CF6-80C2 series specifications

The CF6-80C2 is a ubiquitous engine, with more than 3,200 units in operation and powering five widebody aircraft families.

The General Electric (GE) CF6-80C2 series is one of the most popular widebody engines in operation. The first engines were delivered in 1986 and there are still outstanding orders for 747-400s with CF6-80C2 engines. A main factor in its popularity is that it has 13 main variants and it powers five main widebody types. There are more than 1,200 aircraft and in excess of 3,200 installed engines in operation. The large number in service and the young age of the aircraft it powers, mean that the CF6-80C2 will continue to operate for at least another 20 years.

Configuration

The CF6-80A and -80C2 are derived from the CF6-50, developed to power the DC-10 and later the A300B2/B4 and 747-200 in the 1970s.

The CF6-50 and -80 are two-shaft engines. The -50 has an 86.4-inch fan diameter, a three-stage low pressure compressor (LPC), 14-stage high pressure compressor (HPC), two-stage high pressure turbine (HPT) and four-stage low pressure turbine (LPT). Eight variants were rated at 51,000lbs-54,000lbs thrust for the DC-10-30 and 747-200. The fan diameter and configuration gave it a bypass ratio of 4.21-4.31, depending on thrust.

The CF6-80A was a simple derivative of the -50 series, with the same fan diameter and engine configuration and lower thrust ratings. The -80/-80A1 are rated at 48,000lbs thrust, and the -80A2/-A3 at 50,000lbs thrust. All power the 767-200 and A310-200. The first -80As entered service in 1981.

The -80C2 series differs from the -80A only in that the -80C2 has a large fan diameter of 93 inches. This larger fan is turned through the use of a five-stage LPT, which is one more stage than the -50/-80A engines have.

The CF5-80C2 family has 13 main variants *(see table, page 12)*. These variants use a two- or three-character suffix to describe the engine's application. The first character of the suffix is the letter A, B or D, to denote the use of the engine on Airbus, Boeing or McDonnell Douglas (MDC) aircraft. The -80C2 is utilised on the A300-600 and A310, the 767 family and 747-400, and the MD-11.

The second character is a digit denoting the engine number in the series. The use of a third character will be an F, which indicates that the engine has full authority digital engine controls (FADEC). Engines without the F suffix use power management controls (PMC). Some variants offer both PMC and FADEC controls, while some offer one or the other option.

"FADEC controls allow the engine's fan N1 speed to be corrected to the actual thrust rating, so that it is possible to calibrate the correct N1 to get the correct thrust," explains Frank Herr, customer programme manager CF6 projects at MTU Maintenance. "The PMC is a less accurate control, so they generally have lower EGT margins and are removed earlier due to EGT margin erosion. The -B6F, for example, gets 30-40% more on-wing time than the -B6 due to higher EGT margin."

Family members

There are five A variants of the CF6-80C2: the -A1, -A2, -A3, -A5 and -A8. Only the -A5 is offered with both PMC and FADEC controls, while all the others have only PMC controls.

The -80C2A1 is rated at 59,000lbs thrust, flat rated to 86 degrees Fahrenheit (30 degrees centigrade), and powers the A310-200 *(see table, page 12)*. The flat rating temperature of 30 degrees centigrade is the 'corner point' temperature. That is, the engine can be maintained at maximum thrust up to an outside air temperature (OAT) equal to the corner point temperature. Exhaust gas temperature (EGT) is then held constant by the pilots adjusting the N1 power setting by following guidelines in the manual. The N1 setting is related to the OAT, so N1, and therefore engine power, reduce as OAT increases.

The -80C2A2 is rated at 53,500lbs thrust, flat rated at 111 degrees Fahrenheit (44 degrees centigrade), and powers the A310-200/-300. This high corner point temperature allows the engine to offer maximum thrust up to a high OAT of 44 degrees, making it appropriate for operations in hot environments.

The -80C2A3 is rated at 60,200lbs thrust and is flat rated up to 86 degrees Fahrenheit (30 degrees centigrade), and powers the A300-600 *(see table, page 12)*.

The-80C2A5 and -A5F are both rated at 61,300lbs thrust and are flat rated up to 86 degrees Fahrenheit. They power the A300-600 *(see table, page 12)*.

Most A300-600s are powered with -A3 or -A5 engines. The earlier-built aircraft were equipped with -A3 engines, while later builds were certified only with the higher-rated -A5 engines, which have higher rates of engine deterioration when operated at maximum thrust compared to the lower-rated -A3s. The -A5s, however, have more reserve power.

