

## CHAPTER 6

# AIR COOLING AND SEALING SYSTEMS

### Objectives

1. This Chapter explains gas-turbine engine cooling and sealing systems to the extent required by the relevant Skill and Knowledge Specification (SAKS) for your trade in this subject area. When you have read the Chapter you should be able to satisfy the following objectives:

- State why air cooling systems are needed.
- State why different pressures of cooling air are required at different points in the system.
- Explain how cooling of the various components is achieved.
- State the need for sealing main shaft bearings and explain how this is achieved.

### Introduction

2. In Chapter 1 of this Section we discussed the main airflow and working cycle of a gas-turbine engine and found that a major function of the airflow through the engine was to act as a cooling medium and that only a small proportion of the air was used to support combustion. In fact, because of the intense heat developed, gas-turbine engines only became practical power units when it was discovered that the air flow could be used to 'insulate' the structural materials and thus provide acceptable working temperatures for the materials. Many parts of the engine, made from light alloy or ferrous metals, have to be protected from the very high flame temperatures. To achieve this, an efficient and effective cooling system is needed, and this is provided by ducting cooling air from the main gas stream.

3. In addition to its function of cooling, the airflow is also used to pressurize oil seals and bearings to prevent oil leakage. We thus have the two functions of cooling and sealing to consider. In general, independent airflows are taken from the engine compressors to provide:

- Low pressure air for sealing.
- Intermediate pressure air for some cooling functions.
- High pressure air for the remainder of the cooling functions.

These are considered in the paragraphs that follow.

## Internal Cooling Airflow

4. Because of the different design features of different gas-turbine engines, the cooling airflow varies considerably from one engine type to another. However, the basic principles remain the same and can be explained by using an example. Fig 2.6.1 shows the cooling and sealing airflow of a modern two-spool, low ratio by-pass engine. To show the cooling airflow more clearly, the by-pass and main airstream air paths have been omitted.

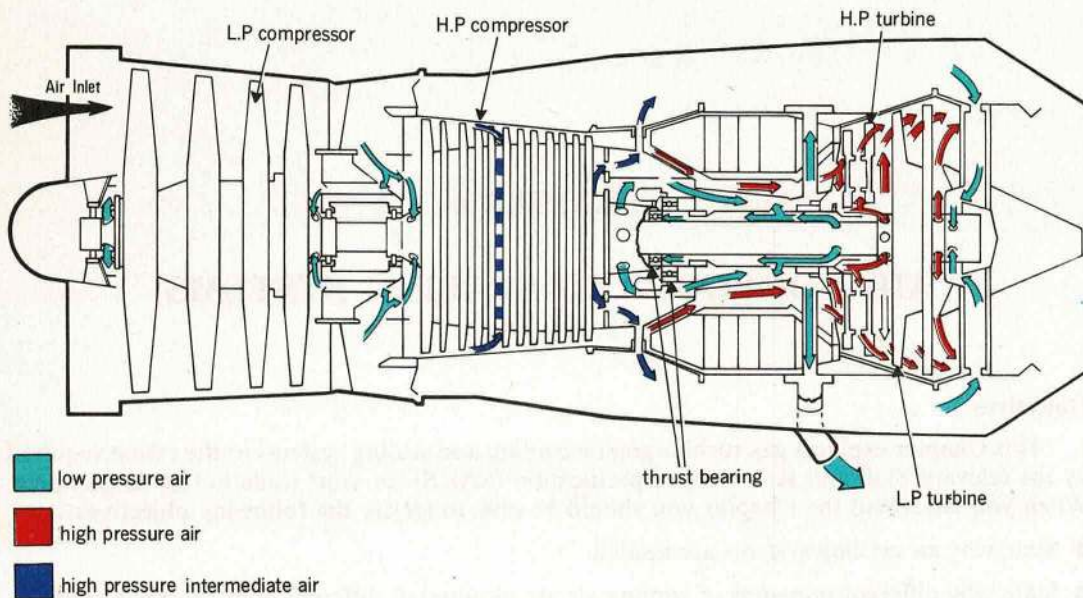


Fig 2.6.1 Internal cooling and sealing air flow

5. A study of Fig 2.6.1 will show that air is supplied from the low pressure compressor and also from the high pressure compressor. This gives the range of pressures required, as mentioned in para 3. After doing its job, the air is either vented directly to atmosphere or fed into the exhaust gas flow.

