



Intitulé de la formation : Master mecanique

Intitulé de la matière : Anglais technique

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Section 1: Iron and Steel

The earth contains a large number of metals which are useful to man. One of the most important of these is iron. Modern industry needs considerable quantities of this metal, either in the form of iron or in the form of steel. A certain number of non-ferrous metals, including aluminium and zinc, are also important, but even today the majority of our engineering products are of iron or steel. Moreover, iron possesses magnetic properties, which have made the development of electrical power possible. The iron ore which we find in the earth is not pure. It contains some impurities which we must remove by smelting. The process of smelting consists of heating the ore in a blast furnace with coke and limestone, and reducing it to metal. Blasts of hot air enter the furnace from the bottom and provide the oxygen which is necessary for the reduction of the ore. The ore becomes molten, and its oxides combine with carbon from the coke. The non-metallic constituents of the ore combine with the limestone to form a liquid slag. This floats on top of the molten iron, and passes out of the furnace through a tap. The metal which remains is pig-iron.

We can melt this down again in another furnace - a cupola - with more coke and limestone, and tap it out into a ladle or directly into moulds. This is cast-iron. Cast-iron does not have the strength of steel. It is brittle and may fracture under tension. But it possesses certain properties which make it very useful in the manufacture of machinery. In the molten state it is very fluid, and therefore it is easy to cast it into intricate shapes. Also it is easy to machine it. Cast-iron contains small proportions of other substances. These non-metallic constituents of cast-iron include carbon, silicon and sulphur, and the presence of these substances affects the behaviour of the metal. Iron which contains a negligible quantity of carbon, for example wrought-iron, behaves differently from iron which contains a lot of carbon.

The carbon in cast-iron is present partly as free graphite and partly as a chemical combination of iron and carbon which we call cementite. This is a very hard substance, and it makes the iron hard too. However, iron can only hold about $\frac{1}{2}\%$ of cementite. Any carbon content above that percentage is present in the form of a flaky graphite. Steel contains no free graphite, and its carbon content ranges from almost nothing to $\frac{1}{2}\%$. We make wire and tubing from mild steel with a very low carbon content, and drills and cutting tools from high carbon steel.

Section 2: Heat Treatment of steel

We can alter the characteristics of steel in various ways. In the first place, steel which contains very little carbon will be milder than steel which contains a higher percentage of carbon, up to the limit of about $\frac{1}{2}\%$. Secondly, we can heat the steel above a certain critical temperature, and then allow it to cool at different rates. At this critical temperature, changes begin to take place in the molecular structure of the metal. In the process known as annealing, we heat the steel above the critical temperature and permit it to cool very slowly.

This causes the metal to become softer than before, and much easier to machine. Annealing has a second advantage. It helps to relieve any internal stresses which exist in the metal. These stresses are liable to occur through hammering or working the metal, or through rapid cooling. Metal which we cause to cool rapidly contracts more rapidly on the outside than on the inside. This produces unequal contractions, which may give rise to distortion or cracking. Metal which cools slowly is less liable to have these internal stresses than metal which cools quickly.

On the other hand, we can make steel harder by rapid cooling. We heat it up beyond the critical temperature, and then quench it in water or some other liquid. The rapid temperature drop fixes the structural change in the steel which occurred at the critical temperature, and makes it very hard. But a bar of this hardened steel is more liable to fracture than normal steel. We therefore heat it again to a temperature below the critical temperature, and cool it slowly. This treatment is called tempering. It helps to relieve the internal stresses, and makes the steel less brittle than before. The properties of tempered steel enable us to use it in the manufacture of tools which need a fairly hard steel. High carbon steel is harder than tempered steel, but it is much more difficult to work.

These heat treatments take place during the various shaping operations. We can obtain bars and sheets of steel by rolling the metal through huge rolls in a rolling-mill. The roll pressures must be much greater for cold rolling than for hot rolling, but cold rolling enables the operators to produce rolls of great accuracy and uniformity, and with a better surface finish. Other shaping operations include drawing into wire, casting in moulds, and forging.

Section 3: Lubrication of Bearings

The machine tools in a workshop sometimes have their own electric motors, or they may take the power they need from a motor which feeds several machines. The shafts which carry the power from the motor to the machines need some kind of support to keep them steady.

We call these supports bearings. There are different types of bearings for different purposes. We can classify them according to whether they take the load on the shaft or the thrust along the axis of the shaft. The former type is known as a journal bearing, and the latter type as a thrust bearing.

