The JT8D will be around for another 20 years and its role is evolving into a low utilisation engine. An examination of workscope patterns and contents and costs per flight hour are made for engines in a passenger and freight operation.

Economics of baby JT8D maintenance

Baby JT8Ds still operate in numbers exceeding 6,900, with about a further 850 spare powerplants. The 727, 737-200 and DC-9 are now being phased out of major airline fleets after several tentative plans to do so over the past 15 years. These aircraft will still be operated by secondary airlines around the world, while the number of 727 freighters continues to increase. The importance of the JT8D Baby series and its maintenance costs cannot therefore be overlooked.

A study of the JT8D's operation, periodicity of shop visits and their technical contents will provide a guide to maintenance cost per engine flight hour (EFH) or engine flight cycle (EFC) for JT8D operators.

The JT8D fleet has a shop visit rate (SVR) of about 0.165–0.200 per 1,000FH. The average removal interval for a a shop visit is therefore about 5,000–6,000FH. The engines in service generate about 3,600 shop visits a year and the engine is a major source of business for many engine shops around the world.

JT8D in operation

The Baby JT8D series operates short to medium FCs on the 727, 737 and DC-9 in a variety of roles.

The 737-200 and DC-9 have remained in a short-cycle passenger role. The 727 has two roles of passenger and freight operations. About 500 727s are configured as freighters and many are used in small package operations and generate low annual utilisations. This means about 1,600-1,700 JT8Ds are operated at low utilisations.

This number of 727Fs will continue to grow by as much as 300 as major airlines retire more of their fleets and get converted to freighters. Delta's last 727-200s have recently been bought for this purpose. The engines powering these aircraft will all require an appropriate maintenance programme.

Utilisations on passenger aircraft are about 2,000–2,500FH per year, or about 200FH per month. "The passenger operators of the 727, 737 and DC-9 operate average cycles between one and two FH per cycle," explains Mark Schuldiner, executive vice president at M&M Aircraft Services.

The cycle times on passenger aircraft also vary. "The DC-9s and 737-200s are operated on one-hour cycles," says Charles McIvor, president of The Wood Group. "The 727s in passenger operations operate longer cycles closer to two hours". Average cycle time for most passenger operations is 1.2–1.4FH and so an airline will accomplish about 1,800–1,900FC per year.

Most 727s operated by freight carriers fly just one return flight per night, five or six nights per week for about 50 weeks per year. "We are now finding that the freight carriers often fly the 727s on FCs between two and two and a half FH". Average freight airline utilisation is about 900FC and 1,600FH per year at an average 1.8–2.1FH per FC.

A fleet of engines that have always been operated by the same airline would be expected to conform to a fairly similar and ordered removal and shop visit pattern.

There are many other JT8D-powered aircraft that have changed ownership and operator, resulting in alterations to their maintenance programmes.

The JT8D fleet has experienced several downturns and parking and then restoration and re-entry into service as a result. A large number have also been traded by brokers and owned by lessors, which have different maintenance requirements to airlines. Engines have also been broken into modules, which have then been swapped and exchanged. The maintenance history of many engines is therefore chequered.

Engine removal pattern

The standard engine removal pattern for the Baby JT8D series has been an alternation of removals for engine shop visit 1 (ESV1) and engine shop visit 2 (ESV2).

These two shop visits are loose definitions, but the ESV1 generically involves a heavy hot section inspection and the ESV2 a full overhaul.

Both visits were performed at similar and constant intervals of about 5,000–6,000EFH. The majority of the JT8D's life limited parts (LLPs) have lives of 20,000EFC, although some have lives as short as 15,000EFC. The similarity of the lives of the LLPs meant they could all be replaced at the same time. This could be planned to occur during an ESV2.

Shop visit intervals of 4,000EFC are fairly regular. This means LLPs could be placed every fourth shop visit, say after 16,000EFCs. This way the remaining life of LLPs would be the same throughout an entire engine. Maximum utilisation could be gained from the life of the LLPs and so the cost of replacing them with a new set could be amortised over the largest possible number of EFCs, keeping the cost per EFH or EFC to a minimum.

The switch to low-utilisation operations has resulted in some JT8Ds altering their shop visit programme to a system of two successive ESV1s and an overhaul.

