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GAS TURBINE ENGINES (CASA ATPL)

CHAPTER 6 – REVERSE THRUST AND AUGMENTATION

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REVERSE THRUST

Modern aircraft braking systems, which incorporate sophisticated anti-skid and auto braking, are extremely efficient. The braking of an aircraft can be enhanced by using reverse thrust.

The advantages of reverse thrust are obvious. Stopping distances are reduced, adding a margin of safety. Reverse can also be used for ground manoeuvring, although it is not recommended. Turboprop aircraft are the exception.

Thrust reversing is achieved by applying a forward vector to the thrust on landing or a rejected take off, then increasing that thrust.

<u>When an aircraft is certified, reverse thrust is not used when calculating take off performance and landing data.</u>

There are three basic Thrust Reversal Systems presently in use on turbojet and turbofan engines, they are;

- External reversers,
- Clamshell Doors, and
- Cascade Vanes and Cascade Petal Doors.

External Reversers

Sometimes called Bucket Doors, were the original system used on early turbojet engines (JT3C on B707).The rear of the exhaust pipe is shaped like two halves of a bottomless bucket which are hinged, to enable them to swing backwards when selected. These reversers would be actuated by <u>Hydraulics</u>, although some systems used <u>Pneumatics</u> (DC8).

These doors then deflect the exhaust gas to give it a forward vector. Refer Figure 6-1.

Figure 6-1 External Reversers (Fokker F100)

Clamshell Doors

These reversers resemble two halves of a clam and are fitted to the inside of the exhaust duct. The exhaust gas is directed through vanes in the top and bottom of the exhaust duct. Refer to Figure 6-2. This installation is used on the low by-pass turbofans, (JT8D on the B727). Both the by-pass air and the core air are used for reversing. Most are activated by the aircraft hydraulic systems.

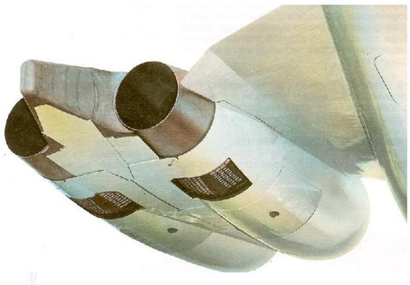

Figure 6-2 Internal Clamshell Reverser (VC10)

Cascade Vanes

As 80% of the thrust produced on a High By-pass Turbofan is produced by the by-pass air, only that air is used for reversing. Blocker Doors are used in the by-pass duct and a Translating Sleeve slides back to expose the Cascade Vanes. Refer to Figure 6-3 and 6-5. The by-pass air is then directed through these vanes. As with the other systems cascade vanes use Hydraulics to activate the reversers, although the B787 uses Electrics for its reversers.

The Boeing C-17 has a rare form of the above type in which even the exhaust from the core is redirected along with the main fan air. This gives the C-17 stopping ability, unrivalled among large jet-powered aircraft.

A variation of the Cascade Vanes is the Petal Door Principle. This has the added advantage of the speed brake effect. They can also be referred to as Blocker Doors. Refer to Figure 6-4.

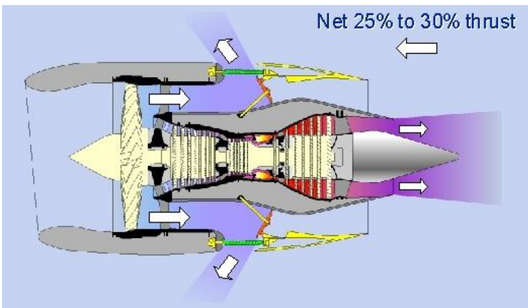

Figure 6-3 Blocker Doors

Figure 6-4 Petal Doors (A340)

Figure 6-5 Cascade Vanes (B747)

REVERSE THRUST OPERATION

In order that the pilot may have information regarding the position of the reverse thrust doors, Reverse Thrust Warning Lights are fitted. They are;

- Reverse UNSTOWED which is an amber light which indicates that the Translating Sleeve is Not Fully Closed, and
- FULL REVERSE, a green light, which confirms Blocker Doors are now fully closed.

These lights are displayed on the ECAM or EICAS.

Reverse thrust is used only on the ground. Inadvertent deployment in flight is a very serious situation and normally means a timely engine shutdown. Some aircraft have a system to automatically retard the thrust lever should a reverser unlock above idle (B747).

