New narrowbodies are being acquired on the basis of lower operating costs. One element of this is engine maintenance costs. Analysis of on-wing performance & maintenance costs reveals that the JT8D-200, CFM56-5B/-7 & V.2500 have similar economics.

Maintenance cost analysis: JT8D-200, CFM56-5B/-7 & V.2500

Many airlines are opting for single-type narrowbody fleets on the basis of improved operating economics. Older aircraft types like the MD-80 still have the advantage of lower capital and depreciation costs. Younger types must compete with lower cash operating costs, of which engine maintenance charges play an important role. Despite the well publicised long on-wing times modern engines achieve, older generation powerplants have the advantage of maturity, durability and low parts costs. A comparison of maintenance costs of the JT8D-200 (MD-80), CFM56-5B (A320 family), CFM56-3/-7 (737 Classic & 737NG families) and V.2500-A1/A5 (A320 family) will contribute to an analysis of the difference in operating efficiency between aircraft types.

Engines in operation

The four variants of the JT8D-200 are the -209 rated at 18,500lbs, the -217A/C rated at 20,000lbs and -219 rated at 21,000lbs *(see table, this page)*.

The CFM56-5B is a family with six variants rated between 22,000lbs and 33,000lbs *(see table, this page)*, and the CFM56-7 family has six ratings between 19,500lbs and 27,300lbs *(see table, this page)*. The V.2500-A5 family has five variants rated between 24,000lbs and 33,000lbs *(see table, this page)*.

JT8D-200, CFM56-5B, CFM-7 & V.2500-A5 FAMILY THRUST RATINGS & APPLICATIONS

JT8D-200 series			
Engine type	JT8D-209	JT8D-217A/C	JT8D-219
Thrust rating lbs	18,500	20,000	21,000
Application	MD-81	MD-82/88/87	MD-83/88

CFM56-7 series						
Engine variant	-7B18	-7B20	-7B22	-7B24	-7B26	-7B27
Thrust rating (lbs)	19,500	20,600	22,700	24,200	26,300	27,300
Application	737-600	737-600 737-700	737-600 737-700	737-700 737-800 737-900	737-800 737-900	737-800 737-900

CFM56-5B series						
Engine variant	-5B5	-5B6	-5B4/7	-5B1	-5B2	-5B3
Thrust rating (lbs)	22,000	23,500	27,000	30,000	31,000	33,000
Application	A319	A319	A319 A320	A321	A321	A321

V.2500-A5 series					
Engine variant	V.2522-A5	V.2524-A5	V.2527-A5	V.2530-A5	V.2533-A5
Thrust rating (lbs)	22,000	24,000	27,000	30,000	31,000
Application	A319	A319	A319 A320	A321	A321

The aircraft powered by these engines all operate short-haul sectors for most operators. Engine flight cycle (EFC) times of 1.5 flight hours (FH) or engine flight hours (EFH) are not uncommon. Long range missions are now being flown by some 737NG and A320 operators.