The rotating shaft bears on a stationary bush or tube. We therefore have two metal surfaces in close contact with each other, and sliding over each other often at high speed.

This will cause friction and the bearing will become heated. So we have to protect the metal surfaces from overheating and damage. First of all, we avoid making the shaft and the bush of the same material. The shafting itself is generally of steel, but we use another metal such as cast-iron or bronze or white metal for the bush. At a certain temperature, the metal in the bush will seize or run, and this will prevent damage to the shaft. But of course it will not prevent overheating from occurring.

However, we can reduce the danger of overheating by lubrication. We have a thin film of oil between the two metallic surfaces to keep them apart. The internal friction of oil is much less than the friction between two solids, and generates less heat. Lubrication also offers another advantage. A film of oil on the metal surfaces will prevent them from corroding by protecting them from the air.

The sort of lubricant which we use depends largely on the running speed of the bearing. We can use grease in low-speed bearings, but grease offers more resistance to the turning movement of the shaft. A lighter oil causes less friction, and so an oily lubricant is better for high-speed bearings. The rotation of the shaft carries the film of oil round the inside of the bearing and keeps the shaft from contact with the bush which houses it. We can feed the oil into the bearing in several ways. Sometimes we allow it to drip down under the influence of gravity. More commonly, a pump or gun feeds it in under pressure. In motor-car and other engines, we half cover the bearing in an oil-bath, and oil splashes up into it. We can reduce the amount of friction even more with rolling bearings. The hardened steel balls in this type of bearing roll round in a finely-ground ball race, and make little more than point contact with the race.

Section 4: The Lathe

The lathe is one of the most useful and versatile machines in the workshop, and is capable of carrying out a wide variety of machining operations. The main components of the lathe are the headstock and tailstock at opposite ends of a bed, and a tool-post between them which holds the cutting tool. The tool-post stands on a cross-slide which enables it to move sideways across the

saddle or carriage as well as along it, depending on the kind of job it is doing. The ordinary Centre lathe can accommodate only one tool at a time on the tool-post, but a turret lathe is capable of holding five or more tools on the revolving turret. The lathe bed must be very solid to prevent the machine from bending or twisting under stress.

The headstock incorporates the driving and gear mechanism, and a spindle which holds the workpiece and causes it to rotate at a speed which depends largely on the diameter of the workpiece. A bar of large diameter should naturally rotate more slowly than a very thin bar the cutting speed of the tool is what matters. Tapered centres in the hollow nose of the spindle and of the tail stock hold the work firmly between them. A feed-shaft from the headstock drives the tool-post along the saddle, either forwards or backwards, at a fixed and uniform speed. This enables the operator to make accurate cuts and to give the work a good finish. Gears between the spindle and the feed-shaft control the speed of rotation of the shaft, and therefore the forward or backward movement of the tool-post. The gear which the operator will select depends on the type of metal which he is cutting and the amount of metal he has to cut off. For a deep or roughing cut the forward movement of the tool should be less than for a finishing cut. Centres are not suitable for every job on the lathe. The operator can replace them by various types of chucks, which hold the work between jaws, or by a front-plate, depending on the shape of the work and the particular cutting operation. He will use a chuck, for example, to hold a short piece of work, or work for drilling, boring or screw-cutting. A transverse movement of the tool-post across the saddle enables the tool to cut across the face of the workpiece and give it a flat surface. For screw-cutting, the operator engages the lead-screw, a long screwed shaft which runs along in front of the bed and which rotates with the spindle. The lead-screw drives the tool-post forwards along the carriage at the correct speed, and this ensures that the threads on the screw are of exactly the right pitch.

Section 5: Welding

There are a number of methods of joining metal articles together, depending on the type of metal and the strength of the joint which is required. Soldering gives a satisfactory joint for light articles of steel, copper or brass, but the strength of a soldered joint is rather less than a joint which is brazed, riveted or welded. These methods of joining metal are normally adopted for strong permanent joints.

The simplest method of welding two pieces of metal together is known as pressure welding. The ends of metal are heated to a white heat - for iron, the welding temperature should be about 1300°C - in a flame. At this temperature the metal becomes plastic. The ends are then pressed or hammered together, and the joint is smoothed off. Care must be taken to ensure that the surfaces are thoroughly clean first, for dirt will weaken the weld. Moreover, the heating of iron or steel to a high temperature causes oxidation, and a film of oxide is formed on the heated surfaces. For this reason, a flux is applied to the heated metal. At welding heat, the flux melts, and the oxide particles are dissolved in it together with any other impurities which may be present. The metal surfaces are pressed together, and the flux is squeezed out from the centre of the weld. A number of different types of weld may be used, but for fairly thick bars of metal, a vee-shaped weld should normally be employed. It is rather stronger than the ordinary butt weld.

