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DOCUMENT TITLE
GAS TURBINE ENGINES (CASA ATPL)

CHAPTER 5 – INTERNAL AIR SYSTEMS

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COOLING AND SEALING FLOWS

As a result of the burning of fuel and air, the internal components of the engine are exposed to extremely high temperatures. It is also worth noting, that the action of compressing the air also creates a large temperature rise.

Both the turbine and the compressor are finely balanced engine assemblies. They both rely on extremely close tolerances, especially blade tip to case clearance, in order to provide the high thermal efficiencies, of which the modern jet is capable. To achieve these efficiencies, these two sections of the engine require special attention with regard to cooling airflow. Refer to Figure 5-1.

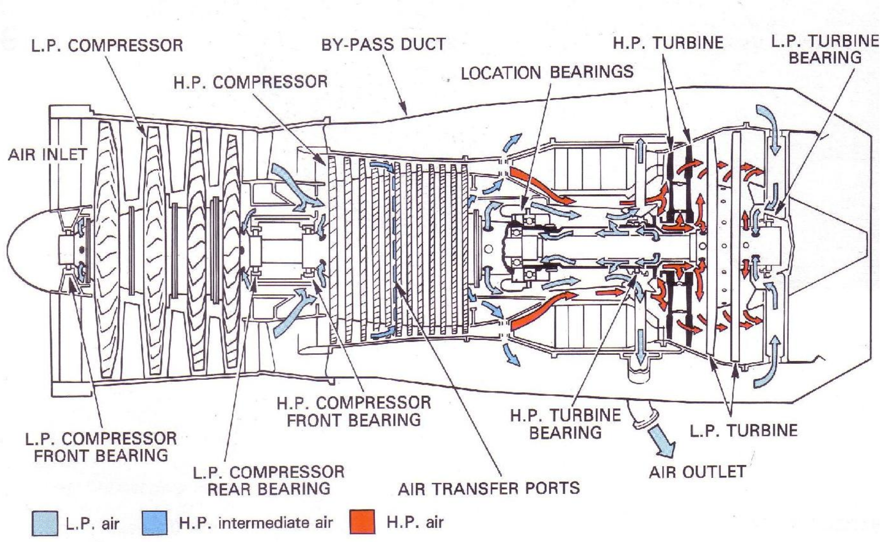

Figure 5-1 Internal Air Cooling Flows

Compressor Cooling

It is important for the thermal expansion to be uniform over the entire compressor to achieve the close tolerances required within the compressor. <u>High pressure air (hot) is transferred to the front of the compressor, while low pressure air (cool) is used in the rear stages of the compressor</u>. Air used for cooling the later engine stages is taken from early compressor stages to prevent any large reduction in engine performance. The slight loss in performance is virtually recovered by exhausting the used cooling air at high pressure when it has done its work

Turbine Cooling

The main requirements for air cooling are at the combustion and turbine operating stages. Air is directed around each individual combustion chamber to reduce temperatures as much as is practicable.

Air is then passed over the nozzle guide vanes and onto the turbine blades. <u>High pressure and low pressure compressor air is used to cool the turbine rotor discs and blades</u>. It also provides an air seal between the blade tip and the casing. This enables the turbine to operate at temperatures above the normal melting point of the metal without affecting the blade or nozzle guide vane integrity. Refer to Figures 5-2 and 5-3.