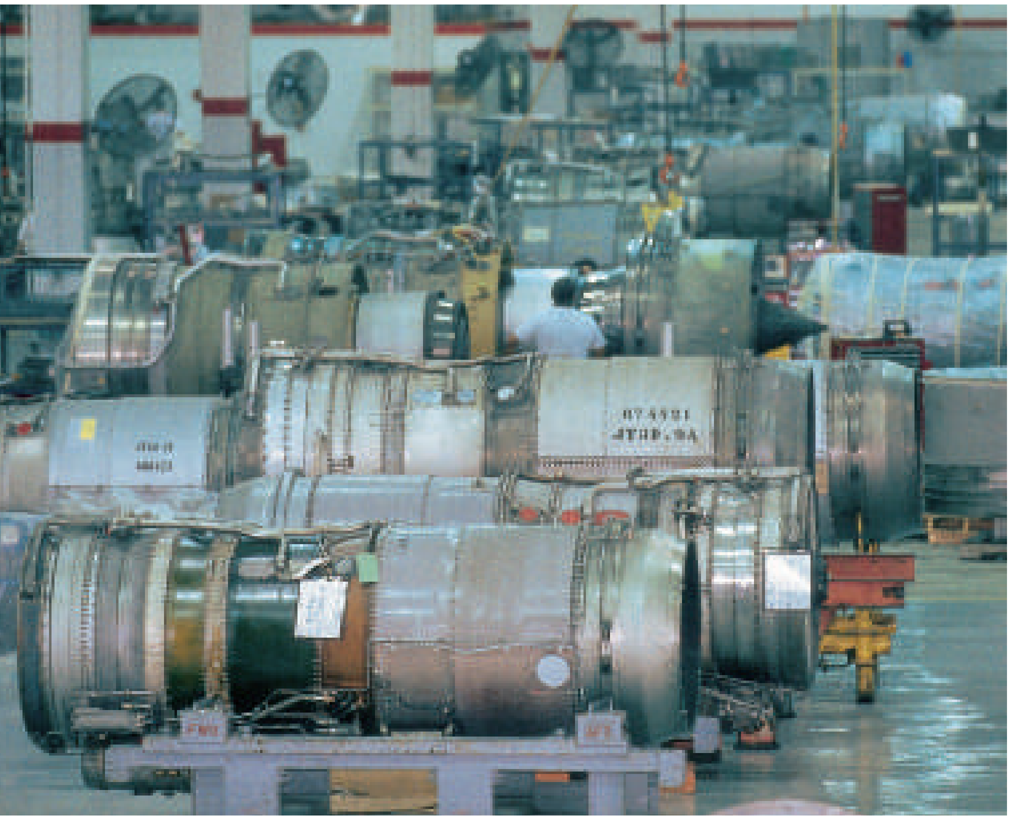
The CFM56-5/7 and V.2500 have been conceived around a family concept, where lower thrust variants have higher exhaust gas temperature margin (EGT) and so a potentially longer on-wing life. Overall maintenance costs per EFH are affected by on-wing time, consequent shop visit workscope, shop visit workscope pattern, lives of life limited parts (LLPs) and their actual replacement interval.

Most LLPs in these engine families have lives in the region of 15,000-30,000EFCs. Since engines typically achieve shop visit removal intervals of 7,000-12,000EFH, equal to 4,700-8,000EFC, LLPs must be replaced every second, third or fourth shop visit, which means that these engines have larger workscopes than those operating long-haul missions. LLPs influence engine management, and, with their short average EFC time and high cost, also greatly affect maintenance cost per EFH.

Engine performance

JT8D-200

Most MD-80 operators fly average EFC times of 1.25EFH, and annual utilisation is in the region of 2,400EFH. Jose Leon, senior vice president of marketing at Aerothrust explains that the



The JT8D-200 is mature engine and has short on-wing times compared to modern types. The JT8D-200, however, has a lower requirement for man-hours and cheaper parts and LLPs than modern types. These counter its shorter shop visit intervals and its costs per engine flight hour are similar to modern engine types.

JT8D-200 is now mature and typically has a restored EGT margin of 18-25 degrees centigrade following a shop visit. "Most operators manage the JT8D-200 with an alternating pattern of hot section and overhaul shop visits. Actual EGT margin after a shop visit depends on engine variant and shop visit workscope," says Leon.

"Rate of EGT margin erosion is about four degrees centigrade per 1,000 EFCs," says Leon.

Rudiger Urhahn, executive vice president for the engine service centre at SR Technics, explains that EGT margin deterioration is about 2.4 degrees per 1,000EFH for the lower rated -217A, but is actually lower at about 1.8 degrees per 1,000EFH for the higher rated -217C/-219.

These rates of EGT margin erosion allow on-wing times of about 10,000-12,000EFH. The engine does, however, have other removal drivers, which include oil consumption, vibration and LLP replacement. "There are many small airworthiness directives (ADs) that affect the JT8D-200, but nothing too serious that drives removals. The engine is relatively free of serious ADs," says Leon.

"Typical on-wing intervals are 7,000EFC up to a partial overhaul or engine shop visit one (ESV1) and about 10,000EFH from an ESV1 to an overhaul or engine shop visit two (ESV2)," says Leon. Once unplanned removals are taken into account, most operators can achieve an average interval between shop visits is 6,200EFH and 4,000EFC.