The heat for fusion welding is generated in several ways, depending on the sort of metal which is being welded and on its shape. An extremely hot flame can be produced from an oxyacetylene torch. For certain welds an electric arc is used. In this method, an electric current is passed across two electrodes, and the metal surfaces are placed between them. The electrodes are sometimes made of carbon, but more frequently they are metallic. The work itself constitutes one of them and the other is an insulated filler rod. An arc is struck between the two, and the heat which is generated melts the metal at the weld. A different method is usually employed for welding sheets or plates of metal together. This is known as spot welding.

Two sheets or plates are placed together with a slight overlap, and a current is passed between the electrodes. At welding temperature, a strong pressure is applied to the metal sheets, the oxide film, and any impurities which are trapped between the sheets, are squeezed out, and the weld is made.

Section 6: Steam Boilers

Large quantities of steam are used by modern industry in the generation of power. It is therefore necessary to design boilers which will produce high-pressure steam as efficiently as possible. Modern boilers are frequently very large, and are sometimes capable of generating 300,000 lb. of steam per hour. To achieve this rate of steam production, the boilers should operate at very high temperatures. In some boilers, temperatures of over 1650°C may be attained. The fuels which are burned in the furnace are selected for their high calorific value, and give the

maximum amount of heat. They are often pulverised by crushers outside the furnace and forced in under pressure.

Modern boilers which employ solid fuels are usually too large to be hand-stoked, and stoking is then carried out by mechanical stokers, which ensure that an adequate quantity of fuel is conveyed into the furnace at the proper speed. The air which is needed by the fuel for combustion is blown across the fire grate by steam jets or fans. The amount of air which is allowed to enter is just more than sufficient for complete combustion of the fuel. An insufficient supply of air will prevent complete combustion, but any air in excess of the minimum merely reduces the temperature of combustion. The hot gases which are produced by the combustion of the fuel are circulated round banks of water-tubes. These are inclined at an angle over the furnace, and connect the upper and lower steam drums. A large proportion of the heat is absorbed by the water in the boiler. The remainder may be used to heat up the incoming air-supply through an air-heater. The water and steam in the boiler should circulate freely. The water and steam circuits are designed to allow the greatest possible fluid velocity to be attained, and rapid movement of the fluid is achieved by forced circulation. This assists rapid heating and also prevents the formation of steam pockets in the tubes.

Loss of efficiency in the boiler will be caused by the dissipation of heat through the walls of the combustion chamber. This heat loss can be considerably reduced by the use of firebricks round the walls of the chamber. This helps to insulate the chamber and to conserve the heat which is generated. However, at the temperatures which are attainable in modern boilers, the solid walls of the furnace are liable to be damaged by excessive heat. To avoid this, they are often lined with water-tubes, and some of the heat of combustion is absorbed by the water.

Section 7: Steam Locomotives

From the date of the introduction of the steam locomotive about 130 years ago, there was a continuing increase in the size and weight of trains. This necessitated engines of greater and greater power. In order to achieve this increase in power, much higher steam pressures were required. The modern steam locomotive is capable of generating steam pressures often in excess of 300 lb/in², against the 50 lb/in² pressure of Stevenson's 'Rocket'. Normally the demand for increased steam capacity is met by increasing the size of the boiler. However the boiler of a steam locomotive is strictly limited in size by the dimensions and load capacity of the railway

track which it works on. It is therefore necessary to have a very large heating surface within the boiler.

There are two fire-boxes inside the boiler, an inner one and an outer one, which extend a long way forward. The inner fire-box is linked by tubes to the fire-plate at the front of the boiler. Practically the whole of the heating surface, which includes these fire-tubes, is surrounded by water. A high rate of evaporation in the boiler is essential, in order to generate the large quantities of steam which are required. For this purpose a powerful draught of air is blown over the fire. The steam which is evolved is passed through a super-heater, which raises its temperature and makes it as dry as possible. Rapid evaporation at the heating surface tends to make the steam wet. The use of wet steam necessitates excessively high pressures in the cylinder. Super-heating the steam enables the requisite power to be obtained with considerably lower pressures.

