The DC-10 can be operated under MSG2 and MSG3 maintenance programmes. MSG3 offers new operators a chance to take advantage of extended check intervals and to reduce maintenance costs that are already low for an aircraft of its age and generation.

Maintenance cost budget for DC-10s

The DC-10 has entered its twilight years. Many have now been or are due to be converted to freighters. A minority of the global fleet is still configured as passenger aircraft, but even this portion is diminishing. Consequently, the DC-10's airframe and component and maintenance charges for the freighter aircraft are now important to operators and would-be operators.

This guide provides an analysis of the DC-10's airframe and component maintenance requirements, their periodicity, cost and resulting cost per flight hour (FH) for the aircraft.

DC-10 in operation

The DC-10-30 and -40 freighters are operated on both north-south routes to and from the US, trans-Atlantic networks and to a smaller degree in the Asia Pacific region. Annual utilisations for most aircraft are about 3,500FH per year.

Domestically operated DC-10-10s in the US generate less FHs. Passenger carriers with -30s and -40s have similar levels of utilisation to freight operations. Passenger and freight operations for the -30 and -40 use aircraft on 4.0–6.0FH flight cycles (FCs). An average FC of 5.0FH therefore means annual FC utilisation is 700.

Maintenance programme

The DC-10 was originally operated with a maintenance steering group 2 (MSG2) maintenance programme. In recent years a MSG3 programme has been developed for the aircraft.

The objective of the new programme is to simplify the DC-10's maintenance and reduce checks and manhours (MHs).

The MSG 2 programme originally started with A check intervals of 250FH, C check intervals of 3,000FH and D check intervals of 20,000FH. "The D check was a structural check, with two groups of structural samplings," explains Donal Boylan, vice president technical at Ten Forty Corporation. "One group was mandatory for every aircraft, and thus was performed on each aircraft in all D checks. The other group was sampling items which had to be performed on one-fifth, one-seventh or one-twelfth of the fleet. An airline with three aircraft therefore has to customise its maintenance programme and spread sampling over the fleet. One with five aircraft could do a fifth of the sampling on each of the aircraft".

Over the years DC-10 operators managed to escalate their intervals; particularly for the A and C checks. A check intervals were increased to 450–650FH, C checks to 4,500–5,500FH, while most D checks were kept at 20,000–22,000FH.

The DC-10's ageing aircraft programme issued during the early 1990s complicated maintenance. The programme has three major elements: corrosion prevention and control programme (CPCP), structural inspection document (SID) and ageing aircraft modifications. The CPCP and SID are repetitive issues, while the ageing aircraft modifications have to be completed once.

However, most DC-10s have had ageing aircraft modifications terminated, leaving just the CPCP and SID. The CPCP has to be repeated at calendar intervals, while the SID inspections have to repeated at different numbers of flight cycles.

Since the CPCP and SID were issued as airworthiness directives (ADs), complications were added to the maintenance programme. CPCP and SID inspections were out-of-phase with escalated C and D check intervals, and the two had to be coordinated. As a result in many cases calendar intervals of 18 months and five to seven years were introduced for the C and D checks.

There were also zonal inspections which had to be made at 4,000FH intervals. Overall, the DC-10's maintenance programme became very messy under MSG2. C checks in some cases became escalated to 4,000FH to coincide with zonal inspections. This was made even worse by the zonal inspections being vague and open to interpretation.

Structural sampling caused further problems when aircraft changed operators. "Because operators had their aircraft incorporated into their own sampling programme and each aircraft had a particular group of sampling inspections carried out on it, introducing a used aircraft into another fleet meant it had to be bridged into the new carrier's sampling programme," explains Boylan. "This sometimes means 100% of all sampling has to be performed on an aircraft even straight after having had a D check".

MSG2 airframe checks

The DC-10's maintenance programme under MSG2 has pre-flight, daily and eight-day checks for line maintenance. Each involves typical line activities.

