Maintenance costs are an important element of cash operating costs, and are increasing as a percentage of total costs for the 727-200F & DC-8 series. The full maintenance costs of the 727-200F, DC-8 series, 737-300F/-400F & 757-200F are analysed.

Narrowbody freighter maintenance costs

The older generation narrowbody freighters range in age from 25 to 40 years old, and their maintenance costs are high and still increasing.

Low capital cost has always been a deciding factor in fleet replacement decisions for freight aircraft operating at low rates of utilisation. Direct operating cash costs, including maintenance, have usually had a secondary influence. Younger aircraft need to have a large enough advantage over existing older freighters in terms of cash operating costs and low enough capital or financing costs for freight airlines to justify their acquisition. A fleet switch can also be triggered, however, by the constant increases in the direct cash operating costs of older freighters, and their waning reliability.

While a large number of DC-8s have been retired from service, and many others will be retired before they go through their next D check, operators have to consider the economics of replacement options. The 757 is a smaller DC-8 replacement candidate, while several widebodies provide similar or larger payload capacities. There are still about 250 727-200Fs in operation, and each year more are retired. The 737-400 and 757-200 straddle the 727-200F in payload capacity, so both are 727 replacement candidates.

It is relatively easy to establish fuel burn and crew costs, and the 737 and 757 clearly have an advantage over the older types in this regard. Maintenance costs, however, comprise many elements, so it is less clear which types hold an advantage and what the extent of that advantage is. The elements of maintenance include: line and ramp checks; base maintenance; heavy component repairs and overhaul; rotable component maintenance and management; and engine maintenance. An analysis of these elements for the 727-200F, DC-8F, 737-300/-400F and 757-200F is therefore an important factor in determining the point at which it becomes economic for operators to acquire new aircraft to replace the 727 and DC-8.

Initial considerations

The maintenance costs of these freight aircraft can be partially derived from their passenger counterparts. Care should be taken, however, since there are several differences between passenger and freighter aircraft that will compound to result in large differences in total maintenance cost per flight hour (FH) between the two. The first of these is the way in which freight aircraft are utilised. Not only are freighters often operated at low rates of utilisation, but their average flight cycle (FC) times are often different to those of passenger aircraft, which has a corresponding impact on their maintenance programmes. Freight aircraft can often be placed on low-

Many DC-8s have been forced into retirement by high maintenance costs. This has led to a surplus of engines and rotable components on the market, which has resulted in a small reduction in costs. The cost of heavy checks are now prohibitive for most operators, however, and most will be retired over the next five years.

Base check-related costs of 727s have been reduced by switching the aircraft to a MSG3 maintenance programme. The resulting costs per FH are still high, however, compared to younger generation 737-300/-400s and 757-200s.

utilisation maintenance programmes as a result.

A second maintenance difference concerns the amount of man-hours (MH) and materials used during line and ramp checks and base maintenance, which are lighter with freight aircraft.

A third main difference concerns the FH intervals achieved between base checks. While these intervals can be relatively high for passenger aircraft, freighter aircraft often accumulate fewer FH between base checks, which means that full check intervals are rarely utilised. Some freighter aircraft maintenance programmes have check intervals specified in calendar time for this reason. Freighter aircraft still often generally achieve fewer FH between base checks.

A fourth main difference is that the number of MH used in base checks is often smaller for freighter aircraft. Izo Nezaj, general manager at Commercial Jet, explains that this is because freighter aircraft do not incur the costs associated with passenger operations, relating to: seats; galleys; passenger service units; in-flight entertainment equipment; panels; lavatories; carpets; lighting; oxygen generators; and most of the safety equipment. Freighter aircraft will, however, have the cargo door, and its associated mechanism, and the cargo loading system. These features will therefore add to their maintenance requirements. Nevertheless, freighters usually have overall lower MH and material consumption for base checks compared to passenger aircraft of a similar age.

A fifth main difference will be the cost of components per FH due to differences in average FC time.