The superheated steam is passed to the steam-chest which is attached to the cylinder. From the steam-chest it is introduced into the cylinder at the appropriate moments through ports. These ports are opened and closed by slide valves, which are actuated by the rotation of the locomotive crankshaft. The steam is admitted under pressure to one side of the cylinder, and drives the piston forwards. The inlet port is then closed, and a second charge of steam is admitted at the other side of the cylinder to drive the piston in the reverse direction.

The exhaust steam from the first charge is driven out into the atmosphere through a blast pipe. This is done in order to increase the draught over the fire. The reciprocating action of the piston is changed into a rotational movement of the wheels by a connecting rod and crank.

Section 8: Condensation and Condensers

Steam which is admitted to a cold engine cylinder is liable to be partially condensed by contact with the cylinder walls. That part of the steam nearest to the walls is cooled and condenses as a film of water. The volume of steam in the cylinder is thereby considerably reduced, and more steam must be admitted in order that the pressure is sufficiently high to drive the piston along the cylinder. Condensation in a cylinder therefore raises the steam consumption of the engine and thereby lowers its efficiency. It is therefore necessary to devise means of getting rid of this

condensation as far as possible, and in modern reciprocating steam engines, condensation problems have been practically eliminated.

This is effected by superheating the steam in the boiler and also by fitting steam jackets Round the cylinder. These are fitted into the annular space between the cylinder and the cylinder liner, and are connected to the steam supply. By raising the temperature of the cylinder walls in this way, the outward flow of heat is greatly reduced.

Steam which is exhausted from the cylinder still has a considerable heat content, and in order that this heat energy should not be wasted, the steam is condensed and passed back to the boiler as hot feed water. Rapid condensation is accomplished by means of a condenser. In this condenser, a liquid coolant is circulated through banks of metal tubes. By flowing over these tubes, the steam is caused to transmit some of its heat to the liquid, and a rapid drop in temperature occurs. The steam condenses, and is collected at the bottom of the condenser as condensate. By ensuring that there is no contact between the condensate and the coolant, a pure distilled water can be produced which is ideal for boiler feed water. This type of condenser is commonly used where pure water is not plentiful. The condensate is usually reheated, so that it may be circulated back to the boiler at an adequate temperature. In other types of condensers, which are known as jet condensers, the steam is cooled by allowing it to mix intimately with jets of cold water which are injected into the condenser. By this means, rapid condensation takes place, and the mixture of condensate and coolant is withdrawn by means of an extraction pump. The water which is normally used as a coolant cannot usually be utilised in the boiler, and cannot therefore be recirculated.

Section 9: Centrifugal Governors

Most engines in industrial use are rated to run at a constant speed, irrespective of the load they carry. In order to keep the engine speed within the limits which it was designed for, a device which is known as a governor is incorporated in the engine. Its function is to control the running speed under all conditions of load.

The simplest form of governor consists of a pair of balls which are attached to vertical shaft by means of arms. These balls act as weights. While they are stationary, they are acted on only by gravity. Now the vertical shaft is geared to the engine, and rotates with it. When the engine starts,

it causes the shaft to rotate, and this forces the rotating balls outwards under the influence of centrifugal force. This movement of the balls at the end of their arms is transmitted to a sleeve which is free to slide up and down the shaft. As the engine increases speed, it rotates the shaft more quickly, and the weights rise further against the force of gravity. The sleeve also rises up the shaft, and when it rises beyond a certain point, it operates a throttle valve lever, and so reduces the flow of steam. The engine speed will then decrease, and as the sleeve slides down, it opens the throttle valve again. When the engine is running at constant speed, it produces a state of equilibrium in the governor, with the centrifugal force equal and opposite to the controlling force - that is, the weight of the governor and its gear. Governors which are required to work at very high engine speeds are normally weight-loaded. A weight is attached to the sleeve, and serves to prevent the sleeve from rising too far.

Both the simple and weight-loaded governors depend on gravity and must therefore be kept in a vertical position. This is often a disadvantage, and may be obviated by the use of a spring instead of a weight. The spring performs the same function as the weight, and keeps the sleeve depressed. It can be mounted in any position. By making simple adjustments to the loading on the spring, the governor speed can easily be altered. The governor is mounted in a dome-shaped housing which contains the spring and the bell-crank levers, on which the rotating balls are pivoted. Ball bearings at the pivots and at the top of the spindle serve to reduce wear and friction. As the spindle rotates, it causes the weights to fly outwards, and this movement about the pivot raises the sleeve against the pressure of the spring. Equilibrium is attained at a constant engine speed by the balancing of the centrifugal force and the compressive load on the spring.

