C-17 Globemaster Jet Engine Thrust Reversers

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The ever-adaptable jet engine not only provides forward thrust for aircraft flight, but it can be configured to provide reverse thrust. This reversal can augment the safe braking of both commercial and military aircraft during landing.

Gas turbine or jet engine thrust power is equal to the momentum increase in the mass flow from engine inlet to exit, multiplied by the flight velocity. The actual thrust force produced in the engine (and pulling the plane forward) is the summation of all the axial components of the pressure and frictional forces generated by the gas path flow on stators and struts attached to the engine case. Case engine mounts then transmit the thrust forces to the wing pylon (for a wing-mounted jet engine) to pull the aircraft forward.

A jet engine thrust reverser is a device mounted in the engine nacelle to divert some portion of engine flow in a forward direction to flight, using the momentum of the reversed flow to slow the aircraft. It is activated by the pilot or the aircraft flight control system on landing. (An attentive passenger can detect its deployment by a sudden high- pitched increase in engine noise, just after touchdown.) The thrust reverser deployment alters engine thrust forces reviewed in the last paragraph, so that the wing pylon now pulls back on the aircraft's forward motion.

There are a variety of thrust reverser designs, for both turbojets and turbofan engines. I refer the reader to engine OEM publications, such as one by Rolls-Royce[1], for more details.

C-17 THRUST REVERSERS PROVIDE UNIQUE VERSATILITY

The deployment of thrust reversers on the U.S. Air Force's McDonnell Douglas/Boeing four-engine C-17 Globemaster is an example of the unique versatility they can offer to aircraft operation.

The C-17 Globemaster III (shown in Fig.1) is typically

Figure 1. McDonnell Douglas/ Boeing four engine C-17 Globemaster III in flight.

