and cokes.

[1] **to force a shutdown (of the unit)** — вызвать остановку (агрегата).

PULVERIZED COAL FURNACE

Coal may be fired as a finely powdered fuel that is injected into the furnace. The coal is pulverized to a fineness of 70 per cent or more through a 200 mesh sieve. It is then transported by hot primary air (which also dries the coal) to the furnace.

The majority of all central steam generators operating at 200,000-lb steam per hr and over are fired by pulverized coal. The number of pulverizers are determined by pulverizer capacity and stand-by requirements. Larger installations have two, three or four pulverizers. Provision for three pulverizers, one for each row of burners plus one for stand-by is not unusual. Pulverized coal-fired boilers may be either the dry bottom or slag-tap type. Vertical, horizontal, opposed, or tangential firing methods may be employed.

The size of the unit, its pressure and temperature, available space, fuel characteristics, ash-fusion temperature, type of burner, and ash removal method determine the volume of the furnace, the extent of water cooling, and the ultimate design of the entire steam-generating unit.

Pulverized coal furnaces are usually convertible to firing with oil or gas. Units near oil refineries may utilize fluid coke.

Pulverized coal firing removes a limitation on the amount of fuel that can be burned in a boiler (with stoker firing there is a definite limit).

The type and multiplicity of burners, their arrangement and the flame shape will determine the furnace width and depth dimensions. The furnace height is a function of the required furnace volume. The exit temperature of the gases should be below the ash-fusion temperature of the lowerest quality fuel to be used. Thus, coal with a large percentage of low-fusion ash will require larger waterwall surfaces, which in turn make a larger furnace volume necessary. Superheater requirements may govern exit temperatures.

All pulverized coal-fired furnaces constructed today are partially or completely water-cooled. If tangential firing is used, the furnace must be completely water-cooled, because there is considerable flame impingement. It is desirable to eliminate, as much as possible, blasting of flames against the furnace walls. Molten ash particles stick to and dissolve most refractories. Heat and high sulphur content may induce a slow attack or tube wastage of the water-cooled walls. Flame length varies with coal particle size (the length is shortened by uniformly fine pulverization), the percentage and composition of the volatile constituent, turbulence, furnace temperature, and excess air. With proper mixing, the flame length may be as short as 10 ft. Helical or U-shaped paths[1] may be provided for long flames, the furnace shape being adapted to the available space.

In a wet-bottom (slag-tap) furnace, 40 to 60 per cent of the total fired ash leaves with the combustion gases, and in a dry-bottom furnace, 80 to 90 per cent. An individual burner may be reduced to about 35 per cent of its maximum continuous rating. With 15 to 22 per cent excess air, the unburned combustible is under I per cent. The excess air requirements will vary from 10 to 30 per cent. As the percentage of ash increases, the amount of excess air must also increase if the combustible loss is to be held to a constant minimum. For optimum efficiency, the combustible loss is balanced against the dry gas loss.

[1] **U-shaped paths** — U-обраэные траектории (пути, формы)

GAS BURNER

Gas is burned in many industrial furnaces because of its cleanliness, ease of control of furnace atmosphere, ability to produce a long slow burning flame with uniform and gradual energy liberation, and ease of temperature regulation. Natural gas is used for steam generation in gas-producing areas and in areas served by natural-gas transmission lines[2] where coal is not available at a competitive price. It is also burned extensively in coal- or oil-fired units[3] during the summer months in districts served by natural-gas pipe lines, at which time the absence of the domestic heating load creates a temporary surplus of natural gas. By-product gas such as blast-furnace gas may be available at the steel mills for steam generation. Because of the variable or seasonal supply of gaseous fuels, combination burners have been developed to permit the simultaneous burning of the available gas together with pulverized coal or oil in an amount sufficient to produce the required steam.

When a molecule of combustible gas is mixed with the oxygen necessary for its combustion at a temperature above the ignition temperature, combustion is practically instantaneous. For steam generation, where a short flame is desired in order to reduce the required furnace volume, the burner should provide for rapid and thorough mixing of the fuel and air in the correct proportions for good combustion. For such applications, a good burner is primarily a proportioner and mixing device. In industrial furnaces where long "lazy" flames are desired, slow and gradual mixing of the air and fuel in the furnace is necessary.

In the burner the gas, under pressure in the supply line, enters the furnace through a burner port and induces a flow of air through the port. Mixing is poor, and a fairly long flame results. The flame can be shortened by use of the ring burner, m which the gas flows through an annular ring and induces air flow both around and within the annulus of gas.

[2] **in areas served by natural-gas transmission lines** —в областях, через которые проходят магистральные газопроводы природного газа.
[3] **coal- or oil-fired units**—агрегаты, использующие угольное или жидкое топливо

STOKERS

A stoker should not only be designed from the combustion point of view, but it must be mechanically strong to withstand ail working stresses due to high temperature, etc. A simple design will ensure low first cost, minimum maintenance and operation for long periods without failure. Some of the factors to be aimed at in stoker design are: maximum rates of burning, highest continuous efficiency and the unlimited choice of fuels.

Any study of the use of stokers must begin with an analysis of the four principal constituents of coal, namely, moisture, volatiles, mixed carbon and ash, or more generally, water, tar, coke and dirt. These determine the features which should be embodied in the stoker and furnace equipments so that proper treatment of the coal at the correct time is effected on its passage through the furnace. Whichever of the two types be used the coal has to be taken from the bunkers to the feeding hoppers on the boilers. The coal falls by gravity from the bunkers through a valve into feeding chutes. In some installations automatic weighers are included in the downspouts between the cut-off valves and the boiler feed hoppers. The cut-off valves may be operated from the firing floor by means of chains. The chutes are one of two types namely, traversing and fixed.

There are usually two or three chutes for large boilers. The traversing chutes travel the full width of the feeding hopper, the motion being affected by means of a continuously rotating screwed shaft which engages with a special nut attached to the chute. The operating shaft has right- and left-hand helical grooves and the nut is designed so that at the end of its travel it reverses automatically.

The chutes are operated from the stoker drive, there being two or four chutes for large boiler units. Coal chutes are of welded mild steel plates, wearing plates also being included.

SPREADER STOKERS

The spreader stoker is designed to throw coal continuously onto a stationary or moving grate. A spreader stoker is equipped with a moving grate which travels toward the feeder mechanism and discharges the refuse continuously. Coal is fed from the hopper by means of a reciprocating feeder plate having a variable-speed drive which for best performance should be regulated automatically to feed coal in accordance with the demand for energy.

The coal is delivered by the feeder to a rapidly revolving drum or rotor on which are fastened specially shaped blades which throw the fuel into the furnace and distribute it uniformly over the grate. Coal can be distributed thus for a total distance of about 22 ft. The feeder mechanism is built in standardized widths, and several units may be installed across the front of the larger furnaces. Air is supplied by means of a blower to the space under the moving grate through an adjustable damper. The active fuel bed is normally not over $1^1/_2$ in. deep so that an adequate supply of air can penetrate the fuel bed and enter the furnace. Active fuel beds much thicker than $1^1/_2$ in. will produce excessive amounts of smoke. Much of the volatile matter is distilled from the coal before it strikes the fuel bed, and the caking properties of the fuel are thus destroyed, thereby making it possible to burn[1] even the strongly caking bituminous coals. Since the fuel bed is thin and undisturbed and the ash is cooled by the flow of- air through it, trouble with clinkering or fusing of the ash is uncommon, and this stoker can burn almost any kind of bituminous coal. Since the finer sizes of coal are burned in suspension, large furnaces are required, and objectionable quantities of dust may be discharged from the installation if it is not designed correctly and if dust collectors are not installed to clean the gases leaving the steam-generating unit. Also, it is standard practice to install high-velocity steam jets in the furnace to promote turbulence, improve combustion, and reduce smoke.

Large units provided with continuous ash-discharge grates are capable of burning 12 to 15 tons of coal per hr. Small units may have stationary grates with clean-out doors through which the ashes may be removed manually with a hoe, or they may have dump grates operated by a power cylinder in which grate sections may be tilted periodically to dump the ashes.

The spreader stoker is simple in construction and reliable in operation. It can burn a wider variety of coal successfully than any other type of stoker. Maximum continuous combustion rates of 45 to 60 psi of grate area per hr are normally used. When provided with automatic regulation of fuel and air in accordance with the demand for energy, this stoker is very responsive to rapidly fluctuating loads.

However, it is not so adaptable to light-load operation as other types of stokers because of the difficulty of maintaining ignition and combustion in the very thin fuel bed with a cold furnace. It is because of the thin fuel bed and the continuous, uniform firing of coal that the spreader stoker overcomes the smoke-producing problem associated with the thick intermittently hand-fired fuel bed.

[1] **making it possible to burn** — давая возможность сжигать

CHAIN- AND TRAVELLING-GRATE STOKERS

A chain-grate stoker has a moving grate in the form of a continuous chain. The upper and lower runs of the chain are supported on a structural steel frame. The chain is driven from the stoker front by means of sprockets mounted on a rotating shaft which is actuated by a ratchet mechanism and hydraulic cylinder. The grate bars are made of heat-resistant cast iron, are cooled by the air supplied for combustion, and form a flat undisturbed surface for the fuel bed.

Coal from the stoker hopper is placed on the moving grate in a uniform layer, the depth of which is control led by the vertical movement of an adjustable fuel gate. The depth of the fuel bed is usually between 3 and 8 in. depending upon the kind of fuel being burned. The speed of the grate may be adjusted, usually between the limits of 4 and 20 in. per min, so that the combustible material is burned before the ash is discharged from the rear end into the ashpit.

The shearing action of adjacent grate bars as they pass around the curved supporting member at the rear of the stoker provides a self-cleaning action for the grate bars. Air is supplied under adjustable pressure to several compartments under the grate. Thus the supply of air to various sections of the fuel bed may be adjusted to suit the combustion requirements.

When bituminous and other high-volatile coals are burned, high-velocity air jets are installed in the front furnace wall. The volatile matter that is released from the incoming green coal is mixed with the swirling turbulent air that is introduced above the, distillation zone. Two important results are thereby accomplished: 1) the volatile matter is burned smokelessly, and 2) a high-temperature zone is formed which provides for stable ignition of the incoming coal. The existence of this highly incandescent zone of turbulent combustion over the front end of the stoker makes mixing arches in the furnace unnecessary, and an open furnace with vertical walls similar to the spreader-stoker furnace may be used.

The small sizes of anthracite which cannot be sold for a domestic fuel and the small sizes of coke which are too small to charge into the blast furnace, called coke breeze, are important stoker fuels in certain localities. These fuels contain practically no volatile matter. Because of the fine size and large total surface of the incandescent carbon in the fuel bed, all the oxygen combines with carbon a short distance above the grate unless fuel-bed air velocities are so high as to almost lift the fuel from the grate. Under these conditions, large amounts of fine particles of carbon are blown upward into the furnace.

It is necessary to maintain a hot zone above the entering fuel to ignite the fuel on the grate. Accordingly, furnaces for burning anthracite and coke breeze are constructed with a long rear arch and over-fire air injection through the rear arch.

The net effect is to maintain a hot zone over the incoming fuel and to blow the fine particles of carbon onto the front of the stoker so as to assist ignition and retain them in the combustion zone until they are burned. Over-fire air injection and a high furnace are necessary to burn the CO that is formed in the fuel bed.

The travelling-grate stoker is similar in general appearance and operation to the chain-grate stoker except that individual grate bars or keys are mounted on carrier bars which extend across the width of the stoker and are attached to and driven by several parallel chains. Since adjacent grate bars have no relative motion with respect to each other, this stoker is particularly applicable to the burning of the fine sizes of anthracite and coke breeze in which all the fuel may pass through a screen having 3/16-in. round openings.

CHAPTER II

HEAT TRANSFER AND STEAM GENERATION

Boilers, superheaters, economizers, condensers, evaporators, coolers, and heaters are types of equipment that are used to transfer energy from one fluid to another through a metal surface that prevents the fluids from mixing. Since most of this equipment operates at temperatures that are considerably different from room temperature, the equipment and interconnecting piping are insulated to prevent transfer of energy to or from the atmosphere. The design of the amount of heat-transfer surface and its arrangement and the selection of the insulation to be applied to the equipment are based on the laws of heat transfer and economics.

MODES OF HEAT TRANSFER

Heat has been defined as energy that is being transferred across the boundaries of a system because of a temperature difference. This transfer may occur through the mechanism of conduction, convection, or radiation, either separately or in combination.

Heat is transferred by conduction through a solid, partly as a result of molecular collisions but primarily as a result of a flow of electrons which is induced by a temperature difference. Metals that are good conductors of electricity are also good conductors of heat. Poor conductors (good insulators) are solids that have low density because of the presence of large numbers of small pores or pockets containing air which reduce to a minimum the cross-sectional area of the solid material through which the electrons may flow. Conduction also occurs in liquids and gases at rest,[1] that is, where there is no motion other than the random motion of the molecules. Since the energy is transferred as a result of random molecular collisions, the conductivity of liquids and gases is low as compared to the conductivity of solids.

Convection occurs when, either because of a difference in density or because of the operation of a fan or pump, a fluid flows across a hot or cold surface and exchanges energy with that surface. The heated or cooled fluid may then flow to some other region. Since convective heat transmission always involves a flowing fluid, the laws governing heat transfer by convection are closely related to the laws of fluid dynamics.

Radiation involves the transfer of energy through space in the form of electromagnetic waves that are different from light waves only in their length (frequency). Since radiant energy travels in straight lines with the velocity of light and may be absorbed, reflected, or transmitted by the receiving surface in a manner similar to the action of light, the laws of optics are important in the study of radiant-energy transfer.

In general, a heat exchanger consists of a metal wall through which heat flows from one fluid to another. Heat transfer through the wall follows the laws of conduction. Heat transfer between the moving fluid and the wall involves convection, in addition to which radiation may be important at high temperatures.

' **In liquids and gases at rest** — в жидкостях и газах, находящихся в состоянии покоя

STEAM GENERATION

Steam is used for space heating, in manufacturing processes, and for power generation. Except for hydroelectric power plants, practically all the central-station generating capacity is in the form of steam turbines. Because of the magnitude of the load and the economies that are effected through the use of the smallest possible number of largest machines, most central-station turbines now being built are in the size range of 1000,000 to 600,000 kw. It is standard practice to install one steam-generating unit per turbine. Consequently, these turbines require steam-generating units in the capacity range of 750,000 to over 3,000,000 lb. of steam per hr.

The steam boiler is a pressure vessel in which feedwater can be converted into saturated steam of high quality at some desired pressure. When other heat-transfer surfaces such as superheater, air heater, or economizer surfaces are combined with boiler surface into a unified installation, the name steam-generating unit is applied to the complete unit.

Boilers in which the water is inside the tubes are called water-tube boilers, whereas boilers that have the hot products of combustion in the tubes and the water outside the tubes are called fire-tube boilers. Boiler heating surface is defined as that surface which receives heat from the flame or hot gases and is in contact with water. The area is based on the surface receiving the heat, that is, the outside area of water tubes and the inside area of fire tubes.

BOILERS

Fire-tube boilers. These are boilers with straight tubes that are surrounded by water and through which the products of combustion pass. The tubes are usually installed within the lower portion of a single drum or shell below the water-line.

Water-tube boilers. These are boilers in which the tubes themselves contain steam or water, the heat being applied to the outside surface. The tubes are usually connected to two or more drums set parallel to, or across, the centerline. The drums are usually set horizontally.

Tube shape and position. The tubular heating surface may be classified: 1) by form— either straight, bent, or sinuous or 2) by inclination — horizontal, inclined, or vertical.

Firing. The boiler may be either a fired or an unfired pressure vessel. In fired boilers the heat applied is a product of fuel combustion. A nonfired boiler has a heat source other than combustion.

Circulation. The majority of boilers operate with natural circulation. Some utilize positive circulation in which the operative fluid may be forced "once through" or controlled with partial recirculation.

Furnace position. The boiler is an external combustion device in that the combustion takes place outside the region of boiling water. All heat must be transferred through the heating surface to reach the water. The relative location of the furnace to the boiler is indicated by the description of the furnace as being internally or externally fired: 1) the furnace is internally fired if the furnace region is completely surrounded by water-cooled surfaces; 2) the furnace is externally fired if the furnace is auxiliary to the boiler or built under the boiler.

General shape. During the evolution of the boiler as a heat producer many new shapes and designs have appeared. Some of these boilers have become popular and are widely recognized in the trade, including the following:

1. Fire-tube boilers — horizontal return tubular, short firebox, compact, locomotive, vertical tube (steam jenny), Scotch type, and residential units.

2. Water-tube boilers — both horizontal straight tube and bent tube units. The horizontal straight tube boiler may have a box type header made of steel plate, or a sectional header each section of which connects the tubes in a single vertical row. The bent tube boiler may have one to four drums. If the drum is parallel to the tubes, the boiler is long — longitudinal drum; if across the tubes, it is a cross drum. If the furnace is enclosed with water-cooled surfaces, it is a waterwall (water-cooled) furnace.

THE TWO-DRUM WATER-TUBE BOILER

A typical small two-drum water-tube boiler is fired by a spreader stoker equipped with a dump grate. By means of baffles, the gases are forced to follow a path from the furnace to the boiler exit. This arrangement of gas flow is known as a "three-pass" design. A water level is maintained slightly below the midpoint in the steam drum. Water circulates from the steam drum to the lower or mud drum through the six rows of tubes in the rear of the boiler-tube bank where the comparatively low gas temperature results in a low heat-transfer rate. Circulation is from the mud drum to the steam drum through the front boiler tubes and the side-wall furnace tubes. The side-wall furnace tubes are supplied with water from the mud drum by means of circulators connected to rectangular water boxes located in the side walls at the level of the grate. Water for the front-wall tubes is supplied to a round front-wall header by downcomer tubes connected to the steam drum and insulated from the furnaces by a row of insulating brick. Most of the steam is generated in the furnace-wall tubes and in the first and second rows of boiler tubes which can "see" the flame in the furnace and absorb energy by radiation.

Boilers of this type have been standardized in a range of sizes capable of generating 8,000 to 50,000 lb. of steam per hr.

The position of the drums and the shape of the tubes result in a compact unit having a well-shaped and economically constructed furnace. By simple changes in the arrangement of furnace-wall tubes, the design can be adopted to almost any kind of firing equipment and fuel.

THE BENT-TUBE BOILER

The bent-tube boiler offers many advantages over the straight-tube boiler, including the following: 1) greater economies in fabrication and operation because of the use of welding. improved steels, waterwall construction, and new manufacturing techniques; 2) greater accessibility for inspection, cleaning and maintenance; 3) ability to operate at higher steaming rates and deliver drier steam.

The main elements of the bent-tube water-tube boiler are essentially drums (or drums and headers) connected by bent tubes. With a water-cooled furnace, bent tubes are arranged to form the furnace enclosure, making it integral with the boiler.

The early bent-tube boilers were of the four-drum type. Although many operators still prefer it, there is a decided trend to use two drums or three drums.

In modern bent-tube units, the capacity is held to less than 20,000 lb. steam per hr per ft of width. The smaller bent-tube boiler has been fairly well standardized into a relatively small number of types. The boiler is either of refractory wall or waterwall construction, sometimes with a steel casing designed for nonpressure operation. Popular boilers are the two-drum low head, the three-drum low head, two-drum inclined as well as various package boiler designs. The standardized design used in industrial plants is available in capacities to 100,000 lb. steam per hr. Design pressure varies from 160 to 825 psi with temperatures up to 850° F.

Integral furnace. In its early development stages, the bent-tube boiler was set over a brick or refractory furnace, and all heat-absorbing surfaces were inside the boiler itself. As furnace size and temperatures increased, refractory maintenance became excessive, particularly when firing with pulverized coal.

The higher gas temperatures caused increased slagging or fouling of the boiler surfaces. The furnaces were first partly then later completely, water-cooled to overcome these difficulties. Besides decreasing maintenance and boiler slagging, the waterwalls also generated steam, provided excellent circulation, and aided in obtaining higher capacities.

Furnace waterwalls were first applied to existing boilers, the water circulation being more or less independent of the boiler circulation. Later the furnace water-cooled surface and the boiler surface were integrated.

With the advent of pulverized coal, it became necessary to prevent the ash from slagging at the bottom of the furnace. This was accomplished by installation of a waterscreen, consisting of a crisscross of water tubes protecting the furnace floor (and the ash) from radiation. As furnace input increased, the entire floor was water-cooled and designed for continuous or intermittent discharge of molten slag. Still later a redesign of the floor resulted in the dry-ash furnace bottom.

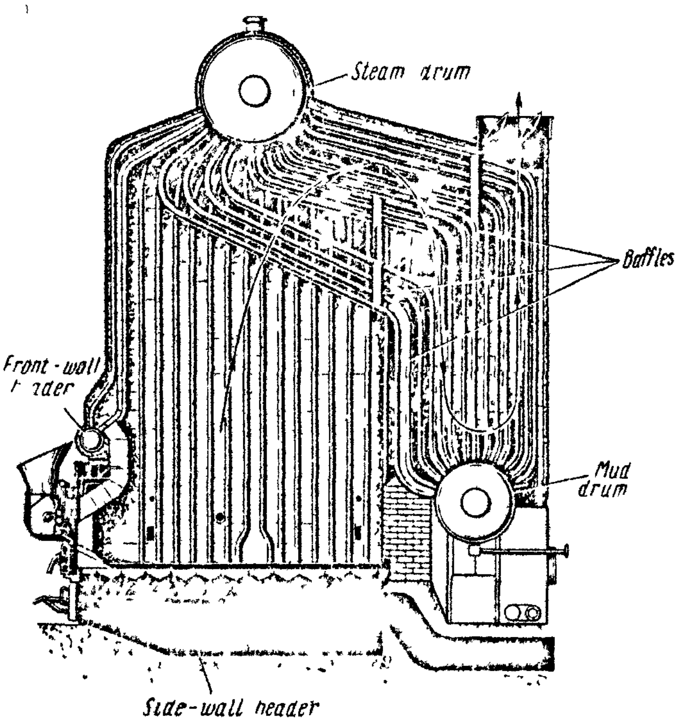

Fig. 3. Two-drum bent-tube boiler with spreader stoker and water-cooled furnace

Design. With the exception of models of obsolete design or of very recent development, such as the positive circulation boiler, the bent-tube boiler is inherently a multidrum boiler.

There may be two, three or four drums-one lower drum with the remainder at the top of the boiler. The lower drum is the mud drum, which has a blowdown valve for removal of sludge and concentrations of salts. The upper drums are steam and water drums.

Although they are called steam drums, actually some of them may be water filled. Steam separators (drum internals) eliminate entrained moisture and precipitate, purifying the steam.

The tubes are either inclined or arranged in vertical banks within the combustion space, or they may comprise water-walls backed with refractories. The bent tube allows great flexibility in design, particularly with regard to drum arrangement, as it may enter the drum radially.

Boiler and furnace wall tubes are usually supported by the drums or headers to which they are connected. Some boilers are bottom supported, and others are suspended from the upper drums.