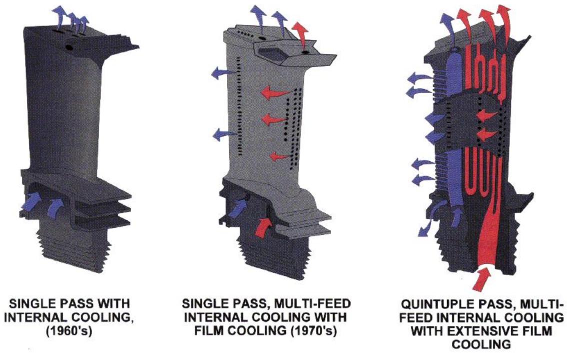

Figure 5-2 Turbine Blade Cooling

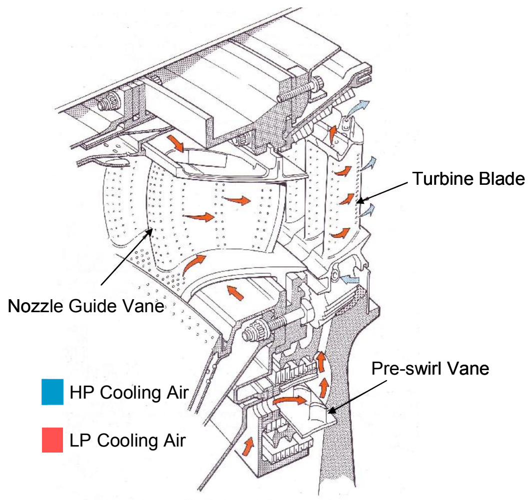

Figure 5-3 NGV and Turbine Cooling

By controlling the operating temperature of the blades, the cooling effect is transmitted to the turbine disc, and expansion and contraction of the turbine assembly is kept within acceptable limits. The flow of cooling air through the turbine stages of a jet engine is absolutely vital to the life of the components. Refer to Figure 5-4.

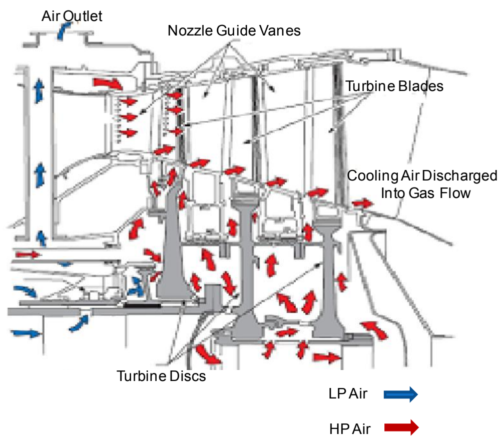

Figure 5-4 Turbine Disc Cooling

Internal Air Cooling and Sealing

As discussed, all sections of the engine are cooled. The compressor cooling flow needs to be separated from the turbine cooling flow. To achieve this, Air Seals, called Labyrinth Seals are used. These seals use a higher pressure air to form an air seal. Refer to figure 5-5.

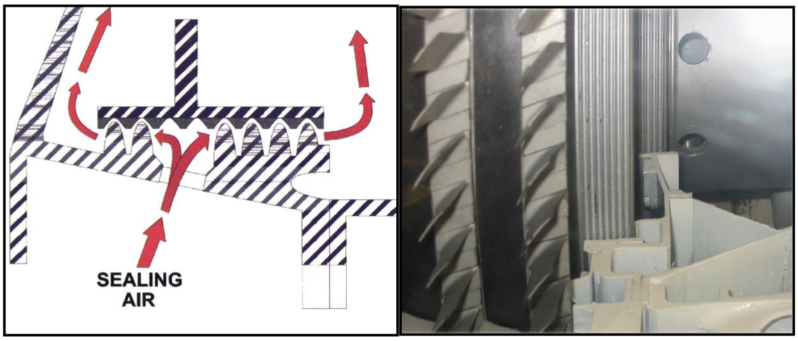

Figure 5-5 Labyrinth Type Air Seals

Accessory Cooling

Most of the accessories driven by the engine are mounted on the accessory drive casing, and as such become hot because of their location, as well as the work they are required to perform. Cooling air is often supplied to various components, such as generators and starter motors, to lower their operating temperature and improve efficiency. Such air can be supplied by the fan outlet or by ram air scoops on the side of the engine cowling in flight, or air from the LP compressor while the aircraft is stationary.

Bearing Sealing

Bearings used on turbine engines require very little cooling, as they are lubricated and cooled by the engine oil system. However, it is necessary to prevent oil from entering the airflow and thus causing problems with air purity for air conditioning system use. To achieve this, compressed air from the compressor is used to pressurise the seals, known as labyrinth seals, to stop the air leakage. Refer to Figure 5-6.