The economics of the DC-10's maintenance will be largely influenced by the periodicity of the checks and their MH consumption. Aircraft utilisation will be another factor. For the basis of analysing maintenance costs it is assumed the DC-10 flies average FCs of 5.0FH and

The DC-10 can be operated under MSG2 and MSG3 maintenance programmes. A large bridging check is required to take the aircraft to MSG3, which may deter operators with aircraft that are old or due to be retired. New operators have to revert to the aircraft's original MPD maintenance check intervals if they stay with MSG2.

achieves an annual utilisation of 3,500FH and 700FC.

Line maintenance checks basically require MH inputs and the use of materials and consumables. They also involve the continual removal and replacement of line replaceable units (LRUs) and rotable components. These rotables are maintained on an on-condition basis; not those scheduled for repair during heavier checks. The cost of dealing with LRUs is dealt with later.

A check intervals are 450–650FH. Some operators with a lot of experience, such as Finnair, have intervals as long as 650FH. Although Finnair no longer operates the DC-10, it manages Air Liberté's fleet under a MSG2 programme. Similarly, AOM has an interval of 600FH.

A conservative interval for estimating maintenance costs would be 600FH. In reality the actual interval is likely to be about 550FH. The A check is comprised of 1A, 2A, 3A, 4A, 5A and 6A job cards. These are typically equalised by operators into a standard A check package. The A check cycle will therefore be completed after about 3,300FH.

The A check cycle is independent of the C check cycle. Therefore it does not have to be terminated when the C check is performed.

The C check has an interval of 4,500–5,500FH and 18 months in most cases. It is made up of 1C, 2C, 3C and 4C job cards. Like the A check, the C check package is equalised into a standard package. An interval of 5,000FH would mean the check has to be performed every 17 months at an annual utililisation of 3,500FH per year.

The C check cycle is independent of the D check cycle, but airlines try to co-ordinate the fourth C check with the D check to minimise downtime. This would then be at 20,000–22,000FH and five to six years.

Any estimation of MH for checks has to take into account several aspects. Basic checks incur MH for routine inspections, administration and docking. Routine inspections result in non-routine work or defects. The ratio of defects will vary according to several factors. The DC-10 has a reputation, however, for low defect ratios in checks relative to other aircraft of a similar age.

Other items are the additional MH for ageing aircraft work, engine changes and changes of heavy components such as landing gear and the auxiliary power unit (APU).

MH estimates can be further complicated by airlines getting deals from third-party maintenance providers which guarantee up to a specified level of defects in an overall cost.

Check inputs

Estimating MH consumption for line checks is difficult because of the nature of an airline's operation. For example, a critical mass of line mechanics are required at each line station. The fleet size and timing of flight arrivals influences the number of line mechanics required. Airlines will sub-contract line maintenance at outstations, making it harder to estimate the amount of labour required.

To make a broad assessment, Boylan estimates that four mechanics can manage a fleet of three-to five aircraft for all types of line check. Assuming each person provides 55MH labour per week, the airline will have 275–350MH per week available. This will equal about 100MH per aircraft per week for the line checks. At the assumed rate of utilisation, the labour content for line checks will be 1.50MH per FH or 7.4MH per FC.

At a labour rate of $40 per MH, this will equal $60 per FH, or $300 per FC. Consumables and materials plus interior items cost about $7,000 a week for passenger aircraft and $3,000 for freighters.

A checks consume about 600MH for routine and defect items, and out-of-phase ageing aircraft items. The consumption can vary up to 800MH for the basic package, including an allowance for cleaning and interior work. "We use about 830MH for the A check, says Francois Albrecht, sales and marketing director at AOM Industries. "Our aircraft are managed on the KSSU programme. There is a large difference between this and other MSG2 programmes".

The 600MH consists of about 200MH for routine items and up to 350MH for defects and interior work. Little other work is done during A checks, although the opportunity might be taken to perform an engine or landing gear change. These MH are discussed separately here. Another 50MH will be used for a few modifications covered by service bulletins (SBs) and special items.