Section 10: Impulse Turbines

In an impulse turbine steam is admitted through a nozzle and directed against one or more rows of blades. Prior to passing through this nozzle, the steam is at high pressure but low velocity. The nozzle normally consists of a convergent and divergent section. In the former, the steam suffers a drop in pressure, but its velocity is increased. The function of the divergent section is to reduce to a minimum the tendency of the fluid to turbulence, and thus to ensure that the fluid flow is as smooth as possible.

On emerging from the nozzle at its maximum velocity, the steam impinges on the row of moving blades which project radially from the turbine shaft. In this axial-flow type of turbine, the steam flow is along the axis of rotation of the shaft, and therefore the blades radiate outwards

from the shaft. On entering the blades, which are set at a definite angle to the steam flow, the steam is deflected from its original path. In being deflected, it exerts an impulsive force on the blades, which causes them to rotate. While passing over the blades, the steam suffers a slight reduction in velocity through friction. In a simple turbine, it is then passed out into the atmosphere, or to a condenser, where it is condensed and led back to the boiler. However, after leaving the blades of the turbine, the steam still possesses a considerable velocity, and this may be utilised in another type of turbine by passing it through a series of two or more turbine wheels. This is known as velocity-compounding. On passing through the first row of moving blades, the steam encounters a row of stationary blades which deflect the steam on to a second row of moving blades, and so on. Each time part of the kinetic energy of the steam is lost through friction, and therefore the velocity of the steam is progressively reduced. In order to compensate for this, the blades in each successive row are made progressively larger in cross-section, and their pitch is increased. In this way, a larger proportion of the kinetic energy of the steam can be utilised than in the simple turbine.

Another type of turbine in common use is known as the pressure-compounded turbine. It incorporates several rows of blades, but each one is enclosed between diaphragms to form a separate pressure stage. After passing through the first set of blades, the steam is directed through nozzles set in the succeeding diaphragm, and impinges on the following row of blades.

Section 11: The Petrol Engine

In the internal combustion engine, heat is generated by the combustion of an inflammable charge inside a cylinder, and the heat energy is immediately converted into mechanical energy. Some heavy internal combustion engines use a gas fuel or else Diesel oil, and the fuel/air mixture may be ignited either by a spark or by compression of the mixture. However, for small i.c. engines, such as those which are used in motor-cars, the charge is a mixture of petrol and air, and is ignited by a spark from the distributor.

When the mixture is ignited, the products of combustion expand down the cylinder, which is fitted with a reciprocating piston. The downward movement of the piston is converted into a rotational movement of the crank-shaft by means of a connecting rod. As the crankshaft rotates, the piston is driven upwards again, and the exhaust gases are expelled through the exhaust valve

in the cylinder head. When the piston nears the top of this stroke, the inlet valve is opened and the exhaust valve closed. The piston then descends on the induction stroke, and draws a fresh charge into the cylinder. As the piston rises again on the compression stroke, the charge is compressed and ignited, and the cycle begins again. This is the four-stroke cycle which is in common use. An alternative cycle is the two-stroke cycle, which combines the exhaust and compression strokes into one.

The combustion of the mixture does not take place instantaneously. The spark is therefore timed to occur before the piston reaches top dead centre, otherwise maximum pressure would not be reached in time. By the time the piston is at top dead centre, combustion is well under way and the expansion of the gases is beginning. Once combustion starts, it should be carried through the mixture very rapidly, and this is assisted by making the clearance space above the piston as small as possible, and by careful design of the cylinder head. Rapid propagation of the flame through the compressed gas is also assisted by creating turbulence in the gas.

Most small i.c. engines in common use have four cylinders, which fire in a definite and regular sequence. This is necessary, otherwise the torque which the pistons impart to the crankshaft will be irregular and uneven. The torque is liable to be uneven in any case when the engine is running slowly, and a flywheel is fitted to the crankshaft to damp out these variations.

It is essential for the inlet and exhaust valves to open and close at exactly the appropriate moment in relation to the position of the piston. Therefore they are actuated by a cam-shaft running in phase with the crankshaft.

