PW2000 & RB211-535 specifications

The RB211-535 & PW2000 series have seven variants between them. Their characteristics and specifications are described.

The 757 family is powered by two main engine types: the PW2000 and RB211-535, each with three variants.

The 757-200 was offered with the RB211-535C, -535E4, -535E4-B, PW2037 and PW2040 engines. The 757-300 was offered with the RB211-535E4-B, -535E4-C, PW2037, PW2040 and PW2043.

The initial engine variants powering the 757-200, which entered service in 1983, were the PW2037 and the RB211-535C. Soon afterwards, Rolls-Royce (RR) developed the RB211-535E4, with the -535C powering just 58 aircraft. Pratt & Whitney (PW) introduced the higher-thrust-rated PW2040 in 1987.

RB211-535

In addition to the RB211-535C, there are three variants of the RB211-535E4: the -535E4, -535E4-B and -535E4-C.

The RB211-535E4 replaced the -535C and entered service in 1984 with Eastern Air Lines. Shortly afterwards, 18 aircraft originally fitted with the -535C were re-engined with the -535E4.

The RB211-535 has the three-shaft design of the original RB211 family. This separates the fan and low pressure compressor (LPC) on the low pressure shaft of a two-shaft engine into a low pressure shaft (fan) and intermediate pressure shaft (compressor). This allows the intermediate pressure compressor (IPC) to turn at a higher speed than the LPC is able to in a two-shaft engine. The IPC and high pressure compressor (HPC) therefore require fewer stages than the compressor sections of a two-shaft engine. This gives the RB211-535 a shorter, stiffer structure, and results in a low rate of exhaust gas temperature (EGT) margin erosion. It also reduces the need for compressor variable guide or stator vanes.

The RB211-535 has a fan diameter of 74.1 inches, a six-stage IPC, a six-stage HPC, a single-stage high pressure turbine (HPT), a single-stage intermediate pressure turbine (IPT), and a three-stage low pressure turbine (LPT). This basic configuration has been used on every variant of the RB211-535. The 12 compressor and five turbine stages compare to the PW2000's 16 compressor and seven turbine stages.

The RB211-535C was the last variant of the RB211 family to use fan blades with a mid-span shroud. The -535C is rated at 37,400lbs thrust. The new -535E4 introduced the use of wide-chord fan blades, which do not have a mid-span shroud. Their wider chord means there are fewer blades in the fan section, which improves fuel burn efficiency and resistance to foreign object damage.

The -535E4 variant has a rating of 40,100lbs thrust *(see table, page 13)*. The later -535E4-B variant, introduced on the 757-200 in 1989, is rated at 43,100lbs thrust. The -535E4-C, powering the 757-300, is rated at 43,100lbs thrust. All three variants have the bypass ratio of 4.3:1.

The -535E4 also featured extensive use of advanced computer-designed aerodynamics, resulting in, among other things, the wide-chord fan blade.

RR's development of the Trent engine family and its 04 HP (high pressure) module meant that later production examples of the RB211-535E4 benefited from Phase 5 combustor technology. This reduced NOx emissions.

RR further developed the -535E4 to become the higher-thrust -535E4-B, which went into service with American Airlines in 1989. The third variant, the -535E4-C, went into service on the 757-300 in 2001.

According to ACAS, there are currently 577 RB211-535E4-powered 757s, of which 349 have the original RB211-535E4 and 216 (757-200, -200EM, -200PCF and -300) have the -535E4-B. Only 12 757-300s have the -535E4-C, operated by Continental and the now defunct ATA Airlines.

The final order status for the 757 saw RR with 59% of the 1,049 aircraft built. The RB211-535 was also chosen by 43 (78%) of Boeing's 55 customers for the 757. The -535E4 engine has also recently been used on the Tupolev Tu-204 family.

The RB211-535E4-powered 757 is the quietest airliner in its class, and meets both Chapter/Stage 3 and 4 limits with large margins.

PW2000

There are three variants of the PW2000: the PW2037, PW2040 and PW2043.

The PW2037 entered service on the 757-200 in 1984 with Delta Airlines. It is

The RB211-535E4 became the most popular engine selection for the 757-200/-300, powering 59% of the 1,049 aircraft built.

a conventional two-shaft turbofan engine, with a 78.5-inch-wide fan, a four-stage LPC, 12-stage HPC, two-stage HPT and five-stage LPT. The two-stage HPT design gives the PW2000 better fuel burn performance than the RB211-535.

The PW2037 is rated at 38,250lbs thrust and has a bypass ratio of 6.0:1. The PW2040's thrust rating goes up to 41,700lbs, and the engine entered service in 1987 for UPS. The PW4043 was certified in 1995, but did not enter service until 2002 with Northwest, and is rated at 43,000lbs thrust.