Urhahn explains that the JT8D-200 is capable of an overhaul interval of about 22,000EFH, with a performance restoration in between.

The typical pattern of removals fits well with the uniform 20,000EFC life of LLPs throughout the engine. The JT8D-200 will only be able to conform to an alternating shop visit pattern of ESV1 and ESV2 workscopes if the LLPs are replaced at the ESV2. A need to replace them at the ESV1 will increase the workscope. The aim should therefore be for the LLPs to be replaced at the ESV2, which implies either the second or fourth shop visit in succession. An average shop visit interval of 4,000EFCs means LLPs could get replaced at the fourth shop visit, leaving a 'stub life' of about 3,500EFC when they are removed.

"The uniform life of LLPs in the JT8D-200 rarely limits on-wing intervals," explains Urhahn.

CFM56-7

The CFM56-7 family overall has high EGT margins for new engines. The oldest are four years old and few have had their first shop visit. The lowest rated -7B18 has an EGT margin of about 117 degrees, while the -7B28 has a margin of about 65 degrees. EGT margin is generally so high as not to be expected to cause removals.

The lower rated variants are expected to have an EGT margin erosion rate of about four degrees per 1,000EFC; similar to the JT8D-200. This means their first run could be as long as 17,000EFC; equal to 10 years of operations in some cases.

The higher rated engines are expected to have an EGT margin erosion rate of seven degrees per 1,000EFC, and so a possible first on-wing run of 11,000EFC.

On-wing times and engine management are complicated by LLPs. These vary from 13,000EFC to 20,000 EFC in the high pressure (HP) spool, and 16,000EFC to 30,000EFC in the low pressure (LP) spool. CFM International aims, however, to standardise these to 20,000EFC in the HP section and 25,000/30,000 in the LP section.

The timing of LLP replacement will depend on the current and subsequent expected removal interval.

Low rated engines are expected to have first runs of 14,000-17,000EFC (21,000-25,000EFH) and second runs of 11,000-13,000EFC (16,000-19,000EFH). Shorter life parts would be replaced at the first shop visit, with all remaining LLPs replaced at the second removal.

High-rated engines would have shorter intervals of 11,000-14,000EFC (16,000-21,000EFH) for the first run, and 9,000-11,000EFC (13,000-16,000EFH) for the second run. The time at second removal would total 20,000-25,000EFC. It is possible that 30,000EFC parts could be left in the engine at this stage for replacement at the third shop visit. All shop visits will still involve extensive disassembly to replace LLPs, thus making each visit a heavy workscope.

EGT margin after the first shop visit is expected to be about 70% of the original, and so become a more limiting factor. Margins will therefore be 40 degrees for high rated engines and 85 degrees for low rated variants. EGT erosion rates should also be higher, reducing on-wing runs to about 80% of the first.

CFM56-5B

The CFM56-5B series was designed to provide a range of thrust ratings for the whole A320 family. It has one more low pressure compressor (LPC) stage than the -5A series and the option of a double annular combustor (DAC). The -5B series has experienced technical problems with several operators, which have forced early removals and therefore prevented airlines from realising potential on-wing times.

The CFM56-5B family has a high EGT margin. The higher rated variants

The V.2500 suffered initial reliability problems. These have been overcome and the engine is demonstrating that it is capable of shop visit removal intervals of up to 15,000EFH. Intervals between overhauls are up to 25,000EFH. The lives of its LLPs are uniformly set at 20,000EFC, and this simplifies shop visit planning. These factors all contribute to a low cost per EFH.

have margins of about 66 degrees centigrade, while the lowest rated engines have margins in the region of 150 degrees. "The EGT margin for the mid-thrust -5B1 is about 110 degrees for a new engine, but is about 70-80 degrees centigrade after a shop visit," says Urhahn.

Rates of EGT margin deterioration are about 3-4 degrees per 1,000EFH, depending on operation. This rate of EGT margin erosion means it would not be a main driver of removals for a first shop visit.

EGT margins are reduced by about 30% from their original after the first shop visit.

