# PW4000-94 specifications

## The PW4000-94 powers more than 700 1980s-generation widebodies. It's thrust ratings vary from 52,000lbs to 62,000lbs.

The Pratt & Whitney (PW) PW4000-94 series powerplant, with a 94 inch-fan diameter, is the first of three family series. With certified thrusts of 52,000-62,000 pounds, it powers the A310-300, A300-600, 747-400, 767-200/300 and MD-11 aircraft. For twin-engine aircraft, the PW4000 is approved for 180-minute extended-range twin-engine operations (ETOPs). The two subsequent and more powerful series developed for the A330 and 777 aircraft have 100- and 112-inch diameter fans.

There are 10 main application/thrust variants of the PW4000-94 series: the PW4052, PW4056, PW4060, PW4062, PW4152, PW4156, PW4158, PW4460, and PW4462. The characteristics of all these variants are summarised *(see table, this page).*

The system for the PW4000-94's nomenclature uses the second digit to indicate the airframe manufacturer application for which the engine variant is used, and the last two digits to indicate the thrust at which the engine is rated. For the second digit, a 0 indicates that the engine is used on a Boeing aircraft, a 1 denotes Airbus, and a 4 McDonnell Douglas. If the last two digits are 52, this indicates a rating of 52,000lbs thrust. The use of 56, 58, 60 and 62 therefore indicates thrust ratings of 56,000lbs, 58,000lbs, 60,000lbs and 62,000lbs. For example, the PW4156A is rated at 56,000lbs thrust and powers an Airbus aircraft, in this case the A310-300. It also has an improved take-off rating 'boost' option for hot-and-high operations.

The PW4000-94 was launched in 1982 and received its FAR Part 33 certification in 1986. The first PW4000-94, a PW4152, was installed on an Airbus A310 delivered to Pan Am in 1987. Subsequently, the family was certified on the following aircraft: A300-600 (PW4158), 767-200/-300 (PW4052, PW4056, PW4060 and PW4062), 747-400 (PW4056 and PW4062A), and the MD-11 (PW4460 and PW4462).

Apart from take-off thrust ratings, the main differences between the engine variants are associated engine mountings, nacelles, quick-engine-change (QEC) and full authority digital engine control (FADEC) configurations. Although PW has originated service bulletins (SBs) so that the engine can be converted from one aircraft application to another, such exercises are rare in practice, even for engine sale or lease situations.

By September 2007, these versions of the PW4000 had accumulated in excess of 89 million engine flight hours (EFH) and 18.4 million engine flight cycles (EFC).

While there is no modular interchangeability between the PW4000-94 and its two larger siblings, there is some parts commonality with the 100-inch version at the line-replaceable-unit (LRU) level. Some internal components are also interchangeable. Likewise, there is also some commonality of engine shop tooling with the 100-inch version, with 67% of the tools being identical.

The engine incorporates single-crystal superalloy turbine blade materials and has FADEC as standard. For a further reduction in emissions, especially NOx, Technology for Advanced Low NOx (TALON) combustor technology (derived from the 112-inch fan model) became available as an option in the late 1990s. TALON uses segmented, replaceable liner panels for improved maintainability, and air blast fuel nozzles for better fuel atomisation and mixing. The PW4000-94 engines are flat rated at 30°C, 33°C or 42°C. The bypass ratio ranges from 4.8 to 5.1, the overall pressure ratio from 27.5 to 32.3, and the fan pressure ratio from 1.65 to 1.80.

Today, there are 2,169 PW4000-94s in the world fleet, powering about 717 aircraft. Around half of all these engines power 225 747-400s. The next largest engine fleet grouping is for 205 767-200/-300s. Meanwhile, the PW4000-94 also powers about 147 A300-600s, and 48 A310-300s. About 75 MD-11s are also equipped with the PW4460/62.

The PW4000-94 can broadly be divided into two groups on the basis of its style of operation. Most engines are operated on long average EFC times, of five hours or more per cycle, which is typical of 767, 747-400 and MD-11 applications. These long cycles minimise engine wear and maximise on-wing life. In contrast, the engines operated on the A300-600 and A310 have shorter average EFC times.

### LLP lives

All PW4000-94s have the same core architecture and stage configuration. Each therefore has a fan, four-stage booster or low pressure compressor (LPC), an 11-stage high pressure compressor (HPC) , a two-stage high pressure turbine (HPT), and four-stage low pressure turbine (LPT). For the 94-inch engine, most life limited parts (LLP) have lives that are mostly fixed at either 20,000 engine flight cycles (EFCs) or 15,000 EFCs. Engines rated at 50,000lbs, 52,000lbs and 56,000lbs thrust have

**PW4000-94 SERIES THRUST RATING & SPECIFICATION DATA**

| Engine model | Take-off thrust lbs | Flat rate temp deg C | EGT red line deg C | Aircraft application |
|---|---|---|---|---|
| PW4052 | 52,200 | 33 | 644 | 767-200/-200ER/-300 |
| PW4056 | 56,750 | 33 | 654 | 767-200/-300 |
| PW4056 | 56,750 | 33 | 654 | 747-400 |
| PW4060 | 60,000 | 33 | 654 | 767-300/-300ER |
| PW4060A | 61,570 | 33 | 654 | 767-300/-300ER |
| PW4152 | 52,000 | 42 | 644 | A310-300 |
| PW4156 | 56,000 | 30 | 654 | A300-600/A310-300 |
| PW4156A | 56,000 | 33 | 654 | A310-300 |
| PW4158 | 58,000 | 30 | 654 | A300-600 |
| PW4460 | 60,000 | 30 | 654 | MD-11 |
| PW4062 | 62,000 | 30 | 654 | 767-200/-300 |
| PW4062A | 62,000 | 30 | 654 | 747-400 |
| PW4462 | 62,000 | 30 | 654 | MD-11 |


*The majority of PW4000-94s are used to power long-haul aircraft, including about 220 747-400s. Having been modified, the PW4000-94 is capable of removal intervals exceeding 18,000EFH.*

LLPs with lives of 20,000EFC, and engines with higher ratings have lives of 20,000EFC.