The time between engine removals would also be maximised if possible to amortise the resulting cost over the highest possible number of EFHs or EFCs.

Changing patterns

This basic and easy to manage maintenance programme has not been adhered to for all JT8Ds and this is due to a number of factors. Previous gluts of JT8Ds made it more economical to exchange engine modules requiring a shop visit with time-continued modules, than to put the worn module through a shop. This was one cause of a mis-match of LLPs throughout the engine. Many engines now have LLPs with a range of remaining lives. This means less of their lives can be utilised.

Another reason for having variable or 'stub' LLP lives is that some disks are found to have corrosion when they are inspected during a shop visit. This will lead to a single disk being replaced, causing further variation.

One of the JT8D's most notorious problems has been corrosion of the high pressure compressor (HPC) disks between the 7th and 13th stages on engines operated under a low utilisation programme. Corrosion on these disks has been found as a result of low utilisation or parking.

This issue has been addressed by Service Bulletin (SB) number 6038 and Airworthiness Directive (AD) number 98-12-07. This concerns engines that are operated for less than 1,300EFH or 900EFC per year.

The SB accounts for these disks by stipulating certain inspection intervals and subsequent replating treatment and remaining life depending on the utilisation of the engine. Ultimately the SB forces inspection of the disks and replacement prior to the full utilisation of their lives. The inspection further involves the HPC being de-bladed and re-bladed. The inspection had a 10-year hard time, but has now been reduced to seven years. The inspection involves accessing the HPC, which means an extensive disassembly.

"For low utilisation operators, the issue of SB 6038 means the HPC disks have to be inspected every seven years," explains Bob Nichols, chief operating officer at Aeroturbine. "Most JT8D engines will have a shop visit every five to seven years. Low utilisation operators are likely to perform the SB 6038 inspection every shop visit, increasing the content of the workscope.

"The 1st and 2nd stage high pressure turbine (HPT) blades are also tired after this amount of time and so just about all areas of the engine except the LPC have to be worked on," says Nichols.

"It has almost got to the point that everything is done to a low utilisation engine in every shop visit except the LPC section. Engines on a low utilisation operation are now going through a shop visit pattern which is becoming consistently heavy" explains Nichols. "Engines that remain on a high utilisation pattern of operation lend themselves to alternating ESV1/ESV2 shop visit programmes".

Removal intervals

The removal rate on the JT8D is largely driven by the deterioration of the turbine and hot section. The intervals between the ESV1 and ESV2 and between ESV2 and ESV1 are similar.

The resulting EFH interval is influenced by the EFH:EFC ratio, that is the operator's average flight time. Typical removal intervals are 4,000–6,000EFC. The actual time on-wing will also depend on the extent of the previous shop visit.

Most operators expect a SVR of between 0.16 and 0.2 shop visits per 1,000EFH. The number of EFCs between removals is more constant. "The actual interval tends to be more cycle related," says Schuldiner. "This works out at 5,000–7,000EFH and engine managers in airlines tend to perform a shop visit workscope to get this length of run. They also manage the engine and its shop visit workscopes so that they do not have to touch each module at every visit".

"A passenger airline flying up to 3,000FH per year would then expect a shop visit every 12–18 months," explains Ken Gulain manager overhaul marketing at General Electric Engine Services. The passenger operations tend to be more varied, however. Airlines such as Hawaiian fly about 20 minutes per cycle in a salty environment, while carriers such as Sun Country and American Trans Air fly three hour sectors.

Passenger airlines average about 2,400FH per year, and with an average FC time of 1.35FH would achieve about 1,800FC annually. On-wing times of 4,500EFC and 6,300EFH would be expected and so a shop visit would occur about every 18 months to two years.

A 727 freight operator typically achieves average longer flight cycles of 1.8–2.1FH and about 900FC and 1,600FH annually, and on-wing times of 5,000EFC and 8,100EFH. At this rate of utilisation and achieved on-wing times a shop visit would be expected every five years.

Workscopes

The classic JT8D maintenance programme of alternating ESV1 and ESV2 shop visits is a generic system that most JT8D operators have used for several decades.