LLP lives for the CFM56-5B are 25,000-25,000 in the LP spool and 15,000-20,000 in the HP spool. The CFM56-5B is expected to conform to a pattern of alternating light and heavy shop visit workscopes; similar to the JT8D-200. The first removals are expected to have an interval of about 10,000EFH/6,700EFC. "We have achieved intervals of about 15,000EFH/11,500EFC on first runs since we cured technical problems with modifications, but they were about 10,000EFH/8,000EFC before," says Urhahn. "We expect the second removal interval to be driven by LLPs. This is complicated by the variation in LLP lives with thrust rating."

The second interval is estimated to be about 8,000EFH/5,300EFC. The combined interval of the first two removals means that LLPs with lives of up to 17,000EFCs would have to be replaced at this shop visit.

Parts with longer lives of up to 20,000EFC would be replaced at the third shop visit, and parts with even longer lives would be removed the fourth or even fifth shop visit. This results in heavy workscopes for most shop visits, since a high level of disassembly is required. "The first shop visit will be a core refurbishment in most cases and LLP replacement as required, while the second shop visit will be heavier and driven by LLP status," says Urhahn.

V.2500-A5

Like the CFM56-5B and -7, the V.2500-A5 has high EGT margins. The high rated variants at 33,000lbs thrust have a margin in the region of 50 degrees centigrade. EGT margin deterioration is also low compared to its main competitor, the CFM56-5B. "We have not had a single V.2530 removal due to EGT margin deterioration, although others operated by customers in hot environments have been removed for EGT margin erosion," says Ralph Gaertner, propulsion systems engineering V.2500 at Lufthansa Technik. "Also, none of our 33,000lbs rated engines have been removed due to EGT margin erosion, but these are young. These might be the first V.2500s to be removed due to EGT margin erosion."

Estimates are that the V.2500-A5 loses about 2.7 degrees of EGT margin per 1,000EFH. This would allow a first on-wing run of up to about 18,000EFH.

Gaertner explains the EGT margins on the lower rated variants are so high that the engines are not flat rated. Flat rating is normally required with engines to preserve some EGT margin at take-off at high ambient temperatures. The EGT margin of low-rated V.2500 variants is high enough for flat rating to be unnecessary.

The V.2500 has experienced technical problems, that, as with the CFM56-5B, have prevented potential on-wing intervals from being realised. "The first of these were the fourth and sixth stage compressor blade root failure. Another was tip curling of compressor blades. There were several others in addition, including oil leakage and smell in the cabin," explains Gaertner. "These all led to short on-wing times because of fixes. Now that we have overcome these technical issues, on-wing intervals are increasing to about 8,000EFH. Some airlines are achieving intervals as long as 14,000EFH, but interval of course depends on EFH:EFC ratio."

Ralph Teschner, manager of powerplant engineering for the V.2500 at MTU Maintenance, explains that the -A1 series had engines removed primarily due to EGT margin loss, and also hot section deterioration and HP compressor damages. "The V.2500-A5 series engines are usually not limited by EGT margin," says Teschner "but usually because of hardware deterioration in the combustor and hot section, and damage to the high pressure compressor (HPC)."

Teschner explains that on-wing intervals vary widely, but are in the order of 10,000EFH (6,000-7,000EFC) for V.2500-A5 engines in airline operation. "Most usual shop visits are core refurbishments, with the LPT and LPC/fan being overhauled at a subsequent or later shop visit."

Lothar Burdenburg, director of marketing at MTU Maintenance, explains that the V.2500 has more consistent on-wing times/shop visit intervals after its first removal than does the CFM56-5B, which has about 30% shorter intervals subsequent to the first on-wing run. "A probable first on-wing run is in the region of 15,000EFH (10,000EFC)," says Burdenburg. "Sometimes engines receive an overhaul at this stage and then have second on-wing runs of 12,000-13,000EFH (8,000-8,600EFC). These on-wing intervals then remain fairly constant."