The PW2000 was the first to offer Full Authority Digital Electronic Control (FADEC), an electric engine control system. The PW2000 also uses new materials, new airfoil profiles, new combustor configurations and other special technological features.

There are 429 757s powered by the PW2000 series engines. Most of these, 289, are equipped with the PW2037, while 140 are powered by the PW2040.

The ACAS fleet database lists no aircraft fitted with the PW2043 engines, although this could be because current PW2000 engines can be converted to a PW2043 through simple minor external modifications.

RB211-535E4 & PW2000 THRUST RATING & SPECIFICATION DATA

Engine	Aircraft application	Take-off thrust lbs	Max EGT take-off	Bypass ratio	Flat rated temp deg C
PW2037	757-200	38,250	897	6.0:1	30.55
PW2040	757-200/-300	41,700	897	6.0:1	30.55
PW2043	757-200/-300	43,100	897	6.0:1	30.55
RB211-535C	757-200	37,400	N/A	4.3:1	29
RB211-535E4	757-200/-300	40,100	850	4.3:1	29
RB211-535E4-B	757-200/-300, Tu-204	43,100	897	4.3:1	29
RB211-535E4-C	757-300	-E4-B plus 4%	877	4.3:1	29

Noise compliance

Both engine series and their various models are compliant with Chapter/Stage 3 noise requirements.

In June 2001 a new Chapter/Stage 4 noise standard, more stringent than Chapter/Stage 3, was adopted. From 1st January 2006, the new standard applied only to newly certificated aircraft and to Chapter/Stage 3 aircraft for which re-certification to Chapter/Stage 4 is requested. The 757 therefore does not have to comply with Chapter/Stage 4 requirements.

Chapter/Stage 4 noise rules are that only aircraft certified after 1st January 2006 should have a cumulative noise reading of 10 EPNdB lower than their permitted Chapter/Stage 3 cumulative noise emissions.

The 757 family has Chapter/Stage 3 compliance margins varying from 11.30 EPNdB to more than 22 EPNdB. They are therefore all still Chapter/Stage 4 compliant by 1.3-12EPNdB.

Although the 757 does not have to be Chapter/Stage 4 compliant, it would if regulations change, and could become so with no additional modifications.

The RB211-535E4-powered variants have the highest noise compliance margins, with many having a margin of more than 20EPNdB.

NOx emissions compliance

The Phase 5 combustion technology and the excellent noise output, meant that the RB211-535E4 was the most environmentally friendly engine available for the 757. The new combustor allowed the engine's NOx emissions to meet CAEP IV standards. The older engines, which have Phase 2 combustors, do not have to comply with CAEP IV standards.

Etops

Shortly after the 757 entered service in the early 1980s, extended-range twin-engine operations (Etops) were pioneered, making possible the operation of twin-engined aircraft on long-range missions over water or remote areas with no suitable alternate airports. Etops is only permitted once a particular airframe-engine combination has demonstrated a specified level of in-service reliability. It also requires the aircraft to have specific equipment and safety equipment configuration, and operators to implement specific maintenance and operational procedures.

The RB211-535E4-powered 757-200 was certified for 120-minute Etops in 1986. This means that the aircraft is permitted to follow a route over water provided it is within 120 minutes' flying time of a suitable diversion airport when operating with one engine shut down.

The PW2000-powered 757 achieved 120-minute Etops certification in 1990, and a few months later the RB211-powered aircraft achieved certification for 180-minute Etops. The PW2000-powered aircraft achieved 180 minutes certification in 1992.

Most long-distance routes over water and remote areas can be flown directly with an aircraft that has 180-minute Etops certification.

Major upgrades

Most upgrades and modifications have been for the PW2000 series of engines with only a handful of active airworthiness directives (ADs) for each of the engine series.

As the PW2000 and RB211-535 were developed and superseded, more upgrades and modifications were required to improve the existing engines in operation.

PW introduced the Performance Improvement Package (PIP) in 1988, and the Reduced Temperature Configuration (RTC) in 1994. Both improved durability.

The PIP and RTC were a modification to existing engines and a new configuration for subsequently manufactured engines. The other modification available on the PW2000 was the external modification to upgrade an engine to the PW2043 specifications, which again improved durability.

RR's major upgrade (available as a modification, but rarely taken up) involved using new Phase V combustor technology.

PW2000 (PIP)

In 1988, PW brought out the PIP, a new package to improve durability (SB 72-143). This improvement involved modifications to, among other things, the fan exit case and liners, P2.5 bleed valve ducts, number 4 bearing cooler assembly and oil cooler manifolds.