The ESV1 is generically a hot section inspection (HSI) and deals with other problems that are revealed when the low pressure spool is exposed. An ESV1 therefore becomes a HSI and a variable additional workscope, depending on what is found when the engine is opened.

An ESV1 will involve the routine or basic content of a shop visit. This is the minimal requirement of disassembly, cleaning, inspecting, re-assembly and testing. These functions have to be performed for both the ESV1 and ESV2, although it will be larger for the ESV2.

The HSI is common to all ESV1s. The content typically includes removal, inspection, cleaning and repair and replacement of combustors and fuel nozzles. The nozzle guide vanes are also removed and exchanged and the outer outlet ducts repaired. The ESV1 will also often involve changing the engine's gearbox, external components and oil and filters.

Depending on condition, parts will either be repaired or replaced. First stage HPT blades (T1 blades) are coated or scrapped according to their condition. "There have been so many repairs developed for the JT8D over the years that there is a repair scheme for virtually every component in the JT8D," explains Nichols. Repairs will incur higher labour cost, while replacement will not increase labour requirement but will increase cost of materials. Overall, it is generally more cost-effective to repair material, than to replace it with new.

The on-condition nature of maintenance means the content of ESV1 can easily escalate. If T1 blades are in a bad condition then the LPT has to be removed to get access to the HPT, which increases the workscope.

Disassembling the engine to perform the HSI may then reveal an imbalance in other modules of the engine. This then increases the workscope and can easily lead to the workscope becoming an overhaul or ESV2.

"The content of an ESV1 can vary widely," explains Nichols. "The lightest basically amounts to a hot section inspection. A medium-sized workscope would be an HSI plus refurbishment of one or two other modules. The largest ESV1 would constitute an HSI plus the inspection and repair of all major modules (effectively an ESV2)".

The on-wing time since the last shop visit will also determine the content of the workscope. "If there has been more than 3,000 cycles since the last shop visit then the workscope will be heavier. For example, the T1 and T2 nozzle guide vanes will likely have lost their coatings," says Nichols.

Overall ESV1s are getting larger. "Some ESV1s are larger than expected. It might be prudent for an operator to budget for every other ESV1 to be larger than was normally expected in the past," recommends Schuldiner.

"Low utilisation operators tend to do more work on an ESV1 because of the SB 6038 inspection and the LPT containment AD. The heavier content of these ESV1s also defer a full ESV2 or overhaul," explains Gulain. "Engines used on a low utilisation operation therefore tend to conform to a pattern of two successive heavy ESV1s followed by a full overhaul. "Engines operated on a passenger level of utilisation will use the standard pattern of alternating ESV1s and ESV2s".

The ESV2 has traditionally been a full overhaul, following the HSI in ESV1. A full overhaul involves the disassembly, inspection and repairs on all five major modules. This includes the LPC, HPC, HPT, LPT, gearbox and combustion module.

Additional module work included in the ESV2 are: the intermediate case, the diffuser case, the fan case, the accessory gearbox and the exhaust case. Apart from these modules the bearings will be inspected and LLPs replaced if appropriate. Other smaller modules will be inspected and repaired on an on-condition basis.

The JT8D's maintenance pattern is generally structured on the basis that the

SUMMARY OF BABY JT8D MAINTENANCE CHARGES

Style of operation	High utilisation passenger	Low utilisation freight
FH per year	2,400	1,600
FC per year	1,800	900
FH:FC ratio	1.35	1.80
First shop visit		
Description	ESV1	Heavy ESV1
On-wing time-EFH	6,100	9,000
On-wing time-EFC	4,500	5,000
Man-hours	2,000	2,400
Material costs $	300,000	430,000
Sub-contract repairs $	40,000	50,000
Second shop visit		
Description	ESV2	Heavy ESV1
On-wing time-EFH	6,100	9,000
On-wing time-EFC	4,500	5,000
Man-hours	2,500	2,400
Material costs $	550,000	430,000
Sub-contract repairs $	80,000	50,000
Third shop visit		
Description	n/a	ESV2
On-wing time-EFH	n/a	9,000
On-wing time-EFC	n/a	5,000
Man-hours	n/a	3,000
Material costs $	n/a	650,000
Sub-contract repairs $	n/a	90,000
Total shop visit costs (labour @$50/man-hour)	**1,195,000**	**2,090,000**
Total EFH	12,150	27,000
Total EFC	9,000	15,000
$/EFH or EFC	**98/133**	**77/139**
LLP lives-EFC	20,000	20,000
Utilised LLP lives-EFC	18,000	10,000/19,000
LLP cost-$	475,000	475,000
LLP cost-$/EFH or EFC	20/27	20/35
Total maintenance reserve budget-$/EFH or EFC	**117/160**	**97/174**