Most LLPs in older V.2500-A5s have lives of 20,000EFC, with the exception of

JT8D-200, CFM56-5B, CFM56-7 & V.2500 PERFORMANCE AND MAINTENANCE COSTS

Engine	JT8D-200	CFM56-5B	CFM56-7 High rating	CFM56-7 Low rating	V.2500
EFH:EFC ratio	1.5	1.5	1.5	1.5	1.5
1st removal					
S-V interval: EFH	6,200	10,000	16,000	21,000	15,000
S-V interval: EFC	4,000	6,700	11,000	14,000	10,000
S-V cost $	500,000	850,000	825,000	825,000	800,000
2nd removal					
S-V interval: EFH	6,200	8,000	13,000	16,000	10,000
S-V interval: EFC	4,000	5,300	9,000	11,000	6,700
S-V cost $	1,000,000	1,000,000	1,150,000	1,150,000	1,300,000
Maintenance cost $/EFH	121	103	67	55	85
LLP lives EFC	20,000	9,000 -30,000	13,000 -30,000	13,000 -30,000	20,000
Replacement interval	4th S-V	1st-4th S-V	1st-3rd S-V	1st-3rd S-V	2nd S-V
List price $	1,000,000	1,600,000	1,700,000	1,700,000	1,600,000
LLP reserve $/EFH	42	85	57	66	65
Total maintenance cost $/EFH	**165**	**190**	**125**	**121**	**150**

the HPC drum which had a life of 8,000EFC and is now 16,000EFC. This should be increased to 20,000EFC. All new V.2500-A5 engines have uniform LLP lives of 20,000EFC, which make engine management and shop visit planning easier.

Burdenburg explains that the V.2500 typically has an alternating shop visit pattern of performance restorations and overhauls. The on-wing intervals of which the engine is capable mean that LLPs can be replaced every second shop visit. Having an overhaul as the first shop visit means, followed by alternating performance restorations and overhauls, means that LLPs will come due for replacement during the performance restoration. This is less convenient than replacement during an overhaul, since an overhaul requires a high level of disassembly. Replacement at a performance restoration will require a higher level of disassembly and re-assembly than would otherwise be required, raising workscope and increasing man-hours (MH).

"An alternative strategy would be to have a performance restoration after the first removal at about 15,000EFH (10,000EFC), and the subsequent on-wing time would be about 10,000EFH (7,000EFC), which would be followed by an overhaul," says Burdenburg. The total time on-wing would approach the limit of LLPs, or even reach the limit of the one part with 16,000EFC. The LLPs would then be replaced at the overhaul, with a stub life of 3,000-4,000EFC. Subsequent management would be an overhaul and LLP replacement every second shop visit. The interval would be in the region of two runs of 10,000-12,000EFH, equal to a total time of 13,000-16,000EFC.

Workscopes & inputs

JT8D-200

Maintenance management for the JT8D-200 is simplified with most JT8D-200s being managed on an alternating ESV1 and ESV2 shop visit programme.

"The workscope for an ESV1 usually includes the refurbishment of the hot section, repair of nozzle guide vanes and combustors, in particular the HPT and possibly the LPT," explains Leon. "The ESV2 usually involves a higher level of disassembly and repair of most of the engine, although repair to the LPT is sometimes not required."

The man-hours (MH) used in the ESV1 range from 1,800 to 2,200. Materials consumed usually total about $250,000 and further sub-contracted repairs add another $100,000 to the shop visit. Labour charged at $70 per MH takes the total for an ESV1 to about $475,000-500,000 *(see table, this page)*. This does not include any provision for LLPs.

MH used for a heavier ESV2, which involves the replacement of LLPs, are in the region of 4,500. Materials consumed cost in the region of $400,000, while sub-contracted repairs will cost up to $300,000. Taking the total shop visit cost to about $1 million *(see table, this page)*.

These two shop visits performed at average intervals of 6,200EFH will have a maintenance cost of $121/EFH *(see table, this page)*.

These costs could be reduced by the high volume of parts currently on the market at low values.

Replacement of LLPs will affect maintenance costs per EFH. A full set of LLPs for the JT8D-200 has a list price of $1 million. If engines can be managed so they are replaced at the fourth shop visit, shop visit management will be made easier and remaining stub life of LLPs at replacement will be kept short. Replacement at a fourth shop visit, with an average removal interval of about 4,000EFC will see parts removed with about 4,000EFC remaining. This will result in an LLP cost of $62 per EFC, or $42 per EFH for an average EFC time of 1.5EFH. The total for shop visit inputs and LLPs is in the region of $165 per EFH *(see table, this page)*. "While a full set of new discs and shafts costs about $1 million, there are many used parts available on the market at low values. Careful selection can save costs," explains Leon.

