CFM56-5A/-5B modification programmes

There are several upgrade and modification programmes for the CFM56-5A and -5B series of engines. Some of these have been incorporated. The most important new modification is the Tech Insertion programme, which will come available in late 2007.

The CFM56-5A1 was the first engine to power the A320 into service in 1987 and to be certified for extended twin-engine operations (ETOPs) on the aircraft. In addition there are the -5A3, -5A5 and -5A4. The -5A series was followed in 1994 by the -5B series, of which there are nine main variants *(see CFM56-5A/-5B series specifications, page 6)*.

-5A series TOW modification

The first major CFM56-5 modification, which has long since been integrated into the installed fleet, but which should nevertheless be mentioned here for the sake of completeness, is the exhaust gas temperature (EGT) margin upgrade that was applied to the -5A series powering A319s and A320s. This modification provides the engine with a higher certified EGT limit of 915 degrees, compared to 890 degrees on unmodified engines.

The modification is achieved through several hot section modifications. Engines with this modification are identified by an '/F' suffix on the name plate.

Also referred to as the 'Time On Wing' (TOW) upgrade, this modification is transparent in operation, since it does not alter the EGT limits indicated on the flightdeck instruments. The modified engines therefore still have an indicated 890°C EGT redline, but an actual corresponding EGT limit of 915°C. Unmodified engines have an indicated and actual EGT limit of 890°C.

The indicated EGT redline temperatures of 890°C are the same for modified and unmodified engines, since two different limits would require different calibrations of flightdeck instruments and could also possibly risk confusing flightcrew. When the modified engines appear to be at their redline limits, their EGTs are actually 25 degrees lower than the certified limit, thereby providing a comfort zone and ensuring that EGT margin deteriorates at a lower rate.

The three of the four -5A variants that had this modification are the -5A1, 5A4 and -5A5, and are identified as the -5A1/F, -5A4/F and -5A5/F. The CFM56-5A3 is the same as CFM56-5A1/F, with an EGT redline of 915 degrees, but it has a higher take-off thrust rating of 26,500lbs thrust. This compares to the -5A/F's rating of 25,000lbs thrust.

The /F modification was also applied on the production line to new manufactured engines, from October 1992 to the -5A1, from February 1994 to the -5A4/F, and from February 1996 to the -5A5/F.

3-D Aero -5B upgrade

The original -5B series engines, which had the basic name designation, are known as the classic variants. There are only six of them, with ratings between 31,000lbs and 22,000lbs thrust. Fewer than 300 classics were produced from 1993 to 1996, and these were shortly followed by an enhanced model.

The enhanced -5B/P model has been in production since 1996. It is an upgrade that can be retrofitted to classic engines, but it was also the standard build specification from 1996.

The /P upgrade involved improved '3D-Aero' turbomachinery components, replacing the original build standard from 1994. These improvements resulted in 3% lower specific fuel consumption (sfc) compared with the original -5B standard. The /P series includes all nine -5B variants rated between 32,000lbs and 21,600lbs thrust.

Most of the classic engines in the global fleet have now been upgraded, and only 48 remain unmodified. Air France is one notable large operator that has upgraded all its A320 engines to /P status.

The /P modification includes the following specific features: redesigned high pressure combustor (HPC) blading; a new high pressure turbine (HPT) blade with improved cooling; and a redesigned low pressure turbine (LPT) stage 1 nozzle.

All nine /P variants are certified with an EGT of 940°C, which is 10°C lower than the unmodified standard.

-5B series 'Acoustic Upgrade'