majority of the engine's modules have twice the durability of the hot section. The hot section will therefore need to be inspected and repaired at every shop visit and all other modules at every other shop visit.

The ESV2 is a performance restoration workscope and all parts of the engine are worked on except the low pressure compressor (LPC), or fan assembly. The LPC lasts the longest of all the modules and often can be worked on every third shop visit. The LPC therefore is worked on half the time during an ESV1 and the other half during an ESV2. This is another factor that increases the workscope of the ESV1.

"The ESV2 will also include a complete disassembly of the engine and de-blading and removal of LLPs when appropriate, as well as the stripping and re-coating of stators and vanes and replacement of blades," says Schuldiner. "An engine can only have a 30% content of B-class blades on a disk. A B-class blade is a repaired one with a chord width less than the specification of a new blade. As blades wear their chord decreases and this ultimately leads to blade repair and replacement. Blades and stators will, however, last up to 7,000EFH when given an aluminide coating. This coating means compressors can be up to 70–80% more efficient when their blades have this coating. There is also no limit to the number of times blades can be repaired unless they have been affected by foreign object damage".

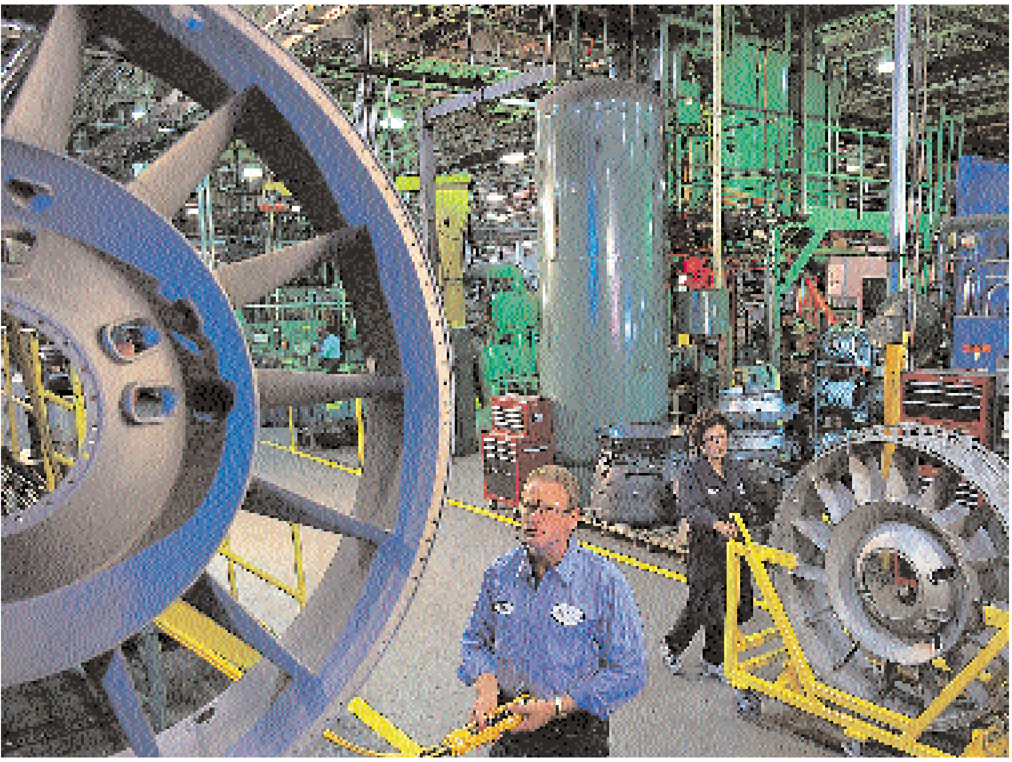
Schuldiner also explains that all bearings and LLPs will be replaced and external components will be overhauled during an ESV2. Some airlines have managed their engines so that LLP replacement for the entire engine is avoided at the same shop visit. "An airline might therefore change LLPs in the LPT and HPC at the same time and other LLPs during a separate shop visit," explains Schuldiner. "This avoids excessive expenditure for LLP replacement at one visit and then a lower cost during another visit".