PW2000 RTC

The RTC was certified in September 1993 and introduced as the improved manufactured version of the PW2000 in 1994. It was designed with new temperature reduction features as well as increased capability in the second generation FADEC. The new configuration was offered on new engines, and as an option to modify older PW2000 engines to RTC standards with a Compressor Exit Temperature (CET) kit.

The RTC modification included improvements to the second vane and

The PW2000 is concentrated among three big carriers; Northwest, United and Delta. These three operators accounts for 305 of the 429 PW2000-powered 757s built.

airseals, blade and vane clearances to optimise efficiency, and the application of a thermal coating to the first vanes. The first turbine blade had a metal temperature margin of 300°F, the fan blade and spinner cap were more robust, additional sound treatments were added, and the LPC was supercharged. These new RTC features contributed to a 1+ dB reduction in noise, a 50°F reduction in EGT and another 1% improvement in specific fuel consumption.

The RTC modification improved reliability, durability, on-wing times and environmental performance, and reduced total maintenance costs and fuel burn.

Upgrade to PW2043

PW2000 engines can be 'upgraded' to PW2043, thereby increasing their thrust rating and performance capability. The PW2043 provides additional thrust at high altitudes and/or elevated temperatures, through minor external modification (some software modifications and the addition of an extra fuel pump). Enhancements to the upgraded engine have increased its time on-wing and lowered maintenance costs.

Northwest Airlines, the intended launch customer for the aircraft/engine combination, had ordered 16 PW2043-powered 757-300s, but actually took delivery of 16 PW2040-powered 757-300s. To date, no PW2043 engines have been delivered, although it is still listed as a legitimate engine option for the 757-300.

RB211-535 Phase V

In 2000, RR introduced the Phase V combustor that would allow the RB211-535E4 engines to comply with new CAEP IV regulations for NOx emissions being introduced, even though the RB211-535E4 did not actually need to comply with CAEP IV. RR had already developed a new combustor for the Trent series of engines to meet CAEP IV emissions levels, and decided to integrate this into new-production RB211-535E4s.

The combustor was known as Phase V, and was standard in later engines. The modification (SB72-C23-) meant lower NOx emissions, with major changes to the combustor as well as some of the adjacent hardware. It proved to be less popular than expected and fewer than 200 engines have the Phase V technology.

Airworthiness directives

The RB211-535 series comes under the jurisdiction of the UK Civil Aviation Authority (CAA). The CAA has been responsible for issuing ADs for RR engines, although recently this has been more the remit of the European Aviation Safety Agency (EASA).

The PW2000 series comes under the jurisdiction of the American Federal Aviation Administration (FAA).

In 2003 the CAA issued AD G-2003-0007 for the RB211-535. It stated that focused inspections must be carried out on the Group A (critical) parts to prevent Group A (critical) rotating engine part failure.

In 2005 ADs were issued about both engine series. The FAA said that its study into failures of critical rotating PW2000 series engine parts necessitated obligatory inspections. It required revisions to the airworthiness limitations section of the manufacturer's manual and an air carrier's approved continuous airworthiness maintenance programme to incorporate additional inspection requirements. AD 2005-18-03 was issued to prevent critical life-limited rotating engine-part failure. This enhanced rotor inspection was connected to the FAA's safer skies initiative.

Acting on behalf of EASA, the CAA issued AD G-2005-0028 R1 instructing an enhanced inspection of the HPC interstage 1-2 weld for all RB211-535-series-equipped aircraft. This was after an overhaul inspection of HPCs 1 and 2 rotors had identified cracks running in an axial direction in the region of the weld and between the stage 1 and 2 rotor discs, representing a potential hazard to the rotor integrity.

A year later, EASA issued AD 2006-0182, saying that the HPT discs on the RB211-535 series failed to meet the inspection acceptance criteria and were returned to RR with cracks in the disc rim. The conclusion was that this was due to scores within the cooling air holes in the disc rim possibly introduced during manufacture or overhaul. This AD mentioned the CAA AD (G-2004-0027) that had addressed the same issue about 18 months earlier.

In the past 18 months there have been three ADs: one about the PW2000 series (AD 2007-02-06); and two about the RB211-535E4 series (EASA 2008-0045 and FAA 2008-13-20).

AD 2007-02-06 required a one-time focused inspection of PW2000 eighth-stage HPC drum rotor disk assemblies due to a failure caused by tooling damage.

A detailed inspection of the RB211-535E4's LPT discs during module overhaul and refurbishment found a processing error, which meant that items with undetected cracks could be in operation. AD 2008-0045 dealt with this problem and required removal, inspection and replacement of the affected parts. The module overhaul and refurbishment processes are being reviewed. The most recent, AD 2008-13-20 requires repetitive inspections of the aft hinge fittings and attachment bolts of the thrust reversers for signs of damage. Corrective measures were then to be taken. This AD was issued after many cases of failure, due in particular to high operational loads. AC