MODULE 15

FOR A CERTIFICATION

GAS TURBINE ENGINE

Aviation Maintenance Technician Certification Series

COMPLIANT WITH EASA European Aviation Safety Agency EASA PART 66/147

AIRCRAFT TECHNICAL BOOK COMPANY

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REVISION LOG

VERSION	EFFECTIVE DATE	DESCRIPTION OF CHANGE
001	2019 01	Module Creation and Release

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15.3 - INLET

COMPRESSOR INLET DUCTS

The air entrance is designed to conduct incoming air to the compressor with a minimum energy loss resulting from drag or ram pressure loss; that is, the flow of air into the compressor should be free of turbulence to achieve maximum operating efficiency. Proper inlet design contributes materially to aircraft performance by increasing the ratio of compressor discharge pressure to duct inlet pressure. (***Figure 3-1***)

This is also referred to as the compressor pressure ratio. This ratio is the outlet pressure divided by the inlet pressure. The amount of air passing through the engine is dependent upon three factors:

1. The compressor speed (rpm).
2. The forward speed of the aircraft.
3. The density of the ambient (surrounding) air.

Turbine inlet type is dictated by the type of gas turbine engine. A high bypass turbofan engine inlet is completely different from a Turboprop or turboshaft inlet. Large gas turbine powered aircraft almost always have a turbofan engine. The inlet on this type of engine is bolted to the front (A flange) of the engine. These engines are mounted on the wings, or nacelles, on the aft fuselage, and a few are in the vertical fin. A typical turbofan inlet can be seen in ***Figure 3-2***.

Since on most modern turbofan engines the huge fan is the first part of the aircraft the incoming air comes into contact with, icing protection must be provided. This prevents chucks of ice from forming on the leading edge of the inlet, breaking loose, and damaging the fan. Warm air is bled from the engine's compressor and is ducted through the inlet to prevent ice from forming. If inlet guide vanes are used to straighten the air flow, then they also have anti-icing air flowing through them. The inlet also contains some sound reducing materials that absorb the fan noise and make the engine quieter.

Turboprops and turboshafts can use an inlet screen to help filter out ice or debris from entering the engine. A deflector vane and a heated inlet lip are used to prevent ice or large chunks from entering the engine.

On military aircraft, the divided entrance permits the use of very short ducts with a resultant small pressure drop through skin friction. Military aircraft can fly at speeds above Mach 1, but the airflow through the engine must always stay below Mach 1. Supersonic air flow in the engine would destroy the engine. By using convergent and divergent shaped ducts, the air flow is controlled and dropped to subsonic speeds before entering the engine. Supersonic inlets are used to slow the incoming engine air to less than Mach 1 before it enters the engine.

TURBINE ENGINE INLET SYSTEMS

The engine inlet of a turbine engine is designed to provide a relatively distortion free flow of air, in the required quantity, to the inlet of the compressor. (***Figure 3-3***) Many engines use inlet guide vanes (IGV)

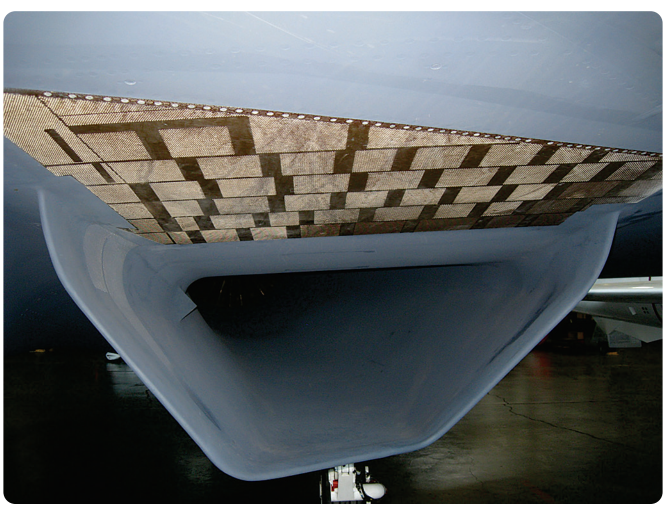

Figure 3-1. Military style short intake duct.

Figure 3-2. Typical turbofan inlet.

Figure 3-3. Inlet fan blades and guide vanes (inner circle) on a GEnx engine.

to help straighten the airflow and direct it into the first stages of the compressor. A uniform and steady airflow is necessary to avoid compressor stall (airflow tends to stop or reverse direction of flow) and excessive internal engine temperatures in the turbine section. Normally, the air inlet duct is considered an airframe part and not a part of the engine. However, the duct is very important to the engine's overall performance and the engine's ability to produce an optimum amount of thrust.

