Abdulla Aljunibi

AIR SYSTEMS

TURBINE ENGINE COOLING

The intense heat generated when :

- fuel and air are burned necessitates that some means of cooling be provided for all internal combustion engines.

The burning process in a gas turbine engine is

- continuous,
- nearly all of the cooling air must be passed through the inside of the engine

If only enough air were admitted to the engine to provide an ideal

- air/fuel ratio of 15:1,
- internal temperatures would increase to more than 2 200°C.

The large surplus of air cools the hot sections of the engine to acceptable temperatures ranging from

- 800-1 150°C

Because of the effect of cooling,

- the temperatures of the outside of the case are considerably less than those encountered within the engine.

The hottest area occurs

- in and around the turbines.

Although the gases have begun to cool a little at this point:

- the conductivity of the metal in the case carries the heat directly to the outside skin.

Secondary air passing through the engine:

- cools the combustion chamber liners.

The liners are constructed to induce a :

- thin, fast moving film of air over both the inner and outer surfaces of the liner

The exhaust turbine bearing is the most :

- critical lubricating point in a gas turbine engine

because of the

- high temperature normally present.

In some engines

- air cooling is used in addition to oil cooling the bearing, which supports the turbine.

Secondary air flow for cooling is provide by :

- bleeding air from the early stages of the compressor.

It is used to cool

- turbine disk
- vanes
- blades
- exhaust bearing

Additionally:

- some turbine wheels may have bleed air flowing over the turbine disk, which reduces heat radiation to the bearing surface.

ZONE COOLING

Turbine powerplants can be divided into: primary zones

- that are isolated from each other by fireproof bulkheads and seals.

The zones are the:

- fan case compartment
- intermediate compressor case compartment
- the core engine compartment

Calibrated airflows are supplied to the zones to:

- keep the temperatures around the engine at levels that are acceptable.

The airflow provides proper ventilation to:

- prevent a buildup of any harmful vapors

Zone 1

Zone 1 is:
- around the fan case that contains the accessory case and the electronic engine control (EEC).

This area is vented by using:
- ram air through an inlet in the nose cowl and is exhausted through a louvered vent in the right fan cowling

If the pressure exceeds a certain limit:
- a pressure relief door opens and relieves the pressure

Zone 2

Compressor case components

Zone 2 is cooled by:
- fan air from the upper part of the fan duct and is exhausted at the lower end back into the fan air stream.

This area has both:
- fuel and oil lines

so removing any unwanted vapors would be:
- important (so it doesn't ignite)

Zone 3

Zone 3 is the area:
- around the high pressure compressor to the turbine cases.

This zone also contains :
- fuel and oil lines and other accessories

Air enters from the:
- exhaust of the precooler and other areas
- and is exhausted from the zone through the aft edge of the thrust reverser inner wall and the turbine exhaust sleeve.

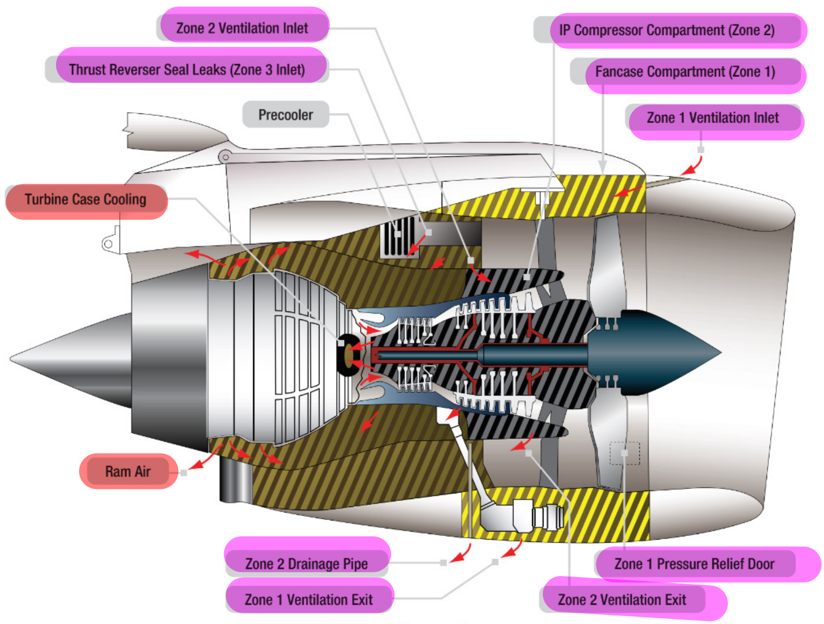

Figure 12-1. Zone cooling.

To properly cool each section of an engine, turbine engines must be constructed with:

- a fairly intricate internal air system.

This system must take:

- ram and/or bleed air and route it to several components deep within the core of the engine

In most engines, the compressor, combustion, and turbine sections all utilize:

- cooling air to some degree.

Internal cooling of the engine can be divided in to the following sub systems:

- Compressor cooling
- Combustion chamber cooling
- Turbine disc cooling
- Turbine NGV and blades cooling
- Accessory section

COMPRESSOR COOLING

The temperature at the rear stages of the compressor is about:

- 350°C-400°C

This is a relatively:

- high temperature

and to minimize the effect of this on the compressor material:

- the compressor rotor cavity is supplied with air from an intermediate compressor stage, which is relatively colder.

COMBUSTION CHAMBER COOLING

A typical combustion section consists of an:

- outer casing with a perforated inner liner

The perforations are:

- various sizes and shapes, each having a specific effect on flame propagation and cooling

In order to allow the combustion section to mix and cool the combustion gases, :

- airflow through the combustor is divided into primary and secondary paths

Approximately 25 percent of the incoming air is directed:

- inside the liner.