Differences in average FC time will also affect engine removal intervals and therefore engine maintenance costs per FH.

Maintenance analysis

There are several types of freight operation, and these influence the annual utilisations generated by aircraft. The DC-8 and 727-200 have been used extensively in trans-US and trans-European small- and express-package operations that often generate low annual utilisations. The aircraft are also used in general freight operations, which tend to have longer average FC times and generate higher annual utilisations.

The 727-200F, DC-8-60 series, DC-8-70 series, 737-300/-400 and 757-500 have also been analysed in two different operating scenarios. The first is a low-utilisation, express-package type of operation, which only generates about 700FC per year. At an average FC time of 2.0FH, they would accumulate about 1,400FH per year. The general freight operation is taken to have a longer average FC time of 3.0FH, with the aircraft generating about 2,500FH and 800FC per year.

The full direct maintenance costs of these aircraft types have been calculated on a per FH basis for these two styles of operation. Five main elements of total maintenance costs are discussed and summarised *(see table, page 60).*

Maintenance programmes

An examination of aircraft maintenance programmes is the first step in determining complete aircraft maintenance costs.

The 727 has both MSG2 and MSG3 maintenance programmes. Most operators have MSG2 maintenance programmes, but these all now differ, as they have been adapted extensively since the aircraft's original maintenance planning document (MPD). There are the regular C check items with intervals averaging 3,000FH. D checks take place every tenth C check. There are also three ageing aircraft programmes, and check workscopes have to be planned to minimise downtime. Rotable repairs were hard-timed, but many operators have since adapted to on-condition maintenance programmes.

The 727's MSG3 programme, which has only been adopted by a few operators, is a system of C check tasks, which have a basic interval of 3,000FH and 24 months. There are 2C, 3C and 4C multiples. The C4 check has 1C, 2C and 4C tasks, and a 12,000FH/96-month interval. The ageing aircraft programmes have been incorporated into the C checks, and rotables are maintained on an on-condition basis.

Under this maintenance programme an aircraft operating at 1,400FH per year will accumulate about 2,100FH between checks, while an aircraft operating at 2,500FH per year will be able to use the full 3,000FH interval within the 24-month calendar limit.

The DC-8 has an MSG2 programme, with C checks every 3,000FH and 24 months. Aircraft operating at 1,400FH or 2,500FH per year will both be able to use the full 3,000FH interval. The average D check interval is 25,000FH and 120 months, so it is performed about every fifth C check.

The 737-300/-400's maintenance programme is based on a basic A check task interval (1A) of 250FH and a basic C check task interval of 4,000FH.

There are three additional task multiples of A check items: the 2A, 4A and 8A items. The cycle of A checks is therefore completed at the A8 check, which has an interval of 2,000FH. This means that the 1C items come due at the end of every second A8 check, every 4,000FH.

The 737-300 and -400 have overall maintenance costs that are lower than the 727-200's. The 737-300/-400 also have lower fuel and crew costs, but have smaller payload capacities.

In addition to the 1C tasks, there are four other C check task groups: the 2C, 4C, 6C and 8C tasks. There is also a group of tasks called the structural inspection (SI) tasks, which have the same 24,000FH interval as the 6C tasks. The 8C tasks have an interval of 32,000FH.

Operators have two choices in running maintenance programmes. The first is for tasks to be made at their respective intervals, in which case the C7 and C8 checks are both large in content and workscope. This way the base check cycle is completed at the 8C check every 32,000FH. The 6C and 8C tasks do not come into phase until the end of the third cycle; that is until the C24 checks.

The second option is for the base check cycle to be terminated at the C6 check every 24,000FH, in which case the 4C and 8C are done early and out of sequence.

The 757 is an MSG3 programme, with ageing aircraft tasks built into the base check inspections. There are two separate programmes for system and structural tasks. System tasks have FH intervals, while structural tasks have FC intervals. These groups can be performed separately or together at the operator's discretion.