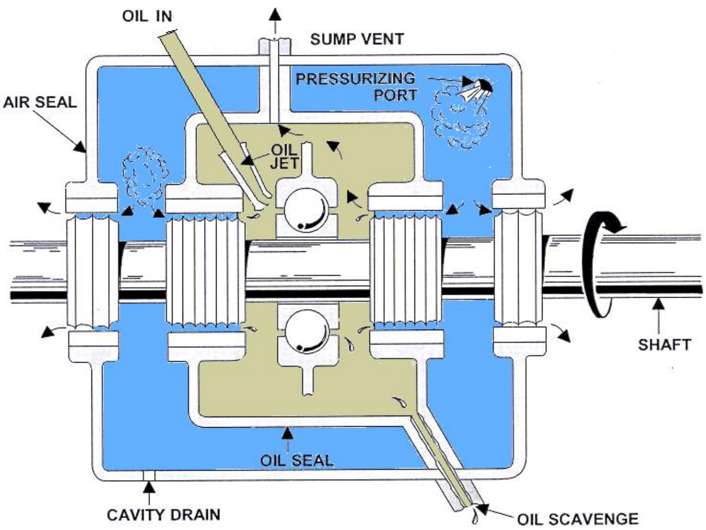

Figure 5-6 Labyrinth Type Oil Seal

Should these seals malfunction, oil may enter the engine air system. Figure 5-7 demonstrates the result.

Figure 5-7 **Labyrinth Air Seal Malfunction.**

TURBINE OVERHEAT SYSTEM

Some engines may be fitted with a Turbine Overheat System, which monitors the intermediate turbine cooling air and provides a visual indication should the temperature exceed a predetermined maximum. Refer to Figure 5-8. It is similar to the engine fire detection system, and will usually consist of either, two spot detectors or a thermocouple sensor. The warning indications in the cockpit usually consist of;

- a master warning light,
- an overheat light,
- a fire warning light, and
- an audible warning.

A turbine overheat indication is treated as an engine fire warning.

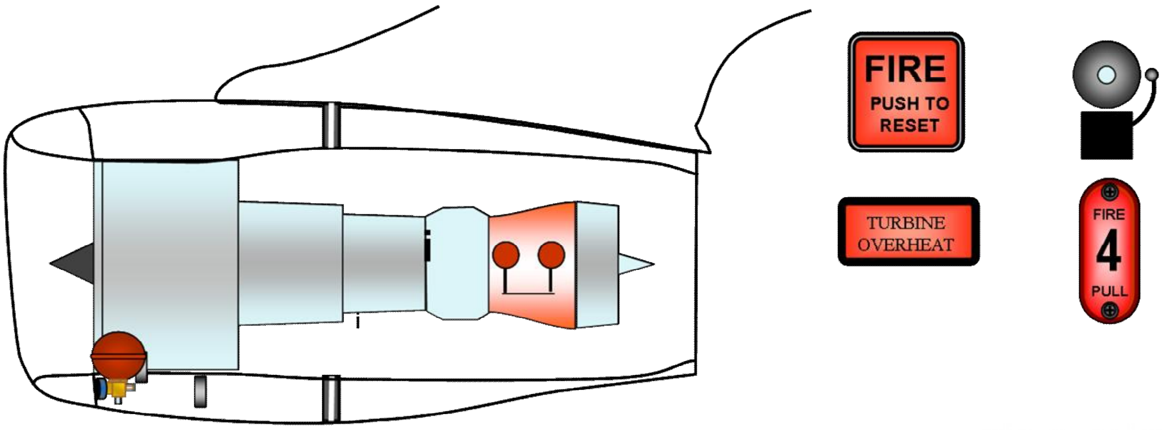

Figure 5-8 **Turbine Overheat Warning System**

ENGINE BLEED AIR SYSTEM

Bleed air in gas turbine engines is compressed air taken from within the engine, from the later compressor stage(s), and diffuser, before the fuel is injected in the burners. Bleed air is used on many aircraft systems because it is easily available, reliable, and a potent source of power.

Engine bleed air supply can be divided into two main categories. They are;

- Bleed air supply for the engine operating systems, and
- Bleed air supply for the aircraft operating systems.

Engine Operating Bleed Air

Engine bleed air is generally taken from the highest pressure air source available, which is Diffuser Air. This supply is for the engines own use for systems such as;

- Engine anti-ice,
- Labyrinth, seal pressurizing,
- Engine Bleed Valve control, and
- Engine internal cooling.

Aircraft System Bleed Air

Aircraft bleed air is taken from the later stages of the LP and HP compressor stages and supplies the aircraft Common bleed Air Manifold, to supply systems including airconditioning, pressurization and engine starting. Refer to Figure 5-9. This is covered in depth in Aircraft Systems.

