OPERATION OF A JET ENGINE

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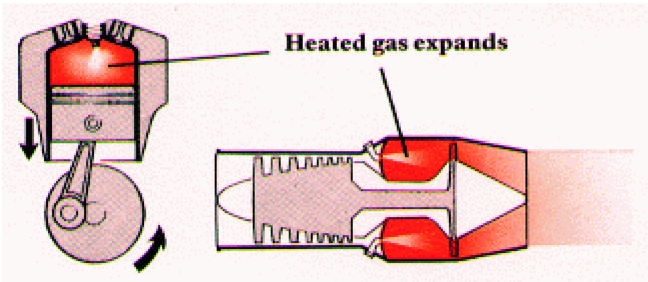
December 14, 2000

HOW DOES A JET ENGINE WORK?

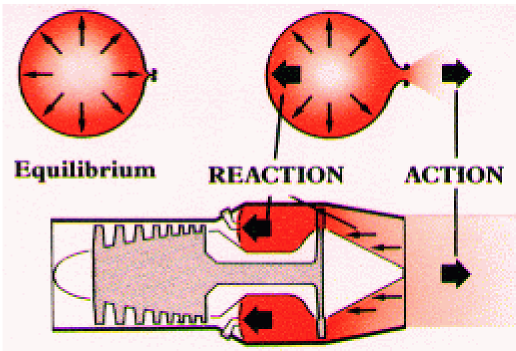
The jet engine is actually the gas turbine and it is an internal combustion engine which produces power by the controlled burning of fuel. In both the gas turbine and the motor car engine, air is compressed, fuel is added and the mixture is ignited. The resulted hot gas expands rapidly and is used to produce the power.

In the motor car engine, the burning is intermittent and the expanding gas moves a piston and crank to produce rotary or shaft power that is transmitted to the road wheels.



In the gas turbine, the burning is continuous and the expanding gas is ejected from the engine as an action. Using the principle expounded by Sir Isaac Newton in the 17th century - to every action there is an equal and opposite reaction - this action creates a reaction of equivalent force.

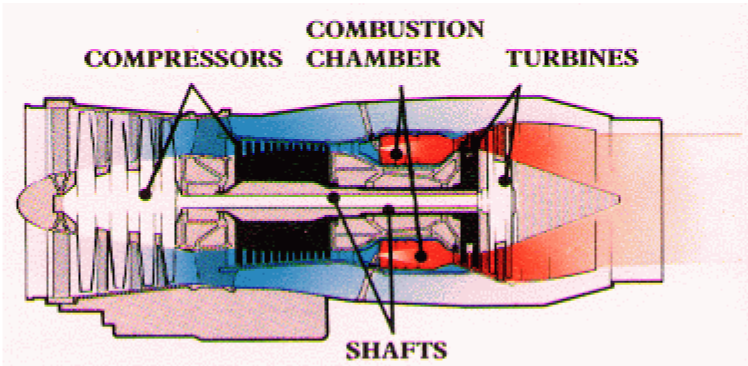
Reaction can be simply demonstrated by blowing up a balloon. When the balloon is inflated and the neck is closed, it is in a state of equilibrium; the air inside is pressing equally in all directions. When the neck is opened, the compressed air is released as an action, which creates a reaction in the opposite direction. This reaction is felt on the front inner surface of the balloon and drives it forward. This demonstration shows that the reaction is an internal function and does not, as is often assumed, result from the pressure of the gas stream on the atmosphere.



The section of the gas turbine in which combustion takes place, known as the "hot end," operates in the same way as the balloon. The reaction to the gas stream that is ejected from the nozzle is felt on the parts of the engine opposite the nozzle, mainly the front of the combustion chamber and the tail cone. This force, termed thrust, it then transmitted from the engine casing to the airframe, through the engine mountings, to propel the aircraft. The thrust of an engine is measured in pounds force (lbf), kilograms force (kgf) or the international unit, the Newton (N).