CFM56-7

The CFM56-7 is expected to conform to an alternating light and heavy shop visit pattern like many other engine types. Actual workscopes and levels of parts repair and replacement can only currently be estimated.

A performance restoration is expected to use about 2,500MH and $400,000-500,000 in materials. This will probably rise to about $600,000 for the subsequent performance restoration (third shop visit). A further $200,000 might be used for sub-contract repairs. A labour rate of $70 takes the total shop visit cost to $775,000-875,000 *(see table, this page)*, not including any provisioning for LLPs.

An overhaul is likely to consume about 3,200MH and $600,000-700,000 in materials and $300,000 for sub-contracted repairs. A labour rate of $70 per MH takes this to $1.1-1.2 million, not including LLPs *(see table, this page)*.

The issue of varying LLP lives and on-wing lives for different thrust ratings complicates LLP replacement.

High-thrust-rated engines might be expected to achieve 16,000EFH/11,000EFC for their first removal interval and 13,000EFH/9,000EFC for their second interval. The total time at the second removal would be about 30,000EFH/20,000EFC. It is likely all parts with lives up to 25,000EFC would be replaced at this stage, leaving just four parts to be replaced at the third shop visit. This would be at a total time close to the 30,000EFC limit of the remaining parts. A full set of LLPs costs about $1.7 million.

The cost of two shop visits would be equal to about $67 per EFH *(see table, page 24)*. Additional costs for LLPs would be about $57 per EFH, for an engine operating an average EFC of 1.5EFH, taking total cost to $125 per EFH *(see table, page 24)*.

Low-rated engines are expected to reach 21,000EFH/14,000EFH at their first removal and a further 16,000EFH/11,000EFC to their second removal. Total time at the second shop visit would be 37,000EFH/25,000EFC. Expected shop visit costs would take maintenance costs to $55 per EFH.

The longer intervals and total time to the second shop visit would mean LLPs with lives up to 20,000EFCs (all those in the HP section and possibly a few from the LP section) would have to be replaced at the first shop visit, and all remaining parts replaced at the second. The cost per EFH, for an engine operating an average EFC of 1.5EFH, of parts removed at the first shop visit would be equal to about $45/EFH. A further cost of $21/EFH would be incurred for the LLPs replaced at the second.

Total cost per EFH for maintenance and LLPs in respect of the first two removals would be $121 per EFH *(see table, page 24)*. The advantage of long on-wing intervals would be countered by the need to replace a high proportion of LLPs at the first shop visit.

Mature engines are expected to achieve shorter on-wing times of 10,000EFH/7,000EFC, while shop visit costs will rise. Maintenance reserves could therefore rise to $200 per EFH.

CFM56-5B

The on-wing intervals up to the first two removals are expected to total about 18,000EFH and 12,000EFC.

Inputs for the first shop visit are expected to be about 3,000MH and $650,000 for materials and sub-contracted repairs. The cost of labour would take this to $850,000 *(see table, page 24)*.

The second shop visit is estimated to require about 3,900MH, based on an overhaul of the LP and HP spools. Cost of materials and sub-contract repairs is about $750,000. A labour rate of $70 per MH will take total cost for the shop visit to about $1 million *(see table, page 24)*.

Amortised over the total time of 18,000EFH, maintenance cost is equal to $103 per EFH *(see table, page 24)*.

LLP replacement is complicated by the different lives of parts. Replacement of some will be as early as the first shop visit, while others will be kept in the engine until the third or fourth removal.

The subsequent on-wing times after the second removal are expected to be in the region of 5,500EFC. A full set of LLPs costs $1.6 million, and their pattern of removal at various shop visits equals a cost of $127 per EFC, or $85 per EFH for an average EFC of 1.5 EFH *(see table, page 24)*.

The total cost for shop visit inputs and LLPs is in the region of $190 per EFH *(see table, page 24)*.

This will rise as intervals between shop visits reduce and content of workscopes increase with higher rates of parts replacement.

The CFM56-7 is expected to achieve impressive shop visit intervals of up to more than 20,000EFH. These contribute to low costs per EFH despite expensive LLPs.