For operations where the EFH:EFC ratio is about 5:1, LLP-associated engine removals will not usually be a problem.

There are two parts with lives of 30,000 EFC: the LPT shaft and the LPT coupling. Since most engines accumulate only 600-700EFC per year, it is unlikely that these two parts will have to be replaced. Moreover, the LLPs with lives of 20,000EFC will have to be replaced only after 30 years in some cases.

According to Wayne Pedranti, engineering group program manager at UK-based Total Engine Support (TES), a complete set of LLPs has a current list price of $3.5 million.

Given that EFH times per cycle vary for different operations, the accumulated EFH intervals between LLP replacement therefore vary with application. For example, A310s and 767s powered by PW4152,s PW4156s and PW4056s have LLPs with lives of 20,000EFCs. These aircraft typically operate at 3.0FH per FC and the engines can achieve 16,000-18,000EFHs and 5,000-6,000EFCs between removals. In this case, LLP replacement will occur every three to four shop visits, or every 50,000-55,000EFH.

The higher thrust engines (such as PW4158s on A300-600s) which contain LLPs lifed at 15,000EFC, and which operate FH:FC ratio of 1.5, will incur LLP replacement at every fourth shop visit, equating to every 22,500EFH (assuming shop visits typically occur every 6,000EFHs or 3,700-4,000EFCs).

The highest thrust-rated PW4060/62s, operated on the 767 and MD-11, also have LLPs with lives of 15,000EFC. These aircraft typically operate with FC times of 5-9FH. Moreover, average engine shop visit intervals are typically every 15,000EFH. While the shorter-cycle (5.0EFH) engines will have LLPs replaced every fifth shop visit (equating to 75,000EFH), with the longer cycles of 9.0EFH, the same engine model will achieve a longer cumulative LLP on-wing life of up to 135,000EFH. LLPs will only need to be replaced every nine or 10 shop visits.

"Pratt & Whitney has designed LLPs to have the same lives so that operators do not have to manage removals around the expiry of individual LLPs," explains Pedranti. "It was meant to ensure that everything synchronises such that the first time the engine comes in, you just 'go into' the core, and the second time the engine comes in, there is a heavier workscope and this provides an opportunity to change LLPs. While this is what was designed to happen, the reality is that it does not."

## EGT margin & flat rating

To guarantee how a new engine will perform, there are two different flat rating concepts used by engine manufacturers. One concept is to rate the engine to a constant compressor speed. The other concept is to flat rate the engine to a constant exhaust gas temperature (EGT). PW uses the latter of the two. The flat rate temperature is the outside air temperature (OAT) above which the EGT is held constant, or 'flat rated', by reducing thrust. Moreover, as long as the OAT is below the corner point, then the thrust is constant. The EGT rises as OAT increases, and the EGT rises at a constant rate of 2.8 degrees centigrade per one degree centigrade increase in OAT when thrust is held constant at the maximum rating.

In the case of the PW4000-94 family, all family engines have the same gas path design. Higher thrust ratings are achieved by a higher throttle setting and by adding more fuel and higher rotational speeds. In essence, a PW4462 has to work much harder to maintain 60,000lbs thrust than a PW4152 does at 52,000lbs thrust. This is reflected by the higher rated variants having lower flat-rated temperatures *(see table, page 10)*. Also illustrated are the respective maximum permissible EGT redline operating temperatures for the various models within the PW4000-94 family.

It should be noted that because the PW4152 works less and has a greater EGT margin, it can maintain constant thrust up to an OAT of 42°C, whereas a PW4460 can only maintain constant thrust to a temperature of 30°C as it is operating much closer to its EGT margin.

EGT margin is the difference between the constant actual flat-rated EGT and the red-line temperature limit. As a result, even though this PW4152 has a flat rate of 42°C, its absolute EGT is lower than that of the PW4462 at its respective 30°C flat rate temperature. While this is true for a new engine, the constant EGT at flat rate becomes hotter as the engine deteriorates through accumulated flight cycles. In general therefore, and given that the different thrust-rated PW4000-94 share a common gas path, new engines with higher thrust typically have higher EGT than that of a lower thrust version. Therefore, the higher thrust engine would have the shorter on wing life.

When early models of the PW4000-94 were released, there was no international standard on the flat-rate temperature. These early engines had therefore been assigned flat-rate temperatures that were dependent on the engine design in relation to operational thrust expectations. These varied from 33°C to 42°C. Later models of the engine were subject from the outset to an international standard which assigned the flat-rate on a 'standard day' of ISA+15 (30°C) rating for take-off. However, the maximum continuous figures are still dependent on the design of the engine, hence the wide variation, and are set by the interactions between the compressors and turbines. AC