DOCUMENT

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DOCUMENT TITLE

GAS TURBINE ENGINES (CASA ATPL)

CHAPTER 7 – ACCESSORY DRIVE, STARTING AND IGNITION

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ACCESSORY DRIVE

The accessory drive gearbox provides the power for hydraulic, pneumatic and electrical mechanisms for use on the engine and in the aircraft. It is also used to drive fuel pumps, oil pumps, tacho-generators and various other devices necessary for efficient engine operation.

The drive for the accessory unit is taken from the high pressure compressor shaft (either N_2 or N_3), via an internal gearbox, to an external gearbox which provides the mountings for the accessories and the starter motor. Refer to Figure 7-1.

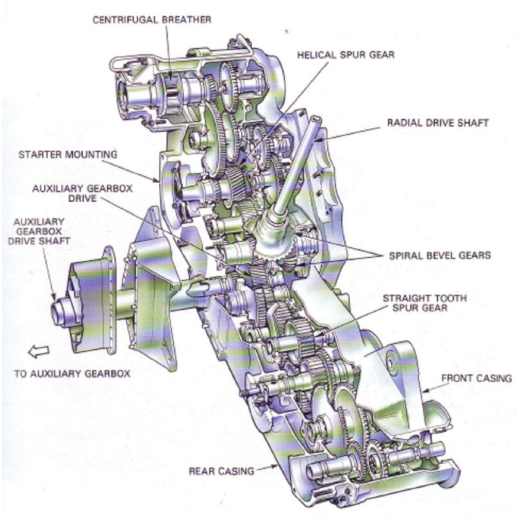

Figure 7-1 Accessory Case

Starter Drive

All gas turbine starting systems work by commencing the Brayton Cycle. The starter motor is fitted to an accessory gearbox, which is connected to the highest pressure spool, usually N_2,(N_3 on RR RB211). Refer to Figure 7-2.

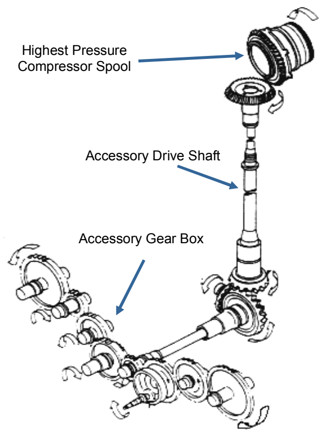

Figure 7-2 Starter Drive Train

During an engine start a pneumatic starter does a lot of work, therefore it can build up a lot of heat. A starter motor Duty Cycle is used to give the starter time to cool off between starts.

A typical duty cycle is, one minute, one minute off, one minute on, then thirty minutes off.

Mechanical failure of an accessory could cause the failure or the whole gearbox with the associated loss of the engine.

To prevent this happening a shear shaft (weak section in the shaft), is fitted to some of the drives. This weak section is machined into the drive and is known as the shear neck. It is designed to fail at a load perhaps 25% in excess of the normal maximum for the particular component being driven by that shaft.

In circumstances of excessive overload, the shear section will break, allowing failure of the individual component while the rest of the gearbox and accessories continue as normal. This feature is not utilized in the drives of primary engine accessory units, such as HP fuel pumps and oil pumps, because any failure of these components would necessitate the immediate shutdown of the engine. Refer to Figure 7-3.

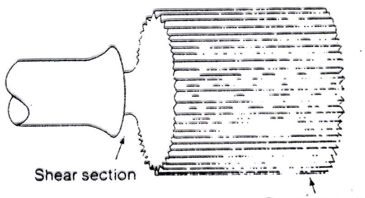

Figure 7-3 Shear Shaft.

STARTING

On gas turbine engines, the starting process and the ignition process are achieved by separate systems. To start the engine, firstly the compressor/turbine assembly must be rotated to a speed at which sufficient air is delivered by the compressor to the combustion chamber and then to mix with the fuel. Secondly, a source of ignition of the fuel/air mixture in the combustion chamber must be provided by the ignition system. During a normal start up sequence, the two systems are coordinated by the flight crew to ensure that the engine lights up correctly. After light up, the systems are automatically monitored to ensure that normal engine operations can be sustained.