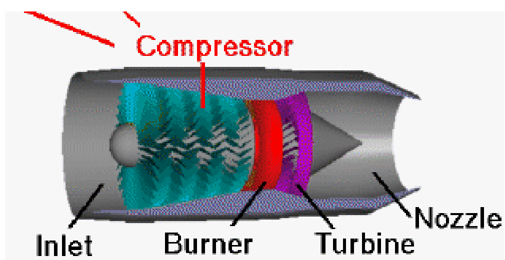
The gas turbine engine is basically a machine designed to accelerate a stream of gas that is used to produce the reactive thrust necessary to propel the aircraft.

The gas turbine has three main components:
- Compressor,
- Combustion chamber
- Turbine.



The fan takes in vast amounts of air and provides most of the engine's thrust. The compressor compresses that air to speed it up. The diffuser slows down the compressed air and prepares the air to enter the combustor at a lower speed so it can mix with fuel properly for efficient combustion. A combustor then mixes air with fuel and ignites it to produce thrust. A turbine consists of one or more rows of blades mounted on a disc or drum behind the combustor. The spinning of the turbine turns the shafts which run the compressors and fan, as well as engine accessories such as generators and pumps.

The compressor



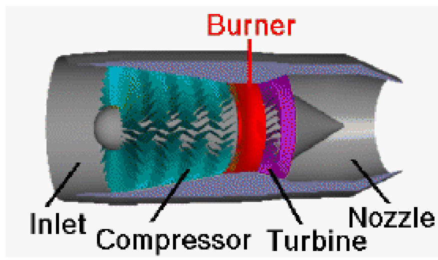
Situated at the front of the engine, the compressor draws air in, pressurizes it, then delivers it into the combustion chamber. There are two types of compressor design, centrifugal and axial flow.

The centrifugal flow compressor consists of an impeller supported in a casing which houses a ring of diffuser vanes. The impeller is driven at high speed, by the turbine, and air is drawn through its center. Centrifugal action forces the air radially outwards and accelerates it into the diverging diffuser outlet, which further increases the pressure. The pressurized air then passes into the combustion system.

The axial flow compressor consists of a number of stages of alternate rotating and stationary aerofoil-section blades which force the incoming air through a convergent annular duct. The rotating blades are carried on discs or a drum and driven by a turbine via a connecting shaft. As the air passes through each stage it is accelerated by the rotating blades and forced rearwards through the static blades, known as vanes, which reduce the velocity and increase the pressure. The pressure is gradually built up as the air passes through the compressor stages until it reaches the combustion system.

Gas turbines often have more than one compressor. This is because many stages of compression are required to achieve a high overall pressure and, since each compressor stage has an ideal rotational speed for best efficiency, if all stages are on the same shaft only some will run efficiently. To overcome this, the compressor can be divided into two or three parts, each driven by a separate turbine and rotating at its most efficient speed. This method enables compression ratios up to 30:1 to be achieved, resulting in extremely high efficiency and very low specific fuel consumption.

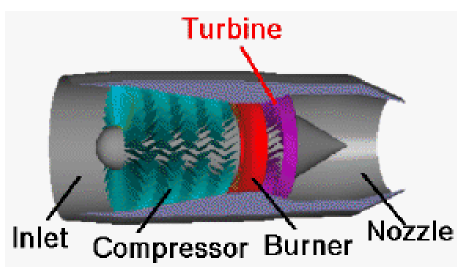
The combustion chamber



This is an annular tube, or ring of tubes, made from heat-resistant steel, in which the fuel and air are mixed and ignited. It is designed to achieve the most efficient combustion of the mixture so that the maximum possible heat energy is extracted from the fuel to give the greatest rise in temperature and hence expansion of gases.

The air from the compressor, at pressures up to 450 pounds per square inch (3.1 MPa), passes into the combustion chamber where it is mixed with the vaporized fuel sprayed from burners located in the head of the chamber. The mixture is ignited, during the engine starting cycle, by igniter plugs located in the combustor. Once ignition has taken place, the igniters are isolated and combustion is continuous.