A gas turbine engine consumes considerable more airflow than a reciprocating engine. The air entrance passage is correspondingly larger. Furthermore, it is more critical in determining engine and aircraft performance, especially at high airspeeds. Inefficiencies of the inlet duct result in successively magnified losses through other components of the engine. The inlet varies according to the type of turbine engine. Small Turboprop and turboshaft engines have a lower airflow than large turbofan engines which require a completely different type of inlet. Many Turboprop, auxiliary power units, and turboshaft engines use screens that cover the inlet to prevent foreign object damage (FOD).

As aircraft speed increases, thrust tends to decrease somewhat; as the aircraft speed reaches a certain point, ram recovery compensates for the losses caused by the increases in speed. The inlet must be able to recover as much of the total pressure of the free airstream as possible. As air molecules are trapped and begin to be compressed in the inlet, much of the pressure loss is recovered. This added pressure at the inlet of the engine increases the pressure and airflow to the engine. This is known as "ram recovery" or "total pressure recovery." The inlet duct must uniformly deliver air to the compressor inlet with as little turbulence and pressure variation as possible. The engine inlet duct must also hold the drag effect on the aircraft to a minimum.

Air pressure drop in the engine inlet is caused by the friction of the air along both sides of the duct and by the bends in the duct system. Smooth flow depends upon keeping the amount of turbulence to a minimum as the air enters the duct. On engines with low flow rates, turning the airflow allows the engine nacelle to be smaller and have less drag. On turbofan engines, the duct must have a sufficiently straight section to ensure smooth, even airflow because of the high airflows. The choice of configuration of the entrance to the duct is dictated by the location of the engine within the aircraft and the airspeed, altitude, and attitude at which the aircraft is designed to operate.

DIVIDED ENTRANCE DUCT

The requirements of high speed, single or twin engine military aircraft, in which the pilot sits low in the fuselage and close to the nose, render it difficult to employ the older type single entrance duct, which is not used on modern aircraft. Some form of a divided duct, which takes air from either side of the fuselage, has become fairly widely used. This divided duct can be either a wing root inlet or a scoop at each side of the fuselage. (***Figure 3-4***)

Either type of duct presents more problems to the aircraft designer than a single entrance duct because of the difficulty of obtaining sufficient air scoop area without imposing prohibitive amounts of drag. Internally, the

Figure 3-4. An example of a divided entrance duct.

problem is the same as that encountered with the single entrance duct: to construct a duct of reasonable length with as few bends as possible. Scoops at the sides of the fuselage are often used. These side scoops are placed as far forward as possible to permit a gradual bend toward the compressor inlet, making the airflow characteristics approach those of a single entrance duct. A series of turning vanes is sometimes placed in the side scoop inlet to assist in straightening the incoming airflow and to prevent turbulence.

VARIABLE GEOMETRY DUCT

The main function of an inlet duct is to furnish the proper amount of air to the engine inlet. In a typical military aircraft using a turbojet or low bypass turbofan engine, the maximum airflow requirements are such that the Mach number of the airflow directly ahead of the face of the engine is less than Mach 1. Airflow through the engine must be less than Mach 1 at all times. Therefore, under all flight conditions, the velocity of the airflow as it enters the air inlet duct must be reduced through the duct before the airflow is ready to enter the compressor. To accomplish this, inlet ducts are designed to function as diffusers, decreasing the velocity and increasing the static pressure of the air passing through them. (***Figure 3-5***)

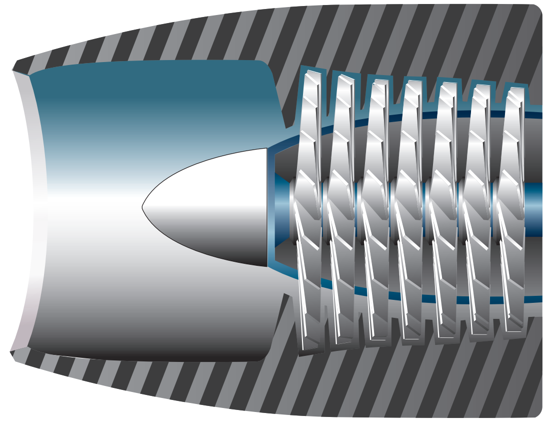

Figure 3-5. An inlet duct acts as a diffuser to decrease the airflow velocity and to increase the static pressure of air.