The gas baffles are arranged in many different patterns, with the gas flowing across and along the tubes in one or more passes. The tendency toward slag adherence is decreased if tubes are vertical or nearly vertical. To avoid particularly abrasive coal ash or unsatisfactory fusion characteristics, the boiler design must consider both these possibilities.

The bent-tube boiler is suitable for operation with oil, gas, coal, bagasse or wood. Burning methods include oil or gas burners and stoker firing. For sizes over 100,000 lb. steam per hr pulverized coal or crushed coal (cyclone furnace) firing is used. The firing is usually manually or semiautomatically controlled.

THE HORIZONTAL STRAIGHT TUBE BOILER

The horizontal straight tube boiler covers a range of capacity and pressure between that of the fire-tube boiler and the large central steam generator. It is used in industrial applications primarily for process steam, occasionally for heating, and sometimes for power generation. The horizontal straight tube boiler is limited to an hourly production of about 10,000 lb. steam per ft of boiler width. It is simple in operation and has low draft loss.

The straight tube boiler is made up of banks of tubes that are usually staggered, the tubes are inclined at an angle (5 to 15 deg) to promote circulation and expanded at the ends into headers.

The header (either a box header or a sectional header) provides flat surfaces for tube connections. It may be connected to the drum by means of circulation tubes (downcomers or downtakes for supplying water to the tubes, uptakes or risers for discharging water and steam from the tubes) or by sheet steel saddles. The drum may be either longitudinal (long) or across (cross) with reference to the axis of the boiler tubes. Some boilers have a portable firebox with wrapper and furnace sheets instead of a drum. The high end is usually the firing end. The area of the heating surface (and the capacity) is varied by changing the tube length and the number of tube row in both height and width. The tubes, 3 to 4 in. in diameter, are spaced 7 to 8 in. on centers horizontally and 6 in. on centers vertically (except slag screen tubes, which are on about 12 in. centers). The tubes are all of the same diameter and length, never over 18 to 20 ft.

As the pressure increases, the header design changes. Greater tube spacing is required, and the tubes must be smaller in diameter.

Internal fireside baffles may be horizontal (parallel with and between the tubes) or vertical (across the tubes). The baffling is arranged for two or three gas passes across the tubes. In the headers opposite the tube end, there is a handhole of sufficient size to permit removal or renewal of the tubes and the inspection of tubing and cleaning of the tube interior. Handholes are elliptical in shape, machined to form a smooth gasket seat and fitted with forged steel handhole plates.

Superheaters with a maximum temperature rise of about 100° F may be installed. They are termed overdeck and interdeck depending upon their location in the boiler.

Circulation. The steam and water rises along the inclined tubes to the front headers, then through the headers and circulation tubes to the drum. The water then circulates through the downcomers to the rear header and finally to the tubes to complete the cycle. In the long drum boiler, the water is diverted by a baffle plate back through the steam drum. In the cross drum boiler, steam separators (drum internals), are often used to eliminate entrained moisture and precipitates, thereby purifying the steam. If the tubes discharge to the steam drum at or above the waterline, the boiler is known as an exposed-tube boiler, otherwise it is a submerged-tube boiler.

Fuels and fuel firing. The horizontal straight tube boiler is suitable for operation with oil, gas, coal, bagasse, or wood.

Burning methods include oil and gas burners with hand or stoker firing. Pulverized coal firing is rarely used. The firing is usually manually controlled,

THE HORIZONTAL-RETURN TUBULAR BOILER

In the horizontal-return tubular (HRT) fire-tube boiler the boiler shell is a horizontal cylinder closed at each end by a flat tube sheet or head. The fire tubes, which are usually 3 to 4 in. in diameter, extend through the boiler from one tube sheet to the other and are rolled or expanded into the tube sheets at each end, thus serving not only as flues through which the hot combustion products flow but also as tie rods to hold the flat tube sheets in place against the steam pressure in the boiler. The flat surfaces of the heads above the tubes are braced to the boiler shell by diagonal braces.

The boiler supported by a steel frame, is provided with a brick setting which encloses the furnace, and is fired by a single-retort underfeed stoker. The gaseous products of combustion from the stoker pass over a bridge wall at the rear of the stoker which is intended to promote turbulence, then through the brick furnace under the boiler shell to the rear of the boiler. They then flow through the boiler tubes to the front of the boiler after which they pass a damper and are discharged to a chimney.

A water level is maintained a short distance above the тор tubes so as to provide adequate surface for the separation of the steam from the water and, at the same time, to keep water in contact with all surfaces across which hot gases are flowing. The water level in the boiler is indicated by a water column which is connected to the boiler by two pipes, one above and one below the water level. The water in the water column is thus maintained at the same level as in the boiler, and this level is indicated by a glass tube attached to the water column.

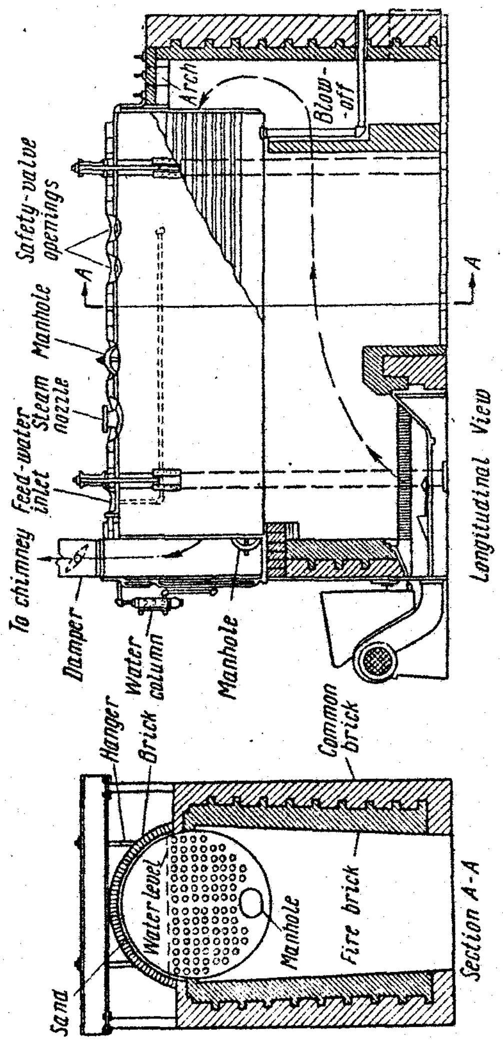

Fig 4. Horizontal-return turbular boiler set over a single-retort underfeed stoker

A blow-off line is connected to the bottom of the drum at the rear. Valves in this line are opened periodically and some of the boiler water is blown to a sewer, thus carrying out of the system the impurities that are coming into the boiler in the feedwater. It is common practice in these small boilers to add chemicals to the feedwater. These chemicals are intended to prevent the scale-forming impurities in the feedwater from precipitating on the heating surfaces as an adherent scale. If the boiler produced dry steam, all these impurities remain in the boiler. They must be removed by periodic blowdown in order to maintain the concentration in the boiler water below a level that will cause scale formation.

The boiler shell is provided with suitable opening for the attachement of spring loaded safety valves, feed-water inlet, a steam outlet nozzle, and manholes or cleanouts.

Since this boiler is provided with a brick furnace which is external to the boiler itself, it is known as an externally filed boiler.

SUPERHEATERS

Superheated steam is produced by causing saturated steam from a boiler to flow through a heated tube or superheater, thereby increasing the temperature, enthalpy, the specific volume of the steam.

It should be noted that in an actual superheater there will be a decrease in steam pressure due to fluid friction in the superheater tubing.

Maximum work is obtained when a fluid expands at constant entropy, that is, without friction and without heat transfer to the surroundings. By calculations it will be found that the constant-entropy expansion of 1 lb. of dry saturated steam at 1000 psia to a final pressure of 1,0 psia will result in the conversion into work of 417 Btu, whereas the expansion of superheated steam at the same initial pressure, 1000 psia but at 1000° F, to the same final pressure of 1,0 psia will result in the conversion into work of 581 Btu, an increase of 39,3 per cent.

In addition to the theoretical gain in output due to the increased temperature of superheated steam as compared to saturated steam, there are additional advantages to the use of superheated steam in turbines. The first law of thermodynamics states that all the work done by the turbine comes from the energy in the steam flowing through the turbine.

Thus, if steam enters the turbine with an enthalpy of 1300 Btu per lb. and the work done in the turbine is equivalent to 300 Btu per lb. of steam, the enthalpy of the exhaust steam will be 1300 - 300 = 1000 Btu per lb., neglecting heat transfer to the surroundings. If sufficient energy is converted into work to reduce the quality of the steam below about 88 per cent, serious blade erosion results because of the sand-blasting effect of the droplets of water on the turbine blades.

Also, each 1 per cent of moisture in the steam reduces the efficiency of that part of the turbine in which the wet steam is expanding by 1 to $^1/_2$ per cent. It is necessary, therefore, that high-efficiency steam turbines be supplied with superheated steam. The minimum recommended steam temperature at the turbine throttle of condensing turbines for various initial steam pressures is as follows:

Throttle Steam Pressure, psia	*Minimum Steam* Temperature, °F
400	725°
600	825°
850	900°
1250	950°
1450	1000°
1800	1050°

The decreased strength of steel at high temperature makes it necessary to use alloy steels for superheater tubing where steam temperatures exceed 800° F. Alloy steels containing 0,5 per cent of molybdenum and 1 to 5 per cent of chromium are used for the hot end of high-temperature superheaters at steam temperatures up to 1050° F, and austenitic steels such as those containing 18 per cent chromium and 8 per cent nickel are used for higher temperatures.

Superheaters may be classified as convection or radiant superheaters. Convection superheaters are those that receive heat by direct contact with the hot products of. combustion which flow around the tubes. Radiant superheaters are located in furnace walls where they "see" the flame and absorb heat by radiation with a minimum of contact with the hot gases.

In a typical superheater of the convection type saturated steam from the boiler is supplied to the upper or inlet header of the superheater by a single pipe or by a group of circulator tubes. Steam flows at high velocity from the inlet to the outlet header through a large number of parallel tubes or elements of small diameter. Nipples are welded to the headers at the factory, and the tube elements are welded to the nipples in the field, thus protecting the benders from temperature stresses due to uneven heating during final welding.

The amount of surface required in the superheater depends upon the final temperature to which the steam is to be superheated, the amount of steam to be superheated, the quantity of hot gas flowing around the superheater, and the temperature of the gas. In order to keep the surface to a minimum and thus reduce the cost of the superheater, it should be located where high-temperature gases will flow around the tubes. On the other hand, the products of combustion must be cooled sufficiently before they enter the superheater tubes so that any ash that may be present has been cooled to a temperature at which it is no longer sticky or plastic and will not adhere to the superheater tubes. In a modern two-drum steam generating unit fired by a continuous-ash-discharge spreader stoker, the superheater is located ahead of the boiler convection surface and at the gas exit from the furnace. In installations burning coal having a high content of low-fusing-temperature ash, it may be necessary to place a few boiler tubes ahead of the superheater.

ECONOMIZERS AND AIR HEATERS

The largest loss that occurs when fuel is burned for steam generation is the so-called "sensible heat" carried away in the hot flue gas. The efficiency of a steam-generating unit provided with good fuel-burning equipment is a function of the flue-gas temperature.

Theoretically, the minimum temperature to which the products of combustion may be cooled is the temperature of the heat-transfer surface with which they are last, in contact. In the conventional boiler the theoretical minimum flue-gas temperature would be the saturation temperature of the water in the boiler tubes. The relative amount of boiler heat-transfer surface required to cool the products of combustion from 1500° F to lower temperatures is based on saturated water in the boiler tubes at 1000 psia. It will be noted that, as the temperature difference decreases, each increment of added surface becomes less effective and that the amount of surface required to cool the gases from 700° to 600° F is about 60 per cent of that required to cool the gases from 1500° to 700° F.

In general, it is not economical to install sufficient boiler surface to cool the gases to within less than 150° F of the saturation temperature of the water in the tubes, because sufficient heat cannot be transmitted to the tubes at such low temperature difference to pay for the cost of the boiler surface.

The gases must be cooled from the boiler exit-gas temperature to the flue-gas temperature required for high efficiency by means of heat exchangers supplied with fluids at temperatures less than the saturation temperature at the boiler pressure. This can be done in an air heater supplied with the air required for combustion at room temperature or in an economizer supplied with boiler feedwater at a temperature considerably below the saturation temperature, or both. In many installations, it is economical to install a small boiler and a large economizer and air heater and to deliver the gases to the economizer at temperatures as high as 900° F rather than to cool the gases to lower temperatures by a larger boiler.

In a typical economizer feedwater is supplied to the inlet header from which it flows through a number of parallel circuits of 2-in. o.d. tubes[1] of considerable length to the discharge header. If the inlet header is at the bottom so that the water rises as it flows from tube to tube, the hot gas normally enters at the top and flows downward. Thus the coldest gas wilt be in contact with the coldest tubes, and it is possible to cool the gas to within 125° to 150° F of the temperature of the inlet water if sufficient surface is installed.

Since the economizer has water in the tube and a dry gas around the tube, the major resistance to heat transfer is on the gas side. In order to increase the surface exposed to the gas per linear foot of tube and thus increase the effectiveness of the tubular surface, the economizer has fins welded to the top and bottom of each tube. This increases the surface available for heat transfer from the gas without substantially increasing the pressure drop of the gas as it flows across the surface. The gas flows at right angles to the tubes, and the 2-in. finned tubes are staggered to promote effective scrubbing of the outside surface by the gas so as to improve the overall heat-transfer coefficient.

Where scale-free feedwater is available or acid cleaning of heat transfer surfaces is used to remove scale, the flanged return bends may be eliminated. The flow circuits then consist of continuous welded tubing between inlet and outlet headers.

[1].**parallel circuits of 2-in. o.d. tubes**— параллельные линии из двухдюймовых труб

TYPES OF ECONOMIZERS

Economizers for power station service are of two classes, steaming and non-steaming. Both have been used and choice will depend largely on the feed-water temperature and the boiler pressure. If the turbines are bled to such an extent that the final feed-water temperature is raised to within a few degrees of the saturation temperature, it is apparent that no further heat can be added in an economizer unless a steaming economizer is used. The function of this economizer is to supply the boiler with a percentage of wet steam along with the feed water and a number of pipe connections are taken from the economizer outlet to the boiler drum. A saving may be effected in both capital cost of the boiler and building with large steaming economizers. The construction and location of both classes of economizers are similar, the chief difference being that only one outlet connection is required on the non-steaming economizer. With a steaming economizer, boiler baffles are eliminated resulting in a reduction of draught loss and fan power. During intermittent feeding with cold feed, temperature changes occur at the economizer inlet joints which may result in joint failure.

Modern economizers are constructed with steel tubes, which are necessary for high pressures. In order to conserve space, the tube surface is usually made in one continuous loop with connection pieces between the ends of the horizontal tube sections. Early designs used cast-iron tubes, the tubes being screwed into the headers. In modern economizers the tubes made of steel are usually $2^1/_2$ or 3 in. in diameter and are rolled into one or two headers only. Feed water is fed to one end of the lower header and distributed to each of the parallel-tube circuits. The last tube element may be rolled directly into the drum, and there is a growing tendency in design to eliminate all bolted return bends, the tube being in one continuous loop.

In constructions of continuous and of return bends, the bends are usually made of forged steel and are carefully machined to receive the tube ends. Gaskets which are necessary where the tube ends bear against the female joint of the return bend, may be of some soft material such as cranite. In order to keep the gas passage restricted to the straight section of the tubes and to give support to the tubes, it is customary to use tube sheets of cast iron. The outside casing is then made of removable steel-plate panels which are insulated, it thus being necessary to remove the whole side to obtain access to a certain tube. When there is a reversal of gas passage, soot hoppers are commonly placed below the economizer to collect any soot carry-over from the boiler, the soot being piped to the ashpit.

Economizers when used in combination with air heaters are practically always set nearest to the boiler flue-gas exit. Although most economizers do not heat the feedwater to a point where it vaporizes, a number of steaming economizers have been built and operate successfully. In these, the individual parallel-tube elements run separately to the top rear drum of the boiler and are rolled directly into the drum. Relief connections between the drum and the economizer are not provided. In addition to a gain in over-all boiler efficiency of 10 to 12 per cent, depending upon the drop in gas temperature, an economizer will provide nearly as much additional generating capacity. Maintenance, it is claimed, will amount to as little as ½ to 1 per cent per year.

THE AIR HEATER

The tubular air heater is constructed by expanding vertical tubes into parallel tube sheets which form the top and bottom surfaces, respectively, of the gas inlet and outlet boxes. The tube bank is enclosed in an insulated casing so constructed that the inlet air at room temperature can be admitted to the heating surface at the upper end from a fan or blower. The air passes downward around the tubes in a direction opposite to the flow of the hot gases and leaves the air heater at the lower end of the tube bank. Deflecting baffles are installed to guide the air and reduce frictional resistance at the turns. A by-pass damper and baffle permit by-passing the air around the upper half of the tube surface on light load when there is danger of corrosion due to low flue-gas temperatures. Long tubes closely spaced to maintain high air and gas velocities and countercurrent flow of gases and air make it possible in many installations to cool the gases to a temperature 100° to 200° F below the temperature at which the hot air is discharged.

Let us consider another type of air heater which operates on the regenerative principle. A drum filled with corrugated sheet-steel plates is rotated about a vertical shaft at about 3 rpm by means of a small motor. Hot flue gas passes downward through the right side of the rotor from a duct connected to the economizer or boiler. An induced-draft fan may be connected by a duct to the lower side of the air-heater casing. This fan induces a flow of the gases through the boiler, economizer, and air-heater surfaces, and discharges them to waste up the chimney. The cold air from a forced-draft fan flows upward through the left side of the rotor, where the air is heated, after which it is delivered through suitable duct work to the stoker or burner in the furnace. Any point on the corrugated sheet-metal surface of the rotor is rotated alternately into the hot descending gas stream and the cold ascending air stream, thus transferring energy from the hot gas to the cold air.

Radial seals with rubbing surfaces on them are mounted on the rotor and make contact with a flat section of the casing between the hot-gas and cold-air ducts, thus minimizing leakage between the two streams of fluid. The depth of the rotor is normally between 3 and 4 ft. The unit is also made for operation about a horizontal shaft with horizontal flow of gas and air where building space makes such an arrangement desirable.

The maximum air temperature that can be used in stoker-fired installations without increasing grate maintenance is about 300° F, since the grate surface which supports the hot fuel bed must be cooled by the air to a temperature below which the iron grates will not be damaged. Air temperatures of 600° F are often used with pulverized coal. Since the stoker limits the heat-recovery possibilities of the air heater, both economizers and air heaters are usually installed in stoker-fired high-pressure steam-generating units. Where oil, gas, or pulverized coal is burned, an air heater is often installed without an economizer, although in many high-pressure units it may be more economical to reduce the boiler surface and use an economizer. The air heater is necessary in modern pulverized-coal plants since the coal is dried in the pulverizer by hot air to reduce power consumption and increase the capacity of the mill.

AIR PREHEATERS

Air preheaters are installed to preheat the air required for combustion, the heating medium being the flue gases leaving the economizer. The use of preheated air assists early gasification and ignition of the carbon and promotes high furnace temperature.

The final temperature of the air will depend upon the method of firing and classes of coat. For pulverized fuel firing air temperatures of 450° to 650° F are possible, whereas in stoker-fired boilers the maximum permissible temperature would be about 400° though in practice temperatures of 250° to 300° F are more usual for chain-grate stokers. Preheated air is a necessity with pulverized fuel firing, a decided advantage to stoker-firing and is the only simple means available for the reduction of the final flue-gas temperature.

There are four types of heaters: 1) tubular; 2) plate; 3) rotary or regenerative; 4) tubular-needle or gilled.

In the tubular heater the air is passed across the tubes and the flue gases pass through the tubes or vice versa. Cleaning is easier when the gases pass through the tubes. The rate of heat transfer is low and the space occupied is generally prohibitive. This type of heater may be used with high temperatures. Trouble is experienced in cleaning long tubes and there is added disadvantage in that considerable space is necessary for withdrawal of the tubes.

The plate type was very popular until the rotary heater was developed. The gilled or needle type of heater is also in use. The tubes are of cast iron, the gases passing through plain tubes and the air over the pointed gill surfaces.

THE STEAM-GENERATING UNIT

For operation at pressures below the critical pressure, a steam-generating unit consists of a boiler, superheater, air heater, and (or) economizer. The furnace walls are either partially or fully covered with boiler tubes. In general, most of the steam is generated in the furnace-wall tubes since they can absorb radiant energy from the high-temperature flame.

A typical stoker-fired steam-generating unit in the smaller size range[1], has a capacity of 72,500 lb. of steam per hr. The gases as they leave the completely water-cooled furnace pass across the superheater surface, then the convection tubes of the boiler, then upward through a small economizer, downward through a tubular air heater, dust collector, and fan, to the chimney. The boiler is of the two-drum type without gas baffles; that is, it is a single-pass boiler. The internal baffles in the steam drum are so arranged that the last four rows of boiler tubes in which the heat-transfer rate is quite low are downcomers. Since a major item in the cost of a boiler is the drums, as many boiler tubes as possible are placed between the drums. A large amount of surface is required to cool the gases from the temperature at which they leave the superheater to the final temperature.

Depending upon the steam pressure, the feedwater is heated in regenerative feed-water heaters to 275° F to over 600° F, depending on pressure, before being admitted to the economizer. Essentially, the economizer raises the feed-water temperature almost to the saturation temperature, the boiler supplies the latent heat, and the superheater supplies the superheat. It will be noted that, as the pressure increases, a decreasing portion of the total energy absorption occurs in the boiler and that, for pressures above the critical, there is no boiler. Supercritical-pressure steam generators essentially are economizers connected to superheaters. There is no steam drum since there is no boiling and no steam to be separated from water at a constant temperature.

At the higher pressures at which natural circulation boilers may be used, the boiler becomes a smaller part of the installation and the superheater and reheater become a larger portion of the total heat-transfer surface.

Modern high-capacity steam-generating units have been developed to the point that they can be depended upon to carry heavy loads continuously for months at a time. Their reliability is approximately equal to that of modern steam turbines. Consequently, most new central-station power plants are built on the unit system: that is, with each turbine generator supplied with steam from its own steam-generating unit. Thus, turbine-generator units in capacities up to 500,000 kw are being supplied with steam from a single steam-generating unit. One of the major reasons for this arrangement is the decreased cost per unit of capacity which results from increased size.

[1] **a typical stoker-tired steam-generating unit in the smaller size range** — типичный парогенератор с механической топкой из серив малых агрегатов

HIGH-CAPACITY, HIGH-EFFICIENCY STEAM-GENERATING UNITS

Such units are currently being designed for capacities from 750,000 to 3,000,000 or more lb. of steam per hr at pressures of 1200 to 5000 psia and temperatures of 950° to 1200° F. Because of the quantity of fuel burned, they are designed for efficiencies of 87 to 90 per cent and always include a large air heater. They are fired by pulverized coal or cyclone furnaces, or, where the economics of the situation permit, by gas or oil or a combination of these fuels. Since it is standard practice to install one steam generator per turbine, they are very carefully designed to insure reliable and continuous operation for long periods of time. Depending on boiler insurance requirements and state laws, they may be operated for two to three years without a major shutdown for cleaning and overhaul.