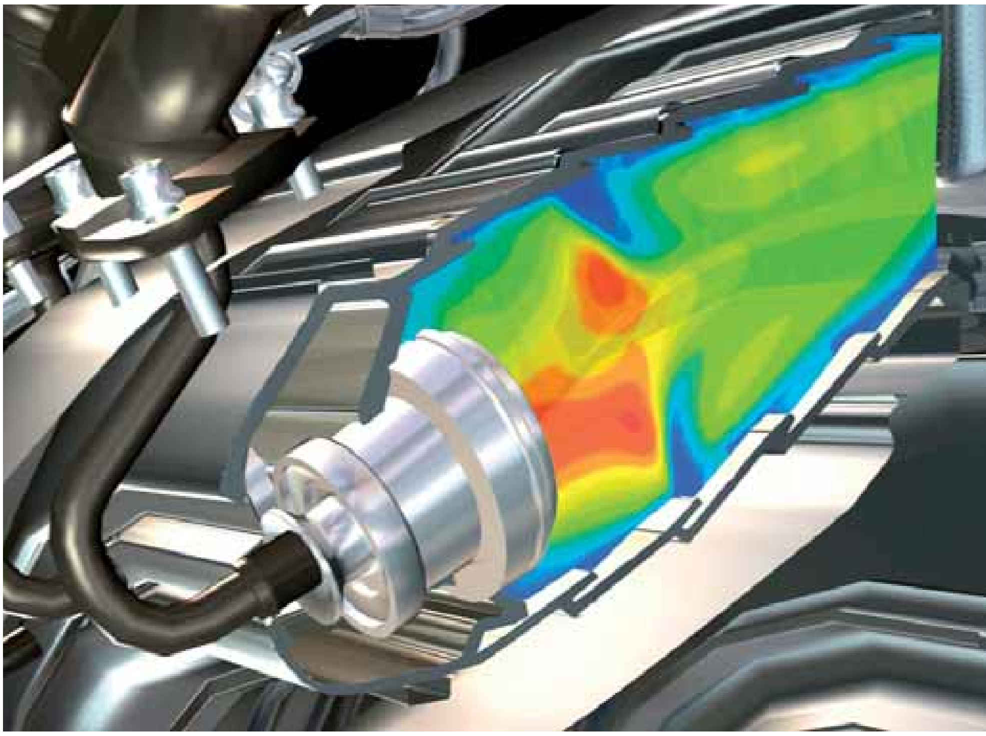
In 2002 CFMI announced that CFM56-5B engines could be equipped with an acoustic upgrade package, which included a distinctive 'chevron' type exhaust nozzle. The upgrade aimed to reduce the engine's cumulative noise signature to at least 10 EPNdB (equivalent perceived noise decibels) below Stage III levels. Specifically, the technology developed included: a core chevron nozzle; and improved reverser and inlet linings on the nacelle. The A321 with CFM56-5B/P engines in the highest maximum take-off weight (MTOW) configuration of 93.5 tonnes has a Stage IV margin of 1.2 EPNdB, and 11.2 EPNdB versus Stage 3 limits. The lower the MTOW configuration of the aircraft, the higher the margins relative to these limits. The acoustic package has been available in production since January 2004. Most of the A321 aircraft with the CFM56-5B3/P engine have the acoustic package.

LLP life extension

CFMI has a specific policy of gradually increasing the life of life limited parts (LLPs) on the CFM56-5A and CFM56-5B engines based on in-service experience. According to CFMI, the actual lives of the LLPs are being extended in anticipation of the fleet leader so as not to affect operations. The objective is of course to ensure that the LLPs are used to their full potential. These are 30,000 engine flight cycles (EFCs) for fan/booster module LLPs, 20,000EFC for core module LLPs and 25,000EFC for LPT module LLPs.

"CFMI is working on the programme, and life limits are revised every week. At this time we believe that about 80% of the parts have been certified for their target lives," says Paolo Lironi, senior technical manager at IASG. "We are also aware that CFMI is providing the biggest operators with some warranty conditions in case the life extension will not be met."

"LLP life extensions will be a 'double-



One feature of the Tech Insertion programme will be a TAPS combustor. This will reduce NOx emissions to a level that provides a margin over CAEP 6 standards.

tier' benefit, not only to the operators, but also to the leasing community which will be able to reduce maintenance reserves because of the extensions," notes Abdol Moabery, president of GA Telesis. "At the same time, it will benefit the likes of GE and MTU, which offer power-by-the-hour maintenance programmes, since they will not have to replace the LLPs as often."

This could help to eliminate the current problem, which is that 25-30% of LLP life is typically wasted because of varying lives in a stack. Indeed, taking the industry at large, hundreds of millions of dollars of cycle life are probably lost because LLPs do not have enough life to justify reinstalling them on the aircraft at shop visits. If operators can now plan for three shop visit cycles instead before changing an LLP (the initial operation from new, followed by two more shop visits), that will have a significant impact in terms of cost savings.

DAC upgrade

The Double Annular Combustion (DAC) chamber was first applied on CFM56-5B engines, to reduce NOx emissions. The resultant model designation then became 'CFM56-5B/2'.

In 1995, the SR Group, at the time including Swissair and Sabena, opted for this engine model. The DAC was innovative and it was the first of this type proposed to operators. The DAC incorporates a second dome, or inner ring, of fuel nozzle ports. Each nozzle has a second tip which serves this inner ring. At low power levels, only the outer (pilot) stage is used. This stage is designed with low throughflow velocities and low airflow to promote stable operation and complete combustion. At high power, both stages are operational, but the majority of the fuel and air is burned in the inner (main) stage. The higher throughflow velocities in this stage reduce combustor residence time. Total combustion airflow through the swirlers is more than twice as much as a conventional combustor.