The system 1A tasks have a basic interval of 500FH. There are 2A, 3A, 4A and 6A tasks, with the cycle completed at the A12 check at an interval of 6,000FH. There are two groups of structural A check tasks: the 1SA and 350FC and the 5SA at 1,500FC. Most passenger operators combine the 1A and 1SA tasks in the same check, to simplify planning. The 1SA could, however, be combined with the 2A tasks if the aircraft were operated at an FH:FC ratio of more than 3:1.

The basic 1C system tasks have an interval of 6,000FH and 18 months. This means that the aircraft would have to complete 4,000FH per year if it were to utilise the full 6,000FH interval. There are also 2C, 3C and 3C multiples with respective intervals, and the full cycle lasting up to 24,000FH and 72 months.

The basic 1SC structural tasks have an interval of 3,000FC and 18 months, which therefore means that the the 1C and 1SC tasks have to be grouped together. Because of the FH:FC ratio of most operators, the structural tasks' full FC intervals are rarely utilised. There are 2SC, 3SC and 4SC multiples, with the cycle lasting up to 12,000FC and 72 months. The base check cycle is completed at the C4 check, which comprises the largest group of structural tasks.

Line & ramp checks

As with all aircraft types, narrowbody freighters require a transit check prior to all subsequent flights during the day. They also require a daily or 24-hour check, which is more comprehensive than the transit check. This has to be performed prior to the first flight of each day.

For all aircraft types, the daily or 24-hour check generally uses up to about 5MH when non-routine items are considered. About $15 should be budgeted for materials and consumables. A transit check uses about 2MH and $10 for materials. There is little difference in the MHs and the cost of materials and consumables between the aircraft types for these line and ramp checks.

The 727-200 and DC-8 also have weekly checks in their line and ramp maintenance programmes. The weekly checks have slightly larger workscopes than the daily checks, and are generally used to clear defects that have built up during every seven- to eight-day period. They consume about 6MH and up to $80 for materials.

These inputs are analysed in terms of a standard labour rate for line and ramp maintenance of $70 per MH, and the total cost for all the checks performed on each aircraft over the operating year is expressed by the cost per FH for the two styles of operation *(see table, page 60)*.

A & B checks

As with the base checks, the workscopes of A and B checks for freighters will not include the items associated with the cabin interior that passenger aircraft require. This results in fewer MH being used.

As described, the 727-200F and DC-8 have A and B checks in their maintenance programmes.

The 727-200F has an A check interval of 100FH, and is assumed to use about 80FH of this interval. The aircraft uses a total of about 60MH for an A check and about $250 of materials and consumables. The analysis uses a labour rate of $70 per MH for A and B checks, and the total cost for the 727's A check is about $4,500. This is equal to a cost of $56 per FH *(see table, page 60)*.

The 727-200F has a B check interval of 500FH, and the interval used is assumed to be 400FH. The check uses an average of 450MH, which is equal to a cost of $31,500. With materials and consumables costing $3,500, the total cost for the check is about $35,000. This is equal to $88 per FH *(see table, page 60)*.

The DC-8 has the same A and B check intervals of 100FH and 500FH, and the actual intervals achieved are assumed to be 80FH and 400FH. The DC-8 uses about 60MH and about $250 in materials and consumables for an A check, taking the total cost of the check to $4,500. This is equal to $56 per FH *(see table, page 60)*. The aircraft uses about 400MH for a B check, and together with materials and consumables the check has a total cost of $31,500, which is equal to $79 per FH *(see table, page 60)*.

The A checks for the 737-300/-400 vary in size due to the different task multiples. The labour used for the A1 to A8 checks varies between 85MH and 325MH, equal to $6,000-23,000. The cost of materials and consumables averages $3,500 for the check. The average cost of an A check is $19,500. An actual interval of 400FH between checks means that the cost for A checks equals $96 per FH over the cycle *(see table, page 60)*.