There are three safeguards built into the selection of Reverse Thrust, they are;

- Reverse cannot be selected until the Thrust Lever is at Idle,
- Reverse cannot be activated until the aircraft is on the ground, (Weight on Wheels Logic),and
- RPM cannot be increased above Idle until the buckets/blocker doors are deployed.

The Thrust Lever/Reverse Lever interlock is mechanical. The reverse lever cannot be operated unless the thrust lever is at Idle. Conversely, with reverse selected the thrust lever cannot be advanced from Idle. Refer to Figure 6-6.

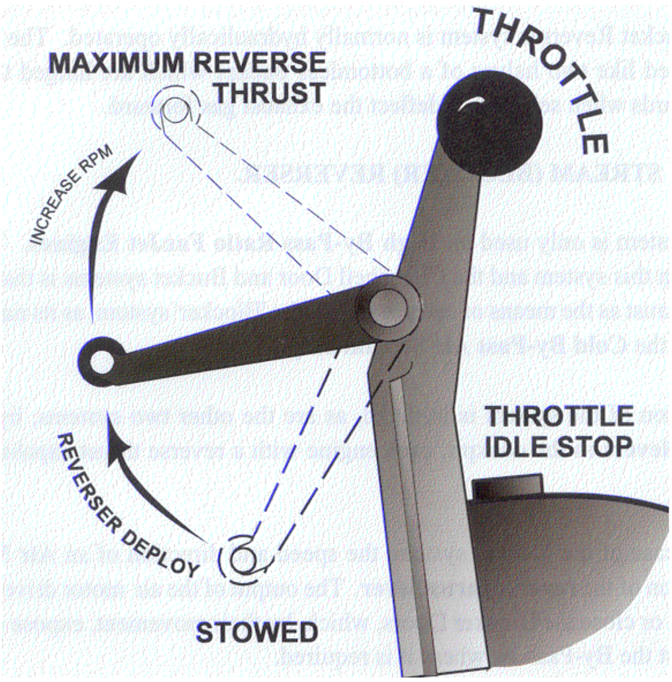

Figure 6-6 Thrust - Reverse Lever Interlock

Reverse Thrust Restrictions

Reverse thrust is most effective at high speeds. Touchdown speeds on a B747 are in the region of 150 knots. As the aircraft slows down the depression in the air intake will overcome the deflection applied to the exhaust gas stream (and any associated debris), and suck it into the compressor with potentially catastrophic results.

To prevent the likelihood of this happening, the reverse thrust lever is returned to the reverse idle position at typically 60 to 80 knots and stowed by 50 knots.

Airbus A380 aircraft have the outboard reversers locked out to prevent FOD ingestion.

Turbo Prop Reversing will be covered in Chapter 10.

THRUST AUGMENTATION

Thrust Augmentation comes in two categories, they are;

- Afterburning (Reheat), and
- Water and Water Methanol Injection.

Afterburning

Thrust Augmentation by afterburning makes use of the unused oxygen in the exhaust to release more heat energy by burning more fuel between the turbine and the propelling nozzle. Afterburning is used to improve takeoff and climb or combat performance and is usually restricted to military aircraft. Refer to Figure 6-7.

Fuel is introduced into the jet pipe through discharge nozzles and ignited, increasing the volume of gas in accordance with Charles' Law.

The jet pipe will have a Variable Area Propelling Nozzle, closed for non afterburning operation and open, to allow for an increased volume of gas during afterburning operation. Refer to Figure 6-8.