As with military supersonic aircraft, a diffuser progressively decreases in area in the downstream direction. Therefore, a supersonic inlet duct follows this general configuration until the velocity of the incoming air is reduced to Mach 1. The aft section of the duct then increases in area, since this part must act as a subsonic diffuser. (***Figure 3-6***)

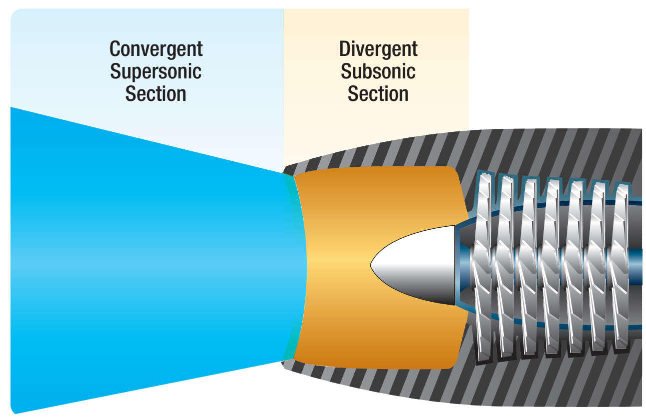

Figure 3-6. The aft section of an inlet duct acting as a subsonic diffuser.

In practice, inlet ducts for supersonic aircraft follows this general design only as much as practical, depending upon the design features of the aircraft. For very high speed aircraft, the inside area of configuration of the duct is changed by a mechanical device as the speed of the aircraft increases or decreases. A duct of this type is usually known as a variable geometry inlet duct.

Military aircraft use the three methods described above to diffuse the inlet air and slow the inlet airflow at supersonic flight speeds. One is to vary the area, or geometry, of the inlet duct either by using a movable restriction, such as a ramp or wedge, inside the duct.

Another system is some sort of a variable airflow bypass arrangement, which extracts part of the inlet airflow from the duct ahead of the engine. In some cases, a combination of both systems is used.

The third method is the use of a shock wave in the airstream. A shock wave is a thin region of discontinuity in a flow of air or gas, during which the speed, pressure, density, and temperature of the air or gas undergo a sudden change. Stronger shock waves produce larger changes in the properties of the air or gas. A shock wave is willfully set up in the supersonic flow of the air entering the duct, by means of some restriction or small obstruction which automatically protrudes into the duct at high flight Mach numbers. The shock wave results in diffusion of the airflow, which, in turn, decreases the velocity of the airflow. In at least one aircraft installation, both the shock method and the variable geometry method of causing diffusion are used in combination. The same device that changes the area of the duct also sets up a shock wave that further reduces the speed of the incoming air within the duct. The amount of change in duct area and the magnitude of the shock are varied automatically with the airspeed of the aircraft.

TURBOPROP AND TURBOSHAFT COMPRESSOR INLETS

The air inlet on a Turboprop is more of a problem than some other gas turbine engines because the propeller drive shaft, the hub, and the spinner must be considered in addition to other inlet design factors. The ducted arrangement is generally considered the best inlet design of the Turboprop engine as far as airflow and aerodynamic characteristics are concerned. (***Figure 3-7***) The inlet for many types of Turboprops are anti-iced by using electrical elements in the lip opening of the intake. Ducting either part of the engine or nacelle directs the airflow to the intake of the engine. Deflector doors are sometimes used to deflect ice or dirt away from the intake. (***Figure 3-8***) The air then passes through a screen and into the engine on some models. A conical spinner, which does not allow ice to build up on the surface, is sometimes used with Turboprop and turbofan engines. In either event, the arrangement of the spinner and the inlet duct plays an important function in the operation and performance of the engine.

TURBOFAN ENGINE INLET SECTIONS

High bypass turbofan engines are usually constructed with the fan at the forward end of the compressor. A typical turbofan intake section is shown in ***Figure 3-9*** Sometimes, the inlet cowl is bolted to the front of the engine and provides the airflow path into the engine. In dual compressor (dual spool) engines, the fan is integral with the relatively slow turning, low pressure compressor, which allows the fan blades to rotate at low tip speed for best fan efficiency. The fan permits the use of a conventional air inlet duct, resulting in low inlet duct loss. The fan reduces engine damage from ingested foreign material because much of any material that may be ingested is thrown radially outward and passes through the fan discharge rather than through the core of the engine. Warm bleed air is drawn from the engine and circulated on the inside of the inlet lip for anti-icing. The fan hub or spinner is either heated by warm air or is conical as mentioned earlier. Inside the inlet by the fan blade tips is an abraidable rub strip that allows the fan blades to rub for short times due to flightpath changes. (***Figure 3-10***) Also, inside the inlet are sound reducing materials to lower the noise generated by the fan.

Figure 3-7. An example of a ducted arrangement on a Turboprop engine.

Figure 3-8. Deflector doors used to deflect ice or dirt away from the intake.

Figure 3-9. A typical turbofan intake section.