The 600MH at an average labour rate of $50 incurs a cost of $30,000.

Rotable repair work is not scheduled for A checks, and so only materials and consumables are required. This incurs a cost of about $5,000.

The A check thus has a total cost of $35,000 incurred every 550FH. The resulting cost per FH is therefore $64 *(see table, page 27)*.

Under MSG2, the C check routine MH consumption varies, but is about 2,100MH. Defect ratios can be as high as 3:1 for the DC-10 in extreme circumstances. "Normally mature aircraft have a defect ratio of 1.5:1," explains Boylan. "Defect MH therefore total about 3,000. This number of MH includes work on the CPCP and SID ADs".

The MH used for AOM's aircraft are lighter by comparison, adjusting the imbalance between A check MH of aircraft managed on different programmes. AOM uses about 4,500 for routine, defects and ageing work in its C checks.

"Interior cleaning is quite thorough at this stage, since all seats are removed, some parts are replaced and galleys and emergency equipment is also cleaned. This uses about 700MH,"says Boylan.

"The MH requirement for SBs is difficult to assess, since aircraft are now maturing and fewer SBs are being performed. The quantity used therefore depends on previous operators' compliance standards. Aircraft might now use about 1,000MH during a C check over the next three to four years," claims Boylan.

This takes total MH consumption for the check to about 6,800. At a labour cost of $50 per MH, cost is $340,000. Again no rotables are scheduled for repair, but about $70,000 is incurred for materials and consumables. Total cost for the check is then taken to $410,000. At an achieved interval of 5,000FH, cost per FH is $82 *(see table, page 27)*. Pekka Pohjolainen, superintendent planning aircraft heavy maintenance at Finnair recommends operators should expect to complete the check in about five days.

The D check normally includes several items in addition to the routine job cards and resulting defects. The ratio of defect items to routine tasks is similar to that in the C check, although on occasions it can be considerably higher. "Routine MHs for the D check are about 16,000," says Pohjolainen. With a defect ratio of about 1.5:1, routine and defect MH will total about 35,000MH, although the defect ratio can be higher than the typical 1.5 level.

Other items that will add considerable MH are interior refurbishment, incorporation of SBs, stripping and painting and the addition of the C check.

Interior refurbishment for passenger aircraft used 6,000–7,000MH. Airlines are now phasing out DC-10s from passenger service and are spending less on interior refurbishment. A budget of 4,000MH should therefore be used for passenger aircraft. Much less will obviously be required for freighters, and a budget of 1,000MH should be made.

A further 2,000MH should be budgeted for SBs incorporation, 2,300 for stripping and painting and about another 1,500 for completing the C check cycle.

"Total MHs easily total 42,000 for the D check," says Pohjolainen. A more conservative budget is for about 45,000MH for passenger aircraft and about 42,000MH for freighter aircraft.

Material and consumable consumption for this check is about $400,000.

Rotable repairs are also scheduled for the D check. A budget of about $400,000 should be made for these items. At a labour rate of $50 per MH, the total cost for the check for a passenger aircraft is taken to about $3.05 million. Amortised cost per FH will therefore be $152 *(see table, page 27)*. "Downtime for the D check is about five weeks," says Pohjolainen.

MSG2 to MSG3

The MSG3 maintenance programme is intended to be flexible and so can be arranged in several ways by operators. "MSG3 builds in the ageing aircraft AD into the aircraft's C checks, explains Boylan. "This avoids the C and D checks being out of phase with the ageing aircraft ADs and the programme getting complicated. All maintenance is done during A, C and structural checks. There are no longer separate zonal and out-of-phase items.

Boylan explains that the advantage of converting to MSG3 is that a new operator using MSG2 has to use the original check intervals. By using MSG3 an airline can go straight to the 5,200FH C check interval. A high utilisation aircraft will then get good FH and MH utilisation with respect to maintenance intervals.