The -80C2A8 is rated at 59,000lbs thrust and flat rated up to 95 degrees Fahrenheit (35 degrees centigrade). It powers the A300-600 and A310-300, and provides operators with the ability to operate at maximum thrust at higher OATs than most other -80C2A series engines.

The -A2, -A3 and -A5 are the most numerous of the -80C2A series. They power 241 aircraft, 163 of which have engines with high thrust ratings. The -A1 and -A8 power just 31 aircraft.

There are seven variants of the CF6-80C2B series: the -B1, -B2, -B4, -B5, -B6, -B7 and -B8. All have FADEC controls, while the -B5, -B7 and -B8 do not offer the option of PMC controls.

The CF6-80C2B1 is rated at 56,700lbs thrust and flat rated to 86 degrees. It was used to power the last 747-200/-300s built in the mid-1980s.

The -80C2B1F is rated at 58,090lbs thrust, and flat rated at 90 degrees Fahrenheit (32.2 degrees centigrade). It was the first CF6-80C2 variant to power the 747-400. Most 747-400s with CF6-80C2 engines utilise this variant.

The -80C2B2 is rated at 52,500lbs thrust, flat rated at 90 degrees Fahrenheit, and powers the 767-200ER/-300ER. The -80B2F is rated slightly higher at 52,700lbs thrust, and powers the same aircraft.

The -B4, -B6, -B7 and -B8 all power the 767-200ER and -300ER, while the -B7 also powers the 767-400ER. The -B4 is rated at 57,900lbs thrust and the -B4F is rated at a slightly higher thrust of 58,100lbs thrust. The remaining engines are all rated at 60,800lbs thrust and flat rated at 86 degrees Fahrenheit *(see table, page 12)*.

The -B5F is rated at 60,800lbs thrust, flat rated at 86 degrees Fahrenheit and is the other engine option on the 747-400, although only a small number of aircraft have this engine.

CF6-80C2 SERIES THRUST RATING & PERFORMANCE DATA

Engine variant	Thrust rating (lbs)	Bypass ratio	Flat rate temperature Degrees C	EGT margin post shop visit Degrees C	Application
CF6-80C2A1	59,000	5.15	30	35-50	A300-600
CF6-80C2A2	53,500	5.31	44	40	A310-200/-300
CF6-80C2A3	60,200	5.09	30	35-50	A300-600
CF6-80C2A5	61,300	5.03	30	35-50	A300-600
CF6-80C2A5F	61,300	5.03	30	35-50	A300-600
CF6-80C2A8	59,000	5.15	35	35-45	A300-600 A310-300
CF6-80C2B1	56,700	5.19	30	35-60	747-200/-300
CF6-80C2B1F	58,090	5.15	32.2	35-50	747-400
CF6-80C2B2	52,500	5.31	32.2	45-60	767-200ER/-300ER
CF6-80C2B2F	52,700	5.30	32.2	45-60	767-200ER/-300ER
CF6-80C2B4	57,900	5.15	32.2	30-50	767-200ER/-300ER
CF6-80C2B4F	58,100	5.14	32.2	35-50	767-200ER/-300ER
CF6-80C2B5F	60,800	5.06	30	35-50	747-400
CF6-80C2B6	60,800	5.06	30	35-50	767-200ER/-300ER
CF6-80C2B6F	60,800	5.05	30	35-50	767-200ER/-300ER
CF6-80C2B7F	60,800	5.05	30	35-50	767-200ER/-300ER/-400ER
CF6-80C2B8F	60,800	5.05	30	35-50	767-200ER/-300ER
CF6-80C2D1F	61,960	5.03	30	30-35	MD-11

The -B1F, -B6/-B6F, -B7F and -B8F are the most numerous variants of the B series, powering 280 747-400s and 350 767s. All are rated at 58,000lbs or 60,800lbs thrust, and so have relatively high thrust ratings.

The CF6-80C2D1F is the only -80C2 variant available on the MD-11, and is rated at 61,960lbs thrust and flat rated at 86 degrees Fahrenheit. This is the highest thrust rating of all -80C2 variants, and powers more than 115 in operation.

All variants have the same basic hardware, with the exception of the difference between PMC and FADEC controls. This means a PMC engine can be changed from one variant to another, as can a FADEC engine. "There is an extensive list of service bulletins (SBs) to change between variants," says Henderson. "There may also be a hardware change required if the engine is being converted to operate at a higher thrust, and a change of rating plug on the electronic engine control (EEC).

In operation

The CF6-80C2 is used across a range of operations, with average engine flight cycle (EFC) times varying from one hour to nine or 10 hours. A few operators, such as Air New Zealand and Qantas, use the CF6-80C2 on their 747-400s and operate the aircraft on ultra-long-haul sectors of 10-13 hours.