There are a variety of different methods used to achieve the initial rotation of the compressor/turbine assembly. They are;

- Cartridge Starters, which are literally large explosive charges which produce a large volume of gas to drive an air type starter motor,
- Hydraulic Motors on some engines double as a starter unit. An external supply of hydraulic pressure is required from a ground power unit. Once started it reverts to its function as a pump, and
- Impingement starting, which directs high pressure air directly onto the turbine blades.

Modern gas turbines now use;

- Electric, and
- Pneumatic Air Starters.

All of these methods work by commencing the Brayton Cycle.

ELECTRIC STARTER MOTOR

Electric motors operate using DC from the main supply are activated by a starter switch in the flight deck. They are coupled to the engine compressor shaft by means of the main accessory driveshaft, from which they are automatically disengaged when the engine has reached self-sustaining speed. Refer to Figure 7-4. Alternatively, they may be disengaged automatically after a preset period of time by a cut-off time switch. Electric Starter Motors are used almost exclusively on modern APUs.

On smaller jet aircraft engines, and light aircraft piston engines, the starter motor doubles as a DC generator once the start has been completed. This arrangement saves weight.

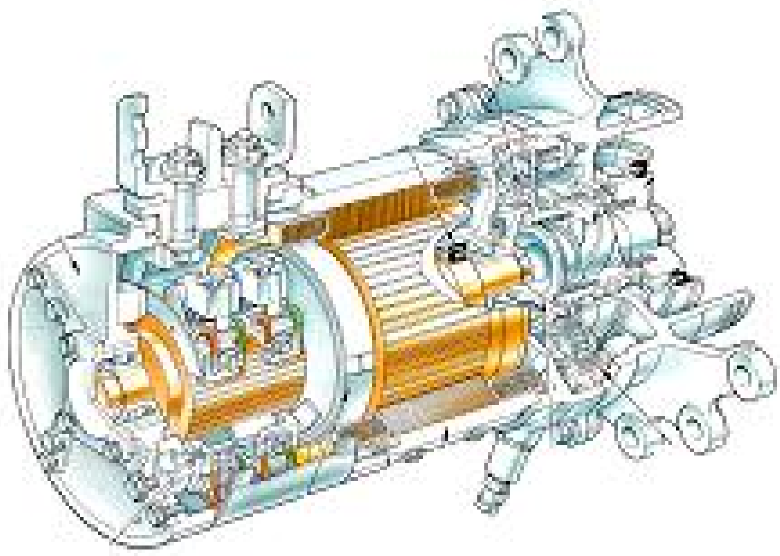

Figure 7-4 28vDC Starter Motor.

PNEUMATIC STARTER MOTOR

These starter motors are popular due to simple design and therefore low maintenance, and may be activated by a suitable source of high pressure air. This air is directed onto the starter motor turbine which drives the starter shaft to the engine compressor shaft. Refer to Figure 7-5. The air may come from any of the following three sources; these are; Refer to Figure 7-6.

- a ground compressor unit,
- an Auxiliary Power Unit (APU), and
- cross - bleed from an operating engine.

Pneumatic Starter Motors are fitted with a clutch assembly to prevent them being driven by the engine .They are also fitted with a shear shaft, (quill shaft) to prevent accessory case damage should the starter seize.

As the new B787 Dreamliner has eliminated the pneumatic system entirely the starting system uses electric starter motors. Like earlier small jet and piston aircraft, these starters turn into generators after engine start