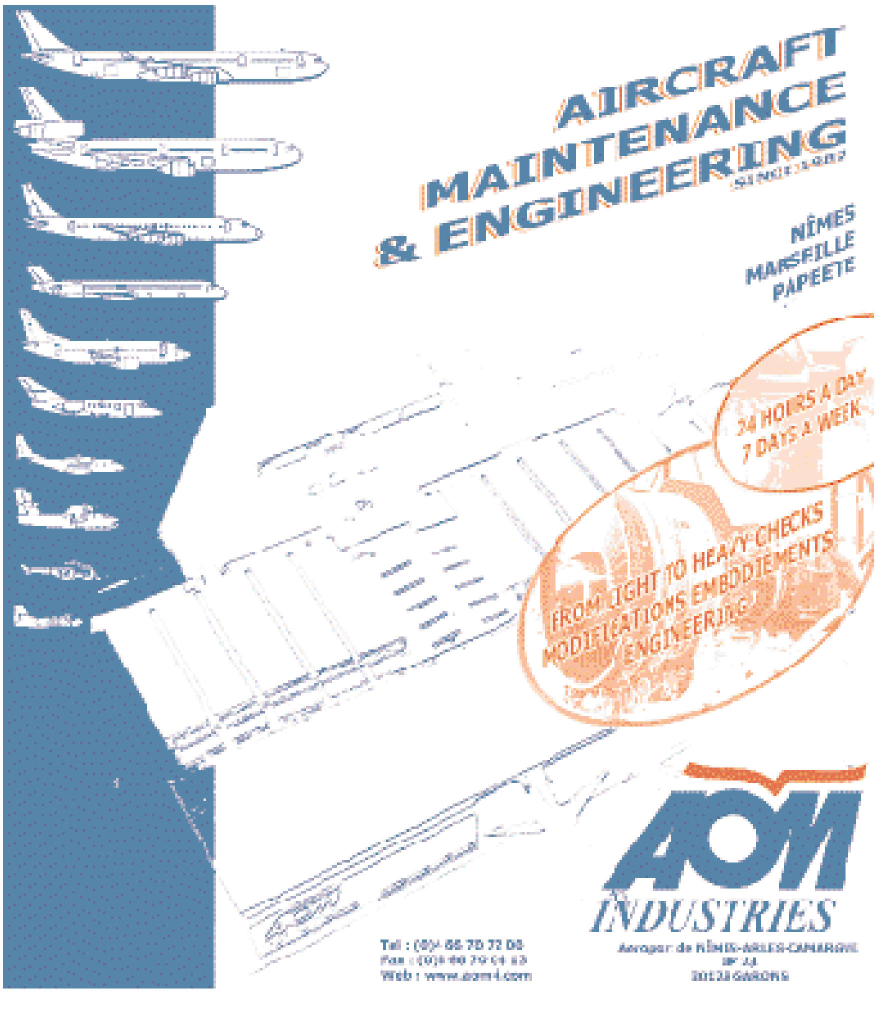
"The A checks in the MSG2 programme were heavier because they had additional out-of-phase items," says Boylan. A check task items in MSG3 have an interval of 450FH. There are three groups of A check multiple tasks; 1A, 2A and 4A items, which are equalised into a standard A check package. This generates A1, A2, A3 and A4 checks, the A4 check being performed at an interval of 1,800FH.

C check task items have an interval of 5,200FH and 15–20 months. There are six groups of multiple task items; 1C, 2C, 3C, 4C, 6C and 8C, which can be equalised into a series of eight C checks; C1-C8. There are only a few 6C and 8C tasks. The flexibility of MSG3, however, means C check items can be equalised further into a simpler series of four checks: C1–C4.

The C check tasks have a basic interval of 5,200FH and so the 8C would be performed at a maximum interval of 41,600FH. At an average FC of 5.0FH, this is equal to 8,320FC.

A shorter cycle would mean the 4C check would have an interval of 20,800FH or 4,160FC.