As this air enters the combustor:

- it passes through a set of vanes which give it a radial motion and slows its velocity to about 5-6 feet per second

The secondary air flows:

- around the combustor's periphery

This flow forms a:

- cooling air blanket on both sides of the liner and centers the combustion flames so they do not contact the liner.

some secondary air mixes with the burned gases to provide an:

- even distribution to the turbine nozzle at a temperature that the turbine section can withstand.

This cooling takes place in two ways:

1, Cooling air removes heat from the combustion liner

2, Cooling air creates a film, which acts as a thermal barrier between the hot gases and the combustion liner.

TURBINE SECTION COOLING

the effectiveness of turbine cooling plays a :
- big role in an engine's performance.

many cooling systems al low the turbine vanes and blades to operate at:
- 300-400°C above the limits of their metal alloys

The most common ways of cooling the components in the turbine section is to use:
- engine bleed air.

Turbine Disk Cooling

Turbine disks absorb heat from:
- hot gases passing near their rim and from the blades through conduction

Because of this:
- disk rim temperatures are normally well above the disk portion nearest the shaft

To limit the effect of these variations:
- cooling air is directed over each side of the disk

For cooling of turbine blades, turbine disks act as:
- heat sinks

The high pressure turbine disks are cooled by:
- compressor discharge air, and low pressure disks by intermediate stage air

Guide Vane and Blade Cooling

To increase the life of the guide vanes and turbine blades they are:
- cooled by compressor air

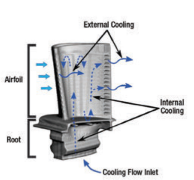

Figure 12-2. Cooling air enters a turbine blade at its root and flows through its airfoil section.

Normally guide vanes are cooled by:
- compressor discharge air into a cavity from above and below them.

As they rotate:
- cooling of turbine blades is more difficult than guide vanes

The process of cooling the turbine blades: Air is supplied through
- drilled holes on the disk front surface, and from there air enters the blades through holes on the blade root.

ACCESSORY COOLING

A considerable amount of heat is produced by some of the :

- engine accessories and electrical generator which may require its own cooling circuit

Air is ducted from:

- intake louvers in the cowlings or may be taken from a stage of the compressor

For oil cooled generators and lubrication oil cooling, an air cooled oil cooler is used where

- fan air is used as the cooling medium.

Because an accessory unit is cooled during flight by

- atmospheric air

it is usually necessary to provide a:

- circuit for use during ground running when there is no external airflow.

This is achieved by:

- allowing compressor air to pass through nozzles in the cooling air outlet duct.

The air velocity through the nozzles creates:

- low pressure inducing atmospheric air through the intake louvers

ENGINE BLEED AIR

A secondary function of the compressor is to:

- supply air for various purposes on the aircraft

Bleed air can be taken from

- any of the various pressure stages of the compressor.

The exact location of the bleed ports is dependent on the

- pressure or temperature required for a particular job.

The ports are:

- small openings in the compressor case adjacent to the particular stage from which the air is to be bled.

Varying degrees of pressure are available by :

- tapping into the appropriate stage.

Air is often bled from the
- final or highest pressure stage since, at this point, pressure and air temperature are at a maximum.

At times it may be necessary to:
- cool this high pressure air.

If it is used for cabin pressurization or other purposes to which excess heat would be uncomfortable or detrimental, the air is sent through an:
- air conditioning unit before it enters the cabin. Bleed air is utilized in a wide variety of ways

Some engine bleed air external air services include:
1. Cabin pressurization, heating, and cooling;
2. Deicing and anti-icing equipment;
3. Pneumatic starting of engines;
4. Auxiliary drive units (ADU).

ENGINE ANTI-ICING CONTROL

To prevent ice formation, turbine engine inlets are typically equipped with some form of:
- anti-ice system

Icing conditions are most likely when :
- operating the engine at high speeds on the ground

Ice can form in the inlet at temperatures up to:
- 5°C due to the chilling effect of high inlet velocities.

During flight, anti-icing is turned on only when:
- a bleed valve directs hot air from the compressor to the inlet leading edge, nose dome, and inlet guide vanes.

After heating the lip:
- air exits through a grill on the intake cowl

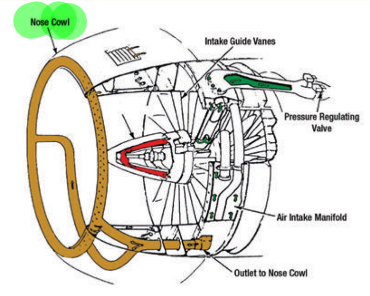

Figure 12-3. Hot anti-ice air flow through the engine inlet.

BEARING CHAMBER SEAL

The bearing chamber seals are pressurized by:
- compressor air.

This air is normally:
- tapped from an intermediate stage of the compressor and supplied through passages or through external tubes

Air is supplied from:
- outside to inside the bearing chamber

Since air pressure is greater than oil pressure:
- air enters the bearing chamber through the seal preventing oil leakage.

EXTERNAL AIR

The engine is covered by the:
- nacelle which includes the

1, inlet cowl
2, fan cowls
3, thrust reverser ducts
4, the exhaust duct.

Apart from covering the engine:
- the nacelle divides the external area to various zones using fire seals.

The seal separates the:
- hot and cold sections and forms a barrier that prevents combustible fumes in the front section from passing into the aft section and igniting on the engine case

For the most part, an engine's nacelle and compressor are cooled by
- ram air which is directed between the engine case and nacelle

This way of cooling is used to:
- ensure that heat generated by the engine does not have an adverse effect on the nacelle
- and to remove any fluid and vapor to reduce fire hazard