6. **Low pressure air.** Air is taken from the low pressure compressor outlet and ducted through the engine to become both a sealing and cooling airflow. This airflow:

- Pressurizes the main bearing oil seals to prevent oil leakage (*see* para 10).
- Provides cooling for the low pressure compressor shaft, the front half of the high pressure compressor shaft, and the turbine shaft.

7. **Intermediate pressure air.** This airflow is taken from an intermediate stage of the high pressure compressor and passes through transfer ports to cool the rear half of the high pressure compressor shaft and also the rear face of the last disc of the compressor; it then flows outwards through tubes to mix with the by-pass airstream.

8. **High pressure air.** This airflow is taken from the high pressure compressor outlet and is ducted to all faces of the turbine discs to maintain the turbine temperature within the required limits. The pressure of the cooling air is greater than that of the hot gases and, since the air is directed outwards across the faces of the turbine discs, it prevents the hot exhaust gases flowing inwards across the discs. Overheating of the turbine discs is, therefore, prevented. The detailed operation is described below.

- Fig 2.6.2 illustrates the turbine cooling airflow of a typical gas-turbine engine. The outward flow of cooling air is controlled by air seals of multi-groove construction and the arrangement is such that the turbine discs obtain the maximum possible cooling from the airflow. Interstage seals are incorporated and they are made in such a way that the front sections provide less restriction to the passage of air than the rear sections do. The result is that the rate at which the cooling air flows across the seals is sufficient to prevent any inward flow of hot gases. The front face of each disc receives a greater airflow than the rear.