In a single-drum unit having a capacity of 800,000 lb. per hr at 1350 psig and 955° F superheat temperatures two large downcomers deliver water from the steam drum to the four headers that supply the furnace-wall tubes in the front, rear, and side walls of the furnace. These furnace tubes deliver their steam-water mixture to the boiler drum. Practically all the steam is generated in the furnace walls. The steam flows from the boiler drum to a heat exchanger that is used for superheat control and then through the counter-flow superheater. It should be noted that the hot end of the superheater is next to the furnace.

There are four rows of boiler tubes between the superheater and the economizer. Final cooling of the gases occurs in a regenerative air heater.

A considerable number of large steam generators of the forced-circulation type have been installed for operation at pressures from 1800 to 2700 psig. Feedwater, is fed through a conventional counter-flow economizer to a boiler drum. Also, steam from the boiler drum flows through a conventional superheater. Water from the boiler drum flows by gravity to a circulating pump which discharges into a distributing header. Water from the distributing header flows through long small-diameter boiler tubes located in the walls and roof of the furnace to the drum, where the steam is separated and the water returns to the pump. Orifices at the inlet to each circuit at the distributing header correctly proportionate the water among the many parallel circuits so that each one receives its proper share. The circulating pump raises the water pressure to about 40 psi above the drum pressure, this being sufficient to overcome the resistance of the flow-controlling orifices and the long circuits of small-diameter tubing. These tubes may be constructed of thinner walls than would be required by the larger tubes that are used in natural-circulation boilers and may be arranged so that the flow is upward, horizontal, downward, or any combination thereof.

In the conventional forced-circulation boiler, the amount of water circulated is four to five times the amount of steam generated and an effective steam-separating drum is as essential as in the natural-circulation boiler. Recent development in feed-water treatment have resulted in feedwater of high purity. This has made it possible to build steam-generating units in which the large horizontal steam drum has been eliminated.

The conventional steam drum is replaced by a vertical water separator. Water is pumped through small-diameter tubes in the furnace walls and is converted into steam of high quality which is discharged into the water separator. Here the small amount of unevaporated water is separated from the steam and is blown down to a lower pressure, carrying out with it any impurities that have been concentrated in the water as a result of evaporation. The dry steam from the separator then passes through four sections of superheater tubing, designated as superheater I, II, III and IV, to the turbine. The steam is resuperheated in the reheater to the initial temperature at a pressure of about 30 per cent of the initial pressure. An economizer and air heater are provided to cool the products of combustion to the low temperature necessary for high efficiency.

For operation at pressures above the critical pressure, 3206 psia, water does not boil. No boiler drum is required, and the steam generator becomes essentially a continuous circuit of steamless steel tubing with intermediate headers of small diameter. Such a unit is known as a "once-through" steam generator.

The unit is fired by eight 10-ft-diameter cyclone furnaces arranged to discharge from opposite sides into a common secondary furnace. The gases flow upward through the secondary furnace and through three parallel vertical passes to three air heaters. The walls of the three parallel vertical passes are constructed of closely spaced steam-generating tubes. The primary and secondary superheater, the first and second reheaters, and the economizer are located in these passes.

The feedwater flows from the economizer section to the cyclones through outside downcomers. From the cyclone, the fluid flows upward through the secondary furnace-wall tubes and the convection section baffle-wall tubes which form the walls of the three parallel gas passes above the furnace. From the baffle walls, the fluid flows through the primary superheater, a heat exchanger or attemperator that is used for superheat control, and then through the secondary superheater to the superheater outlet and turbine. The transition from water to steam occurs in the upper part of the furnace enclosure.

After expansion in the turbine to an intermediate pressure, the steam is reheated in the first -stage reheater to1050° F. After further expansion in the turbine, it is reheated in the second-stage reheater to 1050° F. It should be noted that the superheaters and reheaters occupy a major part of the total volume of the installation.

Final superheat and reheat temperatures are controlled by a heat exchanger between the primary and secondary superheater, damper above the economizers in the three parallel vertical gas passes, and recirculation of gas from a location beyond the economizer to the secondary furnace above the cyclones.

CHAPTER III

HEAT EXCHANGERS

As stated above all power and refrigeration plants contain equipment which has as its major function the transfer of heat from one fluid to another. This equipment includes boilers, superheaters, economizers, heaters, coolers, condensers, and evaporators and is called a heat exchanger. The same laws of heat transfer, fluid flow, and economics apply to all heat exchangers. Heat exchangers differ in design characteristics only because of the different functions which they perform and conditions under which they operate.

Two heat exchangers commonly found in stationary power plants are the steam condenser and feed-water heater. They are distinct and separate pieces of equipment, and they differ in their relative positions and primary functions in the cycle. The purpose of the feed-water heater is to increase the overall efficiency of the cycle. This is accomplished by heating the boiler water before it enters the boiler with either waste steam or steam extracted from the turbine. With the feedwater entering the boiler at high temperatures, the boiler is relieved of a part of its load and temperature stresses within the boiler are reduced. Feed-water heaters are designed as direct-contact heaters or surface heaters.

DIRECT-CONTACT FEED-WATER HEATERS

The direct-contact heater is often called an open heater, although it may operate at pressures above atmospheric pressure. A typical direct-contact heater consists mainly of an outer shell in which are placed trays or pans. Water enters at the top of the shell. It feeds by gravity over rows of staggered trays which break up the solid stream of water. Steam entering near the center of the shell intimately mingles with the water and condenses.

In condensing, the steam gives up heat to the water. The heated water and condensate mixture is collected at the bottom of the shell and is removed by a boiler feed pump. A float control operating the inlet water valve maintains a constant level in the feed-water tank. A vent at the top removes the excess steam and the noncondensable gases. In the larger heaters where the vented steam is appreciable, a vent condenser may be employed. Water, before it enters the tray section of the feed-water heater, is passed through coils in the vent condenser. Heat is transferred from the vented steam to the water as the steam is condensed. The condensate from the vent condenser is returned to the heater. Noncondensable gases are expelled to the atmosphere.

Because of the stress limitations of the heater shell, the steam pressure is limited to a few pounds per square inch above atmospheric pressure, although pressures to 70 psia have been used. Consequently, the feedwater is rarely heated above 220° F. If direct-contact heaters are used in series, a feed-water pump must be installed ahead of each heater. The advantages of the direct-contact feed-water heater are: 1) complete conversion of the steam to water is accomplished; 2) noncondensable corrosive gases are removed from the feedwater; 3) the removal of impurities in the water is possible; 4) the water is brought to the temperature of the steam; 5) the heater acts as a small reservoir.

CLOSED FEED-WATER HEATERS

Closed heaters or surface-type feed-water heaters are of the shell and tube design. Generally, the water is introduced to the heater through tubes around which the steam circulates. Closed heaters may be classified as single- or multipass and straight tube or bent tube. In a single-pass heater the water flows in only one direction. In a multipass heater the water reverses direction as many times as there are passes. In a two-pass straight tube type of closed feed-water heater water enters at the bottom of one end of the healer and flows through the lower bank of tubes to the opposite end where its direction is reversed. The water returns through the upper bank of tubes to the outlet at the top. Steam enters the shell at the top and flows toward each end, and condensate leaves the shell at the bottom.

A floating head is provided to permit the tubes to expand. Vents at the top are provided to remove gases trapped in the shell. This heater is designed for a water pressure of 1100 psi. Closed heaters placed in series require only one feed-water pump unless the pressure drop through the heaters is high. If bent tubes are used in place of the straight tubes, no floating head is necessary. However, the bent tubes may be difficult to clean.

In closed heaters the feedwater can never be heated to the temperature of the steam, but generally the terminal temperature difference at the outlet is not greater than 15° F.

To maintain a high overall heat transfer for the heater the water velocity should be high, but pumping costs will limit the velocity. A balance between pumping costs and the amount of heat transferred will result in water velocities of 3 to 8 fps. Generally, the heaters are rated in terms of the square feet of heat-transfer surface and of the quantity of heat transferred.

CONDENSERS

The primary function of a condenser is to reduce the exhaust pressure of the prime mover. A reduction in the exhaust pressure will increase the pressure and temperature drop through the prime mover and will result in a corresponding increase in efficiency and output. Secondary functions of the condenser are: 1) to reduce the amount of make-up boiler feedwater by condensing the steam in order that it can be returned to the boiler; 2) to remove air or other noncondensable gases which are corrosive.

Like feed-water heaters, condensers are classed as direct-contact or surface types.

The direct-contact condenser is a jet condenser consisting of water nozzles, a steam-and-water-mixing chamber, and a Venturi-section or a tailpipe. The jet condenser may be used where it is not necessary to reclaim the condensate. Although it requires more cooling water than a surface condenser, the jet condenser has the following advantages: 1) construction and operation are simple; 2) no vacuum pump is required to remove noncondensable gases from the steam.

The jet condenser is used mainly for small prime-mover installations in industry.

The conventional surface condenser is of shell and tube construction. Cooling water passes through the tubes, and steam circulates around the tubes and is condensed and removed. At no time do the steam and condensate come into contact with the cooling water. Condensers like feed-water heaters, are classified as single- or multipass and straight or bent tube.

Generally, condensers used with prime movers are the straight-tube single- or multipass type.

In a single-pass surface condenser water enters from the bottom left, passes through the tubes, and leaves at the upper right. Steam enters the condenser shell from above, circulates around the nest of tubes, and then flows toward the center or core which is the zone of lowest pressure. Air and other noncondensable gases are removed from one end of the core at the vents. The condensed steam or condensate flows by gravity to the condensate well or hot well. The condensate is then removed from the well by a pump.

Because cooling water is usually corrosive in nature, condenser tubes are often made of special alloys of copper or aluminium. Among these are admiralty metal, muntz metal, arsenical copper, and aluminium brass.

The tubes may be rolled into each end plate. In this case, expansion is taken care of by bowing the tubes. The tubes of some condensers are rolled into and keyed to one end plate and are free to move in the other end plate. Leakage between the tube and end plate is prevented by packing. Expansion and contraction of the condenser shell may be taken care of by providing an expansion joint in the shell wall at one end.

Owing to the expansion and contraction of the exhaust line or nozzle leading from the turbine to the condenser, all condensers are either rigidly suspended from the turbine or connected to turbine by an expansion joint. In the former case, the condenser may be placed on spring supports. The spring supports permit the condenser to rise or fall without overloading the turbine exhaust line. In the latter case, the condenser will be rigidly anchored to the floor. All expansion or contraction in the turbine exhaust line will be taken up in the expansion joint.

There are a number of condenser auxiliaries that are essential to the proper functioning of the condenser: 1) a condensate hot well for collecting the condensate; 2) a condensate pump to return the condensate to a surge tank where it can be reused as boiler feedwater; 3) a circulating pump for circulating the cooling water; 4) an atmosphere relief valve for relieving the pressure in the condenser in case the condenser or auxiliaries do not function properly; 5) an air ejector or a vacuum pump for removing the noncondensable gases from the condenser.

The condensate pump and circulating-water pump are generally of the centrifugal type. If the source of the cooling water is a lake or a river, there is no need for water conservation. However, in many localities, the water supply may be low. In such a case, the cooling water, after passing through the condenser, is pumped to a cooling pond or cooling lower where it is cooled by contact with air and then is recirculated through the condenser.

If noncondensable gases are permitted to collect in the condenser, the vacuum in the condenser will decrease. A decrease in the vacuum will result in a decrease in the pressure drop through the turbine and will affect adversely the turbine efficiency. Also, the noncondensable gases are highly corrosive. Thus, their removal in the condenser is essential. They may be removed by a vacuum pump or by a steam-jet air ejector.

Steam enters the first and second stages through nozzles where it acquires a high velocity. The air and some vapor from the main condenser are entrained by the high-velocity steam and are compressed in the first stage, forcing tube. The forcing tube is the Venturi-shaped section. The steam and vapor are condensed on the intercondenser and drained to the hot well of the main condenser.

Air in the intercondenser is then entrained by high-velocity steam leaving the second-stage nozzles and is compressed further in the second stage, forcing tube. Steam is condensed in the aftercondenser and is drained to the main condenser. The air is vented to the atmosphere. Normally, condensate from the turbine condenser is used as cooling water to condense the steam in the ejector. Both the condensate and cooling water will then be returned to a surge tank.

CHAPTER IV

TURBINES

The steam turbine is prime mover in which a part of that form of energy of the steam evidenced by a high pressure and temperature is converted into kinetic energy of the steam and then into shaft work.

The basic advantage of the turbine over other forms of prime movers is the absence of any reciprocating parts. With only rotating motion involved, high speeds are attainable. Since power is directly proportional to torque times speed, an increase in the rotative speed materially decreases the value of the torque required for a given power output. A decrease in the required torque permits a reduction in the size of the prime mover by reducing the length of the torque arm or the force acting on the torque arm. Also, with the absence of any reciprocating parts, vibration is greatly minimized. Owing to the high rotative speeds available with relatively little vibration, the size and cost of the driven machinery, of the building space, and of the foundations are greatly reduced. These advantages are most apparent in large prime movers and permit the steam turbine to be built in sizes of over 350,000 hp in single units, and 760,000 hp in compound units.

TYPES OF TURBINES

Steam turbines may be broadly grouped into three types, the classification being made in accordance with the conditions of operation of the steam on the rotor blades.

The groups are as follows:

1. *Impulse.* This may be divided into

a) Simple impulse	Pressure compounded
b) Compound impulse	Velocity compounded
c) Combined impulse.	Pressure velocity compounded

2. *Reaction* subdivided into
   a) Axial flow
   b) Radial and axial flow
3. *Combination* of 1 and 2.

1. **Impulse Turbines**. In an impulse turbine the potential energy in the steam due to pressure and superheat is converted into kinetic energy in the form of weight and velocity by expanding it in suitably shaped nozzles.

The whole of the expansion takes place in the fixed nozzle passages. As there is no expansion in the passage between the rotor blades, the steam pressure is the same at the inlet and outlet edges of these blades. The steam impinges on the wheel blades causing the wheels to rotate. The expansion is curried out in stages referred to as "pressure stages", each stage being separated from the next by a diaphragm with nozzle openings through which the steam passes on its way through the turbine.

a) Simple impulse. This type has a considerable number of pressure stages, a wheel in each stage having one row of blades. To obtain high economy it is necessary that the steam should flow through the turbine with high velocity. This is attained by provision of a large number of pressure stages, the greater the available heat drop, the greater the number of stages. In the simple impulse turbine a wheel of comparatively large diameter is used in the first stage which can deal efficiently with a large energy drop. This large wheel, under nozzle control of the steam can maintain a higher efficiency over a wider range of load than a small one could and is less liable to be affected by changes of steam conditions. An added advantage of a large wheel is that the maximum rating of the machine can be obtained without by-passing which results in a flat consumption curve being maintained over the whole output range.

b) Compound impulse. This turbine has comparatively few pressure stages, a wheel in each of them provided with two or more rows of blades. Low velocity steam is obtained by the provision of what are usually termed "velocity stages" in each of the pressure stages. In these velocity stages the steam after passing through the first row of blades on a wheel is re-directed on to the second row of blades on the same wheel, and successively on to other rows of blades on this wheel, if provided. The steam is re-directed by arranging stationary blading between each two adjacent rows of wheel blading so that the steam leaving the first row of blades on a wheel in a backwards direction, enters the first row of stationary blades where its direction is reversed ready for entering the second row of blades on the wheel and so on. This action is repeated in each pressure stage on the turbine.

c) Combined impulse. This turbine is a combination of the types a) and b). It consists of one or more pressure stages with a wheel in each of these stages provided with two or more rows of blades. In the velocity compounded impulse turbine the "carry-over" velocity and the speed of the shaft are much less than with the simple impulse machine. Each disk carrying the moving blades is perforated, thus maintaining the same pressure on both sides of the wheel. The pressure velocity compounded design is generally known as the "Curtis" type. The pressure compounded turbine has a higher efficiency since the pressure drop per stage may be arranged to give the most suitable jet velocity for a given speed of the machine.

2. Reaction Turbines. In the reaction turbines expansion takes place in both the stationary and rotating passages and the pressure at entrance to the rotor blades is therefore greater than at exit.

a) Axial flow. In a pure reaction turbine expansion should take place only as the steam passes through the moving blades, the turning effect being due to the reaction consequent on the increase in velocity which accompanies expansion. The reaction turbine has a ring of stationary blades instead of a diaphragm with nozzle passages between the blades of each pair of adjacent wheels. The steam expands in the fixed blades, increasing its velocity, which is imparted to the moving blades on the impulse principle.

Steam is supplied direct to the blading system without expansion in nozzles and the rotation produced is chiefly due to the reaction set up by the steam between the stationary and rotating blades while expanding in them.

b) Radial flow. The Ljungstrom turbine is really a combined radial and axial flow machine. The flow of steam is radial, being admitted at the center of the blade discs and flowing outwards, the steam then being inverted to axial flow in the last stages. The turbine may be constructed for single or double motion. With the double motion design the discs rotate in opposite directions at equal speeds and the relative speed of the blades is therefore equal to twice the running speed. This design consists of one group of radial flow double rotation blading and two groups in parallel of low pressure axial flow single rotation blading, the divided flow in the final stages assisting in the reduction of the "leaving losses". Each steam rotor is coupled to an alternator which carries half the total output.

3. Combination Turbines. This type consists of a machine embodying the "impulse" and "reaction" principles, the high-pressure turbine being the impulse section and the intermediate and low-pressure turbines being the reaction section. Where the term reaction is used it is to be understood that this refers to the "impulse-reaction" type of turbine. The practice in large output high speed sets is to include reaction blading at the low pressure end. The blade areas are large find therefore the leakage areas are proportionately small, and as a double-flow exhaust is used the end thrust is balanced. These arrangements enable the length of the turbine to he reduced.

Further Classification. As the output capacities and working conditions have affected the construction of each particular make it has been suggested that the following particulars be given for each turbine: 1) number of shafts, 2) number of cylinders, 3) number of exhausts, 4) the speed.

Many types of industrial turbines are in use today, depending upon the conditions under which they must operate. They are classified as high-or-low-pressure turbines, according to the inlet pressure of the steam, and as superposed, condensing, and noncondensing turbines, according to the exhaust steam pressure. A superposed or high backpressure turbine is one that exhausts to pressures well above atmospheric pressure, 100 to 600 psi. A superposed turbine operates in series with a medium-pressure turbine. The exhaust steam of the superposed turbine drives the medium-pressure unit. The noncondensing turbine has lower exhaust pressures, but the steam still leaves at atmospheric pressure or above 15 to 50 psi. The exhaust steam may be used for drying or heating processes.

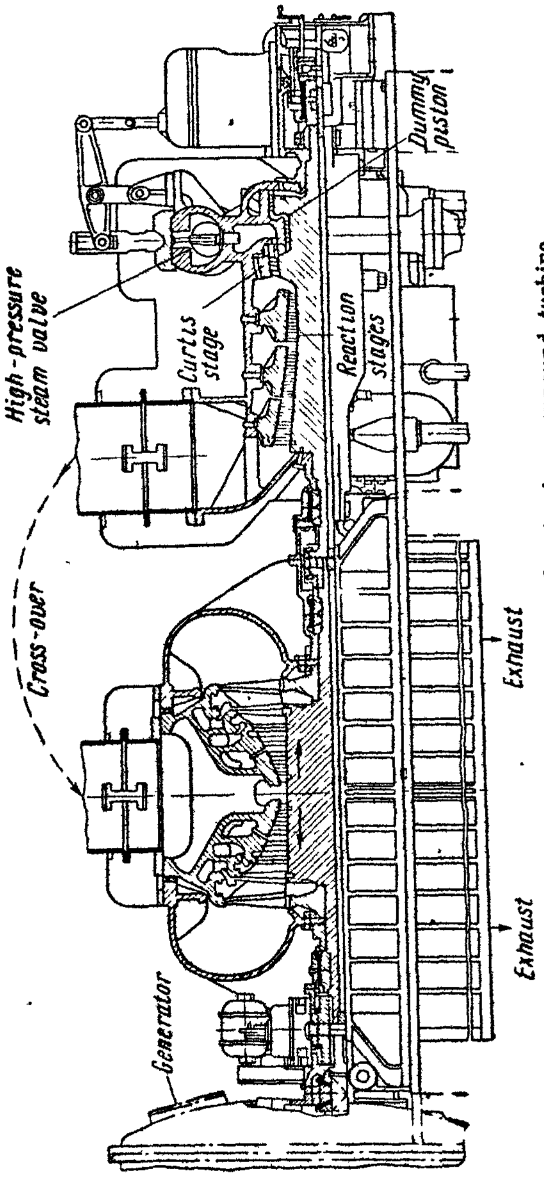

Fig 5. A cross-sectional view of a tandem-compound turbine

The condensing turbine operates at exhaust pressures below atmospheric pressure and requires two auxiliaries: a condenser and a pump. The condenser reduces the exhaust steam to water. As the steam is condensed and the water is removed by a pump, a partial vacuum is formed in the exhaust chamber of the turbine. This type of turbine is used chiefly for the low-cost electric power it produces.

If steam is required for processing, a turbine may be modified by extracting or bleeding the steam.

Extraction takes place at one more point between inlet and exhaust, depending upon the pressures needed for the processes. The extraction may be automatic or nonautomatic. Generally, factory processes require steam at a specific pressure, in the case, and automatic-extraction turbine is necessary. When steam is needed within the power plant itself for heating boiler feedwater, nonautomatic extraction is generally used.

Turbines may be classified according to their speed and size. Small turbines, varying in size from a few horsepower to several thousand horsepower, are used to drive fans, pumps, and other auxiliary equipment directly. The speed of these units is adjusted to the speed of the driven machinery or is converted by a suitable gear arrangement. These turbines are used wherever steam is readily available at low cost or where exhaust steam is needed.

Turbines for the production of electric power range in size from small units to those of over 500,000 kw, and the trend is toward even larger units.

Sometimes turbogenerator units are constructed to operate at 3,600 or 1,800 rpm. The selection of the speed depends almost entirely on the size of the turbogenerator desired. The speed of 3,600 rpm is preferred whenever the size of the turbine permits. The turbine operating at the higher speed has the following advantages: slighter weight, more compactness, and great suitability for high-pressure, high-temperature operation.

With a few exceptions turbines larger than 100,000 kw will operate at 1,800 rpm. All turbines of smaller capacity will run at 3,600 rpm. However, because of the advantages of the 3,600 rpm unit and because of the greater efficiency of large units turbine manufacturers will continue to raise the upper limit of speed and capacity.

Generally, turbogenerators on a single shaft and within a given speed range are constructed with either a single or a double-rotor.

The double-rotor arrangement is used for only the largest turbines falling within a given speed range. A double-rotor unit is called a tandem-compound turbine, and the flow is double-exhaust to accommodate the large volumes of steam occurring at the low-pressure end.