According to IASG, the hot section in DAC engines was reaching higher temperatures than the 'basic' engine model, which had single annular combustor (SAC) chambers. This created several problems with the rear bearings and the low pressure module. Other technical issues on DAC engines included:

- LPT stage 1 blades: The temperature profile of the DAC chamber was different and generated increased internal stress. Several engines suffered blade failures during engine start. CFMI proposed a retrofit programme for all engines, by replacing the parts with a more robust and revised design blade.
- Combustion chamber: Due to the increased temperatures, the combustor suffered early deterioration and several engines had to be removed early due to problems with combustion chamber cracking. CFMI proposed a new chamber design, with improved cooling and materials, allowing the engine to remaining on wing for an increased length of time.
- Turbine rear frame: This is a structural component of the engine that was found to be cracked on several powerplants because of the increased exhaust temperature.

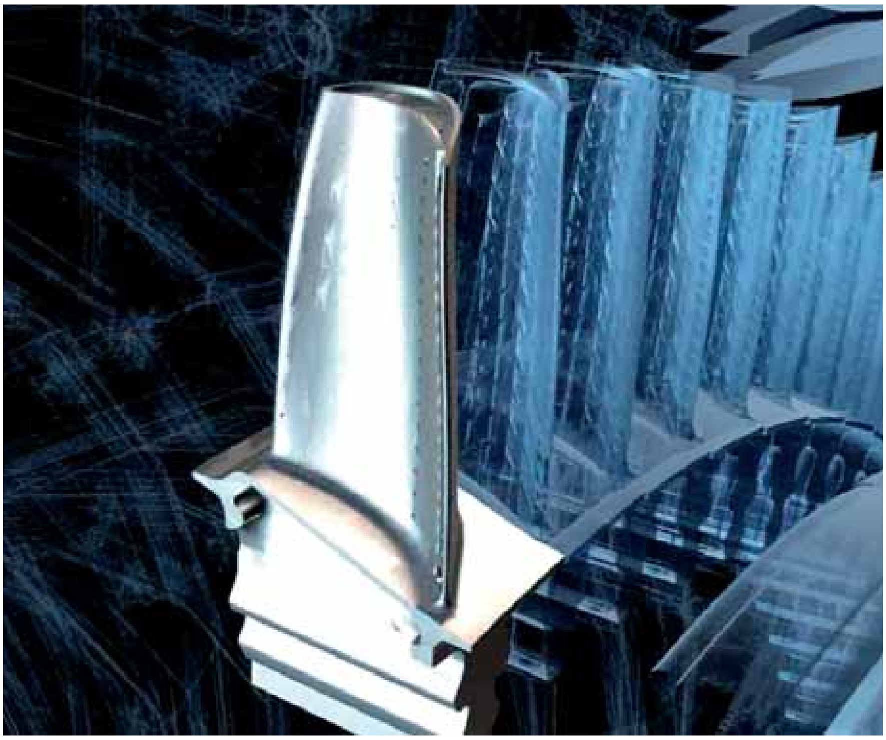
"The issues which affected the DAC engines are now fixed," explains Pierre Bry, vice president of marketing at CFMI. "They have been behind us for quite some time. The DAC burns a little more fuel, about 1%, and mostly at idle speed. The other maintenance cost is due simply to the fact that the DAC cluster is a little more complex, since it has more piping, two sets of injectors, and a centrebody. Importantly, the DAC model is now an engine which has fully equivalent operational capability to the SAC engine. Although the DAC engine burns a little more fuel, it does reduce NOx emissions by as much as 30-40% compared to the SAC."

Moabery notes that with DAC engines the value of the asset is affected by the ability to remarket or re-lease the engine to an operator that does not have DAC engines in the rest of its fleet. "If I have a CFM56-5B that is a DAC engine, it will be almost impossible for me to convince an operator to take it if they do not actually want a DAC, unless there is no other engine available on the market," says Moabery. "Of course, if I have a DAC engine, and there is a requirement for one, then I am going to get the deal. But unfortunately the market is limited to few operators. In addition, if there is a problem with the combustor, and it has to be replaced with a brand new one, the amount of spares in the market will be very limited indeed because fewer than 200 combustors were ever made. In the long run the lack of spares therefore makes the DAC engine more expensive to operate."

Tech Insertion upgrade

In 2004, CFMI launched a single major modification package for the -5B which included major changes aimed at improving fuel burn and EGT margin, and increasing durability. Dubbed 'Tech Insertion', this programme incorporates technologies developed and validated as part of Project Tech56, and includes improvements to the HPC, the combustor, and the HPT and LPT.