The turbine

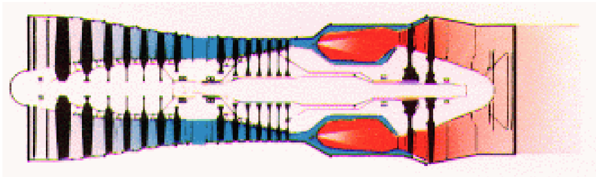


The turbine consists of one or more stages of alternate stationary and rotating aerofoil-section blades. The rotating blades are carried on discs, in a similar way to the compressor, and the discs are connected by a shaft to the compressor rotating assembly. The stationary blades, known as nozzle guide vanes, are housed in the turbine casing. The function of the turbine is to absorb sufficient energy from the hot expanding gases leaving the combustor to keep the compressor rotating at its most efficient speed.

The main types of gas turbines:

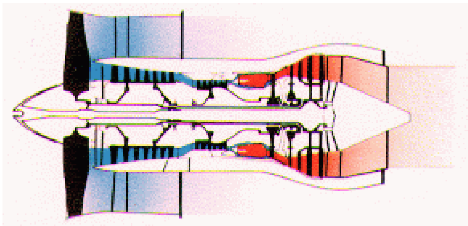
There are four main types of gas turbine engines: the turbojet, turbofan, turboprop and turboshaft. The turbojet and turbofan are reaction engines which derive power from the reaction to the exhaust stream. The turboprop and turboshaft types operate in a different way. They use the exhaust stream to power an additional turbine which in turn drives a propeller or output shaft.

Turbojet



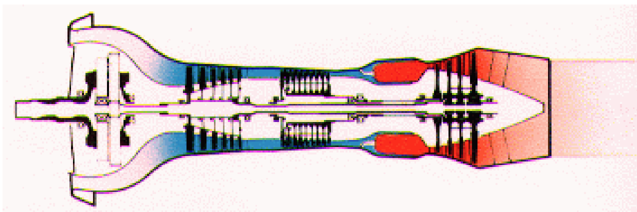
The turbojet, the simplest and earliest type of gas turbine, is used principally in high-speed aircraft where its relatively small frontal area and high jet velocity are advantageous. The turbine extracts only sufficient energy from the gas stream to drive the compressor, leaving the remaining energy to provide the thrust.

Turbofan



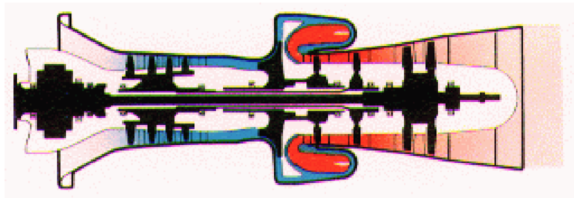
The turbofan is the most common type of gas turbine used for aircraft propulsion today. Part of the air entering the engine is compressed fully and passed into the combustion chamber, while the remainder, compressed to a lesser extent, bypasses the combustion section, to provide cold thrust. This bypass flow rejoins the hot flow downstream of the turbine. The overall jet velocity is reduced to give better propulsive efficiency, lower noise levels and improved specific fuel consumption, which make the turbofan ideal for both civil and military aircraft.

Turboprop



The turboprop is a turbojet with an additional turbine which uses the energy remaining in the gas stream, after sufficient energy has been absorbed to drive the compressor, to drive a propeller. The additional turbine, called the power turbine, drives the propeller through a shaft and a reduction gear. A small amount of residual thrust remains in the exhaust gases during normal operation.