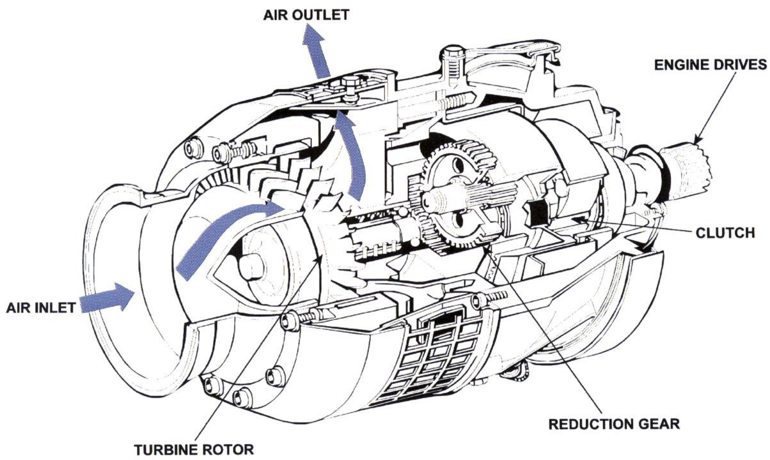

Figure 7-5 Pneumatic Starter Motor

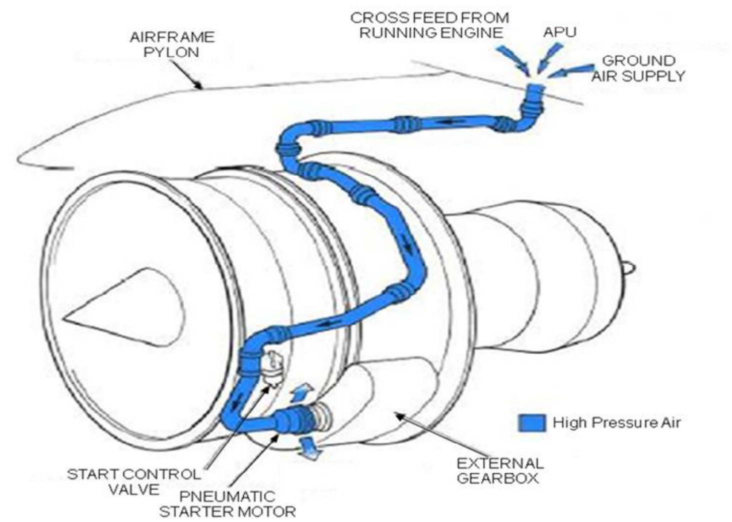

Figure 7-6 Pneumatic Air Sources

IGNITION SYSTEMS

The ignition system of a gas turbine engine must be capable of producing the electrical discharge necessary to ignite the fuel/air mixture in the combustion chamber. It is required to do this during initial start up of the engine, and it must also be available if required to re-light the engine in the event of a flame-out. The electrical energy required to achieve successful ignition of the mixture changes with different ambient conditions and also with change in operating altitude. The higher the altitude, the greater the energy required. Each engine has two ignition systems fitted which consists of an ignition unit, wiring harness and igniter plugs. The power supplied by a particular ignition system may be varied depending on the nature of operation of the aircraft. It is common for one of the ignition systems to be a high energy (HE) unit for engine starting and high altitude re-lighting, and the other to produce a lower energy output which operates continuously to give automatic re-light in the event of a flame-out.

The high energy unit draws electrical power from the main aircraft DC supply. It may be operated together with the starter system during initial engine start-up, or independently for re-lighting. The discharge is directed through a choke which serves to increase the discharge period, and then by a high tension conductor to the igniter plug. The energy is released at the semi-conducting face of the plug. The capacitor is automatically recharged and the process repeats approximately twice per second. Discharge resistors are included in the ignition circuit, between the capacitor and earth, to ensure that no energy remains in the system when the ignition system is switched off.

IGNITION SYSTEM MODES OF OPERATION

The ignition system has four modes of operation. They are;

- **Ground**, for normal engine starting,
- **Continuous Ignition,** which is used for takeoff, landings, icing conditions and any time SOPs require,
- **Flight**, which is used for in-flight starting, and
- **Automatic,** which activates when approaching stall warning, and high AOA. The disruption to the air flow may cause a flameout.

ENGINE START SEQUENCE

To illustrate a typical engine start we will use the sequence of a B737. The engine start panel and fuel shutoff levers are shown below on Figures 7-7 and 7-8.