CHOICE OF TYPE

In large power station using high pressures and temperatures the compound impulse and the axial flow reaction are most common although radial flow machines up to 40 MW, 1,500 rpm, have been adopted. The single shaft turbine is sound, simplifies operation and is general for small and medium sizes.

With radial flow turbines two alternators and two shafts are usual. Another case requiring two shafts is where it is economically justifiable by reason of high steam pressure to have a high pressure section running at a higher speed than a low pressure section. In deciding upon the number of cylinders the efficiency is nearly always of primary importance, and if this is to be a maximum with a large high-pressure turbine at least two cylinders will be necessary. A single-cylinder machine is cheaper in first cost than a multi-cylinder machine of the same output. It is possible to build single-cylinder turbines up to 80 MW at 1,500 rpm and up to 30 MW at 3,000 rpm, but general practice favours multi-cylinder sets for these larger sizes and also to separate high-pressure and low-pressure cylinders if the initial steam conditions are high. In the latter case the multi-cylinder turbine has the advantage that the separate high-pressure cylinder and its components which are subjected to the initial high pressure and temperature may be kept reasonably small. In this way the stresses in these rotating and stationary parts may be kept within the safe limits of the materials available for use.

Further advantages of the use of multi-cylinder sets are that the diameters of the shafts may be kept within reasonable dimensions and designed to ensure that the critical speed is well above the running speed. The multi-cylinder turbine has resulted in a reduction of clearances rendered possible owing to the extremes of temperature in any one casing being reduced, thus enabling a turbine to be run up to speed much quicker than with a large single cylinder. The reduction in diameter of the wheels and shortening of the shafts reduces the stresses and tendency to whip. In some designs of multi-cylinder turbines the H.P. cylinder[1] is of the "pure-reaction" type or even combined impulse and reaction. Some manufacturers do not employ reaction blading in H.P. cylinders on account of the small clearances which are necessary to obtain reasonably good efficiencies. The higher the initial steam pressure, the smaller will be the blade heights at the H.P. end, and it therefore follows that the blade tip clearance with unshrouded blades must be very small to keep down the leakage over the blade tips. Alternatively, if the blades in high-pressure reaction turbines are shrouded to permit of safe blade tip clearances, the axial clearances must be kept very fine.

The disadvantages are that the overall length of the turbine is increased thereby necessitating larger building space and introducing additional losses by the use of interconnecting piping. The number of exhausts to be used will depend chiefly on the size of the turbine. The output of a single exhaust turbine is governed by the area of the exhaust annulus, the latter being limited by the blade tip speed. Losses at the exhaust are composed of the leaving losses and exhaust losses. The former are due to the carry-over velocity of the steam leaving the last row of blades. This loss may be reduced by using a double or triple flow exhaust arrangement, which in turn increases the output of the set. On the other hand the gain is offset by the additional floor space and cost of accommodation. A small drop in pressure must exist if steam is to flow from the last wheel to the condenser, and the heat energy required to produce this flow and make up for the losses due to eddies, etc., is termed the exhaust loss. With a given maximum exhaust area and given back pressure the output is limited if the efficiency is to be maintained and not impaired by high leaving and exhaust losses. To overcome this difficulty at the exhaust end turbines are usually of the multi-cylinder type arranged with single or double flow in a low-pressure cylinder. With large output and low speed, a two cylinder turbine with a single-flow low-pressure cylinder can be used, as the low speed enables the requisite exhaust area to be obtained in a single exhaust.

The simplest type is the single-cylinder turbine, for it is compact and has few parts. Single-cylinder turbines with duplex exhausts are also adopted. The duplex exhaust turbine consists of two sets of low-pressure blading of the rotor, through which the steam flows in parallel, the two streams being brought together in the exhaust branch. With the double-flow turbine the axial thrust, is balanced, since the flows are in opposite directions. In turbines having an intermediate cylinder the steam flow may also be arranged in the opposite directions, thus balancing the thrust. The volume of steam leaving the last wheel of a large turbine is enormous and it is more efficient and cheaper to discharge it to two or more condensers.

The performances of the various types for a given output are very similar and the choice of make is usually decided by the capital cost, steam conditions, output, speed, efficiency, and the opinions of the engineers concerned.

[1] **H. P. cylinder = high pressure cylinder** — цилиндр высокого давления

THE TURBINE NOZZLE

The turbine nozzle performs two functions:

1. It transforms a portion of the energy of the fluid, acquired in the heat exchanger and evi-

denced by a high pressure and temperature, into kinetic energy.

2. a) In the impulse turbine it directs the high-velocity fluid jet against blades which are free to move in order to convert the kinetic energy into shaft work; b) In the reaction turbine the nozzles, which are free to move, discharge high-velocity fluid. The reactive force of the fluid against the nozzle produces motion, and work is done.

For the first function to be performed efficiently, the nozzle walls must be smooth, streamlined, and so proportioned as to satisfy the changing conditions of the steam or gas flowing through the nozzle.

For the second function the nozzle should discharge the find at the correct angle with the direction of blade motion to allow a maximum conversion of kinetic energy into work.

The main consideration in nozzle design is to provide a nozzle of proper wall contour. The contour of the walls depends upon the conditions of the fluid required by the turbine and upon certain properties of the fluid which are influenced by these established conditions. For nozzle design the engineer has at his disposal[1] four fundamental tools or relations. They are: 1) the first law of thermodynamics; 2) the equation of continuity of flow; 3) the characteristic equation of state of the fluid; 4) the equation of the process.

[1] **has at his disposal** — имеет в своем распоряжении

CHAPTER V

PUMPS, DRAFT, FANS, BLOWERS, COMPRESSORS

One of the most important problems of the engineer is the efficient and controlled transfer of fluids from one point to another. This transfer may be opposed by gravitational force, by some other external force, or by friction. Under certain conditions the gravitational force and other forces may act to aid the transfer, but friction always exists as a force opposing motion. The engineer attempts to reduce the effect of friction and at the same time takes advantage of useful forces to produce a motion of the fluids under conditions that can be controlled.

As previously defined, a fluid is a substance in a liquid, gaseous, or vapor state which offers little resistance to deformation. Common examples of the three states of a fluid are water as a liquid, air as a gas, and steam as a vapor. All these types of fluids have a tendency to move because of natural forces acting on them. A city may be supplied with water flowing by gravity from high ground. Air may circulate in an auditorium because of its own temperature difference. Steam rises through the water in a boiler owing to the difference in density or specific weight of steam and water. In many cases, however, the circulation is inadequate, and mechanical equipment must be built to supplement the natural circulation. Often mechanical circulation is the only means of obtaining the desired fluid flow. The equipment for producing this fluid flow is divided into two major classes: pumps for handling liquids, and fans, blowers, and compressors for handling gases or vapors.

Both classes of equipment in various forms may be found in the modern stationary power plant or small mobile power plants such as the aircraft engine, Diesel locomotive, or automobile engine.

PUMP TYPES

The conditions under which liquids are to be transported vary widely and require a careful analysis before the proper selection of a pump can be made. Generally, the engineer purchasing a pump consults with pump manufacturers to obtain the best type for a particular job. However, a fundamental knowledge of the basic types of pumps that are available and a realization that there is a wide variety of the basic types are of great value to the prospective purchaser.

The conditions that will influence the selection of the type of pump are: 1) the type of liquid to be handled; that is, its viscosity, cleanliness, temperature, and so on; 2) the amount of liquid to be handled; 3) the total pressure against which the liquid is to be moved; 4) the type of power to be used to drive the pump.

Pumps may be divided into four major classifications:

1. Piston pumps or reciprocating pumps driven by engines or electric motors.
2. Centrifugal pumps driven by steam turbines or electric motors.
3. Rotary pumps driven by steam turbines or electric motors.
4. Fluid-impellent pumps which are not mechanically operated but are fluid-pressure-operated.

CENTRIFUGAL PUMPS

The centrifugal pump consists of an impeller or rotating section to produce the flow and a casing to enclose the liquid and to direct it properly as it leaves the impeller. The liquid enters the impeller at its center or "eye" and parallel to the shaft. By centrifugal force the liquid passes to the impeller rim through the space between the backward curved blades. The velocity of the liquid with respect to the impeller is in a direction opposite to the impeller motion. The impeller blades are curved backward to permit the liquid to flow to the rim of the impeller with a minimum of friction. As the liquid leaves the impeller, it is thrown in a spiral motion forward with a certain velocity.

The water is guided away from the impeller by two basic types of casing: the volute, and the turbine or diffuser. Liquid enters the impeller at the "eye", is thrown to the outside, and leaves the pump through the expanding spiral or volute casing. The casing has the volute shape to permit flow with a minimum of friction and to convert a part of the velocity head into static head. The static head is the head that overcomes resistance to flow.

The turbine or diffuser pump has the same type of impeller as the volute pump. The casing has a circular shape, and within the casing is a diffuser ring on which are placed vanes. The vanes direct the flow of liquid and a decrease in the velocity of the liquid occurs because of an increase in the area through which the liquid flows. Thus, part of the velocity head is converted into static head as in the volute pump. For a multistage pump, the diffuser pump has a more compact casing than the volute pump. The diffuser-pump design is adaptable to differences in flow conditions since the same casing can be used with various arrangements of diffuser vanes. In the volute pump a variation in the requirements of the volute casing demands alternations in the casing itself. Generally, the volute pump will be used for low-head high-capacity flow requirements and the diffuser pump for high-head requirements.

Both volute and diffuser pumps are classified by the type of impeller, the number of stages, and the type of suction or intake used. A pump having two "eyes" on the impeller is called a double-suction pump. The double suction, one "eye" located on each side of the impeller, permits forces acting on the impeller to be balanced, thus reducing the axial thrust on the shaft. Also, the double-suction pump is used for handling hot water where there is danger of water flashing into steam at points, of low pressure. The double suction offers little resistance to flow; thus, low-pressure areas are less apt to occur[1]. The double-suction pump is used also for large capacities.

When two or more impellers are mounted on the time shaft and act in series, the pump is called a multistage pump, the number of stages corresponding to the number of impellers. A boiler-feed pump is capable of delivering 415,000 lb. of water per hr against a pressure of 1500 psi. Multistaging produces better performance, higher pump efficiency, and smaller impeller diameters for high-pressure heads. Usually each stage produces the same head, and the total head developed is the number of stages times the head produced per stage.

The types of impellers installed in centrifugal pumps are as numerous as the uses to which the pumps are put. Classification, however, can be made by designating the direction of flow of the fluid leaving the impeller. All pumps have the intake parallel to the impeller shaft. The discharge, however, may be radial, partially radial and axial, or axial. In the radial-type impeller the suction and discharge are at right angles[1]. The radial impeller may be of the closed or the open type. The term closed or open refers to the fluid passage within the impeller. The open impeller has one side of the flow path open to the pump casing or housing. The closed impeller has both sides of the flow path enclosed by the sides of the impeller. The partially radial impeller discharges at an angle greater than 90 degrees with intake and is of the open-impeller design.

The axial-flow impeller discharges at an angle of approximately 180 degrees with the intake and is generally of the propeller type.

Each of the impeller types has a specific purpose. The axial-flow type is used to pump large quantities of fluid against a relatively small static head.

It is not a true centrifugal pump but is designed on the principles of airfoil shapes. The radial pump is used for handling smaller quantities of fluid against a high head, because the centrifugal force is high but the flow path is small and restrictive. The open impeller is designed to handle dirty liquids such as sewage, where the flow path must be less restrictive. The partially radial impeller covers intermediate pumping conditions.

[1] **are less apt to occur —** реже встречаются

MECHANICAL DRAFT

In power-plant engineering the fan plays an important part. Generally, in small-furnace installations a stack can produce a draft sufficiently high to supply air adequately to the fuel bed and to remove the flue gases. But the present-day capacities of boilers and furnaces require mechanical draft to supplement the natural draft produced by the stack. Mechanical draft is divided into two systems: forced draft and induced draft. In the forced-draft system the fan is located on the air-intake side of the furnace. A positive pressure, a pressure above atmospheric pressure, is produced under the fuel bed and acts to force air through the bed. The forced-draft system is necessary in installations where the pressure drop in the intake system and fuel bed is high. The pressure drop will be high in installations employing air preheaters and/or underfeed stokers. The underfeed stoker has an inherently deep fuel bed and a correspondingly high resistance to air flow.

Generally, the pressure in a furnace should be slightly less than atmospheric pressure. If it is too high, there will be leakage of asphyxiating gases into the boiler room and the tendency for blow-back when furnace inspection doors are opened. If the pressure in the furnace is too low, there will be air leakage to the furnace with a corresponding reduction in the furnace temperature. Because of these restrictions on the desirable pressure within the furnace, the forced-draft system is generally accompanied by a natural-draft system, in order that the removal of the flue gases may be accomplished. However, if the stack draft is inadequate owing to the high resistance created by the furnace passes, economizers, and air preheaters, an induced-draft system is generally added to supplement the stack draft. In the induced-draft system a fan is placed in the duct leading to the stack.

When a forced-and an induced-draft fans are used in combination the system is called balanced draft. The forced draft fan produces a positive pressure which decreases slightly through the duct work and sharply through the air preheater and fuel bed. If the system is properly controlled, a pressure of a few hundredths of an inch of water less than atmospheric pressure is maintained in the furnace proper. The pressure continues to drop through the boiler passes, economizer, and air preheater until it is raised by the induced-draft fan and by the stack to atmospheric pressure.

The present trend is to construct more furnaces with gas-tight casings in order that they may be operated under pressures well above atmospheric pressure. Combustion efficiency is improved at elevated pressures, and the induced-draft fan with its high maintenance cost can be eliminated completely. A number of furnaces using the cyclone burner are now designed to operate at pressures as high as 80 in. of water above atmospheric pressure.

[1] **at right angles** —...под прямым углом

FANS

Fans are used extensively in the heating and ventilating industry and in most power plants. Their basic design principles fall into two classes: axial-flow fans and centrifugal- or radial-flow fans. Axial-flow fans are basically rotating air-foil sections similar to the propeller of an airplane.

The simplest axial-flow fan is the small electric fan used for circulating air in rooms against very little resistance. Axial-flow fans for industrial purposes are the two-blade or multiblade propeller type, and the multiblade air-foil type. Air enters the fan suction from the left and flows over the rotor with a minimum of turbulence owing to the streamline form of the rotor and drive mechanism. The air stream is straightened by guide vanes located on the discharge side, thus decreasing the rotational energy of the air by converting it to energy of translation.

The axial-flow fan operates best under conditions where the resistance of the system is low, as in the ventilating field. The axial-flow fan occupies a small space, is light in weight, is easy to install, and handles large volumes of air.

Centrifugal fans may be divided into two major classes: 1) the long-blade or plate-type fan, and 2) the short-blade multi-blade fan. The blades of either type may be pitched toward the direction of motion of the fan, radially, or away from the direction of motion of the fan.

A plate-type radial-blade rotor with double inlet is best suited for handling dirty gases, since there are no pockets in the blades to catch and collect the dirt. The rotor has wearing strips welded to the blades to increase their life. The fan is designed for induced-draft service. The housing of such a fan may have catch plates in the scroll face to collect the fly ash.

BLOWERS

Blowers may be divided into two types: 1) rotary, and 2) centrifugal. A common type of rotary blower is the Roots two-lobe blower. Two double-lobe impellers mounted on parallel shafts connected by gears rotate in opposite directions and at the same speed. The impellers are machined to afford only a small clearance between them and between the casing and impellers. As the lobes revolve, air is drawn into the space between the impellers and the casing, where it is trapped, pushed toward the discharge, and expelled. The air is trapped and discharged in volumes equal to the space between the impellers and casing, and the operation is repeated four times for each rotation of the shaft.

In order to change the volume rate of flow[1] or volume capacity[2] of the blower, the blower speed is changed. The pressure developed by the blower will be whatever is necessary[3] to force the air through the piping system. The volume of air delivered by the blower will not change appreciably with variations in resistance to flow. Thus, the blower is called a positive-displacement blower.

Note that at a speed of 600 rpm an increase to pressure from 2 to 3 psi increases the power required by 1,5 times, but the capacity remains fairly constant. Care should be taken in operating any positive-displacement blower. A safety valve or limit valve should be placed on the discharge line to prevent the discharge pressure becoming excessive in case the outlet is fully closed. The limit valve will prevent overloading the discharge line and the driving motor. The advantages of the rotary blower are: 1) simple construction, 2) positive air movement, 3) economy of operation and low maintenance.

Centrifugal blowers and compressors operate on the same principles as centrifugal pumps and resemble to a marked degree the closed-impeller centrifugal pumps. A single-stage single-suction blower is capable of delivering 15,000 cfm against a pressure of 3 psi. The casing or housing is constructed of heavy steel plate, and the impeller is an aluminum-alloy casting. If care is taken in providing the proper drive motor, the overload characteristics of the centrifugal blower will cause no trouble.

For volumes greater than those that can be handled by the single-stage single-suction blower, a single-stage double-suction blower is used. This blower is capable of supplying 86,000 cfm of air at 60° F and atmospheric pressure against a 54-in. water column or 2 psi.

[1] **volume rate of flow** — объемный расход

[2] **volume capacity** — объемная производительность

[3] **will be whatever is necessary** — будет соответствовать необходимости

CENTRIFUGAL COMPRESSORS

Multistage centrifugal blowers when capable of handling gases[1] against pressures greater than 35 psig are generally classed as compressors. They resemble multistage centrifugal pumps, and many of the problems encountered in their design are similar to those encountered in pump design. The impellers of a complete centrifugal compressor unit are of the single-suction type, and passages lead the air or gas from the discharge of one impeller to the suction side of the next impeller.

Because of an increase in temperature of the gas or air as the pressure is increased, cooling is generally necessary. If the pressures are not high, cooling water circulated in labyrinths between impellers may be sufficient. When high pressures are encountered, the gas may be cooled in interstage coolers. The reason for maintaining the gas at a low temperature is to permit an increase in the mass rate of flow with a corresponding reduction in size and horsepower.

Axial-flow compressors are designed on the principles of the airfoil section, and the blade shapes will be similar to the axial-flow fan.

These compressors are an essential part of the gas-turbine cycle. The gas is not cooled between stage, because a portion of the additional work necessary to compress the gas adiabatically over the work necessary to compress it isothermally will be recovered in the gas turbine. The advantages of centrifugal and axial-flow blowers and compressors are: 1) nonpulsating discharge of the gas, 2) no possibility of building up excessive discharge pressures, 3) a minimum of parts subject to mechanical wear, 4) no valves necessary, 5) a minimum of vibration and noise, 6) high speed, low cost, and small size or high capacity.

' **when capable of handling gases** — если они могут работать с газами

CHAPTER VI

POWER-PLANT CYCLES

A cycle is a series of operations or events which occur repeatedly in the same order. A power cycle or power-plant cycle is such a series of events which regularly repeat themselves for the purpose of converting a portion of the stored energy of a fuel into work. There are two general types of power cycles, the closed cycle and the open cycle.

In the closed cycle a working fluid begins at some initial condition, undergoes certain changes through a series of regular events, and returns to the initial condition. Theoretically, no replenishment of the working fluid is necessary.

THE RANKINE CYCLE

The simplest ideal or theoretical power-plant steam cycle is the Rankine cycle. The system contains: 1) a steam-generating unit by which energy is added to the fluid in the form of heat transfer from a burning fuel; 2) a prime mover or steam turbine; 3) a condenser by which energy is rejected to the surroundings by heat transfer, and 4) a boiler feed-water pump.

The following assumptions are made for the Rankine cycle:

1) The working fluid, usually water, is pumped into the boiler evaporated into steam in the boiler, expanded in the prime mover, condensed in the condenser, and returned to the boiler feed pump to be circulated through the equipment again and again in a closed circuit under steady-flow conditions, that is, at any given point in the system, the conditions of pressure, temperature, flow rate, etc., are constant,

2) All the heat is added in the steam-generating unit, all the heat that is rejected is transferred in the condenser, and there is no heat transfer between the working fluid and the surroundings at any place except in the steam-generating unit and the condenser.

3) There is no pressure drop in the piping system, there is a constant high pressure, p_1, from the discharge side of the boiler feed pump to the prime mover, and a constant low pressure, p_2, from the exhaust flange of the prime mover to the inlet of the boiler feed pump.

4) Expansion in the prime mover and compression in the pump occur without friction or heat transfer, in other words, they are frictionless adiabatic or isentropic expansion and compression processes in which the entropy of the fluid leaving the device equals the entropy of the fluid entering the device (pump or turbine).

5) The working fluid leaves the condenser as liquid at the highest possible temperature, which is the saturation temperature corresponding to the exhaust pressure p_2.

If the steam-generating unit is a boiler only, the steam that is delivers will be wet, and its quality and enthalpy can be determined by throttling calorimeter. If a superheater is included in the steam-generating unit, the steam that is delivered will be superheated and its enthalpy can be determined from its pressure and temperature by use of the superheated steam table or the Mollier chart.

The condensate leaving the condenser and entering the boiler feed pump is always assumed to be saturated water at the condenser pressure, and its enthalpy can be found from the steam tables at the given condenser pressure.

Since this cycle assumes frictionless adiabatic or ideal expansion of the steam in the prime mover, the Rankine-cycle efficiency is the best that is theoretically possible with the equipment. Better theoretical efficiencies are possible by using more equipment in more complex cycles.

It should be noted that only a small part of the energy supplied in the boiler as heat[1] is converted into work and the rest is lost in the condenser.

The loss resulting from the heat transferred to the condenser cooling water is, to a large extent, inescapable. The temperature of the cooling water varies only with the atmospheric conditions; thus, it remains almost constant. To lower it by artificial means would require the expenditure of additional energy.

[1] as heat—в виде тепла

THE SIMPLE, OPEN, GAS-TURBINE POWER CYCLE

The power plant consists of three elements: the compressor, the combustion chamber, and the gas turbine.

In the actual gas-turbine power plant, 65 to 80 per cent of the turbine output is required to drive the compressor. In the steam-turbine power plant, the working fluid is condensed with a very large reduction in volume so that less than 1 per cent of the turbine output is required to operate the boiler feed pump which corresponds to the air compressor of the gas-turbine power plant. Consequently, for the same net plant output, the gas turbine must produce three to four times as much power as a steam turbine. Such heat-transfer equipment as boilers, economizers, superheaters, condensers, feed-water heaters, forced- and induced-draft fans, and extensive piping system, all of which are necessary in an efficient steam power plant, are eliminated in the simple gas-turbine power plant. However, if maximum efficiency is desired in the gas-turbine power plant, large heat exchangers, water-circulating pumps and piping are necessary, and the gas-turbine plant loses much of its simplicity.

The efficiency of a simple gas-turbine power plant depends upon the temperature of gas supplied to the turbine and upon the pressure ratio, p_1/p_2.

For a given turbine-inlet temperature, there is a particular pressure ratio which gives maximum efficiency, and this optimum pressure ratio increases with inlet temperature. The marked increase in efficiency with increase in inlet temperature should be noted. As the high-temperature characteristics of metals are improved and inlet temperatures higher than 1,500°F become practical, the use of the gas turbine as an economical prime mover will expand rapidly.