The MH inputs for 757 A checks vary similarly to those for the 737. An actual utilisation of 400FH will see the full cycle of 12 checks being completed in 4,800FH. This is equal to about three and a half years for aircraft operating at the low rate of utilisation, and about two years for aircraft completing about 2,500FH per year. The 12 checks will use a total of about 4,000MH, equal to a labour cost of $280,000. The cost of materials and consumables is about $60,000. The total cost over the cycle of 12 checks therefore equals $70 per FH *(see table, page 60)*.

Base check inputs

With an MSG2 programme the 727 uses 10,000-12,000MH and $200,000-250,000 of materials in lesser C checks. A labour rate of $50 per MH takes the total cost to $500,000-500,000, with materials added. Relatively young 727-200s can be expected to consume 20,000-25,000MH and $400,000-500,000 in materials for D checks. The total check cost is in the region of $1.5 million.

The labour inputs into the checks are similar to those used for current generation medium widebodies. The total cost for all eight checks in the cycle is in the region of $7.0 million, although this will vary widely between different aircraft. This is equal to a reserve of $285 per FH *(see table, page 60)*.

Aircraft operated on an MSG3 programme use fewer MH for checks with the same interval. Lesser C checks consume 7,000-9,000MH, and $125,000-165,000 in materials and consumables, taking the total check cost to $500,000-600,000. The heavier C4 check will use about 12,000MH and $200,000-275,000 in materials and consumables. The total cost for the four checks in the cycle is about $2.5 million, and is equal to a reserve of $210 per FH. Although the MSG3 programme clearly reduces inputs and cost, few operators have adapted to it.

The DC-8 is maintenance intensive as well as old. For example, the aircraft has a lot of time-consuming mechanical items, including flap mechanisms and flight controls. These make the DC-8 labour-intensive, and it can use about 15,000MH and $300,000 of materials in a lesser C check. Aircraft in a better condition will use about 50,000MH, but many have been known to utilise 65,000-80,000MH and about $1.0 million in materials. This is similar to a 747-200/-300. A total of $11-12 million for the base checks will take reserves up to about $450 per FH *(see table, page 60)*. This high cost has forced the retirement of the majority of DC-8s, and will force operators of remaining aircraft to consider replacement options.

While the inputs for base checks on 737-300/-400s and 757-200s have been well documented, fewer MH will be used on these aircraft as converted freighters. There are three main reasons for this: first, in passenger configuration a lot of MH are used removing, cleaning and reinstalling many of the interior items to gain access to areas of the aircraft for structural inspections during heavy checks; second, freighter aircraft only use a fraction of the MH of their passenger counterparts for interior cleaning and refurbishment; and third, freighter aircraft have fewer findings and defects in areas around and below lavatories and toilets. Small savings can also be made from stripping and painting aircraft less frequently.

The 737-300/-400 converted freighters use 3,000-6,000MH for lesser C checks and 10,000MH for the C6 check, with a total of 30,000MH in the cycle. This compares to 38,000MH for passenger versions. With materials and consumables included, the total cost over the cycle will be $2.2 million, equal to a reserve of $105 per FH *(see table, page 60)*.

SUMMARY OF NARROWBODY FREIGHTER DIRECT MAINTENANCE COSTS

Aircraft type	727-200	737-300/ -400	DC-8-60/ -70	757-PW/ 757-RR
	$/FH	$/FH	$/FH	$/FH
Line & ramp checks	287	222	278	195
A & B checks	144	96	135	70
Base checks	285	105	450	190
Heavy components	152	116	285	244
Rotable components	280	220	320	300
Engine maintenance	3 X 100	2 X 210/ 2 X 240	4 X 50/ 4 X 160	2 X 240/ 2 X 355
Total costs	**1,448**	**1,179/ 1,239**	**1,668/ 2,108**	**1,479/ 1,709**
Annual utilisation:				
FH per year	1,400			
FC per year	700			