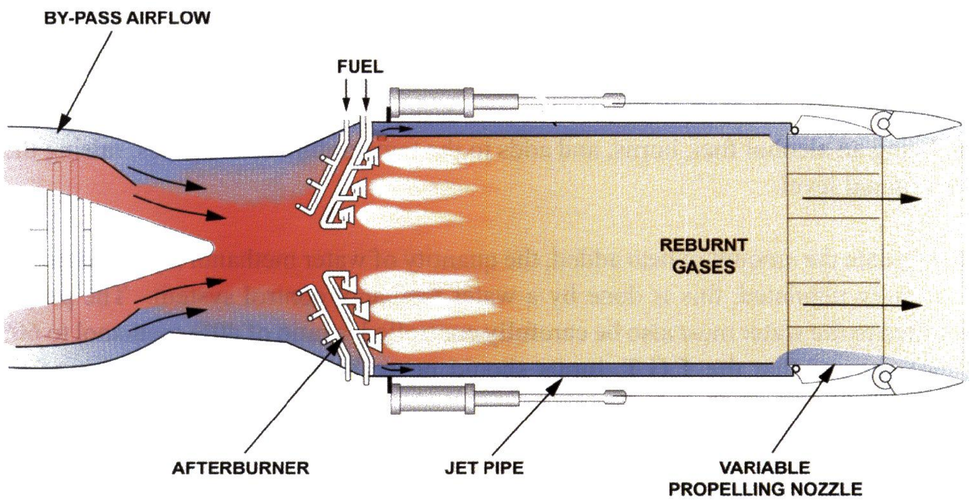

Figure 6-7 Afterburner Detail

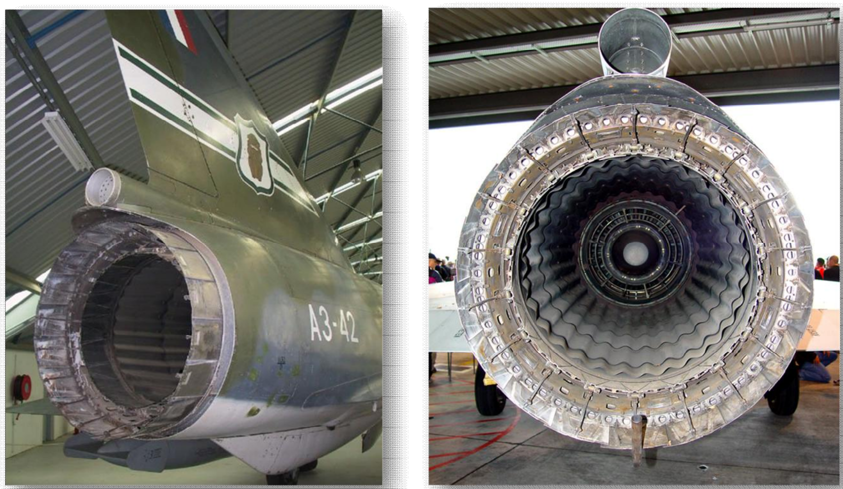

Figure 6-8 Mirage Afterburner with a Variable Propelling Nozzle

Water and Water Methanol

Water and water methanol injection is defined by the method of injection. Simply described Water Injection is injected straight into the intake. Water Methanol is injected into the combustion chamber.

Water Injection can restore the thrust of a turbojet engine and boost output of a turboprop in conditions of high density altitude. The water injection system is typically activated by moving the thrust lever to the take off position.

The power of a gas turbine engine depends on a large extent upon the Mass Flow through the engine. In conditions of hot and/or high temperature, the density and therefore the Mass Flow through the engine decreases, causing a reduction in available power. Water cools the air therefore restoring the Mass Flow. Figure 6-9 shows the thrust restoration profile of a typical turbojet engine.

Although the mass flow can be increased with relatively few problems by increasing the compressor speed, the maximum output pressure must be limited to prevent the compressor case from splitting.

Water Methanol is injected straight into the combustion chamber. Therefore the Mass Flow through the turbine is increased relative to the compressor. This increase in mass flow is not used to increase RPM and therefore compressor pressure.

A pure water injection system does have some drawbacks, not at least because all the water must be used on takeoff if it is not to freeze during flight. Water Methanol is added as an anti-freeze and has an additional bonus. By injecting coolant into the combustion chamber the gas temperature is lowered dramatically which somewhat lowers the power available.

Methanol, being an alcohol fuel, burns, and adds to the temperature of the gasses, raising the E.G.T. back to the original level. This produces a lot of smoke as shown on Figure 6-10.

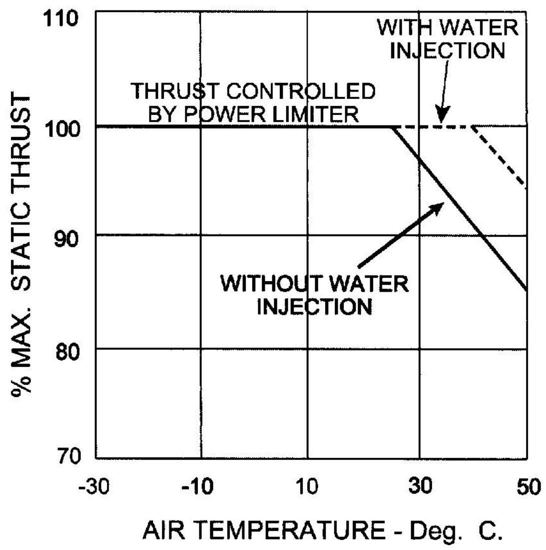

Figure 6-9 Thrust Restoration Profile

Figure 6-10 B707 JT3C Engines with Water Methanol