CHAPTER VII

INTRODUCTION TO ENERGY MANAGEMENT AND ENERGY AUDIT

Energy management is a technical and management function the remit of which is to monitor, record, analyze, critically examine, alter and control energy flows through systems so that energy is utilized with maximum efficiency. It embraces the disciplines of engineering, science, mathematics, economies, accountancy, design and operational research, computation and information technology. The energy manager must also be responsible for the day-to day management of fuels and deliveries, boiler houses, distribution systems, building services, plant, process equipment, polluting exhausts, effluents and waste.

An energy audit is a fundamental part of any energy management programme of any organization that wishes to control its energy costs. The construction of a complete and detailed energy audit is an intricate, tedious but necessary procedure so that major energy use activities can be identified. The aim of energy audit is to obtain a simple, but comprehensive "photograph" of the overall energy situation. But usually all necessary process information is not available and auditor has to conduct some measurements. For instance, proper maintenance of boilers is heavily dependent upon knowledge of stack-gas composition. If there is too much molecular oxygen, the boiler is operating inefficiently; if there is too much or too much smoke, the boiler is operating inefficiently and creating an operation hazard.

ENERGY MANAGEMENT

The ability of any nation to survive economically depends upon its ability to produce and manage sufficient supplies of low-cost safe energy and raw materials.

It has been seen that the world consumption of limited fossil fuel resources currently increases annually by 3 per cent. Projections of this trend shows that all known reserves will be exhausted in the first half of the coming century. Any sustained attempt to reduce rates of energy consumption, even as little as 1 per cent per annum, ensures an effectively eternal future supply as the nations of the world move slowly towards renewable energy economies. Over the past ten years, a further 6,2 per cent of the world fossil fuel store has been consumed, the 'heat limit'[2] has been reached and overtaken, and global climate may be becoming affected. Assuming that the production and release of CFCs can be reduced and eventually eliminated, the long-term solution to these problems is to *institute firm, systematic and effective energy and environmental management.* Governments, industrialists, commercial organizations, public sector departments and the general public have now become aware of the urgent requirements for the efficient management of resources and energy-consuming activities. Most organizations in the materials, manufacturing, retail sectors and in the service industries have created energy management departments, or have employed consultants, to monitor energy consumptions and to reduce wastage.

Energy management is a technical and management function the remit of which is to monitor, record, analyze, critically examine, alter and control energy flows through systems so that energy is utilized with maximum efficiency. It embraces the disciplines of engineering, science, mathematics, economics, accountancy, design and operational research, computation and information technology.

The energy manager must also be responsible for the day-to-day management of fuels and deliveries, boiler houses, distribution systems, building services, plant, process equipment, polluting exhausts, effluents and waste.

Great strides in the now well-established profession of energy management have been made over the past ten years. This chapter summarizes the energy management procedures which have emerged:

ENERGY SURVEYING AND AUDITING

An energy audit is a fundamental part of any energy management programme of any organization which wishes to control its energy costs. The construction of a complete and detailed energy audit is an intricate, tedious but necessary procedure so that major energy use activities can be identified.

The consumption of fossil fuel energy involves five basic processes:

- Energy release via combustion, in which chemical energy is converted to thermal energy
- Conversion of energy to alternative forms (i.e. thermal to mechanical and vice versa)
- Energy distribution to places of use
- Energy utilization for a specific purpose
- Energy rejection to the environment

The *energy audit* is a balance sheet of energy *inputs, throughouts* and *outputs.* Its fundamental equation is as follows:

fuel energy input = energy losses during combustion
+ energy losses during conversion
+ energy losses during distribution
+ energy losses during utilization
+ energy losses from utilization.

PASSIVE ENERGY CASCADING—SUNDRY HEAT GAINS AND LOSSES

Energy losses are strictly those irrecoverable rejections to the external environment. Some energy losses which occur during combustion, conversion, distribution and utilization may become 'sundry gains' which offset some of the energy demands of a secondary utilization. For example, transmission heat losses from the jackets of furnaces and boilers, surface heat losses from internal heat distribution pipelines and heat losses from equipment, plant and processes, supply heat to the internal environment and reduce the demands for primary energy for space heating. Most electricity consumed within the internal environment (i.e. from lighting, electrical machines, electronics, computers, inlet ventilation fans, etc.) ends up as sundry gains. The few exceptions to this rule are the electricity supplied to extract fans, compressed air systems and refrigeration plant, where a sundry 'cold gain' may result in increased space-heating requirements. When the internal environment is cooled via air conditioning, sundry heat gains are disbenefits.

For a heated building the *energy audit equation* becomes:

heating fuel energy input
+ sundry gains from electricity
+ sundry gains from people (and/or livestock)
+ sundry gains from directly-fired process plant and equipment
— sundry losses to cold plant =
energy losses in flue gases + energy losses during conversion + energy losses from external distribution pipelines + energy losses through the external surfaces of the building via heat transmission through the fabric + energy losses in ventilating air + energy losses in process fluids or solids directly rejected to the external environment.

For a cooled building, the energy audit equation becomes:

electrical energy supplied for refrigeration =

energy losses during conversion + energy gains to external distribution pipelines + sundry gains from electricity + sundry gains from people (and/or livestock) + sundry gains from directly-fired process plant and equipment — sundry losses to cold plant + energy gains through the external surfaces of the building via heat transmission through the fabric + energy in ventilating air + energy losses from input process fluids or solids.

THE AIM AND THE DETERMINATION

The aim of the energy audit is to obtain a simple, but comprehensive 'photograph' of the overall energy flow situation within a declared system boundary, which may be, for example, a building, or group of buildings, a factory, or a product line. This picture aids comprehension of the total overall system activity, reveals interrelations and allows priorities to be identified. It highlights major areas where inefficiencies or waste occurs and allows economic estimates, leading to fully-reasoned investment decisions, to be constructed. Diseconomic effects of certain energy-conserving investments will also emerge. Without the information contained in the energy audit, the energy manager operates blinkered and is prone to erratic, ill-conceived and non-optimal decisions.

In constructing the energy audit, the energy manager must adopt the single-minded attitude of the financial accountant when constructing a financial audit. He must not be deflected from the purpose of constructing the balance sheet described by the energy audit equation. It is often easy to become absorbed in intricacies and, as a result, to spiral outwards from the objective.

FLOW CHART FOR THE CONSTRUCTION OF AN ENERGY AUDIT

The energy audit may be neatly subdivided into the *input* side, the *output* side, and the *throughput.*

The *input* side constitutes an analysis of fuel and electricity bills for a representative recent annual period.

The *output* side details the ultimate energy rejection to the external environment, mainly via heat transmission through the building fabric and ventilating air. The data is obtained from a site energy survey.

Analyses of the *throughputs* may require microaudits, or energy balances over individual items of plant and equipment, such as furnaces, boilers, refrigeration systems, steam autoclaves, compressors, etc., to ascertain operating efficiencies and to identify where sundry gains occur.

The systematic approach to an energy audit contains the following sequential steps:

1. Submit preliminary questionnaire.
2. Process responses from questionnaire.
3. Obtain fuel and electricity bills for a recent representative annual period.
4. Analyse fuel and electricity bills.
5. Conduct boiler house survey and efficiency measurements.
6. Investigate energy distribution systems.
7. Perform internal site survey.
8. Construct *input* side of the audit.
9. Obtain local climatic data.
10. Perform external site survey.
11. Quantify sundry gains.
12. Construct *output* side of the audit.
13. Construct the energy audit balance sheet.
14. Investigate any residual and iterate to balance the audit.

15. Analyse *throughputs.*

PRELIMINARY QUESTIONNAIRE

The purpose of the preliminary questionnaire is to extract preliminary information concerning :he site, its function and the activities being conducted. It should include queries as to the purpose and function of the establishment, occupational patterns, air temperature and ventilation requirements. The questions might be asked during an initial meeting between client and consultant, or the questionnaire and responses might be conducted by post at the initial stages of the investigation.

ENERGY CONSUMPTION IN MANUFACTURING

The construction of an energy and materials audit, or input/output balance, is appropriate for any resource-consuming activity. The energy costs of fuels, raw materials and products must be estimated before any realistic attempt can be made to reduce the historical resource content of products. A detailed knowledge of all inputs, throughputs and outputs occurring during manufacture must be obtained before the resource utilization efficiencies of processes can be improved most cost-effectively. The optimal cost-effectiveness resulting from the application of any resource saving technique can never be achieved by restricting examination to individual components of a system. Each system must be studied as a whole to identify major waste centres and to compare the cost-effectivenesses and environmental impacts of the many alternative or retrofit actions possible.

All leaks of fuels, materials and energy should be prevented. Energy may be saved in the careful storage of fuels.

Products

Having built the building blocks, quantity surveying data may be used to assess the energy and environmental costs of products (Table 1, 2).

Table 1. Energy and pollution costs of raw materials[2]

Material	Energy cost, $MJkg^{-1}$	Environmental cost, kg of CO_2 kg^{-1}
Steel	50-65	4.3-6.7
Aluminium	60-270	5.2-2.3
Copper	25-85	2.2-7.4
Zinc	60-70	5.2-6
Lead	25-50	2.2-4.3
Cement	8-9	0.1-0.5*
Plaster	3	0.26
Plastic	10	0.87'
Glass	20-50	1.7-4.3
Brick	2	0.17
Paper	25	2.2
Wood	4-6	0.4-0.5
Rubber	150	13
Sand, gravel	0.1	0.009

* Plus the kg of CO_2 produced in the process itself

[1] Fossil fuel tied up in plastics 140-150 MJ

ENERGY CONSERVATION

The consumption of energy implies four basic processes:

• Combustion
• Transformation
• Utilization
• Rejection to the environment

There is much scope for improvements in all four activities. The efficiencies of combustion processes may be maximized, conversion efficiencies can be increased, activities may be performed more economically, and waste heat or materials may be reclaimed (e.g. by employing heat exchangers, incinerating waste, or recycling waste materials). Energy and material Hows should be redirected, inhibited or enhanced so as to achieve the maximum overall efficiency of resource utilization in space and time. All resource consuming systems should be designed on the basis of least resource running costs, coupled with long-life and low-maintenance requirements, as well as upon initial capital cost. Often, the greatest immediate savings can be made by questioning the purpose of an activity, closely specifying its resource requirements, and ensuring tight controls so that the specification is adhered to.

That which is not measured cannot be controlled. Energy or materials cannot readily be conserved unless accurate and comprehensive measurements in consistent units are first obtained for all consuming activities within the system boundary.

Table 2. Energy and environmental costs of products

Product	Energy cost, MJ	Environmental cost, kg of CO_2
Coal-fired power station	10^{10}	8.66 x l0^{8+}
Nuclear power station	3.5 x 10^{10}	3 x 10^{9+}
North sea oil rig	10^{10}	8.66 x l0^{8+}
Semi-detached house	2.5 x 10^{5}	2 x 10^{4+}
1000 cc motor car	8 x 10^{4}	7 x 10^{3+}
Bus	6 xl0^{5}	5 x l0^{4}
Locomotive	5 x 10^{6}	4.33 x 10^{5}
Ship	2 x10^{9}	1.7 x10^{6}
Jumbo jet	7 x 10^{7}	6 x 10^{6}
Bicycle	6 xl0^{3}	500
Washing machine	8 xl0^{3}	700
Refrigerator	5 x 10^{3}	433
Vacuum cleaner	2.4 x 10^{3}	210
Colour TV	2.5 x 10^{4}	22 x 10^{3}
Radio	1.5 x 10^{3}	130
Record player	2 x 10^{3}	173
3-piece suite	1.8 x 10^{4}	1.56 x 10^{3}
Table	3.5 x 10^{3}	300
Bed	3 x 10^{3}	260
Newspaper	2	0.2
Magazine	10	0.9
Book	15	1.3
Milk bottle	8	0.7
Aluminium can	5	0.4
Plastic bottle	80	7.0
1 m^2 double glazing	6 x l0^{3}	520.0
1 m^2 solar energy collector	3.5 x 10^{3}	300
1 kg insulant	10-200	0.9-17

$^{+}$ plus CO_2 released in cement making

one litre of petrol releases 40 MJ and 3.5kg of CO_2, thus the car would have to travel 10000 miles, or for about 1 year, to match its historical energy cost.

Financial rewards may be gained at little cost by employing 'good-housekeeping' (e.g. structural repairs, draughtproofing and ventilation control, trimming control systems, turning down thermostats, turning off lights, and switching off plant and equipment when not required).

Plant and equipment should be matched to the required purpose and should be selected on sensible extreme conditions. All systems should be operated at rates corresponding to maximum efficiency (normally fully loaded in continuous operation). Intermittent operations and fluctuations should be avoided. Efficiency checks should be carried out frequently using standardized procedures. The use of energy accumulation should be considered to match intermittent supplies with variable demands (i.e. to balance load factors), to peak lop and use off-peak electricity, and to increase overall energy efficiencies of boilers and distribution systems.

Optimal gas and electricity tariffs should be chosen. Electricity should be metered to all sectors and equipment contributing to peak electrical demand should be identified. Attempts should be made to balance electrical load factors by peak demand lopping (i.e. by staggering start-up times, rescheduling peak activities). The use of standby generators for peak lopping might be considered. Electrical motors should be selected so that they run at near full load. The introduction of a 'total energy' system utilizing combined heat and power should be considered. Electricity is the second most expensive commodity (the most expensive is compressed air and should be used only as a last resort).

The installation of thermal insulation and 'resource conserving' capital plant and equipment should follow only after obvious wastages have been identified and eliminated. Insulation should be applied to high temperature surfaces before attempts are made to insulate lower temperature surfaces. The 'law of diminishing returns' applies in so far as a second increment of insulation applied to a surface results in less extra energy savings than the first increment. Doubling the insulation thickness does not double the financial savings. There occurs a financial break-even point when the lifetime savings resulting from an additional increment of insulation equals the cost of the increment. Thereafter, further additions result in net financial losses unless the ratio of the costs for energy to the costs for insulant alters.

Greater energy efficiency always requires an expenditure of materials and vice versa (e.g. the greater the area of a heat exchanger, the more effective the transfer of heat).

High-grade energy (which may be 'hot' or 'cold' with respect to the environmental datum) should not be allowed to be dissipated directly to the environment. The energy rejected from a high-grade process should be collected and redirected via heat exchangers (or simply fans or pumps) to be employed at another place, collected and stored to be employed at another time, or concentrated for another higher-grade purpose using a heat pump or other thermal transformer, as long as these operations are economically justifiable.

Attempts should be made to introduce feedback from energy loss centres to higher-grade stations in the energy flow sequence (e.g. by recycling materials, heat pumping or incinerating waste). Attempts to reduce or reuse waste should be made before any attempts at recycling or recovery. Waste energy and materials should be reused wherever economically possible ensuring that practical grade, time and space-matched uses have been found for the reclaimed amounts. The value of the savings must clearly exceed the cost of recovery.

Solar gains, lighting dissipations and high-temperature thermal loads, emanating from electronics and electrical systems, should be extracted by cooling windows, louvers, shutters, luminaires or equipment, using air or water at outside environmental temperatures. This avoids the wasteful practice in air conditioning systems of allowing such energy to infiltrate into and so disturb the thermal equilibrium of a room, for which it is necessary to use high grade chilled water or refrigerant to remove the excess heat via a large heat transfer surface in order to regain comfort conditions.

Heat distribution systems and hot/chilled water services

All pipework, storage vessels, pumps and valves should be insulated to economic and effective levels. Fabric transmission heat loss calculations should be made and the ratio of heat loss per unit area to heat throughput should be evaluated. The total heat loss associated with energy distribution systems should be estimated for the energy audit. The effective operation of pumps, values and air vents should be ensured. The settings and operations of all control systems should be checked. The integrities of vapour seals on cold pipes and equipment should be maintained.

Space heating systems

Maintenance and operating procedures should be reviewed. Particular attention should be paid to start-up, shut-down times and schedules and control procedures. Heaters and cooling equipment should be correctly sized and positioned. Checks should be made for vertical temperature stratification. Unoccupied zones should be identified. The use of waste heat for space heating should be considered. Combustion efficiency checks should be made for direct-fired heaters. Checks should be made for air leaks into casings. All heat transfer surfaces should be kept clean and free from obstructions. Steam traps should operate efficiently and should not leak. Condensate should be recovered and used for another heating purpose.

Lighting systems

High-efficiency lighting systems should be installed and kept clean. Optimal balances between natural daylighting and artificial lighting in different zones should be sought. In general, the smaller a window, the less transmission losses through the glazing and the greater the amount of artificial lighting required. Different levels of lighting are appropriate for different zones and activities (i.e. design studios versus corridors). Lighting controls should be investigated and reviewed. Lighting should not be provided where it is not needed. Wall colours should be light and reflecting surfaces should be kept clean. Heat recovery from luminaires might be considered.

TRANSPORTATION SYSTEMS

The direct use of fuels for the transportation sector in the United Kingdom has risen from 15 per cent in 1980 to 25 per cent in 1990. Integrated international networks for production and distribution have increased multifold. These transportation networks have resulted in the dispersal of production systems across Europe, to areas where labour, land, raw materials and local facilities are cheaper, whilst distribution outlets and marketing activities remain in urbanized areas. Industrial, commercial and domestic centres have become increasingly separated. A vicious spiral has developed—more suburbs—more traffic—more roads— declining public transport and rail services—more traffic—more suburbs....

An energy-conscious transportation network arranges that least energy is expended in travel along the production and distribution lines. Routes and load schedules of conveyers, trucks and other vehicles both inside and outside the factory should be critically examined to ascertain whether each journey is absolutely necessary? Carrier sizes should match the loads carried and vehicles and equipment should be regularly serviced and lubricated.

WATER CONSERVATION

Water and effluent management often fall within the remit of the energy manager. From an analysis of water bills and water usage patterns, a water audit can be constructed in the same manner as the energy audit. Loss and wastage centres can be identified and rectified. Monitoring and targeting exercises, in comparing current water usage with previous periods, can reveal the onset of new leaks or wastages. Discharge rates of liquid effluent should be correlated with water usage. Possibilities for water cascading, reuse or reclaim should be investigated. Required water qualities for different processes should be specified. Water charges may be based upon rateable value or meter readings. From the water audit, possible financial savings arising from installing a water meter may be estimated. Water consumption in like establishments (e.g. schools, hospitals) can be compared by normalizing monthly usage by working areas, number of personnel or amount of product. Automatic flushing schedules should be optimized and flushing should not occur when not necessary (i.e. when buildings are unoccupied). Infra-red detectors might be employed to detect personnel or flushings, and lights might be controlled by door openings.

RULES FOR THE EFFICIENT CONSERVATION OF ENERGY AND MATERIALS

- The purposes for which expenditures of energy or materials are required should be critically examined.
- As much useful work, heat, or other purpose fulfillment, should be extracted from a degrading energy or materials chain, as is compatible with economic and other considerations.
- The quality, not the quantity, of energy (materials) is the subject of conservation.
- Each energy operation should be examined critically and systematically in isolation and in relation to all other events occurring within the system boundary.
- The manner and extent of all energy and materials use should be challenged, including the appropriateness of the process method and the size of the plant involved.

Sources

- Fuels and materials should be used only when and where required.
- Space or time delays inevitably incur losses.
- Stocks should be maintained at minimum levels plus emergency reserves.
- Attention should be paid to the delivery, storage and handling systems. The financial, energy and materials costs of these should be assessed.
- Comprehensive and accurate monitoring and metering of all energy and materials inputs, throughputs and outputs should be accomplished.
- A continuous fuels log should be maintained.
- Procedures should be standardized.
- Qualities should be checked.
- Information should be easily accessible, comprehensible and disaggregable.
- Attempts should be made to account for all inputs in terms of outputs.
- Storage areas should be made secure against loss or theft.

Plant, equipment, systems, products

- All hardware should be matched to the purpose for which it is required.
- All systems should be operated at rates corresponding to maximum efficiency (normally fully loaded in continuous operation).
- Intermittent operations and fluctuations should be avoided.
- Efficiency checks should be carried out frequently using standardized procedures.
- Plant should be selected on sensible extreme conditions.
- Energy or materials cannot readily be conserved unless accurate and comprehensive measurements in consistent units are first obtained for all activities within the system boundary.
- Greater overall efficiency can always be achieved at the cost of additional complexity.
- Greater energy efficiency always requires an expenditure of materials and vice versa (e.g. the greater the area of a heat exchanger, the more effective the transfer of heat).
- The 'law of diminishing returns applies.
- Side benefits and diseconomies: incidental benefits or penalties arising from each consuming activity should be identified and carefully evaluated.
- Only the most efficient component branches in energy or materials utilization chains should be adopted.
- Overall efficiencies are always lower than that of the most inefficient link in the chain.
- Product designs should maximize lifetime, promote easy maintenance and repair, require little additional energy or materials inputs during active life, and should facilitate re-use, recycling, easy disposal and natural degradation and recycling.

Improvements

- Systems should be modelled and evaluated accurately so that the cost-effectivenesses of conservation options can be compared realistically.
- Careful assessments of real savings should be made, including maintenance costs.
- Full audits in common units should be carried out before and after improvements.
- Evaluations should be obtained with respect to quantities of energy and materials, financial costs of energy and materials, energy costs of energy and materials, exergy degradation and overall exergetic efficiencies.
- Representative periods should be adopted for these analyses.
- A continuous *monitoring and targeting* procedure should be implemented.
- The selection of new plant, processes, or energy (or material) conserving measures should be made, not on least capital cost criterion alone, but upon the basis of least total cost over the lifetime of the system.
- Random factors should be eliminated — the system should be isolated from its external environment.
- All leaks of fuels, materials and energy should be prevented.
- Attempts should always be made to reduce demand before increasing energy or materials supplies.
- It should be ensured that modifications have no hidden diseconomic effects and that they comply with safety, fire and statutory regulations and codes of practice.

Energy and exergy

- Energy (materials) grade and availability should be matched to the purpose for which it is required in terms of temperature, pressure, heat flux, and the qualities of materials.

The choice of an energy (materials) form to suit a particular application should not be made arbitrarily. Forms of different qualities are suitable for specific applications. High-grade energy should be used only for high grade purposes, such as producing work, fuels, materials or electrical potential.

Whenever, or whenever, energy quality (exergy) must be degraded, attempts should be made to:

- Obtain useful heat (i.e. from a temperature reduction)
- Obtain useful work (i.e. from a pressure reduction)

A degrading energy chain should be made to do as much work and other useful activity as possible during the process.

- The input and output grades of energy supplied to and rejected from any particular component activity should be such that the exergetic efficiency of the activity is a maximum.
- Energy flows should be redirected within the overall system such that the overall exergetic efficiency of the system is a maximum.
- If additional energy has to be added to a degrading energy chain, it is more efficient to introduce low-grade energy, preferably 'waste' heat, rejected from a higher grade activity, at the lower end of the chain.

For example, fuel should not be burnt at 1000 degrees centigrade in order to provide space heating for a room whose temperature needs to be raised only a few degrees above that of the outside air.

- If energy is to be removed from a degrading energy chain, it is more efficient to withdraw this energy before it is degraded, using the external environment as a sink, at the higher end of the energy chain.