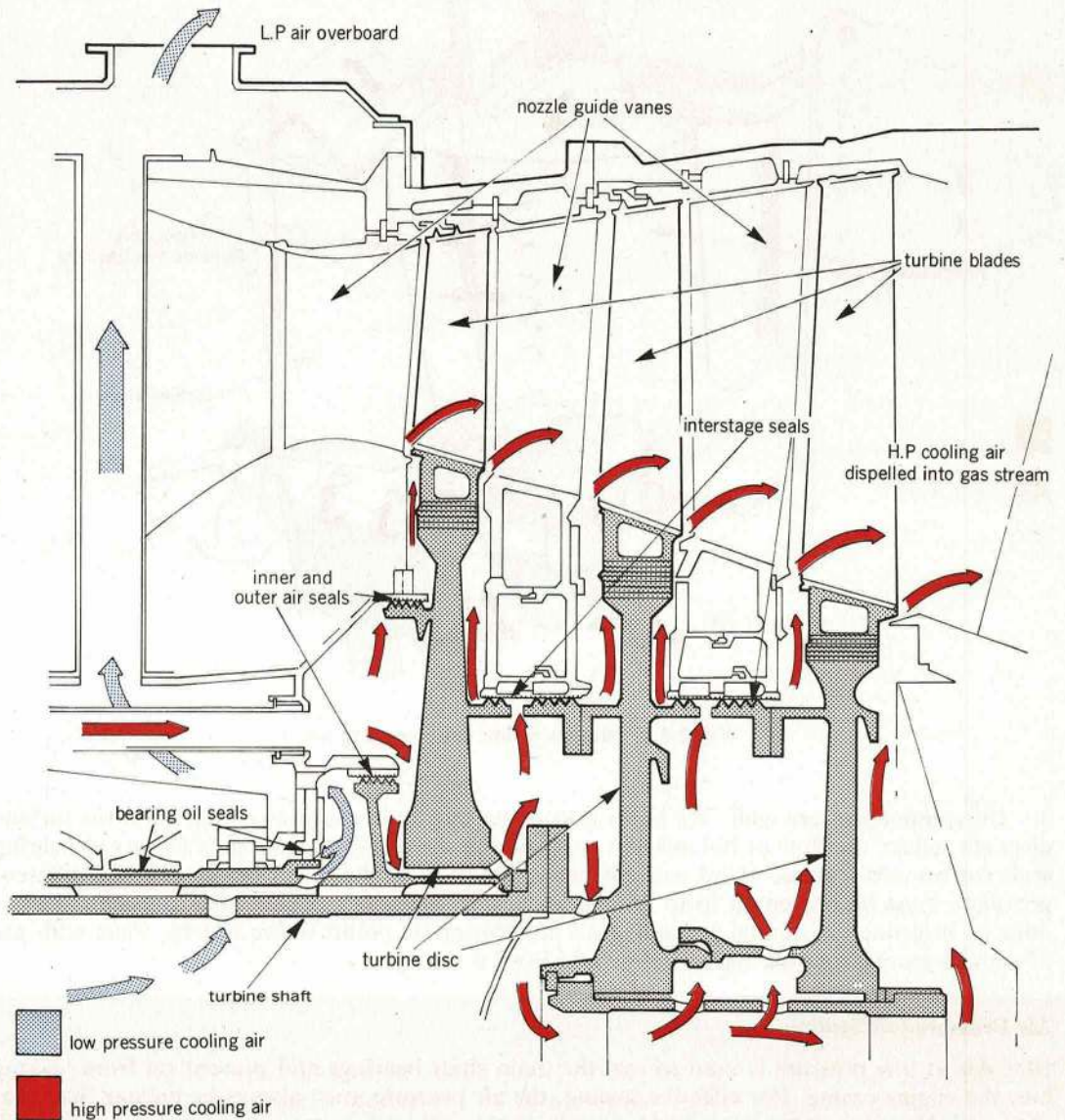


Fig 2.6.2 Turbine cooling air flow

- High pressure cooling air is also directed to the engine's nozzle guide vanes and turbine blades. These components, which are externally heated by the high temperature gas stream, are cooled by ducting the air through air passages formed inside the items themselves (Fig 2.6.3). After completing its task, the air is exhausted into the engine exhaust gas flow and, thence, to atmosphere.

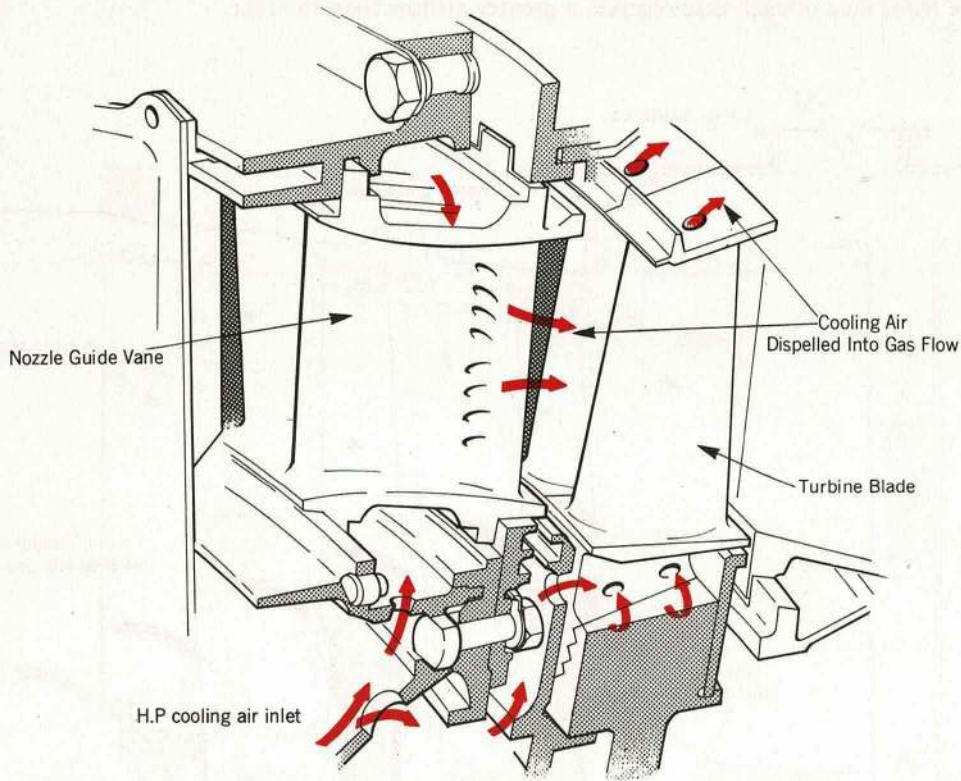


Fig 2.6.3 Nozzle guide vane cooling air

9. **Differential pressure seals.** We know that we require high pressure cooling air at the turbine discs (to reduce the flow of hot exhaust gases across the discs) but low pressure air at bearing seals (to prevent leakage of oil without undue aeration of the oil). The air at these different pressures must be prevented from mixing and, thus, becoming equalized in pressure. This is done by inserting differential pressure seals at appropriate points in the system; these seals are of a multi-groove rotating type (as shown in Fig 2.6.2).