All bleed air systems have one disadvantage; their use causes a loss in thrust with an increase in TSFC.

As air is taken from the latter compressor stages or the diffuser, this affects the cooling and dilution air (secondary air). EGT will rise, thrust will fall, and as the aircraft slows more fuel will be added to maintain airspeed, increasing TSFC. If engine anti-ice is used for prolonged periods, fuel burn can increase by 5%.

Boeing announced that its new aircraft, the 787 would operate without use of Aircraft System Bleed Air (and the two engines proposed for the aircraft, the General Electric GEnx and the Rolls-Royce Trent 1000, are designed with this in mind). This represents a departure from traditional aircraft design, and proponents state that eliminating bleed air improves engine efficiency, as there is no loss of mass airflow and therefore energy from the engine, leading to lower fuel consumption.

Engine Operating Bleed Air is still used in the 787.

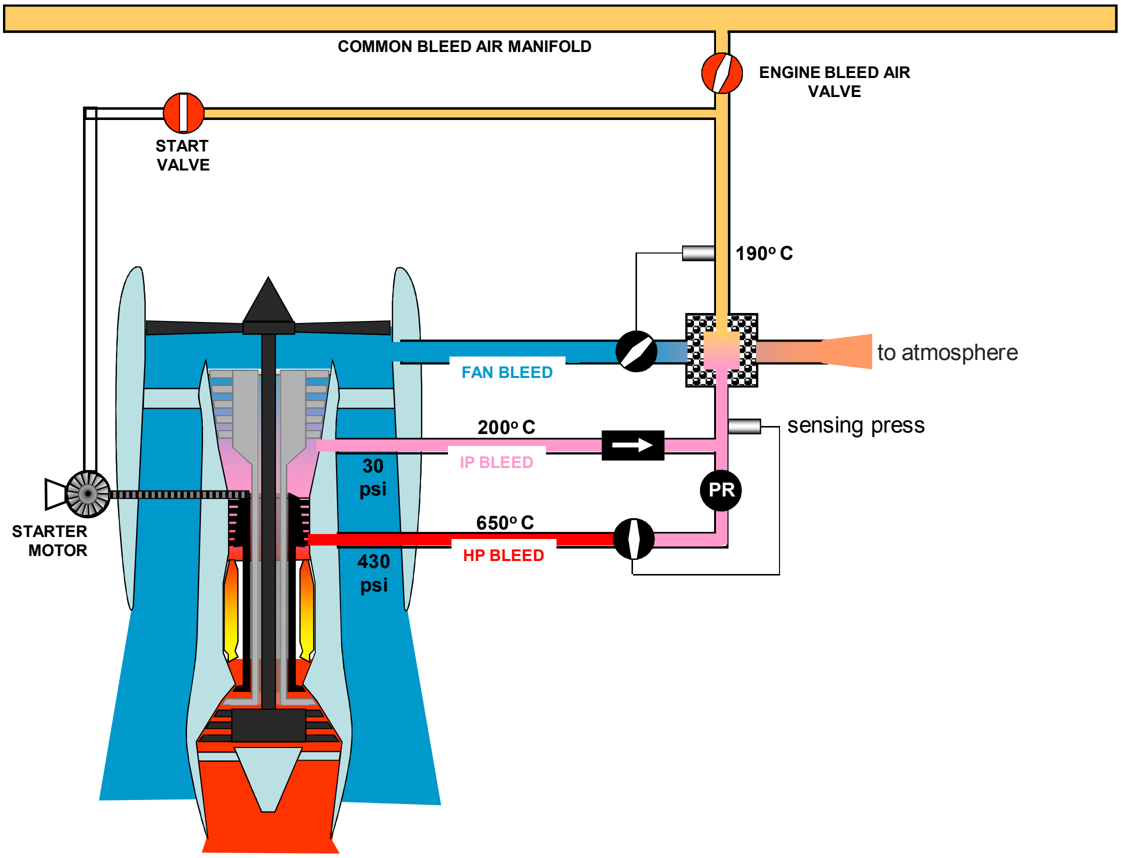

Figure 5-9 Typical Aircraft System Supply