Reclamation

- High-grade energy (which may be 'hot' or 'cold' with respect to the environmental datum) should not be allowed to dissipate directly to the environment. The energy rejected from a

high-grade process should be collected and redirected via heat exchangers (or simply fans or pumps) to be employed at another place, collected and stored to be employed at another time, or concentrated for another higher grade purpose using a heat pump or other thermal transformer, as long as these operations are economically justifiable.
- The effects on the desired purpose of by-passing, deleting, or moving back up degrading energy chains should be examined.
- Attempts should be made to introduce feedback from energy loss centres to higher-grade stations in the energy flow sequence (e.g. by recycling materials, heat pumping or incinerating waste).
- Attempts to reduce or reuse waste should be made before any attempts at recycling or recovery.
- Waste energy and materials should be reused wherever economically possible ensuring that practical grade, time and space-matched uses have been found for the reclaimed amounts.
- The value of the savings must clearly exceed the cost of recovery.

Waste heat, materials and ambient energy
- The use of external waste heat, materials or ambient energy (i.e. solar, wind, waves, tides, external air temperatures) should be considered before increasing the rate of usage of fuels.
- Solar energy is the most pollution-free power source.

Energy storage
- The use of energy accumulation should be considered to:

(1) Balance load factors
(2) Peak lop and use off-peak electricity
(3) Increase overall energy efficiencies of boilers and distribution systems
(4) Harness ambient energy

Management
Great care should be taken to ensure the cleanliness, correct operation and planned systematic maintenance of all storage, release, distribution, utilization, insulation, heat recovery, instrumentation and control systems.

Pollution
- Waste and pollution should be closely monitored and minimized.
- Waste in all forms not only squanders human effort, energy, time and materials, but also damages the external environment and disrupts ecological harmony.
- The reduction of waste is especially desirable where materials have intense availability contents or where their historical availability costs are high. Metals, glass, plastics, paper and refractories are examples of such materials.
- Design improvements, which prolong the lifespan, or promote the reuse or easy recycling of these energy-intensive materials are highly desirable.
- Methods of waste collection, sorting and reclamation should be developed.
- Improved recycling techniques are needed.

Education
- All personnel should be made fully aware of the energy and materials implications of their activities and decisions.
- All associated personnel should be availed information, demonstrations of achievements and reports of failures of 'improvement' activities.

LAWS OF ENERGY AND MATERIALS FLOWS

- Energy or matter can be neither created nor destroyed.
- Energy or matter are always conserved, although transductions may occur.

• Exergy degrades via equilibrium processes.
• All energy and materials tend to degrade to entropic disorder by being dispersed over a greater volume.
• Human consumerism accelerates this process.
• As a result of utilization, energy and materials are eventually downgraded to an equilibrium state having zero availability corresponding to the environmental datum.
• The environmental potential should be regarded as the reference datum.
• The availability of either energy or materials requires a source or sink at a potential different to that of the environment.
• The efficiency of an energy or materials conversion is always less than 100 per cent.
• Decreasing entropy is a futile process in the long term but may be of temporary use in the short term.
• Energy must be lost in reducing entropy (work production).
• The supply of work can reduce entropy (heat pumping).
• Activities, if completely described, all lead to energy or materials rejection to the environmental datum, i.e. the total entropy of the considered control volume through which the energy or materials flow, rises.
• Energy reclamation involves the expenditure of materials.
• Materials reclamation involves the expenditure of energy.
• Reclamation of energy or materials reduces pollution.

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NOTE ON BRITISH AND SI UNITS

Parameter & British Unit	Abbrev.	SI Value
Length:		
Mile	ml	1609,344 m
Yard	yd	0,9144 m
Foot	ft	0,3048 m
Inch	in	0,0254 m
Mass:		
Ton	tn	907,185 Kg
Pound	lb	0,45348 Kg
Ounce	oz	0,02835 Kg
Pressure:		
Pound per square inch	psi	6894,76 Pa
Pound per square foot	psf	1,49 Pa
Temperature:		
Fahrenheit’s scale	F	1,8 t C + 32
Centigrate scale	C	(t F - 32)/1,8
Heat:		
British thermal unit	Btu	1055,06 J
Power:		
Horse-power	hp	735,499 W
Energy power:		
Horse-power-unit	hp-hr	2,648 MJ

СПИСОК УСТОЙЧИВЫХ СОЧЕТАНИЙ

Recording to согласно, в соответствии с
a number of ряд, много
as a rule как правило
as a result of в результате
in compared по сравнению с
as follows следующим образом
as long as до тех пор, пока; если
as *much ... as* столько, сколько
11 такой же мере; до *(перед цифрами)*
as much as possible возможно больше
as well as так же как; а также
be able в лучшем случае
in the same time в то же время
because of из-за, вследствие
by means of посредством
In depending on в зависимости от
due to из-за, вследствие

is due to является следствием, вызывается
in addition to кроме, в добавление к ...
In fact в действительности, на самом деле
In general вообще
In order to для того, чтобы
In the case of в случае
In the course of в течение
In turn в свою очередь
on the other hand с другой стороны
owing to вследствие
per hour в час
regardless of независимо от
to a certain extent до некоторой степени
with a view to с целью; с тем, чтобы

СПИСОК СОКРАЩЕНИЙ

Btu (British thermal unit)	Британская тепловая единица
cfm (cubic feet per minute)	Кубических футов в минуту
cu.ft (cubic foot)	Кубический фут
deg (degree °)	Градус
f (Fahrenheit)	Температурная шкала Фаренгейта
fps (feet per second)	футов в секунду
ft (foot)	Фут
hp (horsepower)	Лошадиная сила *(единица мощности)*
hp-hr (horsepower-hour)	Лошадиная сила в час
hr (hour)	Час
in. (inch)	Дюйм
kW (kilowatt)	Киловатт
min (minute)	Минута
Mw (megawatt)	Мегаватт
o.d. (outside diameter)	Наружный диаметр
lb (pound)	Фунт
psf (pounds per square foot)	фунтов на квадратный фут
psi (pounds per square inch)	фунтов на квадратный дюйм
psia (pounds per square inch absolute)	Абсолютное давление в фунтах на квадратный дюйм
psig (pounds per square inch gauge)	Избыточное давление в фунтах на квадратный дюйм
rpm (revolutions per minute)	Оборотов в минуту

АНГЛО-РУССКИЙ СЛОВАРЬ

A

absorb [əb'sɔ:b] *v* впитывать, поглощать

accessibility [æk,sesı'bılıtı] *n* доступность; легкость осмотра или ремонта

accomplish [ə'kɔmplıʃ] *v* совершать, выполнять; достигать; доводить до конца, завершать

adequate ['ædıkwıt] *a* 1. соответствующий; 2. достаточный

adhere [əd'hıə] *v* прилипать, приставать

adherent [əd'hıərənt] *a* 1. присоединенный, прилипший; 2. вязкий

adjacent [ə'dʒeısənt] *a* примыкающий, смежный, соседний

adjunct ['ædʒʌŋkt] (to) *n* приложение, дополнение

admiralty metal ['ædmərəltı 'metl] адмиралтейский металл, морская латунь

admission [əd'mıʃən] *n* впуск; подвод; подача; наполнение; степень наполнения

adopt [ə'dɔpt] *v* 1. принимать; усваивать; 2. выбирать, брать по выбору

advent ['ædvənt] *n* приход, появление

after condenser ['ɑ:ftəkən,densə] *n* последующий эжекторный подогреватель

aftercooler ['ɑ:ftə,kulə] *n* дополнительный охладитель; вторичный холодильник

aircraft ['ɛəkrɑ:ft] *n* летательный аппарат; самолет

airfoil ['ɛəfɔıl] *n* крыло, профиль крыла

airline ['ɛəlaın] *n* авиалиния

alcohol ['ælkəhɔl] *n* спирт; винный спирт; этиловый спирт

alternative [ɔ:l'tə:nətıv] *a* переменнодействующий, переменный

alternator ['ɔ:ltə'neıtə] *n* генератор переменного тока, синхронный генератор

altitude ['æltıtju:d] *n* высота

amount [ə'maunt] *n* количество; *v* доходить (*до какого-л. количества*), составлять (*сумму*); равняться

anchor ['æŋkə] *v* прикреплять

angle ['æŋgl] *n* угол

annealing [ə'ni:lıŋ] *n* отжиг; отпуск

annular ring ['ænjulə'rıŋ] круговое кольцо

annulus ['ænjuləs] *n* 1. кольцо; кольцевое пространство, зазор; 2. зубчатое кольцо с внутренним зацеплением

anthracite ['ænθrəsaıt] n антрацит

application [,æplı'keıʃən] *n* применение; применимость

apply [ə'plaɪ] *v* 1. прилагать; 2. применять, употреблять; 3. касаться, относиться; быть приемлемым

approximately [ə'prɔksɪmɪtlɪ] *adv* приблизительно, почти

area ['ɛərɪə] *n* 1. площадь; площадка; поверхность; 2. район, область, территория; участок; зона

arrangement [ə'reɪndʒmənt] *n* 1. расположение; 2. устройство

ash [æʃ] *n* зола, пепел

fly a. [flaɪ] *n* зольная пыль, копоть, летучая зола, унос

ashpit ['æʃpɪt] *n* зольник, поддувало, золовая воронка

associate [ə'souʃɪeɪt] *v* 1. соединять, связывать

attain [ə'teɪn] *v* достигать, добиваться

attemperator [ə,tempə'reɪtə] *n* терморегулятор

automatic welder [,ɔ:tə'mætɪk 'w..də] сварочный автомат

auxiliary [ɔ:g'zɪljərɪ] *a* 1. вспомогательный, 2. добавочный, запасной; *n* вспомогательное устройство, вспомогательный механизм

available [ə'veɪləbl] *a* доступный; имеющийся в распоряжении, наличный, применимый; (при) годный

avalanche ['ævəlɑ:nʃ] *v* обрушиваться

B

baffle ['bæfl] *n* перегородка, заслонка, экран

boiler b. ['bɔɪlə] направляющая перегородка котла

deflecting b. [dɪ'flektɪŋ] направляющая перегородка

gas b. [gæs] газовая направляющая перегородка

internal fireside b. [ɪn'tə:nl 'faɪəsaɪd] внутренняя огневая направляющая перегородка

bagasse [bə'gæs] *n* ком сахарного тростника

bank [bæŋk] *n* 1. батарея, группа, ряд; 2. пучок (труб)

bar [bɑ:] *n* стержень, брус, пластинка

carrier b. ['kærɪə] держатель, поддерживающая пластинка

grate b. [greɪt] колосник, колосниковая решетка

bearing ['bɛərɪŋ] *n* подшипник

thrust b. [θrʌst] упорный подшипник, подпятник

bed [bed] *n* 1. станина; рама; 2. фундамент; плита; 3. русло (*реки*); 4. слой, пласт; 5. залежь

hot fuel b. ['hɔtfjuəl] горящий слой топлива

bend [bend] *n* изгиб, колено, отвод; *v* (bent) сгибать(ся); гнуть(ся); изгибать(ся)

flanged return b. ['flændʒd rɪ'tə:n] прифланцованное обводное соединение

binding post ['baɪndɪŋ 'poust] клемма, зажим

blade [bleɪd] *n* 1. лопасть; лопатка; 2. крыло (*вентилятора*)

blade tip ['bleɪd,tɪp] конец лопасти; конец лопатки

blanket ['blæŋkɪt] *n* 1 покрытие; поверхностный слой; защитный слой; 2. покров

blasting ['blɑ:stɪŋ] *n* очистка, обдувка (*струей*)

blowdown ['blou,daun] *n* 1. продувка; *a* нагнетательный

blower ['blouə] *n* воздуходувка; вентилятор, газодувка

centrifugal b. ['sentrɪfjugəl] центробежный вентилятор

positive-displacement b. ['pɔzɪtɪv dɪs'pleɪsmənt] вентилятор с положительной подачей

Rootes two-lobe b. ['ru:ts'tu:loub] Рутсевский вентилятор с двумя зубчатыми колесами

rotary b. ['routərɪ] ротационный вентилятор single-stage single-suction b. ['sɪŋglsteɪdʒ'sɪŋglsʌkʃən] одноступенчатый вентилятор с односторонним всасыванием

boiler ['bɔɪlə] *n* 1. (паровой) котел; 2. кипятильник; испаритель

circulation b. [,sə:kju'leɪʃən] котел с циркуляцией

dry bottom b. ['draɪ,bɔtəm] котел без жидкого шлакоудаления

externally fired b. [eks'tə:nlɪfaɪəd] котел с выносной (наружной) топкой

fire-tube b. ['faɪətju:b] жаротрубный котел

forced-circulation b. ['fɔ:st,sə:kju'leɪʃən] котел с принудительной циркуляцией

horizontal-return tubular b. ['hɔrɪ'zɔntl rɪ'tə:n 'tju:bjulə] горизонтальный котел с обратными дымогарными трубами

natural-circulation b. ['nætʃrəl,sə:kju'leɪʃən] котел с естественной циркуляцией

single-pass b. ['sɪŋglpa:s] одноходовой котел

slag tap b. ['slæg,tæp] котел с жидким шлакоудалением

submerged-tube b. [sʌb'mə:dʒd,tju:b] котел с погружением

two-drum low head b. ['tu:,drʌm'lou,hed] двухбарабанный котел низкого давления

two-drum water-tube b. ['tu:,drʌm'wɔtə,tju:b] двухбарабанный водотрубный котел

water-tube b. ['wɔ:tə,tju:b] водотрубный котел

boiler room['bɔɪlə,rum]котельная

bolt [bɔlt] *v* закреплять болтами

brace [breɪs] *n* связь, скрепление; *v* связывать; скреплять

brick setting ['brɪk'setɪŋ] кирпичная кладка, кирпичная обмуровка

bridge wall ['brɪdʒwɔ:l] перевал (*в мартеновской печи*)

bubble ['bʌbl] *n* пузырек воздуха или газа (*в жидкости*)

burner ['bə:nə] *n* горелка; форсунка; топка; камера сгорания (*газовой турбины*)

combination b. [,kɔmbɪ'neɪʃən] комбинированная горелка

gas b. ['gæs] газовая горелка

ring b. ['rɪŋ] кольцевая горелка

burner port ['bə:nə,pɔ:t] амбразура горелки

by-passing ['baɪpa:sɪŋ] байпассирование (обвод)

by-product ['baɪ,prɔdəkt] *n* побочный продукт

C

calorimeter [,kælə'rɪmɪtə] *n* калориметр

throttling c. ['θrɔtlɪŋ] дроссельный калориметр

capacity [kə'pæsɪtɪ] *n* 1. вместимость; 2. емкость; объем, 3. способность; 4. мощность; производительность, нагрузка

separator c. ['sepəreɪtə] производительность сепаратора; производительность центрифуги

carbon ['ka:bən] *n* углерод

cause [kɔ:z] *v* 1. быть причиной, вызывать; 2. заставлять

char [tʃa:] *n* уголь

charcoal ['tʃa:koul] *n* растительный или животный уголь; древесный уголь

charge [tʃa:dʒ] *n* загрузка

chimney ['tʃɪmnɪ] *n* дымовая труба; дымоход; вытяжная труба

chromium ['kroumjəm] *n* хром

chute [ʃu:t] *n* лоток

circuit ['sə:kɪt] *n* 1. цепь; контур; 2. схема

flow c. [flou] трубопровод

circuitous [sə:'kjuɪtes] *a* завихренный

circulator ['sə:kjuleɪtə] *n* циркуляционный насос

circumferential [sə,kʌmfə'renʃəl]

a относящийся к окружности; периферический
cleaner ['kli:nə] *n* 1. очиститель; 2. фильтр
cleanout ['kli:naut] *n* очистной люк
clearance ['klıərəns] *n* зазор; вырез; вредное пространство (*в цилиндре*)
axial c. ['æksıəl] осевой зазор
blade (tip) c. [bleıd] зазор между направляющими и рабочими лопатками (*турбины*)
safe blade tip c.['seıf'bleıd,tıp] безопасный зазор
clinkering ['klıŋkərıŋ] *n* 1. спекание угля; 2. засорение колосниковой решетки
coal [koul] *n* уголь, каменный уголь
bituminous c. [bı'tju:mınəs] битуминозный уголь, жирный уголь
caking c. ['keıkıŋ] коксующийся уголь; спекающийся уголь
green c. ['gri:n] тощий уголь
pulverized c. ['pʌlvəraızd] пылевидный уголь
coherent [kou'hıərənt] *a* сцепленный, связный
coil [kɔıl] *n* 1. катушка; виток; намотка; спираль; обмотка; 2. змеевик
coke [kouk] *n* кокс
coke breeze ['kouk'bri:z] коксовая мелочь, коксовый шлак
collision [kə'lıʒən] *n* столкновение
column ['kɔləm] *n* столб(ик)
water c. ['wɔ:tə] 1. водяной столб; 2. водомерное стекло
combustion [kəm'bʌstʃən] *n* горение; сгорание; сожжение; воспламенение, возгорание
combustor [kəm'bʌstə] *n* камера сгорания; камера (*прямоточного воздушно-реактивного двигателя*)
commercial [kə'mə:ʃəl] *a* 1. коммерческий, торговый; 2. заводской; промышленный (*процесс или оборудование*) 3. рентабельный; 4. серийный
compressor [kəm'presə] *n* компрессор
air c. [εə] 1. воздушный компрессор; 2. краскораспылитель; пульверизатор
axial-flow c. ['æksıəlflou] осевой компрессор
centrifugal c. [sen'trıfjugəl] центробежный компрессор
multi-stage c. ['mʌltısteıdʒ] многоступенчатый компрессор
single-stage c. ['sıŋglsteıdʒ] одноступенчатый компрессор
condensable [kən'densəbl] *a* 1. конденсирующийся; 2. превратимый в жидкое состояние (*о газе*)
condensate [,kɔnden'seıt] *n* конденсат; *v* конденсировать; сгущать; сжижать; *a* сгущенный; сжиженный
condenser [kən'densə] *n* конденсатор, холодильник, газоохладитель
direct-contact c. [dı'rekt'kɔntækt] смешивающий конденсатор
jet c. [dʒet] струйный конденсатор, впрыскивающий конденсатор
single-pass surface c. ['sıŋglpɑ:s'sə:fıs] одноходовой поверхностный конденсатор
surface c. ['sə:fıs] поверхностный конденсатор
vent c. [vent] конденсатор выпара
conduction [kən'dʌkʃən] *n* проводимость
consumption [kən'sʌmpʃən] *n* потребление, расход
content ['kɔntent] *n* содержание
continuity [,kɔntı'nju:ıtı] *n* непрерывность; неразрывность; целостность
contour ['kɔntuə] *n* контур, очертание; *v* наносить контур; *a* фасонный, профильный
convection [kən'vekʃən] *n* конвекция

conventional [kən'venʃənəl] *a* 1. обычный, общепринятый; 2. стандартный, удовлетворяющий техническим требованиям

convert [kən'və:t] *v* превращать

cool [ku:l] *v* охлаждать

coolant ['ku:lənt] *n* охладитель; охлаждающий агент, хладагент; смазочно-охлаждающая эмульсия

cooler ['ku:lə] *n* 1. холодильник; 2. охладитель; радиатор

cooling pond ['ku:lɪŋ,pɔnd] охлаждающий бассейн, пруд

cooling tower ['ku:lɪŋ,tauə] градирня, башенный охладитель

corrosion [kə'rouʒən] *n* 1. коррозия, разъедание; 2 размыв

cover ['kʌvə] *n* крышка; колпак; кожух

cranite ['krænɪt] *n* кранит (уплотняющий материал)

crank [kræŋk] *n* 1. кривошип; 2. колено; коленчатый рычаг

crankshaft [,kræŋk'ʃɑ:ft] *n* коленчатый вал

crisscross ['krɪskrɔs] *n* перекрестное расположение

cross-section ['krɔs,sekʃən] *n* поперечное сечение, поперечный разрез

crude [kru:d] *a* необработанный, неочищенный

crust [krʌst] *n* земная кора

Curtis stage ['kə:tɪs , steɪdʒ] ступень Кёртиса

cycle [saɪkl] *n* цикл; круг

- **Carnot c.** [kɑ:'nɔ] цикл Карно
- **closed c.** [klouzd] замкнутый цикл
- **gas-turbine power c.** ['gæs ,tə:bɪn'pauə] газотурбинный силовой цикл
- **open c.** ['oupən] незамкнутый (разомкнутый) цикл
- **power-plant c.** ['pauəplɑ:nt] силовой (энергетический цикл)
- **Rankin c.** ['ræŋkɪn] цикл Ранкина

cylinder jacket ['sɪlɪndə ,dʒækɪt] рубашка цилиндра

D

damper ['dæmpə] *n* заслонка, регулятор тяги; задвижка

- **by-pass d.** ['baɪpɑ:s] перепускная задвижка

deal [di:l] (**dealt**) *v* 1. общаться, иметь дело (**with** —с кем-л.); 2. рассматривать вопрос

decrease ['di:kri:s] *n* уменьшение, убывание, понижение; *v* [di:'kri:s] уменьшать (ся), убывать

define [dɪ'faɪn] *v* определять

deliver [dɪ'lɪvə] *v* доставлять

density ['densɪtɪ] *n* удельный вес; плотность

deposition [,depə'zɪʃən] *n* отложение, осадок

depth [depθ] *n* глубина

design [dɪ'zaɪn] *n* проект; конструкция; *v* 1. предназначать; 2. проектировать, конструировать

diffuser [dɪ'fju:zə] *n* 1 диффузор; 2. распылитель

diffuser ring [dɪ'fju:zə ,rɪŋ] диффузорное кольцо; диск центробежного насоса

dimension [dɪ'menʃən] *n* 1. измерение; 2. *pl* размеры, величина; объем

discharge [dɪs'tʃɑ:dʒ] *v* 1. разгружать; 2. выпускать, выбрасывать

disengagement [,dɪsɪn'geɪdʒmənt] *n* 1. выключение; разъединение; 2. выделение

disintegrate [dɪs'ɪntɪgreɪt] *v* 1. разделять(ся) на составные части; раздроблять; 2. распадаться, разрушаться

disk [dɪsk] *n* диск

- **flexible-valved** ['fleksɪbl,vælv] свободный тарельчатый клапан
- **valve d.** [vælv] тарелка клапана

dissolve [dɪ'zɔlv] *v* растворять (ся), испарять(ся), разлагать(ся)

door [dɔ:] *n* дверь, дверца; заслонка; входное или выпускное отверстие; люк
inspection d. [ɪn'spekʃən] смотровое отверстие, смотровой люк
doubling ['dʌblɪŋ] *n* удвоение, сдеаивание
dovetail ['dʌvteɪl] *n* ласточкин хвост (*тип соединения*); деталь в виде ласточкина хвоста; *v* соединять ласточкиным хвостом
downcomer ['daun,kʌmə] *n* 1. спускная труба; 2. циркуляционная труба (*в паровом котле*); 3. наклонный газоотвод доменной печи
downspout ['daun,spaut] *n* нисходящий лоток
downtake ['daun,teɪk] *n* опускная труба
draft [drɑ:ft] *n* 1. тяга; поток; сквозняк; дутье; 2. тяговая сила
balanced d. ['bælənst] уравновешенная тяга
forced d. [fɔ:st] дутье, принудительная тяга
induced d. [ɪn'dju:st] искусственная (косвенная, принудительная) тяга
mechanical d. [mɪ'kænɪkəl] искусственная вентиляция, механическая тяга
natural d. ['nætʃrəl] естественная тяга
drill [drɪl] *v* сверлить, бурить
drive [draɪv] (drove, driven) *v* двигать, приводить в движение
drive shaft ['draɪv'ʃɑ:ft] 1. ведущий вал, приводной вал, вал привода; 2. трансмиссия
droplet ['drɔplɪt] *n* капелька
drum [drʌm] *n* барабан; цилиндр
mud d. [mʌd] грязевик
drum internal ['drʌmɪn'tə:nl] внутреннее устройство барабана
dry-ash furnace bottom ['draɪæʃ,fə:nɪs'bɔtm] дно топки с сухой золой
duct [dʌkt] *n* 1. канал; проход; 2. труба; трубопровод
duct work ['dʌkt,wə:k] система каналов
dust [dʌst] *n* 1. пыль; 2. порошок; *v* удалять пыль
dust collector ['dʌstkə'lektə] пылевая камера, пылесборник, пылеуловитель