The engine powers more than 1,200 aircraft, almost 1,000 of which utilise engines with thrust ratings of 58,000lbs or higher. The remainder use engines with the lower thrust ratings.

The first CF6-80C2s were delivered in 1981. In excess of 3,500 have been built over the last 25 years, with the engine accumulating more than 120 million engine flight hours (EFH) of operational experience. As a consequence GE has been able to identify weaknesses that have enabled it to improve the engine build standard progressively over the production period.

"The build standard of recently manufactured engines is superior to engines built in the early and mid-1980s and 1990s," explains Herr. "The engines can broadly be divided into block 1, block 2 and block 3 engines, with block 1 engines being the first built. Currently produced engines are block 3, and have only FADEC controls. Block 1 and 2 engines are no longer built, and have PMC controls. A -B1F engine built today, for example, can have an EGT margin of 75 degrees centigrade compared to 35 degrees centigrade for a block 1 -B1F built 10 years ago.

"The improvements over the production period come from improved blades and vanes, better life limited parts (LLPs), superior seals and incorporation of many SBs," says Herr. "These have led to higher EGT margins of new engines, lower rates of EGT margin deterioration, and improved EGT margin recovery rates following a shop visit. It is now possible for a block 1 engine to have a higher EGT margin following a shop visit than it originally had when first delivered, as a result of the various improvements made over the production period."

EGT margin

The EGT margin of new engines is mainly irrelevant, since most have passed their first shop visit. The restored EGT margin following a shop visit is more relevant to most operators.

"The rate of original EGT margin recovery will depend on the build standard of the engine, the workscope of previous shop visits, and the number of shop visits the engine has been through," says Herr. "First-run block 3 engines can usually recover 85% of their original EGT margin, which is more than the original margins on older block 1 and 2 engines. It is actually possible for a block 1 engine to recover more than 100% of its original EGT margin by incorporating blades, vanes, seals and cases that have since been developed. Later generation blades, for example, have added 8-10 degrees centigrade to EGT margins. These improved materials have also improved specific fuel consumption."

Nicola Henderson, engineer at Total Engineer Support (TES), explains that lower-thrust-rated variants, with thrust of up to 58,000lbs, will generally have EGT margins of 45-60 degrees centigrade following a shop visit, while engines with higher thrust ratings will have margins of 25-35 degrees centigrade following a shop visit.

The actual EGT margins of different operators will depend on their type of operation and maintenance policy. Finnair operates seven MD-11s on long-haul operations with an average flight cycle (FC) time of about seven hours with relatively high loads, and has an EGT margin of 30-35 degrees centigrade at the flat rate temperature of 30 degrees following a shop visit. "This compares with an EGT margin of about 45 degrees for a new engine," says Tuomo Karhumaki, vice president of the powerplant department at Finnair Technical Services.

The MD-11 has the highest rated variants of the CF6-80C2, and the next lowest are engines rated at 60,800lbs for the different members of the 767 family.

The -B1F powers almost all 747-400s, and is rated at 58,000lbs thrust. It can be expected to have higher EGT margins. Lufthansa Technik has an average post-shop visit EGT margin of about 60 degrees centigrade, which is a high rate of recovery of the original margin. "The EGT margin of new engines is about 64 degrees centigrade," says Paul Lueck, propulsion systems engineering at Lufthansa Technik.

EGT margins are measured at an OAT equal to the flat rating temperature. In the case of most variants this is 30 degrees, but it is higher at 32.2, 35 or 44 degrees with some of the -80C2 family members.

The EGT margin is the difference between the redline temperature of 960 degrees centigrade and the actual EGT produced by the engine.

Thrust is held at a constant rating up to the flat rating temperature, so EGT rises as a higher OAT is experienced. EGT is allowed to rise until the OAT equals the flat rating or 'corner point' temperature. The engine's EGT is then held constant for OATs higher than the corner point temperature via adjustments to throttle settings that result in reductions in thrust as OAT rises. The difference between the engine's EGT and the red line EGT, the EGT margin, is therefore held constant when OAT is higher than the corner point temperature.

Less than maximum thrust is therefore provided when the OAT is higher than the flat rating temperature. This can limit the performance of aircraft when operating in high OATs.

Airlines will have more than the standard EGT margin available in most operating conditions, firstly because thrust de-rate at take-off is often used. A de-rate of a few per cent will reduce the EGT by several degrees, thereby increasing the EGT margin by an equal number of degrees.