Shop visit costs

The resulting labour and materials used during these shop visits will ultimately determine maintenance cost per FH.

There are three variables that have to be considered in the cost of a shop visit: labour, the cost of materials and the cost to the engine shop of sub-contracting repairs. Many engine shops do not have a lot of parts repair capability and so sub-contract a lot of work.

An engine shop will charge customers for three elements. The first and second are labour and materials. The third is special processes, which accounts for the



Operators should be aware that engine shops with small in-house repair capability will charge less for labour but more for part exchanges.

cost of operating machinery to perform special repairs such as grinding or re-plating. The cost of sub-contract repairs is included in the material element of the cost charged to the airline.

If an engine shop has more repair capability it would then be charging more for labour and less for materials. Although the three elements of labour, materials and special processes will vary, their total should be similar from one shop to another.

The amount of basic labour for dis-assembly, inspection, re-assembly and testing should be similar for all ESV1s. The variation in labour used will come from the amount of repairs required. This will increase as the engine gets older or a heavier shop visit is required. The basic labour for a shop visit totals about 1,000 man-hours (MH).

An engine that can have a large proportion of its parts repaired will have relatively high labour cost and low material charges compared to one with a higher degree of parts replacement. In this case labour or exchange fees will be lower but material costs will be higher.

The total amount of labour used can be reduced by engine shops exchanging parts rather than billing for repairs. This reduces turn time, and can also provide an engine shop with the opportunity to make a mark-up on the exchange fee.

The number of MH quoted for a shop visit can therefore be misleading, since each shop has its own level of repair capability. The basic labour for an ESV1 is about 1,300MH. Total labour consumption for an ESV1 varies between 1,500–1,900MH for an engine kept on a typical alternating ESV1–ESV2 shop visit pattern. A conservative budget of 2,000MH should be made since engines are getting older and are being affected by more issues (*see table, page 28*).

Heavier ESV1s for engines operated on a low utilisation programme or becoming subject to ADs or increased work will start at about 2,000MH and can be as high as 2,500MH. A budget of 2,400MH should be made.

Typical labour consumption for an ESV2 will start at 2,000MH and can be as high as 2,500MH for a shop with relatively little in-house repair capability. An ESV2 being performed in a shop with a large amount of repair capability can use as much as 2,800–3,300MH (*see page 28*).

A budget of 2,500MH for an engine operated by a passenger airline should be made, and one of 3,000MH for an engine on a low utilisation style of operation.

As with MH consumption, material costs will depend on the exact workscope. For an engine operated on a high utilisation operation, airlines should budget $300,000 for all materials except LLPs and a further $40,000 for sub-contract repairs for an ESV1. The materials included in this budget are: new parts, materials used to repair parts, lubricants and oils, fuel for the test, consumables and expendables and rotables.

The actual cost of materials not only varies with workscope but with the repair capability of the shop as well. While there is a trade between labour and material costs, the total should be similar for the same workscopes.

These material costs and labour, charged at a burdened rate of $50 per MH, brings the total ESV1 cost to $440,000, except for an allowance for LLPs.

Material budget for an ESV2 will be $550,000 for parts and materials and $80,000 for sub-contract repairs not including LLPs (*see table page 28*).