E

earth satellite ['ə:θ'sætəlaɪt] спутник земли
economizer [i:'kɔnəmaɪzə] *n* экономайзер, подогреватель
non-steaming e. [,nɔn'sti:mɪŋ] не кипящий экономайзер
eddy ['edɪ] *n* вихрь, вихревое движение
effect [ɪ'fekt] *n* 1. следствие, результат; 2. действие, влияние; 3. полезное действие, производительность; *v* производить; выполнять, совершать; осуществлять
sand-blasting e. ['sænd,blɑ:stɪŋ] эрродирующее действие
effective [ɪ'fektɪv] *a* 1. действительный, эффективный; 2. полезный
effectiveness [ɪ'fektɪvnɪs] *n* эффективность
efficient [ɪ'fɪʃənt] *a* действенный; эффективный
ejector [i:,dʒektə] *n* эжектор, струйный насос
air e. [ɛə] эжектор, воздушный отсасывающий насос, струйный насос
steam-jet. air e. ['sti:mdʒet'ɛə] паровой (пароструйный) эжектор
eliminate [ɪ'lɪmɪneɪt] *v* устранять; исключать
embody [ɪm'bɔdɪ] *v* 1. осуществлять (*идею*); 2. заключать в себе; 3. объединять; включать
emission [ɪ'mɪʃən] *n* выделение

enclose [ɪn'klouz] *v* окружать, заключать

engine ['endʒɪn] *n* машина; двигатель; мотор

atomic e. [ə'tomɪk] атомный двигатель

by-pass e. ['baɪpɑ:s] двухконтурный турбореактивный двигатель, ДТРД

combustion e. [kəm'bʌstʃən] двигатель внутреннего сгорания

compound e. [kəm'paund] *n* компаунд-машина

diesel e. ['di:zəl] 1. дизельный двигатель, дизель; 2. тепловоз

double-acting steam e. ['dʌbl ˌæktɪŋ'sti:m] паровая машина двойного действия

internal-combustion e. [ɪn'tə:nlkəm'bʌstʃən] двигатель внутреннего сгорания

multicylinder e. ['mʌltɪsɪlɪndə] многоцилиндровый двигатель

nuclear e. ['njuklɪə] атомный двигатель

piston e. ['pɪstən] поршневой двигатель

reciprocating e. [rɪ'sɪprəkeɪtɪŋ] поршневой двигатель

steam e. [sti:m] 1. паровой поршневой двигатель; 2. паровая машина

turbo-jet e. ['tə:bou'dʒet] турбореактивный двигатель

turbo-prop e. ['tə:bou'prɔp] турбовинтовой двигатель

enthalpy [en'θælpɪ] *n* энтальпия, теплосодержание

entrained [ɪn'treɪnd] *a* захваченный, увлеченный

entropy ['entrəpɪ] *n* энтропия

equipment [ɪ'kwɪpmənt] *n* оборудование; арматура

firing e. ['faɪərɪŋ] *n* оборудование для сжигания топлива

erection [ɪ'rekʃən] *n* установка, сборка, монтаж

essential [ɪ'senʃəl] *a* 1. существенный, неотъемлемый; 2. необходимый, ценный

evaporator [ɪ'væpəreɪtə] *n* испаритель

evidence ['evɪdəns] *n* очевидность, доказательство; *v* служить доказательством, доказывать

exceed [ɪk'si:d] *v* 1. превышать; 2. превосходить

excessive [ɪk'sesɪv] *a* чрезмерный

exhaust [ɪg'zɔ:st] 1. *n* выпуск, выхлоп; 2. выхлопная труба, выпускная труба; 3. истощение; *v* выпускать; создавать вакуум; откачивать, отсасывать; *a* выпускной

exhaust annulus area [ɪg'zɔ:st 'ænjuləs'ɛərɪə] площадь выходного кольцевого сечения

exhaust flange [ɪg'zɔ:st,flændʒ] теплообменник

expand [ɪks'pænd] *v* развальцовывать, раскатывать

expansion [ɪks'pænʃən] *n* 1. расширение, растяжение; 2. вальцовка; раскатка; 3. пространство; протяжение

expansion joint [ɪks'pænʃən ˌdʒɔɪnt] компенсатор, расширительный (температурный) шов

expense [ɪks'pens] *n* трата, расход

extend [ɪks'tend] *v* простирать(ся); тянуть(ся)

external [eks'tə:nl] *a* наружный, внешний

fan [fæn] *n* вентилятор; лопасть вентилятора; *v* вентилировать; подавать воздух

air-foil f. ['ɛəfɔɪl] вентилятор лопастного типа

axial f. ['æksɪəl] осевой вентилятор

centrifugal f. [sen'trɪfjugəl] центробежный вентилятор

forced-draft f. ['fɔ:st,drɑ:ft] дутьевой вентилятор

induced-draft f. [ɪn'dju:st ˌdrɑ:ft] вытяжной вентилятор, дымосос

long blade plate type f. ['lɔŋ bleɪd'pleɪtaɪp] вентилятор

лопастями плоского типа
short-blade f. ['ʃɔ:t,bleɪd] вентилятор с короткими лопастями
feeder ['fi:də] *n* 1. питатель; подающий (питающий) механизм; загрузочное устройство; 2. фидер; 3. дозатор
feedwater ['fi:dwɔ:tə] *n* питательная вода
make-up boiler f. ['meɪkʌp-'bɔɪlə] добавочная питательная вода
scale free f. ['skeɪlfri:] свободная от накипи питательная вода
feeding chute ['fi:dɪŋ,ʃu:t] питатель
female ['fi:meɪl] *a* охватывающий, обнимающий; *c* внутренней расточкой
field [fi:ld] *n* область
filter ['fɪltə] *n* фильтр; *v* фильтровать, процеживать
air f. [εə] воздушный фильтр, воздухоочиститель
fin [fɪn] *n* радиаторная пластина; ребро (*для воздушного охлаждения*)
fire [faɪə] *n* огонь; печь; *v* 1. зажигать, поджигать; 2. загорать(ся)
firebox ['faɪəbɔks] *n* огневая коробка
fire brick ['faɪəbrɪk] огнеупорный кирпич
firing end ['faɪərɪŋ end] топочный конец
fission ['fɪʃən] *n* деление; расщепление (*атомного ядра*)
flake [fleɪk] *n pl* хлопья
flame [fleɪm] *n* пламя
flashing ['flæʃɪŋ] *n* вскипание
float(ing) control ['floutɪŋkən-'troul] 1. астатическое регулирование; 2. управление движением потока
fluctuate ['flʌktjueɪt] *v* колебаться; меняться
flue [flu:] *n* 1. газовый канал, газоход; 2. дымовая труба, дымовой канал; дымоход; 3. воздухопровод, вытяжка; 4. жаровая труба
fluid ['flu:ɪd] *n* жидкость, жидкая среда; *a* жидкий, текучий
fog [fɔg] *n* густой туман
force [fɔ:s] *n* сила; *v* заставлять, принуждать
forced circulation ['fɔ:st,sə:kju-'leɪʃən] принудительная циркуляция
form [fɔ:m] *n* форма, внешний вид; *v* формировать(ся), образовывать(ся).
fouling ['faulɪŋ] *n* 1. неисправность, неполадки; 2. примесь, загрязнение, засорение; образование накипи; 3. нагар
fraction ['frækʃən] *n* частица, доля
freight [freɪt] *n* груз, грузовые перевозки
friction ['frɪkʃən] *n* 1. трение; сцепление; 2. растирание
fuel [fjuəl] *n* топливо
fossil f. ['fɔsl] органическое топливо
waste f. ['weɪst] топливо из отходов
furnace ['fə:nɪs] *n* 1. печь; горн; топка; 2. котел центрального парового отопления
cyclone f. ['saɪkloun] термическая печь с принудительной циркуляцией газа
pulverized coal f. ['pʌlvəraɪzd ,koul] пылеугольная топка
slag-tap f. ['slæg,tæp] топка с жидким шлакоудалением
water screen f. ['wɔ:tə'skri:n] топка с водяным экраном
wet-bottom f. ['wet,bɔtm] топка с жидким шлакоудалением
fuse [fju:z] *v* плавить(ся), сплавлять(ся)
fuse wire ['fju:z,waɪə] плавкая проволока

G

gain [geɪn] *n* 1. прибыль, выгода; 2. увеличение; прирост

gas [gæs] *n.* газ
blast-furnace g. ['blɑ:st'fə:nɪs] колошниковый (доменный) газ
combustible g. [kəm'bʌstəbl] горючий газ
combustion g.-es [kəm'bʌstʃən] *pl* выхлопные газы, продукты сгорания
dry g. ['draɪ] сухой газ
flue g. ['flu:] топочный газ
furnace g. ['fə:nɪs] топочный газ
lean g. ['li:n] тощий газ, газ с низким содержанием паров бензина
gasket ['gæskɪt] *n* 1. прокладка, уплотнение; 2. сальник
gas-tight joint ['gæs,taɪt'dʒɔɪnt] газонепроницаемое соединение (шов)
gear reducer ['gɪərɪ'dju:sə] редукционная зубчатая передача; редукционный клапан; редуктор
generate ['dʒenəreɪt] *v* производить; генерировать, вырабатывать
generation [,dʒenə'reɪʃən] *n* генерация, образование
generator ['dʒenəreɪtə] *n* источник энергии; генератор
"once-through" steam g. ['wʌns,θru:'sti:m] прямоточный парогенератор
gill [gɪl] *n* пластинка, ребро
govern ['gʌvən] *v* регулировать
governer ['gʌvənə] *n.* 1. регулятор, управляющее устройство; 2. уравнитель хода; 3. регулирующий клапан
grade [greɪd] *n* качество, сорт
grate [greɪt] *n* 1. решетка; 2. колосниковая решетка, колосник
dump g. ['dʌmp] опрокидная колосниковая решетка, качающаяся колосниковая решетка
continuous ash-discharge g. [kən'tɪnjuəs'æʃdɪs,tʃɑ:dʒ] решетка с непрерывным удалением золы
gravitation [,grævɪ'teɪʃən] *n* сила тяжести, притяжение
gravity ['grævɪtɪ] *n* тяжесть; сила тяжести
gritty ['grɪtɪ] *a* песчаный; с песком
groove [gru:v] *n* паз; канавка; желоб; бороздка; прорез; шлиц; фальц
guide [gaɪd] *v* направлять
guided missile ['gaɪdɪd'mɪsaɪl] управляемая ракета

H

handhole ['hændhoul] *n* смотровое окно, люк
hazard ['hæzəd] *n* риск, опасность
head [hed] *n* 1. голова; 2. головная часть, передняя часть; 3. головка; 4. днище (котла); **~ on turbine** напор турбины
circulation h. [,sə:kju'leɪʃən] циркуляционный напор
cylinder h. ['sɪlɪndə] 1. головка цилиндра (в двигателе внутреннего сгорания); крышка или дно цилиндра
floating h. ['floutɪŋ] плавающее днище
hemispherical h. [,hemɪ'sferɪkəl] полусферическое днище
static h. ['stætɪk] статический напор
velocity h. [vɪ'lɔsɪtɪ] скоростной напор
header ['hedə] *n* водяная камера; водяной коллектор (*водотрубного котла*)
box h. [bɔks] коллектор коробчатого (прямоугольного) сечения
distributing h. [dɪs'trɪbju:tɪŋ] распределяющий коллектор
inlet h. ['ɪnlet] входной коллектор
sectional h. ['sekʃənəl] секционный коллектор
heat [hi:t] *n* тепло, теплота
latent h. ['leɪtənt] скрытая теплота

sensible h. ['sensıbl] теплосодержание
heat exchanger ['hi:tıks'tʃeındʒə] теплообменник
heater ['hi:tə] *n* нагреватель; подогреватель, калорифер
air h. [εə] воздухоподогреватель; калорифер
closed feed-water h. ['klouzd 'fi:dwɔ:tə] закрытый подогреватель питательной воды
direct-contact h. [dı'rekt 'kɔntækt] смешивающий подогреватель
feed-water h. ['fi:dwɔ:tə] водоподогреватель
gilled h. [gıld] рёберный подогреватель
multi-pass h. ['mʌltıpa:s] многоходовой подогреватель
needle h. [ni:dl] игольчатый подогреватель
plate type h. ['pleıt,taıp] пластинчатый подогреватель
regenerative air h. [rı'dʒenərətıv'εə] регенеративный воздухоподогреватель
regenerative feed-water h. [rı'dʒenərətıv'fi:dwɔ:tə] регенеративный подогреватель питательной воды (регенеративный водоподогреватель)
single-pass h. ['sıŋglpa:s] одноходовой подогреватель
surface h. ['sə:fıs] поверхностный подогреватель
tubular air h. ['tju:bjulə'εə] трубчатый воздухоподогреватель
helical ['helıkl] *a* спиральный; винтовой
high end ['haıend] верхний конец
hoe [hou] *n* гребок
hopper ['hɔpə] *n* бункер; воронка (*загрузочная*); приемный желоб; загрузочный люк
soot h. ['su:t] золовая воронка, сажеуловитель
hot end ['hɔt'end] горячий конец
hot well ['hɔt,wel] горячий источник

I

identical [aı'dentıkəl] *a* 1. тот же самый; 2. одинаковый, тождественный
ignition [ıg'nıʃən] *n* воспламенение, зажигание
immerse [ı'mə:s] *v* погружать
impair [ım'pεə] *v* 1. ослаблять, уменьшать; 2. ухудшать (*качество*); портить, повреждать
impart [ım'pa:t] *v* давать, придавать
impeller [ım'pelə] *n* импеллер, рабочее колесо, ротор, колесо с лопатками
axial-flow i. ['æksıəlflou] импеллер осевого типа
closed i. ['klouzd] закрытый насос
radial-type i. ['reıdjəltaıp] импеллер радиального типа
single-suction i. ['sıŋglsʌkʃən] ротор с односторонним всасыванием
impeller rim [ım'pelə'rım] обод рабочего колеса
impinge [ım'pındʒ] *v* 1. ударяться, падать; 2. приходить в столкновение
impingement [ım'pındʒmənt] *n* удар, столкновение
impurity [ım'pjuərıtı] примесь
incandescent lamp [,ınkæn'desnt 'læmp] лампа накаливания
increment ['ınkrımənt] 1. возрастание, увеличение; 2. приращение
inherent [ın'hıərənt] *a* присущий, неотъемлемый
initial [ı'nıʃəl] *a* начальный, первоначальный
install [ın'stɔ:l] *v* 1. помещать; 2. устанавливать; монтировать
installation [,ınstə'leıʃen] *n* установка
instantaneous [,ınstən'teınjəs] *a* 1. мгновенный, немедленный; 2. одновременный
insulate ['ınsjuleıt] *v* 1. изолировать; 2. разобщать

insulation [ˌɪnsju'leɪʃən] *n* изоляция, изоляционный материал
intake ['ɪnteɪk] *n* всасывание
intercondenser ['ɪntəkənˌdensə] *n* эжекторный подогреватель
intermediate [ˌɪntə'mi:djət] *a* 1. промежуточный; 2. средний
investigator [ɪn'vestɪgeɪtə] *n* исследователь, испытатель

J

jacket water ['dʒækɪtˌwɔ:tə] вода из водяной рубашки
jenny ['dʒenɪ] *n* передвижной подъемный кран
jet [dʒet] *n* струя
air j. [ɛə] воздушная струя
steam j. [sti:m] струя пара
join [dʒɔɪn] *v* соединять(ся)
justifiable ['dʒʌstɪfaɪəbl] *a* позволительный, законный

K

key slot ['ki:slət] шпоночная канавка

L

labyrinth arrangement ['læbərɪnθ ə'reɪndʒment] лабиринтовое уплотнение
latent ['leɪtənt] *a* скрытый
leakage ['li:kɪdʒ] *n* течь; утечка, протекание; просачивание
limit ['lɪmɪt] *v* ограничивать
line [laɪn] *n* линия, сеть; система труб
blow-off l. ['blou'ɔf] выдувная (выпускная) линия
supply l. [sə'plaɪ] подающий трубопровод, питающая сеть
load(ing) ['loudɪŋ] *n* нагрузка
lobe [loub] *n* 1. выступ; кулачок; бобышка; 2. котловина, впадина, углубление; 3. лопасть
lubricant ['lu:brɪkənt] *n* смазочный материал, смазочное вещество, смазочное масло, смазка
lubricate ['lu:brɪkeɪt] *v* смазывать
lubrication [ˌlubrɪ'keɪʃən] *n* смазка, смазывание (*машины*)
lump [lʌmp] *n* крупный кусок

M

machine [mə'ʃi:n] *v* подвергать механической обработке; обрабатывать на станке
automatic multiple-pass arc-welding m. [ˌɔ.tə'mætɪk'mʌltɪplpɑ:s'ɑ:kˌweldɪŋ] автоматически-действующая многоходовая установка для дуговой сварки
machinery [mə'ʃi:nərɪ] *n* машины; машинное оборудование; механизмы; станочное оборудование
machine-tool [mə'ʃi.ntu:l] 1. станок; металлорежущий станок; 2. машина-орудие
magnitude ['mægnɪtju:d] *n* величина, размеры
maintain [men'teɪn] *v* 1. поддерживать, сохранять; 2. обслуживать, эксплуатировать
maintenance ['meɪntɪnəns] *n* 1. поддержание, сохранение; 2. уход, текущий расход; 3. эксплуатация; 4. эксплуатационные расходы
make [meɪk] (made) *v* делать, совершать; *n* изделие
manhole ['mænhoul] *n* лаз, люк; смотровое отверстие; смотровой колодец
manifold ['mænɪfould] *n* 1. коллектор, сборник; 2. разветвленный трубопровод, магистраль; 3. патрубок
exhaust m. [ɪg'zɔ:st] 1. выпускной коллектор; 2. выхлопной трубопровод; 3. выхлопной патрубок
intake m. ['ɪnteɪk] всасываю-

щий трубопровод; 2. всасывающий патрубок

marine [mə'ri:n] *a* морской

mat [mæt] *n* спекшаяся масса

matter ['mætə] *n* 1. вещество; 2. материя; 3. материал

melt [melt] *v* 1. таять; 2. плавить(ся)

mingle [mɪŋgl] *a* смешиваться

mist [mɪst] *n*. (*легкий*) туман; дымка

mixing arch ['mɪksɪŋ,a:tʃ] смесительный свод

muntz metal ['munz'metl] мунцметалл (*медноцинковый сплав*)

moisture ['mɔɪstʃə] *n* влажность, сырость; влага

molybdenum [mə'lɪbdɪnəm] *n* молибден

muffler ['mʌflə] *n* (шумо)глушитель; звукопоглощающее приспособление

multiplicity [,mʌltɪ'plɪsɪtɪ] *n* 1. сложность; разнообразие; 2. многочисленность

N

necessitate [nɪ'sesɪteɪt] *v* делать необходимым; неизбежно влечь за собой, требовать

nest [nest] *n* 1. гнездо; 2. набор, комплект; 3. блок; узел,

nipple [nɪpl] *n* 1. ниппель; соединительная гайка, штуцер; 2. соединительная втулка, патрубок; 3. сопло; 4. наконечник с резьбой

nozzle [nɔzl] *n* сопло, форсунка; наконечник, носок, патрубок; выпускное отверстие
  fixed n. ['fɪkst] неподвижное сопло
  moving n. ['mu:vɪŋ] рабочая лопатка
  steam outlet n. ['sti:mautlet] паровыходной штуцер

nuisance ['nju:sns]. *n* 1. досада; неприятность; 2. неудобство

nut [nʌt] *n* гайка, муфта

O

obsolete ['ɔbsəli:t] *a* вышедший из употребления; устарелый; 2. изношенный

offset ['ɔ:fset] *n* отвод (*трубы*) *v*. возмещать; компенсировать

oil [ɔɪl] *n* 1. масло; 2. нефть; 3. жидкая смазка
  atomized o. ['ætəmaɪzd] распыленная нефть
  residual o. [rɪ'zɪdjuəl] остаточный нефтепродукт, нефтяные остатки

operate ['ɔpəreɪt] *v* 1. работать; действовать; 2. управлять; 3. приводить(ся) в движение; управлять(ся)

orifice ['ɔrɪfɪs] *n* 1. отверстие; 2. устье; выход: проход; 3. сопло, насадок, жиклёр; 4. диафрагма, шайба

outlet connection [,autletkə'nekʃn] выходное соединение

output ['autput] *n* 1. продукция; продукт; выпуск; выработка; 2. пропускная способность; ёмкость; 3. мощность; выработка (*электроэнергии*); производительность

overburden [,ouvə'bə:dn] *v* перегружать

overhaul ['ouvə'hɔ:l] *n* 1. капитальный ремонт; 2. подробный осмотр, разработка; *v* капитально ремонтировать; тщательно осматривать, разбирать

overhead bunker ['ouvəhed,bʌŋkə] верхний бункер

oxygen ['ɔksɪdʒən] *n* кислород

P

pan [pæn] *n* поддон, корыто, лоток
  fuel p. ['fjuəl] топливная коробочка (чашечка)

partly ['pa:tlɪ] *adv* 1. частично; 2. отчасти, до некоторой степени

pipe [paɪp] *n* труба, трубка
tail p. [teɪl] всасывающая труба (*насоса*) 2. выхлопная труба

pipe line ['paɪplaɪn] трубопровод; нефтепровод

piping ['paɪpɪŋ] *n* трубопровод; трубы; система труб

piston ['pɪstən] *n* поршень
***dummy* p.** ['dʌmɪ] уравновешивающий поршень

piston stroke ['pɪstən,strouk] ход поршня

plant [plɑ:nt] *n* 1. завод; фабрика; 2. силовая установка; станция; агрегат
central-station p. ['sentrəl 'steɪʃən] центральная электростанция
condensing p. [kən'densɪŋ] конденсационная станция
industrial p. [ɪn'dʌstrɪəl] промышленное предприятие; промышленная установка; промышленная ТЭЦ
manufacturing p. [,mænju'fæktʃərɪŋ] станция промышленного предприятия
noncondensing p. ['nɔnkən,densɪŋ] неконденсационная (теплофикационная) станция
steam power p. ['sti:m,pauə] паровая электростанция, теплоэлектростанция

plate [pleɪt] *n* плита, плитка; лист; пластина
baffle p. ['bæfl] отражательная плита; отражательный лист; отражатель; перегородка
catch p. [kætʃ] поводковый патрон
corrugated p. ['kɔrugeɪtɪd] гофрированный лист
handhole p. ['hændhoul] люковая пластина из кованой стали, люк
reciprocating feeder p. [rɪ'sɪprəkeɪtɪŋ'fi:də] питательная плоскость с возвратно-поступательным движением
scrubber p. ['skrʌbə] промывная пластина

plunger ['plʌndʒə] *n* 1. плунжер, скалка, скальчатый поршень; 2. шток; толкатель (*клапана*)

poor ['puə] *a* плохой, бедный

precipitate [prɪ'sɪpɪteɪt] *v* осаждать(ся)

pressure ['preʃə] *n* давление
back p. [bæk] обратное давление, противодавление
exhaust p. [ɪg'zɔ:st] давление на выхлопе; давление выхлопа

pressure differential ['preʃə,dɪfə'renʃəl] перепад (разность) давлений

pressure drop ['preʃə,drɔp] падение давления, перепад давления

prime mover ['praɪm'mu:və] первичный двигатель, источник энергии

producer [prə'dju:sə] *n* 1. производитель, изготовитель; 2. газогенератор

promote [prə'mout] *v* способствовать, помогать, поддерживать

propeller [prə'pelə] *n* 1. двигатель; 2. пропеллер; 3. воздушный винт
geared p. [gɪəd] приводимый пропеллер

property ['prɔpətɪ] *n* свойство, качество

provide [prə'vaɪd] *v*. 1. снабжать; обеспечивать; 2. предусматривать (for)

provision [prə'vɪʒən] *n* 1. снабжение, обеспечение; 2. мера предосторожности

proximate ['prɔksɪmɪt] *a* непосредственный

pulverizer ['pʌlvəraɪzə] *n* 1. пульверизатор, распылитель, разбрызгиватель; форсунка; 2. мельница для тонкого размола (измельчения)

pump [pʌmp] *n* насос, помпа; *v* качать, накачивать; откачивать; нагнетать
air p. [εə] 1. воздушный насос, пневматический насос;