Section 12: The Carburation System

Since it is essential to secure rapid and complete combustion in the cylinder of an internal combustion engine, the fuel and air mixture must be thoroughly mixed; and further, it must be in the correct proportions for all running conditions of the engine. This is accomplished by means of a device called a carburettor. In this carburettor, a stream of air blown over a jet mixes intimately with a spray of petrol drawn out of it. The jet is inserted into a choke or venturi in the intake manifold, and is supplied with petrol at atmospheric pressure.

During the suction stroke of the piston, the pressure in the intake manifold is below atmospheric, and air is induced through the intake and over the jet. As there is a further drop in pressure at the venturi, the pressure difference produced is large enough to draw petrol up out of the jet and atomise it. The level of the petrol in the jet is kept constant by the float and needle valve in the float chamber, which acts as a reservoir for the fuel. Above the venturi there is a

throttle valve operated by the accelerator pedal, which controls the amount of mixture admitted to the cylinder.

However, this simple form of single-jet carburettor will not give correct mixture strength for all engine speeds. The chief difficulty encountered is that, at high running speeds, the amount of petrol taken up at the jet will increase faster than the increase in air-flow.

Therefore a carburettor set to give correct mixtures at low speed will give a progressively richer mixture as the speed increases. To compensate for this, a second jet is provided, fed from a well open to the atmosphere and supplied with petrol from the float chamber. Owing to the fact that this compensating jet is larger than the main jet, it can supply petrol at a quicker rate than the main jet until the well is emptied. As the speed is increased, more and more of the petrol required is drawn from the main jet. The compensator jet can now supply only as much petrol as can pass through the small compensator orifice in the float chamber.

Another problem to be solved is that of starting. In order to obtain the rich mixture required for starting, the throttle must be almost closed. As the air velocity is then very low in the venturi, insufficient petrol is drawn out of the jet. This difficulty is overcome by the provision of an idler jet in the wall of the intake manifold near the throttle valve. This jet will only function when the throttle is nearly closed. When it is opened for faster running, the suction round the edge of the throttle decreases, and the idler automatically ceases to act.

Section 13: The Jet Engine

Jet engines with which most modern high-speed aircraft are equipped develop thrust on the same principle as the propellers of conventional aero-engines. In both, the propulsive force is derived from the reaction produced by a stream of air driven rearwards at high velocity.

However, in jet-propulsion the air is directed rearwards in a jet from the engine itself. The earliest forms of jet propulsion, such as the pulsejet utilised in the Flying Bomb, were incapable of functioning at rest, in view of the absence of any means of air-compression. But the introduction of the turbo-jet overcame this problem, since the turbine developed sufficient power to drive a compressor.

Air enters the engine through a divergent inlet duct, in which its pressure raised to some extent. It then passes to a compressor, where it is compressed, and from which it is delivered to the combustion chambers. These are arranged radially round the axis of the turbine, into which the products of combustion pass on leaving the combustion chambers. A proportion of the power

developed by these gases is utilised by the turbine to drive the air-compressor, and the residual energy provides the thrust where by the aircraft is propelled. Due to the expansion of the exhaust gases in the jet-pipe behind the turbine, their exit velocity is very high.

In each of the combustion chambers, there is a perforated flame-tube, into which kerosene is sprayed and ignited. Owing to the need to limit temperatures in the combustion chambers, a large volume of excess air is required. The air/fuel ratio necessary to reduce combustion temperatures to an acceptable level is about 60:1. However with this ratio of fuel to air, the mixture would be difficult to ignite. Therefore only a small proportion of the compressed air is fed into the flame-tube, where it is ignited in a ratio of about 15:1. The remainder enters the flame-tube further down, or mixes with the products of combustion as they leave the tube. By virtue of this dilution of the hot gases with cooler air, the temperature at which they reach the turbine is reduced to about 850° C.

On entering the turbine, the gases pass through nozzles, by means of which they are directed through a ring of blades. These blades, the shape of which is determined by the need to reduce the torque to a minimum, rotate at high speed. Because of the tendency of fast-running blades to creep and change their shape, a special high-nickel alloy is used for them. After passing through the turbine, the gas expands down the jet-tube and is ejected into the atmosphere. Owing to the high proportion of unburnt oxygen often provided in the jet pipe, where by the hot gases are again ignited. This increases their velocity, and provides extra thrust for take atmosphere. Owing to the high proportion of unburnt oxygen in this efflux, after pipe, where by the hot gases are again ignited. This increases their in this efflux, after-burners are pipe, where by the hot gases are again ignited. This increases their thrust for take-off.