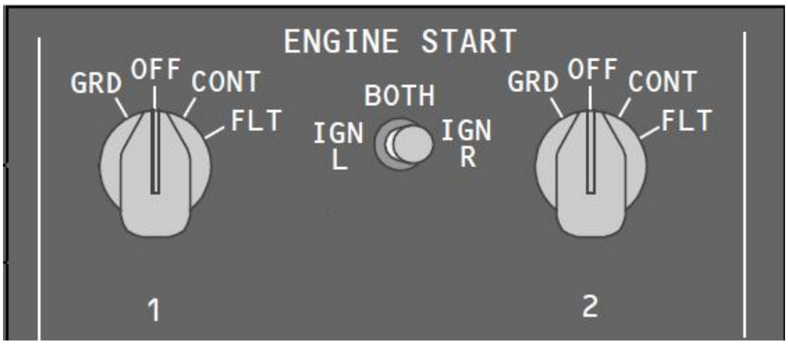

Figure 7-7 B737 Start Panel.

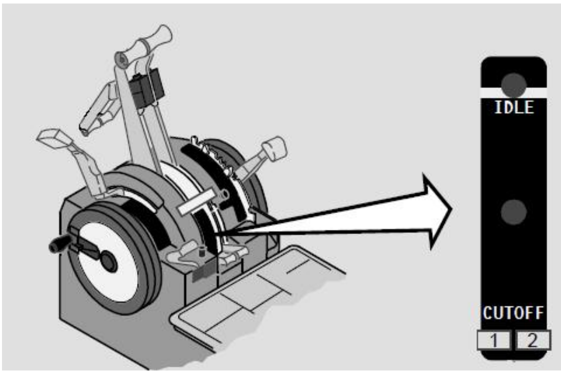

Figure 7-8 B737 Fuel Shutoff Levers.

The Start Sequence begins with;

- Engine start selector–(GRD, (solenoid held).
- Start Valve–OPEN.
- START VALVE amber light –ON.
- HP Spool (N_2 or N_3) -ROTATION.
- At 15% N_1, Fuel Shutoff Lever–OPEN, Fuel and Ignition are now ON.
- Engine LIGHT OFF should be observed on the EGT Indicator.
- At 25% N_2- N_1 ROTATION STARTS.
- At 35% N_2-Start Selector-OFF (solenoid releases).
- Start Valve Light-OFF.
- Start Valve-CLOSED.

The engine is now self sustaining and will accelerate to its Idle RPM. This sequence is illustrated in Figure 7-9.

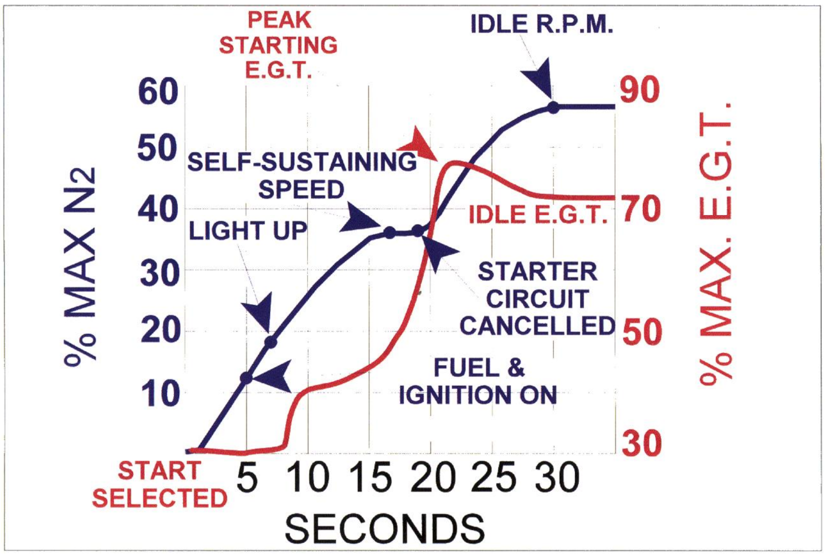

Figure 7-9 B737 Start Sequence.