Turboshaft

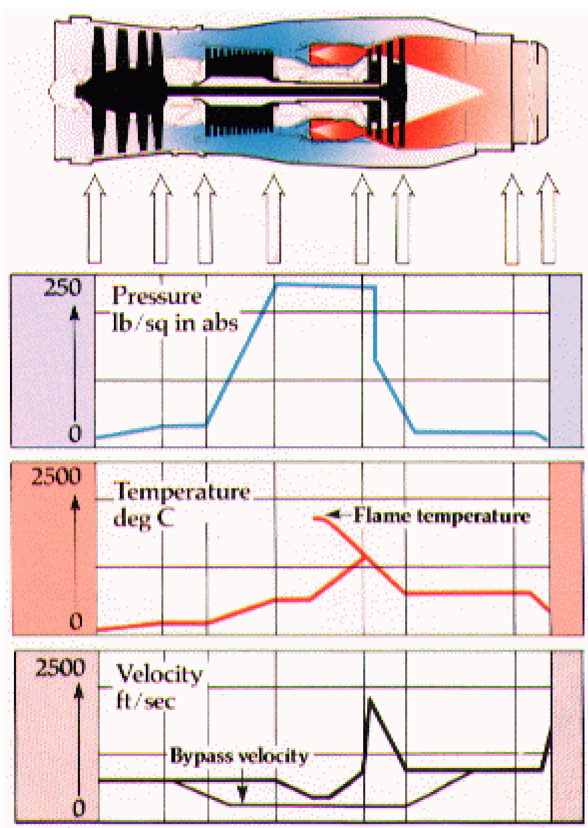


The turboshaft is effectively a turboprop without a propeller, the power turbine in this case being coupled to a reduction gearbox or directly to an output shaft. In the same way as the turboprop, the power turbine absorbs as much of the remaining energy as possible and the residual thrust is very low.

The most common application of the turboshaft is the helicopter, in which the engine drives both the main and tail rotors. Turboshafts are also widely used for industrial and marine installations, including power and pumping stations, hovercraft and ships.

Pressure, temperatures and velocities

The following graphs show the changes in pressure, velocity and temperature of the gas as it passes through the various stages of the engine.



Additions...

Afterburning

Afterburning or reheat, as it is sometimes termed, is a method of increasing the engine thrust for short periods to improve the aircraft take-off, climb and, for military aircraft, combat performance. Unlike a piston engine, the fuel in a gas turbine burns in an excess of air, so there is still sufficient oxygen present to support further combustion. This makes it possible to inject and burn additional fuel in the jet pipe, downstream of the turbine, to increase the engine thrust. Turbofan engines, where the bypass air provides even more oxygen, can achieve thrust increases up to 100 percent with afterburning.

Reverse thrust

Thrust reversal is a method of mechanically deflecting the exhaust stream of a gas turbine forward externally, to act as a braking force when the aircraft lands. The system is most efficient when used at the relatively high speeds immediately after touch-down.

Reverse thrust is particularly useful in adverse weather conditions, and can be used instead of the aircraft's wheel-braking system.

Jet Engine Thrust

The goal of a Turbofan engine is to produce thrust to drive the airplane forward. Thrust is generally measured in pounds of thrust in the United States (the metric system uses newtons, where 4.45 newtons is 1 pound of thrust). A "pound of thrust" is equal to a force able to accelerate one pound of material 32 feet per second per second (where 32 feet per second per second happens to be equivalent to the acceleration provided by gravity). Therefore, if you have a jet engine capable of producing one pound of thrust, it could hold one pound of material suspended in the air if the jet were pointed straight down. Likewise, a jet engine producing 5,000 pounds of thrust could hold 5,000 pounds of material suspended in the air. Similarly, if a rocket engine produced 5,000 pounds of thrust applied to a 5,000 pound object floating in space, the 5,000 pound object would accelerate at a rate of 32 feet per second per second.

Thrust is generated under Newton's principle that "every action has an equal and opposite reaction". In a turbofan engine, air molecules are throwing out of the engine. An individual air molecule does not weigh very much, but the engine is throwing a lot of them and it is throwing them at very high speed. Thrust is coming from two components in the turbofan:

The first component is the gas turbine itself. Generally a nozzle is formed at the exhaust end of the gas turbine to generate a high-speed jet of exhaust gas. A typical speed for air molecules exiting the engine is 1,300 MPH. The second component is the bypass air generated by the fan. This bypass air moves at a slower speed than the exhaust from the turbine, but the fan moves a lot of air.

To generate enough heat jet engines use Jet A kerosene fuel. Since high temperatures are generated jet engine parts are made from composites but also titanium, nickel superalloys and even steel and aluminum. The parts can withstand temperatures up to 3,500 degrees Fahrenheit - much hotter than the melting point of metal.