Aircraft type	727-200	737-300/ -400	DC-8-60/ -70	757-PW/ 757-RR
	$/FH	$/FH	$/FH	$/FH
Line & ramp checks	230	173	221	146
A & B checks	144	96	135	70
Base checks	285	105	450	110
Heavy components	96	74	182	155
Rotable components	280	220	320	300
Engine maintenance	3X 95	2 X 144/ 2 X 180	4 X 50/ 4 X 145	2 X 183/ 2 X 280
Total costs	**1,320**	**956/ 1,028**	**1,508/ 1,888**	**1,147/ 1,341**
Annual utilisation:				
FH per year	2,500			
FC per year	800			

The 757F has similar savings over its passenger variant. The aircraft use 2,500-3,500MH in their lesser checks and about 7,000MH in the C4 check in the first maintenance cycle, consuming a total of 16,000MH. They have a corresponding material cost of $0.5 million. This takes the total cost for base checks in the first cycle to about $1.2 million. Checks in the second cycle use more inputs, with the C8 check using about 8,500MH. The total inputs for the four checks are about $1.6 million.

Aircraft in their second base check cycle operating at 1,400FH per year will have reserves of $190 per FH, while those operating at 2,500FH per year will have reserves of $110 per FH *(see table, this page).*

Heavy components

There are four types of heavy component: the wheels and brakes; landing gear; thrust reversers; and auxiliary power unit (APU).

There are differences between the older and younger types for costs relating to the landing gear, thrust reversers and APU. For example, there is little difference between the landing gear overhaul intervals for older and younger types, but the overhaul and exchange fees for the older types are lower than for younger aircraft, which means that older aircraft have lower costs per FC.

The older aircraft have lower thrust reverser overhaul costs, but have more engines. Overall the older types have higher related costs per FC.

The older aircraft also have higher APU-related costs per FC, because their APUs have shorter removal intervals, although shop visit costs are similar.

The total costs for the these four categories are $300 per FC for the 727 and about $570 per FC for the DC-8s. The 737 and 757 clearly benefit with costs of $235 and $490 per FC. The FC rates are adjusted according to average FC times.

Rotable components

Rotable components can be supplied via a number of different mechanisms and support packages. The simplest ultimately result in a level of guarantee and service for airlines, while also managing inventories, repairs and paperwork. These support packages can be structured to provide airlines with predictable fixed rates per FH. These rates depend on fleet size, aircraft utilisation, and route network.

The 727-200 and DC-8 have the advantage that rotable components are now in high supply and their market value is low. However, their reliability is poor and repair costs are often high compared to those of younger aircraft types.

Typical market rates for complete rotable support packages for the 727-200 are about $280 per FH, and about $320 per FH for the DC-8. This compares to about $220 per FH for the 737-300/-400, and about $300 per FH for the 757-200 *(see table, this page).*

Engine maintenance

727-200

The 727-200 is equipped with a range of JT8D variants. The JT8D fortunately has solid removal intervals, low shop visit costs and a set of low-priced life limited parts (LLPs) with uniform lives of 20,000 engine flight cycles (EFCs).

The JT8D is capable of achieving removal intervals of 4,000-5,500EFC when operated at a cycle time of 2.0-3.0EFH. The engine generally conforms to a simple alternating shop visit pattern of performance restorations and overhauls.

The JT8D is affected, however, by airworthiness directive (AD) 2003-12-07, which relates to engines operated at low rates of utilisation. This AD requires a full inspection of all LLPs every eight years, regardless of their rate of utilisation. This is equal to about 11,000EFC in the case of engines in the first scenario, and is similar to their expected removal interval, so it forces the engine to have a heavy shop visit every removal. It will force engines operated at an average EFC time of 3.0EFH to have a performance restoration about every four years or 10,000EFH, and to have an overhaul about every eight years or 20,000EFH/6,700EFC.

The average cost of a performance restoration is $550,000, and an overhaul about $900,000. A full set of LLPs has a list price of just $700,000. Their full lives can be used for engines operating at cycle times of 2.0EFH, and would have to be replaced every third removal when operating at a cycle time of 3.0EFH. Many operators could now choose not to keep reserves for LLPs, since many used modules are available on the market with time-continued LLPs. Full LLP reserves will be $37-40 per EFC, however.