### Air Pressure Oil Sealing

10. Air at low pressure is used to seal the main shaft bearings and prevent oil from leaking into the engine casing. For effective sealing, the air pressure must always be greater than that of the oil. However, it must not be too much greater, otherwise an excessive amount of air will enter the oil system. De-aeration by means of the de-aerator and the centrifugal breather (see Chap 5) may then become difficult. Fig 2.6.4 shows that the mechanical seals used in air pressure oil sealings are designed to reduce clearance to a minimum; air is fed into the seal at the end remote from the oil feed.

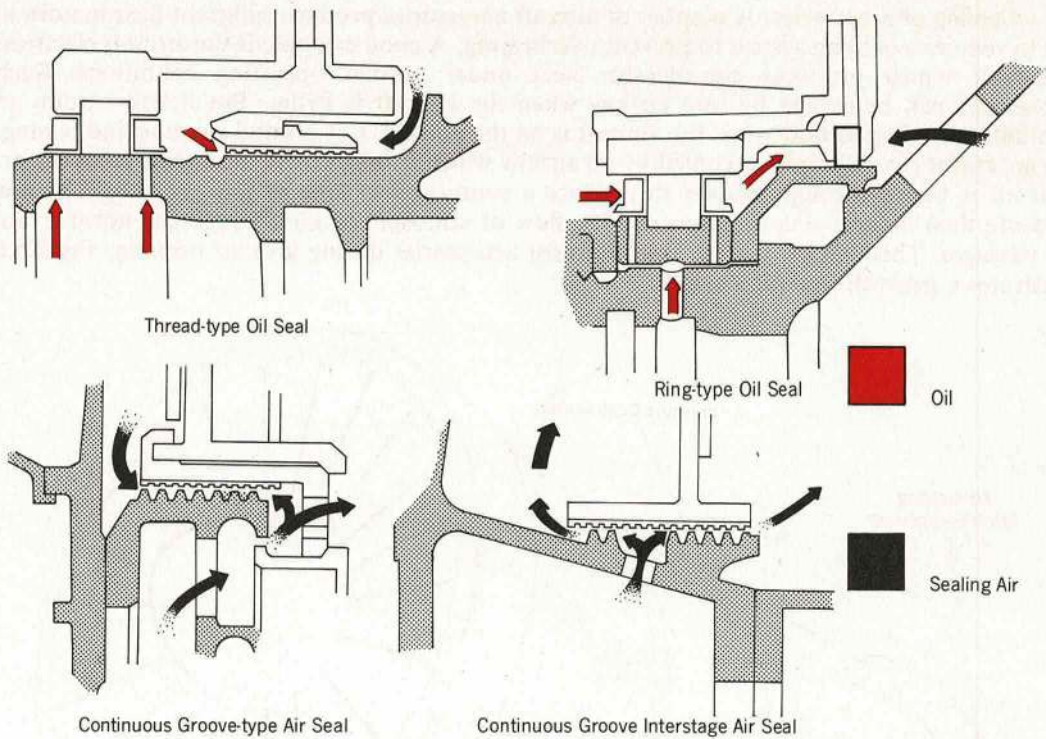


Fig 2.6.4 Typical air and oil seals

### External Cooling

11. **External skin of aero-engine.** Cooling of the external skin of an aero-engine is achieved by suitable design of the aircraft airframe; the layout will depend upon where the engine is fitted and what kind of engine compartment is used. Normally, the cooling and ventilating of an engine bay or pod is achieved by ducting atmospheric air round the engine and spilling it back to atmosphere through suitably placed outlets (Fig 2.6.5). The air is usually taken from a ram inlet but provision is also made to provide a cooling and ventilating airflow during ground running periods. Another function of the cooling airflow is to remove flammable vapours from the engine compartment to reduce the fire risk.