START MALFUNCTIONS

An ABORTED START is conducted when an engine has not accelerated to its IDLE range within a specified period, or has exceeded its limitations during the start cycle. The purpose of this section is to define four situations which require the start to be aborted. These are;

- Hot Start,
- Wet Start,
- Hung Start, and
- Start valve fails to close.

HOT START

This is indicated by a very rapid increase in EGT. This may be caused by a high fuel flow when the start lever is placed to IDLE or an insufficient airflow through the engine resulting in an incorrect air/fuel ratio. If corrective action is not taken, a hot start can result in extensive damage to the engine. The engine start must be terminated immediately by moving the START LEVER to CUTOFF. The engine should continue to be "motored" to lower the EGT to an acceptable residual start temperature. Providing start temperature limitations have not been exceeded, another start may be attempted. It is usual to use both ignition systems for the second attempt.

Hot Start Causes may include;

- incorrect fuel scheduling,
- late ignition sequence,
- aircraft positioning (tailwind),
- defective starter motor, and
- defective combustion chamber drain.

WET START

This occurs if EGT does not rise following movement of the START LEVER to IDLE and fuel flow is indicated. This could indicate that ignition has not occurred. This is known as a WET START. The engine start must be terminated immediately by moving the START LEVER to CUTOFF, and continued to be "motored" to clear the engine of fuel. Motoring time varies with the type of engine and providing there is no sign of vaporised fuel from the tail pipe as observed by the ground crewman, a restart may be attempted. Both ignition sources should be used on the second start.

Wet Start causes may include;

- defective ignition system,
- over scheduling by the FCU,
- defective fuel nozzles, and
- defective pressurising and dump valve.

HUNG START

This is identified by failure of the engine to accelerate during the start cycle following apparently normal light up and early acceleration. This may cause the EGT to rise rapidly, and is usually associated with lean fuel scheduling. Immediate action is the same as that required for a hot start. A further start may be attempted.

Hung Start causes may include;

- defective starter motor,
- insufficient starter power (air or voltage),
- defective starter valve (pneumatic), and
- fuel scheduling to lean.

All three start malfunction require the same pilot actions, but for different reasons. During these procedures the starter motor duty cycle must be adhered to.

START VALVE FAILS TO CLOSE

If the START VALVE light remains on after start or illuminates during flight, the engine should be shut down in a timely manner.

There are numerous other start malfunctions possible, but these are beyond the scope of this text book.

IN FLIGHT STARTING

Tabulated in flight start envelope diagrams are used to determine the best conditions for an in-flight start and that engine windmilling speeds are considered before an engine may be restarted. Speed and altitude determine whether the start can be achieved by engine windmilling or if the engine requires starter assistance.

For a Cross-bleed Start, the start cycle is much the same as for starting on the ground and requires the ignition switch to be held at the GRD START position and released at 50%.

A windmilling start requires the ignition switch selected to FLT START. The acceptable EGT start limit is normally lower due to faster engine acceleration

A low idling engine is susceptible to flame out on descent from high altitudes. Restarts may be attempted but are not assured at high altitudes. Refer to Figure 7-8.

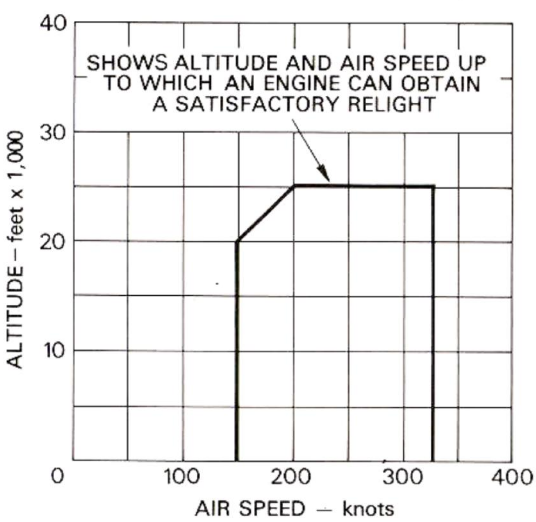

Figure 7-10 B737 In Flight Start Envelope