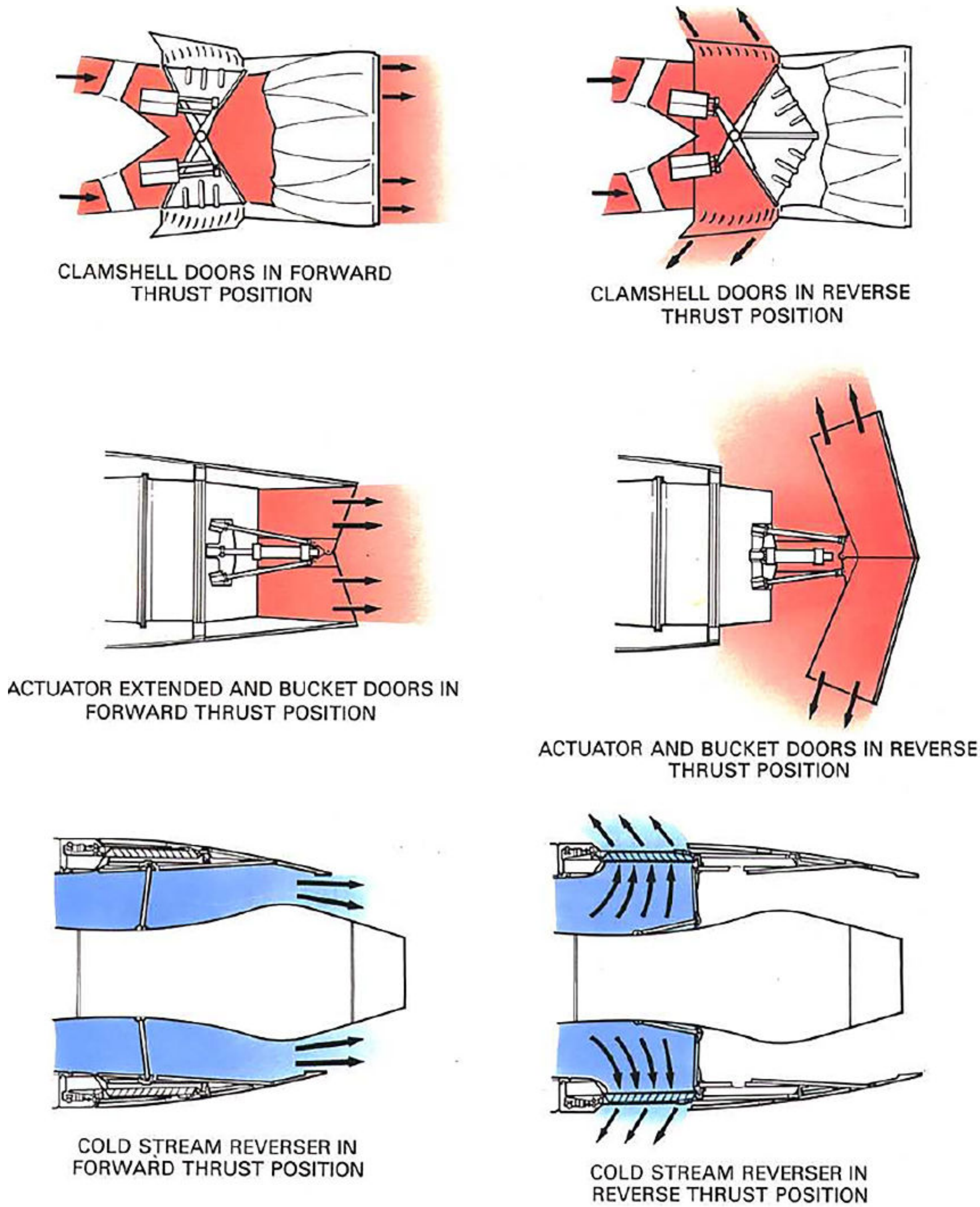

Figure 2. Various thrust reverser designs. The simplified schematic showing the cold stream class is used in C-17 nacelles. (1)

flown by a crew of three and is perhaps the most flexible military cargo aircraft in the world. At a maximum payload capacity of 170,900 pounds, it can carry a 70-ton Abrams tank to a battlefield or, as on August 15, 2021, the US Air Force transported 823 Afghanistan citizens from Kabul in a single flight during a humanitarian mission.

The 174-foot-long C-17 is powered by four Pratt & Whitney F117 turbofan engines, each rated at 40,400 pounds thrust and mounted in nacelles under the high-lift, swept-back 170-foot span wing for maximum ground clearance. C-17 cruise speed is 450 knots (0.74 Mach number) with an unrefueled range of about 2400-2800 nautical miles, depending on which model[2]. A takeoff distance at maximum weight is 8,200 feet.

Designed and built by McDonnell Douglas at their DC-10 plant, the first C-17 flew in Long Beach, California on September 15, 1991. Later, in 1997 the company merged with Seattle's Boeing, with C-17 production continuing in Long Beach, until the last delivery in 2013. In all 279 C-17's were produced, with 223 going to the US Air Force (giving it a monstrous single nation lifting capacity) and the remaining 56 to other national militaries.

The C-17 thrust reversers (identified in Fig. 2 as a cold stream reverser (of fan flow)) are of a unique and flexible design, providing an exit area for reverse flow for only half of their full circular circumference (see Fig. 3). The reverse flow is directed upward and forward, to avoid dust and debris production when landing on an unimproved (austere) field. This reduces the risk of possible debris ingestion, which could damage the F117 engines[4]. (In [4], the video (with sound) shows the C-17 landing with thrust reversers activated (detected by the higher-pitched revved-up engine noise), with no sign of stirred-up ground debris being ingested by the engines.)

With the thrust reversers, the C-17 can operate on unpaved, unimproved runways as short as 3500 feet, and as narrow as 90 feet. On the ground the thrust reversers can back a fully loaded C-17 up a two-degree slope. In flight, the C-17 thrust reversers can be deployed, to provide a rapid aircraft descent.

A C-17 THRUST REVERSER DEVELOPMENT COLLABORATION VIGNETTE

Since the C-17 thrust reverser only provided exit area for the Pratt & Whitney F117 fan flow over about half of the circumference, there was a concern for non-uniform back pressure that would reduce the fan stall margin.

In 1990, my P&W colleague, Senior Fellow and engine stability expert Bob Mazzaway[3] had, evaluated this threat and showed analytically that axial spacing from the fan was sufficient to prevent a problem. Naturally, the Air Force needed a proof test which was scheduled to take place at the P&W test facilities in Florida using the first McDonnell Douglas nacelle.

By sheer luck, my colleague, Senior Fellow and aeroengine expert Pentti Nikkanen walked past the engine with the McDonnell Douglas nacelle on the East Hartford assembly floor, as it was being prepped for shipment to Florida. He noticed that the reverser cascades (see Figures 2 and 3) were missing axial "strongbacks", a structural component that reinforces the thin, high aspect ratio airfoils of the cascade. This prompted an emergency telecon with McDonnell Douglas to alert them. At one point they sent an engineer to inspect the thrust reverser on their DC-10 aircraft nacelle designed by GE. He reported back to the meeting confirming "strongbacks" in that installation. Since the proof-of-concept test was vital to the program, it was decided to wire lace the cascade airfoils to reinforce them. The Air Force was also alerted to the issue. The reinforced cascades lasted long enough to confirm the fan stability predicted by Mazzawy. Testing ended shortly thereafter with the cascades "leaving the premises" …. the wire lacing endured just long enough, having saved the day for both companies. ◆

Figure 3. C-17 wing mounted F117 nacelle with thrust reverser deployed, showing cascades for providing reverse flow on upper half of the nacelle only.

REFERENCES

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