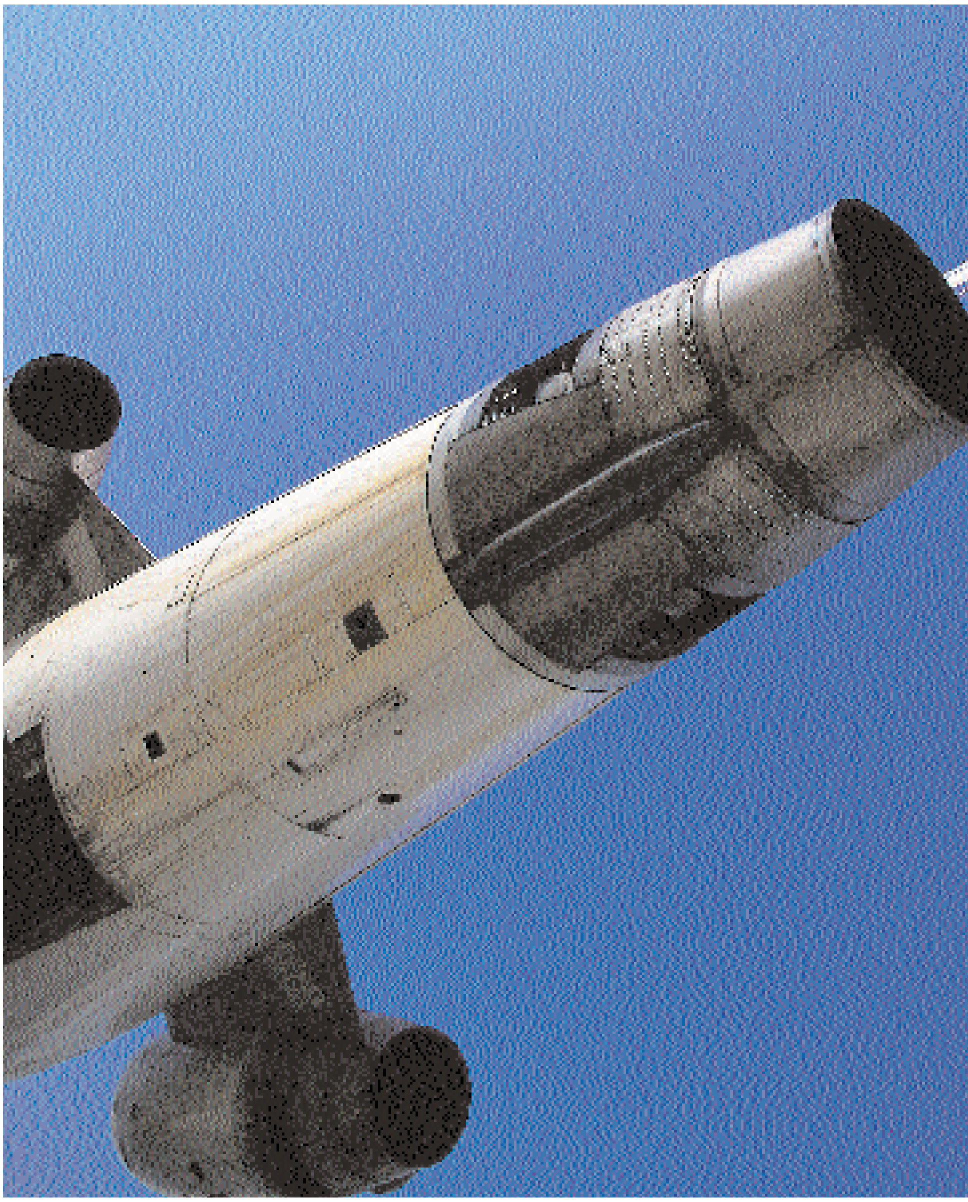
An engine on a low utilisation operation which has a heavier ESV1 workscope and uses about 2,400MH, will consume about $430,000 in materials and another $50,000 in sub-contract repairs. Total expenditure for this shop visit, excluding LLPs, will be about $600,000.

The ESV2 for this engine will require about $650,000 for materials and $90,000 in sub-contract repairs. Total expenditure for all items, except LLPs. will be about $890,000 (*see table page 28*).

The proportion of material costs, sub-contract repairs and labour for the JT8D has changed over the years as an increasing number of repairs have been developed for the JT8D. “As much used material as possible is now being used,” claims Gulain. “The availability is increasing in the secondary market and customers want to avoid repairs. You have to be aware, however, that while used material reduces shop visit cost it also shortens subsequent time on-wing. An airline such as Southwest, which has a high level of utilisation, has less incentive to use used parts because it requires engine durability. Different levels of performance requirements require different levels of new and used parts”.