Total reserves for engines operated at a cycle time of 2.0EFH will be $100 per EFH, and for engines operated at 3.0EFH they will be $95 per EFH *(see table, page 60)*. This is the lowest total engine cost of all aircraft types.

DC-8-60/-70

Although the DC-8 is disadvantaged by its high airframe maintenance costs, the -60 series has low engine maintenance costs thanks to the retirement of large numbers that has left a surplus of used and time-continued JT3D engines on the market. While shop visits are relatively cheap, with a good performance restoration costing up to $350,000 and an overhaul in the region of $0.5 million, remaining operators are now buying time-continued engines when installed ones have lost all their exhaust gas temperature (EGT) margin. A good quality time-continued engine has a value of about $150,000, and a test cell run would add a further $10,000. Operators might expect such an engine to operate for about two to three years or 5,000EFH before it had to be replaced. Poorer quality engines might cost $50,000-75,000 in the current market, and require a further $50,000 for a small performance restoration, with maximum expenditure reaching the $150,000 level.

This would result in reserves of $30 per EFH, or possibly higher at $40-50 per EFH if shorter removal intervals were achieved *(see table, page 60)*. Operators do not have to consider LLP lives and reserves if they buy engines with enough LLP life remaining. Even though the DC-8 has four engines, reserves are low compared to all other aircraft.

The CFM56-2 was used to re-engine the -60 series, producing the -70 series. This lowered the aircraft's noise emissions, reduced the aircraft's fuel burn and gave it longer range. Its engine maintenance reserves are now higher than the JT3D powering the -60 series, but only because this fleet has imploded.

The CFM56-2 has the same core engine as the -3 series, but the -2 has a smaller fan diameter and fan module. The -2's shop visit costs are therefore close to the -3's. The -2 generally achieves removal intervals of 8,000-11,000EFH when operated at average cycle times of 2.0-3.0EFH. This is equal to 3,000-4,500EFC, depending on cycle time.

The engine's three groups of LLPs have lives of 20,000-30,000EFC, and could be replaced every fifth to ninth shop visit, with a stub life of 2,000-3,000EFC remaining. On this basis, LLP reserves would be $75-80 per EFC. Since many DC-8s are likely to be retired over the next few years, operators will be able to avoid replacing LLPs in virtually all cases, and to buy time-continued engines instead if necessary.

Shop visit workscopes are relatively heavy for most removals, and so incur costs of $900,000-1,100,000. Reserves for engines operated at 2.0EFH are therefore $145-160 per EFH, including LLPs. They are $135-145 per EFH for

The 757-200s' maintenance costs are similar or less than the 727-200's, and less than the DC-8's. This advantage comes from all elements of maintenance, with the exception of engine-related maintenance in some cases.

engines operated at 3.0EFC *(see table, page 60).*

737-300/-400

The 737-300/-400 are powered by the CFM56-3, which is now mature in maintenance terms for aircraft that are being converted to freighter. Most 737-400s are equipped with engines rated at 22,000lbs thrust and most -300s are equipped with engines rated at 20,000lbs thrust. These have EGT margins of 35-40 and 55-60 degrees centigrade following shop visits. The engines rated at 22,000lbs thrust can last 5,000-6,000EFC on wing when operating at a cycle time of 2.0FH, and 4,000EFC at a cycle time of about 3.0FH; equal to 10,000EFH and 12,000EFH. Engines rated at 20,000lbs can remain on wing for 14,000EFH at a 2.0FC and 19,000EFH on-wing at a 3.0FC.

At these FH removal intervals, the mature CFM56-3 will generally follow a pattern of alternating shop visits, with a performance restoration being followed by an overhaul. The cost of a performance restoration is $0.9-1.0 million, while an overhaul is $1.4-1.55 million. A full set of LLPs has a list price of $1.55 million, and lives of 20,000-30,000EFC. Considering removal intervals and LLP stub lives, LLP reserves will be about $240 per EFC.