Following its certification at the engine level (FAR33) in December 2006 for the CFM56-5B, Tech Insertion will become available both as a retrofit for in-service engines, and importantly, as the standard production configuration, officially designated as 'CFM56-5B/3' from the end of the third quarter of 2007. Bry points out that the price structure of the CFM56-5B/3 production engine will



The Tech Insertion programme will feature a new low-shock HPT blade contour. This is designed to reduce interaction with the LPT, as well as feature improved cooling to aid reduction in fuel burn.

remain as before, as will the individual list prices for individual parts.

In particular, Tech Insertion uses advanced analytic tools for its twin-annular pre-swirl (TAPS) combustor technology developed for the future GEnx powerplant. This will improve cooling in the existing CFM56 SAC engines. The purpose of TAPS is to reduce NOx emissions, providing a margin over CAEP 6 emissions regulations scheduled to take effect in 2008. Other significant changes in the turbine include a new low-shock, HPT blade contour (validated as part of Project Tech 56). Furthermore, the associated blade design lowers the interaction loss between the HPT and LPT. When combined with additional durability improvements, these modules (with modified cooling) reduce fuel burn through improved efficiency, and lower maintenance costs. The design also includes improved aerodynamics in the rotor blades of the HP compressor and new materials for HPC stator bushings.

Overall, the package aims to provide operators with: 10% longer time on-wing, reflecting an escalation of the average time to first shop visit from 21,000 engine flight hours (EFH) to 23,000EFH; a 5-12% reduction in 'mature maintenance costs' depending on rating; 20-25% lower NOx emissions, in compliance with the latest emissions standard CAEP/6 for its SAC; reduced HPC deterioration (equivalent to 10 degrees centigrade EGT margin; and better fuel burn.

At the beginning of 2007 the price for kits remains undisclosed, but this will become available by the third quarter of 2007. As well as being offered for retrofit at a normal shop visit for engine overhaul, the improvements will become the production-build standard for the -5B. It will also become the technology standard for the - 7B engine on the 737NG.

It should be noted that while the full upgrade incorporates all the above, and is denoted by a '/3' suffix on the engine model name, 'sub-kits' will also be offered that allow operators to individually enhance particular engine modules. This will in effect be a portion of the full Tech 56 programme. These include kits for the HPC, HPT, LPT stage 1 nozzle, variable stator vane (VSV) bushing on the HPC, and a 20,000EFC life limit for LLPs in the core rotor. "Operators can actually choose between one or the other, depending on their particular requirements," notes Bry. "For example, if an operation is running in a hot environment, the engine may benefit from an HPC kit. In short, operators are not forced to swallow all the rest if they do not want to."

Moabery does not believe that the upgrade package will be economically attractive to low-cost carriers (LCCs), or airlines with small fleets. "It really comes down to who the operator is. Some LCCs may not have the capital available to do it. In my opinion the upgrade package will really be better suited to the major airlines, such as Air France and Lufthansa. The cost savings and the reliability benefits across a large fleet should exceed the up-front costs."

IASG's Lironi believes that engines without this set of modifications will hold less value, and operators will benefit from implementing it. "Operators will probably wait for the first engines to validate CFMI's performance promises before they commit to the upgrade. The Tech Insertion cost for the CFM56-3C1 engine is $1.3million, while it is more expensive ($1.8 million excluding LLPs) for the -5B series. If CFMI's indications of increased on-wing life and sfc are verified by operating the engines, Tech Insertion will have to be adopted by all airlines and engine owners. This is similar to what happened with the Phoenix modification on the V2500-A1 engines."

Bry points out that customers for the upgrade will typically be looking for a return on their investment within two or three years. "They will factor everything in such as the cumulative fuel saving and reduced maintenance costs. Also, since they will be removing some of the old blading from the current engine, they could conceivably realise significant savings by choosing to retain those parts and perhaps use them in another engine, or even sell them."

Bry adds that '/3' Tech Insertion engines will enter service with extended LLP lives from the outset: 30,000EFC for the fan/booster, 20,000EFC for the core, and 25,000EFC for the LPT. "When you look at the difference between the CFM56 and the V2500, you consider the costs of the LLP stacks, the lives, and the cost per cycle. We realise a difference of $26 per EFC in favour of the CFM56, simply because the list price for its LLP stack is lower and our lives are longer."

Another factor to be borne in mind is that Tech Insertion engines will be interchangeable with existing, unmodified engines on the same aircraft. For example, an A320 will be able to have a CFM56-5B/3 on one side, and a regular CFM56-5B on the other. The only pre-condition is that operators must ensure that the digital engine control unit is appropriately primed.

Regarding any impact on the asset values in relation to installed user base size, it should be noted that CFMI envisages production rates of more than 1,000 engines per year. Consequently, within three years there will be about 3,000 Tech Insertion engines in operation. AC