The increased number of used and scrapped JT8Ds on the market has increased the availability of parts. “Its very easy to obtain parts for lower-powered JT8D variants,” says McIvor. “Material for high-powered JT8D variants is scarce and so shops are more likely to repair parts for these engines”.

The cost per flight hour for low utilisation engines will be in the region of $100, including LLPs. Operators should note that it can take many years for an engine to go through a full workscope cycle.



Bob Nichols agrees. "The average price of overhauled material is about 70% of list price for new parts. More scarce parts have market values at about 90% of list price".

Life limited parts

The cost of dealing with LLPs is affected by SB 6038. If an engine is operated on a low utilisation operation, inspection of disks quite often results in them being scrapped.

The hard lives of most LLPs is 20,000EFC, although a few have only 15,000 and 16,000EFC lives.

The 7th to 12th HPC disks are often scrapped early on low utilisation engines. "These disks are made of steel alloy and are more susceptible to corrosion," explains Michael Mullens, senior vice-president, operations, at A&T. "Generally these remain in service only about 50% of their lives. The same disks in high utilisation engines and all other LLPs in all engines can utilise most of their lives".

The actual utilisation of LLP lives will depend on the timing of shop visits. An engine on a passenger level of utilisation will accumulate about 18,000EFC every four shop visits, or the second ESV2 in sequence. This is almost ideal timing for LLP replacement. Ones with shorter lives of 15,000EFC will have to be replaced at earlier shop visits. Some can be replaced in a third shop visit, an ESV1, while others in the compressor will have to be replaced at the first ESV2 after just 9,000EFC.

A full set of LLPs for the JT8D is about $475,000. A high utilisation engine will therefore use LLPs at the rate of about $27 per EFC, or $20 per EFH.

The 7th to 12th HPC disks in low utilisation engines, which get scrapped at about halfway through their life will be replaced every second shop visit on average. Low utilisation engines using a shop visit pattern of two ESV1s followed by an ESV2 will probably have to replace the C7 to C12 disks at the second ESV1.

This will be at about 10,000EFC and 18,000EFH. The list price for a set of C7 to C12 disks is about $88,000. The amortised cost for these will be $9 per EFC or $5 per EFH.

Many of the remaining LLPs, which cost about $390,000, could be utilised and so replaced most efficiently at either a heavy ESV1 or an ESV2. Replacing every fourth shop visit, either an ESV1 or ESV2, would achieve full 20,000EFC life utilisations. It would probably not be possible to replace them at this shop visit after using 20,000EFC and 36,000EFH, but near full life utilisation would be achievable. Early replacement every ESV2 would use 15,000EFCs and 27,000EFH of their lives. Amortisation for these LLPs would then be $20–26 per EFC or $11–15 per EFH.

Cost per EFH/EFC

The shop visit intervals and costs described are generic but provide a guide to budgeted maintenance costs.

The engine operated by an airline following an alternating ESV1 and ESV2 shop visit pattern will accumulate about 9,000EFC and 12,000EFH in the intervals for the two shop visits and a total cost of $1,200,000 for the two workscopes except for LLPs. This generates a cost of $97 per EFH or $133 per EFC. To this would be added the LLP cost to bring the total reserve budget to $117 per EFH or equal to $160 per EFC (*see table page 28*).

An engine operated on a low utilisation programme and with an average FH:FC ratio of 1.8:1.0 will probably conform to a workscope pattern of two heavy ESV1s followed by an ESV2. The total on-wing time to complete this cycle is 27,000EFH and 15,000EFC. The total cost for the three shop visit will be about $2.1 million and will generate a maintenance cost of $77 per EFH or $139 per EFC for all items except LLPs. Including LLPs the total reserve budget would be $97 per EFH or $174 per EFC (*see table page 28*).

Considering the JT8D's consistent EFC intervals between shop visits and workscope content, a variation in average EFC length will result in similar shop visit costs but different costs per EFH. For example, an engine in a passenger operation with an average flight cycle time of 1.0FH, will still incur shop visit costs close to $1.2 million, but the cost per EFH will be increased from $97 per EFH to $126 per EFH, plus an allowance for LLPs. AC