The second factor in making more EGT margin available is that most aircraft experience OATs lower than the flat rating temperatures of 30-44 degrees centigrade. Up to the flat rating temperature, the engine's EGT varies at a rate of 3.2 degrees centigrade per degree centigrade variation in OAT. For example, an engine with an EGT margin of 30 degrees at the flat rating OAT of 30 degrees, will actually have an additional 32 degrees of EGT margin when the OAT drops by 10 degrees to 20 degrees centigrade. This would increase the EGT margin to 62 degrees, before any further benefits of take-off de-rate were considered.

EGT will rise as the engine hardware condition deteriorates with utilisation and operation. While the engine's EGT will still be held constant at OATs higher than the flat rating temperature, the difference with the redline EGT will gradually fall as the engine deteriorates. The engine will have zero EGT margin when its EGT at the flat rating OAT is the same as the redline EGT. Engines will still have a large amount of EGT margin available when operating at lower OATs.

Rates of EGT margin loss are significant for engines operated on short average cycle times. Loss of performance is therefore a main removal driver for engines operated on average cycle times of 1-2FH. Rates of EGT margin erosion are lower for engines operated on medium and long average cycle times, and EGT margin loss is not a main removal driver for many CF6-80C2s in operation. This is particularly the case for engines operated in moderate OATs.

CF6-80C2 LIFE LIMITED PART EFC LIMITS

Part name	Life limit A1/A2/A3/A5	Life limit A5F	Life limit B1/B2/B4/B6/B8	Life limit B5/B7	Life limit D1F
Fan disk 1	20,000	15,000	20,000	20,000	20,000
Stg 2-5 spool	20,000	15,000	20,000	15,000	15,000
Forward shaft	20,000	19,600	20,000	20,000	20,000
Fan mid shaft	20,000	20,000	20,000	20,000	20,000
HPC Stage 1 disk	20,000	20,000	20,000	20,000	20,000
HPC Stage 2 disk	20,000	15,000	20,000	15,000	15,000
Stage 3-9 spool	20,000	20,000	20,000	20,000	20,000
HPC Stage 10 disk	20,000	15,000	20,000	15,000	15,000
Stage 11-14 spool	20,000	20,000	20,000	20,000	20,000
Stage 10-14 spool	20,000	20,000	20,000	20,000	20,000
CDP seal			20,000	15,000	15,000
HPT Stage 1 disk	15,000	13,200	15,000	13,200	13,200
HPT Stage 2 disk	15,000	9,000	15,000	9,000	9,000
Spacer impeller	15,000	15,000	15,000	15,000	15,000
Rotating stage seal	15,000	9,000	15,000	9,000	9,000
LPT Stage 1 disk	20,000	20,000	20,000	20,000	20,000
LPT Stage 2 disk	20,000	20,000	20,000	20,000	20,000
LPT Stage 3 disk	20,000	17,400	20,000	17,400	17,400
LPT Stage 4 disk	20,000	20,000	20,000	20,000	20,000
LPT Stage 5 disk	20,000	20,000	20,000	20,000	20,000
LPT Shaft	20,000	20,000	20,000	20,000	20,000

Life limited parts

The CF6-80C2 has 20 or 21 LLPs, depending on engine configuration, which are used in four modules.

The first module is the fan and booster section. "This has four LLPs, which include the fan mid-shaft, fan forward shaft, fan rotor stage 1 disk, and fan rotor stage 2-5 disk," explains Henderson. The list price for the four LLPs is $950,000. GE has a system for stating target lives for LLPs when an engine first enters service, and the target life for LLPs in this module of the CF6-80C2 is 20,000EFC. Several part numbers are available for each LLP, and most have lives of 20,000EFC in this module.

The HPC module has five or six LLPs, depending on configuration. Four are the stage 1 disk, stage 2 disk, stage 3-9 spool, and compressor discharge pressure (CDP) seal. In engines with five LLPs, the fifth LLP is the stage 10-14 spool, while engines with six LLPs have a stage 10 disk and stage 11-14 spool.

Most part numbers have lives of 15,000EFC, although some have lives of 20,000EFC and others have lives limited to less than 15,000EFC. The list price for a set of HPC LLPs is $950,000.

The HPT module has four LLPs: the stage 1 and 2 disks, the spacer impeller and the rotating stage seal. The target life of these parts is 15,000EFC, and many part numbers are certified with this limit. There are, however, several part numbers with lives limited to less than this. In many cases lives are limited to 9,000EFC or 13,000EFC. The list price for these four LLPs is $620,000.

The LPT has six LLPs: the stage 1, 2, 3, 4 and 5 disks, and the LP shaft. Most part numbers have lives of 20,000EFC, but some are restricted to between 15,000 and 20,000EFC. These six parts have a list price of $865,000. AC