V.2500

The V.2500 is also expected to conform to an alternating pattern of light and heavy shop visit workscopes. The expected intervals between each visit are in the region of 10,000-12,000EFH or 6,500-8,000EFC.

International Aero Engines (IAE) has developed an electronic maintenance management planning (EMMP) tool for V.2500 customers. This is part of its total maintenance cost reduction plan. EMMP is a computerised tool to customise maintenance and shop visit planning. Decisions to replace or repair parts, extend the repair or life limits of parts are made with EMMP.

IAE has also developed a system of electronic invoice analysis as a means of identifying cost and removal drivers for the V.2500. This data is used to make product improvements and develop new repairs and reduce scrap rates.

Shop visit inputs total about $800,000 for a performance restoration and $1.3 million for an overhaul. "MH used for either depend on each shop's parts repair capability and consequent sub-contract activity for parts repair" explains Burdenburg. "We repair about 80% of engine components, and really only sub-contract repair of accessories. MH for a performance restoration will be 3,500-4,000, and cost of materials $400,000-450,000 and a further $80,000-100,000 for sub-contracted repairs." Using $70 as a standard labour rate puts the shop visit cost at about $800,000 *(see table, page 24)*.

Burdenburg estimates 5,000MH for an overhaul, $800,000 for materials and $120,000-140,000 for sub-contract repairs. This would total $1.3 million if a labour rate of $70/MH applied *(see table, page 24)*.

The two shop visits over an initial interval of 25,000EFH would equal a rate of $85 per EFH *(see table, page 24)*.

LLPs have uniform lives of 20,000EFC. Replacement of these at a second shop visit would be at a total time of about 15,000EFC. This would leave a 'stub life' of 5,000EFC of removed parts, raising cost per EFH.

A full set of LLPs for the V.2500 has a list price of $1.6 million. LLPs replaced at the second shop visit will result in a cost amortised over 25,000EFH equal to $65 per EFH *(see table, page 24)*.

The cost for maintenance and LLP replacement amortised over the first two runs, at a total time of 25,000EFH, totals about $150/EFH *(see table, page 24)*. This will rise for the subsequent cycle of two shop visits, since workscopes will increase in size, and intervals for the two will reduce to about 21,000EFH.

Summary

Despite being mature and having older technology, the JT8D-200 has competitive costs compared to the V.2500 and CFM56-5B/-7. This is explained by the JT8D-200 having low cost LLPs. The cost of LLPs has a large impact on full cost per EFH because of the short EFC times these engine types operate. The JT8D-200 also has low shop visit costs as a consequence of its simple structure, which reduces MH and material costs. Parts are also cheaper than modern technology engines. Overall, the JT8D-200's low shop visit and LLP costs allow it to overcome its inferior shop visit intervals. Moreover, the JT8D-200 is unlikely to experience a significant escalation in maintenance costs.

The CFM56-5B has been disadvantaged by its early technical problems. These have resulted in shorter on-wing times that would have otherwise been possible. Materials and repairs are also expensive, as are LLPs. The CFM56-5B should achieve longer intervals at maturity, once technical problems have been dealt with. Several LLPs should also have their lives extended. All of these factors will contribute to lowering maintenance costs per EFH.

The benefits of long on-wing intervals are demonstrated by the CFM56-7. The variant should have similar shop visit costs to the -5B, but the -7's superior reliability illustrates the low costs both can probably attain.

It is interesting to note that despite being capable of longer on-wing intervals because of lower EGT margin erosion, the lower rated variants of the CFM56-7 do not achieve overall lower costs per EFH compared to a high rated variant because of LLP replacement timing.

Once the V.2500 has overcome its earlier reliability problems, it should be capable of long shop visit intervals because of a high EGT margin. Also, uniform LLP lives simplify shop visit management and so reduce overall costs. Similar shop visit management and costs indicate what level of cost per EFH the CFM56-5B is also capable of.

What should be noted is that the costs per EFH for the CFM56-5B/-7 and V.2500 are for engines in their first overhaul cycle. After this their removal intervals will reduce and shop visit costs rise, causing an overall increase in costs per EFH. This will reach levels closer to the JT8D-200. AC