Overall, the engines rated at 22,000lbs thrust will have reserves of $240 per EFH for a cycle time of 2.0EFH and $180/EFH when operated at a cycle time of 3.0EFH. Engines rated at 20,000lbs thrust will have reserves of $206 per EFH when operated at a cycle time of 2.0EFH and $144 per EFH when operated at a cycle time of 3.0EFH *(see table, page 60).*

757-200

The 757 fleet is divided between PW2000- and RB211-535E4-powered aircraft. The PW2000 suffered early reliability problems, as a result of which the RB211-535E4 was able to take advantage and gain the majority of customers. Large numbers of PW2000-powered aircraft are operated by Delta, Northwest and United.

The PW2000 fleet is divided between those with the RTC modification, which increases EGT margin, and those without it. About half those built before 1994 do not have the modification, while all other engines do. Those with the modification have removal intervals of 5,500-7,000EFC, which is equal to about 14,000EFH and 17,000-18,000EFH for engines operated at average cycle times of 2.0 and 3.0EFH. Engines without the modification have intervals of 4,000-5,000EFC, which is 10,000EFH and 12,000-13,000EFH for engines operated at cycles of 2.0 and 3.0FH.

Most of the PW2000's LLPs have lives of 20,000EFC, and the shipset has a list price of $3.3 million. It is best for the modified engines if LLPs are replaced every third shop visit so that almost all LLP lives can be used, although the PW2000 can alternate between performance restorations and overhauls. LLP reserves will be $175-185 per EFC.

Lighter shop visits cost $1.5-2.0 million, and overhauls cost $2.0-2.5 million. Reserves for modified engines will cost $150 per EFH and $123 per EFH for operations at 2.0EFH and 3.0EFH. Reserves for unmodified engines will be $205 per EFH and $172 per EFH for operations at 2.0EFH and 3.0EFH.

This will take total reserves to $240 and $183 per EFH for modified engines, and $295 and $183 per EFH for unmodified engines *(see table, page 60).*

The RB211-535E4 is a durable engine, and remains on wing for about 13,000EFH when operating at 2.0EFH, and for about 16,000EFH when operating at 3.0EFH. Loss of EGT margin rarely causes the removal of the engines.

The engine alternates between workscope level 3 and level 4, which cost about $3.3 million and $3.8 million respectively. These shop visit inputs will result in reserves of $275 per EFH for engines operating at 2.0EFH, and $222 per EFH for those at 3.0EFH.

A full set of LLPs has a list price of $2.8 million, and reserves will be about $160 per EFC. The total reserves will be $355 per EFH for engines operated at 2.0EFH, and $280 per EFH for those operated at 3.0EFH *(see table, page 60).*

Summary

Although they have lower engine maintenance costs, the 727 and DC-8 are clearly disadvantaged in terms of all other maintenance costs compared to the 737-300/-400 and 757 *(see table, page 60).* The 727 has overall maintenance costs that are equal to or higher than the 757's, depending on the 757's engine type and rate of aircraft utilisation. The 737-300/-400 meanwhile has an advantage of $200-275 per FH over the 727. This has to be put in perspective against the 727's higher payload, so all operating costs should be considered.

The DC-8-60's costs are up to $350 per FH higher than the 757's, and the DC-8-70 has an even higher difference of up to $600 per FH. The DC-8-60/-70 do, however, have the capacity for up to three more maindeck containers and 25,000lbs more gross structural payload. Another significant issue is the DC-8's poorer reliability, which led, for example, to United Parcel Service retiring most of its DC-8-70 fleet.

Older aircraft can possible savings in engine maintenance and heavy checks. Savings from engine maintenance are only possible, however, because of the large numbers of 727s and DC-8s that have been retired. The cost of heavy checks can be avoided, but only if there are plans to retire the aircraft. AC