[illegible]. поршневой компрессор
boiler feed p. ['bɔɪlə'fi:d] питательный насос котла
centrifugal p. [sen'trɪfjugəl] центробежный насос
circulating p. ['sə:kjuleɪtɪŋ] циркуляционный насос
condensate p. [,kɔnden'seɪt] насос для конденсата, конденсаторный насос
diffuser p. [dɪ'fju:zə] диффузорный насос
double-suction p. ['dʌbl,sʌkʃən] всасывающий насос двойного действия
feed p. [fi:d] питательный насос
fluid-impellent p. ['flu:ɪdɪm'pelənt] *жидкостный насос*
hot-well p. ['hɔtwel] конденсатный насос
multistage p. ['mʌltɪsteɪdʒ] многоступенчатый насос
oil p. ['ɔɪl] масляный насос
piston p. ['pɪstən] поршневой насос
radial p. ['reɪdjəl] радиальный насос
rotary p. ['routərɪ] центробежный (ротационный) насос
single direct-acting steam p. ['sɪŋgldɪ,rekt,æktɪŋ'sti:m] паровой насос одностороннего действия
turbine p.['tə:bɪn] турбонасос
vacuum p. ['vækjuəm] вакуумный насос

Q

quality ['kwɔlɪtɪ] *n*. 1. качество; 2. свойство; особенность

R

radial seal ['reɪdjəl'si:l] радиальное уплотнение
radiation [,reɪdɪ'eɪʃən] *n* излучение, радиация, лучеиспускание
range [reɪndʒ] *n* 1. ряд; 2. сфера, зона, область
rarefy ['rɛərɪfaɪ] *v* разрежать (ся), разжижать(ся)
ratchet mechanism ['rætʃɪt ,mekənɪzm] храповый механизм; храповик
rate [reɪt] *n* 1. темп; ход, скорость; 2. расход (*воды*)
rating ['reɪtɪŋ] *n* 1. мощность, производительность, номинальная мощность, паспортное значение; 2. расчетная величина, параметр
reactor [ri:'æktə] *n* реактивная катушка, реактор; дроссель
nuclear r. ['nju:klɪə] *ядерный реактор*
rear [rɪə] *n задняя сторона; a* задний, расположенный сзади
receiver [rɪ'si:və] *n* 1. приемник, сборник, ресивер; резервуар; бак; 2. колокол воздушного насоса; 3. получатель
receptacle [rɪ'septəkl] *n* 1. вместилище, приемник; хранилище; 2. коробка, ящик
rectangular water box [rek'tæŋgjulə'wɔ:təbɔks] прямоугольная водяная коробка
refer [rɪ'fə:] *v*. 1. приписывать (*чему-л.*), объяснять (*чем-л.*); 2. ссылаться (to — *на что-то, на кого-л.*); 3. говорить (*о чем-л.*); 4. относить(ся)
reflect [rɪ'flekt] *v* отражать (*тепло, звук*)
refractory [rɪ'fræktərɪ] *n* огнеупорный материал, огнеупор(ы)
regardless [rɪ'gɑ:dlɪs] (*употр. как adv*) невзирая на; **(of)** не считаясь с
regenerator [rɪ'dʒenəreɪtə] *n* регенератор
relatively ['relətɪvlɪ] *adv* относительно, сравнительно
release [rɪ'li:s] *v* освобождать, выделять
relieve [rɪ'li:v] *v* 1. уменьшать; 2. ослаблять (*напряжение*); 3. лишать, освобождать (*от чего-л.*)

repair [rɪ'pɛə] *v* ремонтировать, исправлять
requisite ['rekwɪzɪt] *n* то, что необходимо; все необходимое; *a* требуемый, необходимый
reservoir ['rezəvwɑ:] *n* 1. резервуар; 2. водоем; водохранилище; бассейн; 3. коллектор; 4. топливный бак
residue ['rezɪdju:] *n* остаток; вещество, оставшееся после сгорания
resistance [rɪ'zɪstəns] *n* сопротивление
retard [rɪ'tɑ:d] *v* задерживать, замедлять; тормозить
reverse [rɪ'və:s] *v* менять, изменять
riser ['raɪzə] *n* стояк; вертикальный трубопровод
rod [rɔd] *n* стержень, шток
piston r. ['pɪstən] поршневой шток, шатун
side r. ['saɪd] сцепное дышло, спарник
tie r. [taɪ] стяжка; растяжка; соединительная тяга; поперечина
roll [roul] *v* прокатывать; вальцевать
roller ['roulə] *n* вращающийся цилиндр; ролик; вал; вальцовка, роликовая развальцовка
rotor ['routə] *n* 1. ротор; 2. рабочее колесо
row [rou] *n* ряд
run up ['rʌn,ʌp] *v* быстро расти, увеличиваться

S

saddle horse ['sædlhɔ:s] *n* верховая лошадь
sample ['sæmpl] *n* образец, проба
screw [skru:] *n* винт; *v* привинчивать, завинчивать, скреплять винтами
scroll [skroul] *n* спираль; плоская резьба
screwed shaft ['skru:d,ʃɑ:ft] ходовой винт; винтовой шпиндель
seat [si:t] *n* седло; соединение
gasket s. ['gæskɪt] выточка под прокладку
pressure-tight s. ['preʃətaɪt] прочно-плотное соединение
tube s. [tju:b] трубное седло
separator ['sepəreɪtə] *n* сепаратор, сортировочный аппарат
centrifugal s. [sen'trɪfjugəl] центробежный сепаратор
water s. ['wɔ:tə] водоотделитель
sewer ['sjuə] *n* коллектор, канализационная труба, сточная труба
shaft packing ['ʃɑ:ft'pækɪŋ] уплотнение вала
shaft work ['ʃɑ:ft,wə:k] работа на валу
shearing action [,ʃɪərɪŋ,ækʃən] режущее действие
sheet [ʃi:t] *n* лист; полоса; пластина
flat s. [flæt] (*гладкий*) лист
furnace s. ['fə:nɪs] топочный лист
tube s. ['tju:b] трубный лист
shield [ʃi:ld] *n* щит, защитное устройство или приспособление, экран
containment s. [kən'teɪnment] ограждающий щит
shroud [ʃraud] *v* скреплять
shroud band ['ʃraud'bænd] бандажная лента
sift [sɪft] *v* 1. просеивать(ся); 2. проваливаться
silencer ['saɪlənsə] *n* (шумо)глушитель
since [sɪns] *adv* 1. с тех пор; 2. тому назад; *prep* с; после; *cj* 1. с тех пор как; 2. так как; 3. хотя
slack [slæk] *n* угольная пыль; *v* 1. ослаблять, распускать; 2. замедлять(ся)
slag [slæg] *n* шлак, выгарки
slagging ['slægɪŋ] *n* 1. выпуск шлака; 2. ошлакование;

3. разъедание шлаком
smokeless ['smouklɪs] *a* бездымный
soil [sɔɪl] *n* почва, земля
sole [soul] *a* единственный
source [sɔ:s] *n* источник
space [speɪs] *n* место, площадь
spalling ['spɔ:lɪŋ] *n* 1. растрескивание, отслаивание (*кровли, металла, огнеупора*); выкрашивание, откалывание; 2. разбивка (*угля*); разработка крупных кусков (*угля*)
speed [spi:d] *n* скорость
wheel-tip s. ['wi:ltɪp] периферийная скорость (скорость на окружности)
spray [spreɪ] *v* 1. распылять; 2. обрызгивать
sprinkler ['sprɪŋklə] *n* разбрызгиватель; дождевальная установка
spring support ['sprɪŋsə'pɔ:t] рессорная державка; пружинящая опора
sprocket ['sprɔkɪt] *n* звездочка; ведущее колесо
stack [stæk] *n* 1. куча, груда (*угля*); 2. водосточная, дымовая или выхлопная труба; 3. стояк отопительной системы; 4. выводная труба (*отсасывающей вытяжной или вентиляционной системы*)
exhaust s. [ɪg'zɔ:st] выхлопной патрубок
stagecoach ['steɪdʒkoutʃ] *n* почтовая карета, дилижанс
stagger ['stægə] *v* располагать в шахматном порядке; располагать по ступеням или уступами
standardize ['stændədaɪz] *v* стандартизировать; калибровать; нормализовать
stand-by ['stændbaɪ] *a* запасной, резервный
standpoint ['stændpɔɪnt] *n* точка зрения
steam [sti:m] *n* пар
process s. ['prouses] производственный пар
saturated s. ['sætʃəreɪtɪd] насыщенный пар
superheated s. [,sju:pə'hi:tɪd] перегретый пар
vented s. ['ventɪd] выпар
steam-and-water-mixing chamber ['sti:məndwɔ:təmɪksɪŋ 'tʃeɪmbə] смесительная камера для пара и воды
steam cylinder ['sti:m,sɪlɪndə] паровой цилиндр
steel ['sti:l] *n.* сталь
alloy s. [ə'lɔɪ] легированная сталь
austenitic s. [,ɔ:stə'nɪtɪk] аустенитная сталь
stick [stɪk] (**stuck**) *v* липнуть
sticky ['stɪkɪ] *a* липкий, клейкий
stirrer ['stə:rə] *n* 1. стокер, механический загрузчик топлива, механическая (переталкивающая) топка; 2. кочегар
chain-grate s. ['tʃeɪngreɪt] механическая топка с цепной решеткой
continuous-ash-discharge spreader s. [kən'tɪnjuəs'æʃdɪs,tʃa:dʒ 'spredə] топка с разравнивающей решеткой и непрерывным удалением золы
single-retort underfeed s. ['sɪŋglrɪ,tɔ:t'ʌndə'fi:d] одноретортная топка нижнего питания
spreader s. ['spredə] топка с разравнивающей решеткой
travelling-grate s. ['trævlɪŋ ,greɪt] механическая топка с движущимися колосниками
stream [stri:m] *n* поток, река, ручей; струя
strip [strɪp] *n* полоска, пластинка; подкладка
seal s. [si:l] уплотняющая пластинка, гребень лабиринтов уплотнения
wear(ing) s. ['wɛərɪŋ] подкладка для компенсации износа

subject [səb'dʒekt] *v* подвергать (*воздействию, влиянию*)

subsequently ['sʌbsɪkwəntlɪ] *adv* впоследствии, потом, позже

substantial [səb'stænʃəl] *a* значительный, существенный

substitute ['sʌbstɪtju:t] *n* 1. замена; 2. заменитель; *v* заменять; замещать

successively [sək'sesɪvlɪ] *adv* последовательно

sufficient [sə'fɪʃənt] *a* 1. достаточный; 2. имеющий (*что-л.*) в достаточном количестве; 3. подходящий

sulphur ['sʌlfə] *n* сера

sulphuric acid [sʌl'fjurɪk'æsɪd] серная кислота

supercharger ['sju:pə,tʃa:dʒə] *n* компрессор надува, нагнетатель

superheater [,sju:pə'hi:tə] *n* (паро)перегреватель
- **convection s.** [kən'vekʃən] конвекционный перегреватель
- **interdeck s.** [,ɪntə'dek] пароперегреватель (расположенный) между двумя пучками кипятильных труб
- **overdeck s.** ['ouvədek] перегреватель с верхним расположением
- **radiant s.** ['reɪdjənt] радиационный перегреватель

surface ['sə:fɪs] *n* поверхность
- **heating s.** ['hi:tɪŋ] поверхность нагрева
- **heat-transfer s.** ['hi:t,trænsfə] теплопередающая поверхность

suspension [səs'penʃən] *n* взвешенное состояние, суспензия

swamp [swɔmp] *n* болото, топь

system ['sɪstɪm] *n* система
- **air-intake s.** ['ɛərɪn,teɪk] воздуховсасывающая система
- **fuel-injection s.** ['fjuəlɪn,dʒekʃən] топливо-впрыскивающая система
- **lubricating s.** ['lu:brɪkeɪtɪŋ] система смазки

T

tandem ['tændəm] *a* последовательно расположенный (один за другим), сдвоенный

tangential [tæn'dʒenʃəl] *a* тангенциальный; направленный по касательной к данной кривой

tank [tæŋk] *n* бак, резервуар
- **day-t.** [deɪ] расходный бак, бак однодневного расхода
- **feed-water t.** ['fi:dwɔ:tə] питательный резервуар, расходный резервуар
- **storage t.** ['stɔ:rɪdʒ] резервуар для хранения, емкость
- **surge t.** ['sə:dʒ] уравнительный резервуар

temperature ['temprɪtʃə] *n* температура
- **ash-fusion t.** ['æʃ,fju:ʒən] температура плавления золы
- **combustion t.** [kəm'bʌstʃən] температура горения
- **exit t.** ['eksɪt] температура на выходе
- **ignition t.** [ɪg'nɪʃən] температура воспламенения

thence [ðens] *adv* 1. оттуда; 2. отсюда, из этого

threaten [θreɪn] *v* угрожать, грозить

throttle ['θrɔtl] *n* дроссель, клапан

thrust [θrʌst] *n* 1. толчок; 2. удар; 3. осевое давление; напор, нажим; 4. противодавление
- **axial t.** ['æksɪəl] осевое (*аксиальное*) давление
- **end t.** [end] осевое (*аксиальное*) давление, конец со стороны упорного подшипника

torque [tɔ:k] *n* крутящий момент; вращающий момент

torque arm ['tɔ:k,a:m] плечо крутящего момента

transfer ['trænsfə] *n* перенос, перемещение, передача; [træns'fə:] *v* переносить, перемещать, передавать

transmission [træns'mɪʃən] *n* линия передачи

transmit [trænz'mɪt] *v* 1. передавать; 2. отправлять, посылать

transportation [,trænspɔ:'teɪʃən]*n* перевозка, транспорт; транспортирование

tray [treɪ] *n* 1. лоток, желоб; 2. корыто, поддон; 3. тарелка (*турбины*)

staggered t.-s ['stægəd] *pl* ступенчаторасположенные корыта

treatment ['tri:tmənt] *n* обработка

trend [trend] *n* 1. направление; 2. тенденция

tube [tju:b] *n* труба, трубка

finned t. [fɪnd] ребристая труба

fire t. [faɪə] дымогарная труба, жаровая труба (*парового котла*)

forcing t. ['fɔ:sɪŋ] опускная труба

inclined t. [ɪn'klaɪnd] наклонная труба

slag screen t.-s ['slæg,skri:n] *pl* трубы экрана шлаковой воронки

tubing ['tju:bɪŋ] *n* 1. система труб; трубопровод; труба; 2. установка (монтаж) трубопровода, прокладка труб

turbine ['tə:bɪn] *n* турбина

automatic-extraction t. [,ɔ:tə'mætɪkɪks'trækʃən] турбина с регулируемым отбором

bleeder t. ['bli:də] конденсационная турбина с промежуточным отбором пара

condensing t. [kən'densɪŋ] конденсационная паровая турбина

Curtis t. ['kə:tɪs] турбина Кёртиса

double-flow t. ['dʌbl,flou] турбина с двойным выхлопом

extraction t. [ɪks'trækʃən] конденсационная турбина с промежуточным отбором пара

gas t. [gæs] газовая турбина

high-back-pressure t. ['haɪ'bæk,preʃə] паровая турбина с высоким противодавлением

high-pressure t. ['haɪ,preʃə] турбина высокого давления

hydraulic t. [haɪ'drɔ:lɪk] гидротурбина, гидравлическая (водяная турбина)

impulse t. ['ɪmpʌls] свободноструйная (*активная*) турбина

Ljungstrom t. [l'juŋgstrəm] турбина Юнгстрема

low-pressure t. ['lou,preʃə] турбина низкого давления

medium-pressure t. ['mi:djəm,preʃə] турбина среднего давления

multi-cylinder t. [,mʌltɪ'sɪlɪndə] многоцилиндровая турбина

non-condensing t. ['nɔnkən'densɪŋ] паровая турбина с противодавлением

pressure-compounded t. ['preʃəkəm'paundɪd] комбинированная турбина со ступенями давления

reaction t. [ri:'ækʃən] реактивная турбина

simple-impulse t. ['sɪmpl'ɪmpʌls] простая активная турбина, одноступенчатая активная турбина

steam-t. ['sti:m] паровая турбина

superposed t. ['sju:pə'pouzd] предвключенная турбина, турбина с высоким противодавлением

tandem-compound t. ['tændəm'kəmpaund] последовательно-соединенная компаундная турбина

velocity compounded impulse t. [vɪ'lɔsɪtɪkəm'paundɪd 'ɪmpʌls] турбина со ступенями скорости

turbogenerator ['tə:bou'dʒenəreɪtə] *n* турбогенератор

turbulence ['tə:bjuləns] *n* 1. турбулентность; 2. турбулентный поток

U

uneven ['ʌn'i:vn] *a* неровный, шероховатый

unify ['ju:nɪfaɪ] *v* 1. объединять; 2. унифицировать

unit ['ju:nɪt] *n* агрегат, блок, узел

compound u. ['kɔmpaund] двухвальный агрегат

single u. [sɪŋgl] одновальный агрегат

steam-generating u. ['sti:m-ˌdʒenəreɪtɪŋ] парообразующий агрегат, парогенератор

unshrouded [ʌn'ʃraudɪd] (*лопатки*) не имеющие бандажей

uptake ['ʌpteɪk] *n* восходящий дымоход, верхний дымоход, вертикальный канал

V

value ['vælju:] *n* величина; значение; способность

heating v. ['hi:tɪŋ] теплотворность, теплотворная способность, теплопроизводительность

net heating v. ['net,hi:tɪŋ] низшая теплотворная способность

valve [vælv] *n* клапан; вентиль, задвижка, заслонка; распределительный кран

blowdown v. ['blou,daun] продувной, спускной клапан

cut-off v. ['kʌtɔ:f] отсечной клапан

disk v. [dɪsk] тарельчатый (дисковый) клапан

inlet water v. ['ɪnlet'wɔ:tə] входной водяной клапан

limit v. ['lɪmɪt] предохранительный клапан

piston v. ['pɪstən] поршневой золотник

relief v. [rɪ'li:f] 1. предохранительный клапан; 2. разгрузочный клапан; 3. обратный клапан

slide v. [slaɪd] золотник

spring v. [sprɪŋ] пружинный клапан

spring loaded safety v. ['sprɪŋ ,loudɪd'seɪftɪ] пружинный предохранительный клапан

vane [veɪn] *n* лопасть, лопатка

velocity [vɪ'lɔsɪtɪ] *n* скорость, быстрота

"carry over" v. [kærɪ'ouvə] разгоны, скорость срабатывания, предельное возрастание числа оборотов

vent [vent] *n* отверстие (*входное* или *выходное*); вентиляционное отверстие; отдушина; воздушник

Venturi [ven'turɪ] *n* расходомерное сопло; трубка Вентури

vessel [vesl] *n* сосуд, резервуар

fired pressure v. ['faɪəd,preʃə] резервуар под давлением с огневым подводом тепла

unfired pressure v. ['ʌnfaɪəd ,preʃə] резервуар не с огневым подводом тепла

volatile ['vɔlətaɪl] *a* летучий

volume ['vɔljum] *n* объем

volute [və'lju:t] *n* 1. завиток, спираль; 2. спиральный кожух, улитка (*центробежного насоса*); 3. комбинированный диффузор и сборник

W

wastage ['weɪstɪdʒ] *n* изнашивание, потери

waste [weɪst] *n* 1. потери, ущерб, убыток; 2. излишняя трата

waterscreen ['wɔ:tə,skri:n] *n* водяной экран

waterwall ['wɔ:tə,wɔ:l] *n* водяной экран

furnace w. ['fə:nɪs] топочный экран

weight [weɪt] *n* вес

specific w. [spɪ'sɪfɪk] удельный вес

weld [weld] *n* 1. сварка (*метал-*

лов); 2. сварный шов; *v* сваривать(ся)

wheel [wi:l] *n* колесо

overshot water w. ['ouvə,ʃət'wɔ:tə] наливное водяное колесо

paddle w. [pædl] лопастное колесо

water w. ['wɔ:tə] гидротурбина, гидравлическая (водяная) турбина; водяное колесо

whereas ['wɛər'æz] *cj* 1. тогда как; 2. поскольку

whip [wɪp] *v* вибрировать

whirl [wə:l] *v* вертеть(ся); кружить(ся)

width [wɪdθ] *n* 1. ширина; 2. пролет

withstand [wɪð'stænd] (withstood) *v* противостоять, выдержать

wood [wud] *n* 1. дерево; древесина; лесоматериал; 2. дрова

wrought iron ['rɔ:t'aɪən] *пудлинговое железо*, **сварочное** железо, сварочная сталь

Y

yoke [jouk] *n* обойма; хомут; зажим; скоба

CONTENTS

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