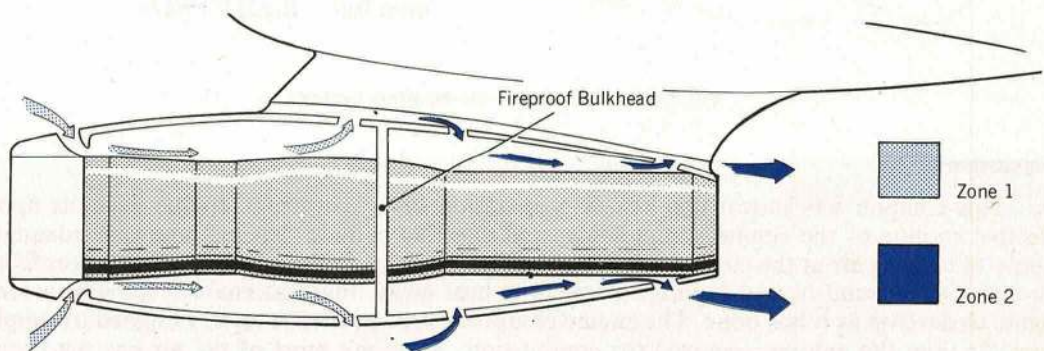


Fig 2.6.5 External air cooling

12. **Cooling of accessories.** A number of aircraft accessories produce sufficient heat in normal use to require a cooling system to prevent overheating. A good example is the aircraft electrical generator which produces considerable heat under normal operating conditions. Such accessories can be cooled by ram airflow when the aircraft is flying. But it will require an alternative cooling airflow when the aircraft is on the ground. For ground running and taxiing, the generator (for example) is cooled by an airflow which is taken from the engine compressor. This air is blown through nozzles to produce a venturi effect area of low pressure. The low pressure then induces a continuous cooling flow of atmospheric air through the normal ram air passages. This is adequate for cooling most accessories during ground running. Fig 2.6.6 illustrates a generator cooling system.

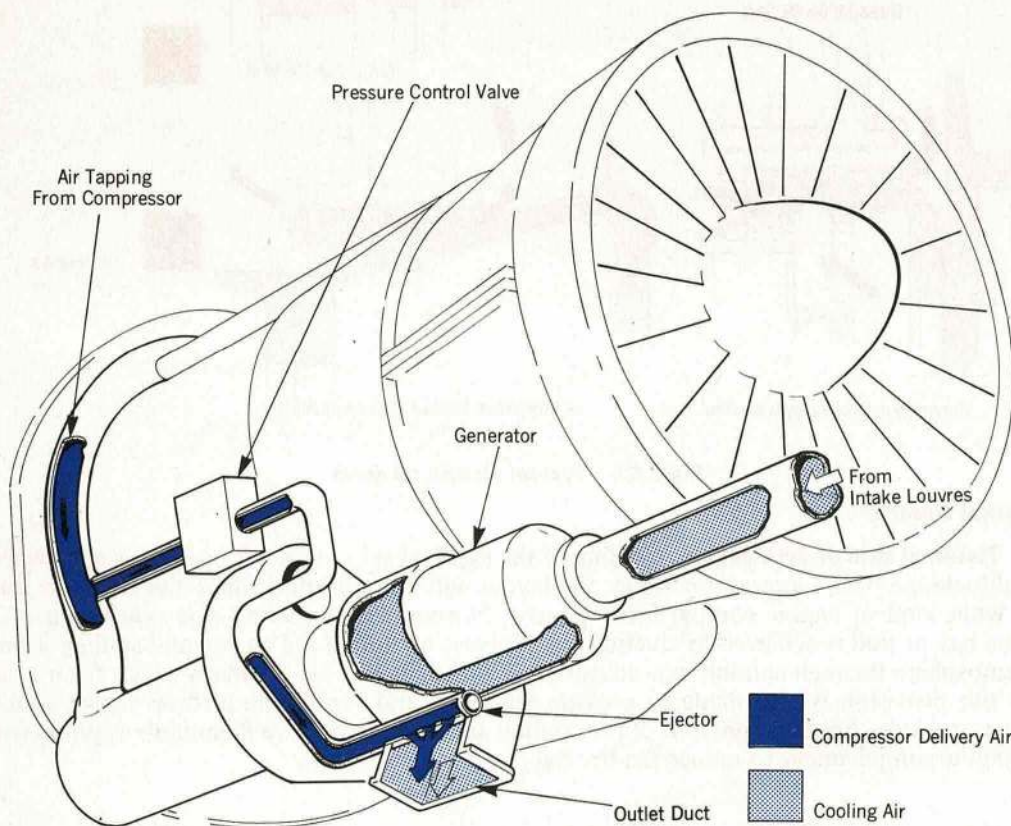


Fig 2.6.6 Generator air cooling system

### Conclusions

13. This Chapter has shown that effective operation of a gas-turbine engine depends upon effective cooling of the engine components; and effective cooling depends upon an adequate supply of cooling air at the correct pressures. In fact, it is the ability of air to absorb heat from the materials around it, and rapidly to carry the heat away, that has enabled the gas-turbine engine to develop as it has done. The engine compressor must, therefore, be designed to supply more air than the amount required for combustion. Although most of the air has the prime task of cooling the hot engine parts, some of it (at low pressure) is required for oil sealing of main shaft bearings.



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