"The structural check in the MSG2 programme had an interval of 20,000FH," says Boylan. "This meant an operator with a 6.0FH average cycle time was performing the check about every 3,300FC. An



With the DC-10 increasing in age, maintenance costs can occasionally be minimised by airlines avoiding engine and heavy component overhauls and using time-continued parts and components from the large amount of inventory available on the market. This will not always be possible, since the supply of components will dry up as operators continue using the DC-10 for another 10–20 years.

operator with a 3.0FH cycle was getting a 6,700FC interval for the same inspection. Structural items are mainly FC driven, so it made sense to change the structural interval to an FC basis".

Under MSG3 the structural check has an interval of 10,000FC. MSG3 also forces 100% sampling compliance on all aircraft. An average cycle time of 4.0–5.0FH therefore results in a structural inspection interval of 40,000–50,000FH; twice the original FH interval under MSG2."

MSG3 allows either the structural check to be equalised into the C checks, or performed independently.

MSG3 airframe checks

By taking the aircraft being operated through a system of C1–C4 checks and a separate 10,000FC structural check, MH estimates for the series can be made.

The A check is much lighter under MSG3 and uses about 450MH for routine, defects and other items such as cleaning and SBs. This is explained by the check being free of out-of-phase ageing items. Material and consumable costs are about $4,000. Therefore total check cost will be $26,500, making the amortised cost for the check $59 per FH *(see table, page 27)*.

The C check under MSG3 is about 10% heavier than under MSG2. This takes routine and defect MH to about 5,600.

No passenger aircraft are operated under MSG3 and labour for interiors are similar to the MSG2 check for freighters at about 200MH. SBs are also similar to the MSG2 C check, increasing total MH to 6,800. Material costs are about 10% heavier at $80,000, and total check costs would be $420,000. An actual interval of 5,200FH will be achieved, and thus a cost of $81 per FH *(see table, page 27)*.

The structural inspection at 10,000FC is very similar to the MSG2 D check. The MSG3 check is slightly heavier, but has the advantage of at least twice the FH interval. Routine and defect MH are about 40,000MH. SBs and stripping and painting will use about 3,500MH, as in the MSG2 D check. The C check cycle does not have to be terminated and only about 1,000MH are required for interior work. This takes total MH for the check for a freighter to about 44,500.

Cost of materials and consumables is about $440,000, while rotable repairs have a similar cost to the MSG2 check of about $400,000.

The check's total cost will be about $3.07 million. At an interval of 10,000FC, the check's cost is equal to $306 per FC, or $61 per FH for an aircraft operating a 5.0FH average FC *(see table, page 27)*.

Additional check items

Besides the items already mentioned, MHs are also required to perform engine and landing gear changes.

An engine change is dependent on the need to remove one for a shop visit. The CF6 and JT9D powering the DC-10-30 and -40 are now mature powerplants. Most operators can expect on-wing times of about 5,000 engine FH. At an annual utilisation of about 3,500FH an operator can expect to perform on average two engine changes a year. Each engine change consumes about 250MH, and so 500MH will be added to the annual MH requirement. Engine changes are usually scheduled to occur during A checks.

"Landing gear changes are only made once every eight years and consume about 900MH," says Pohjolainen. An average of 110MH per year should be added to the annual MH consumption.

Components & rotables

Heavy components and rotables are the other half of the aircraft's maintenance. The items that fall into this category are those which have maintenance programmes outside the airframe checks. They include the landing gear, wheels, brakes, tyres, APU and LRU components.

They either have their own independent maintenance programmes or are maintained on an on-condition basis. Despite some items having on-condition maintenance, it is possible for airlines to monitor removals to get an average, thus making it possible to predict frequency and cost of maintenance.

"The landing gear has a fixed overhaul interval of eight years," explains Alan Carmichael, vice president of product support at AAR landing gear services. At the assumed rate of utilisation a gear would accumulate 28,000FH and 5,600FC between removals. Because of the low frequency of landing removals few airlines operate their landing gear shops, especially most DC-10 operators which have small fleets.

It would be normal for most operators of the aircraft to use a system of landing gear exchanges, whereby an

DC-10-30/-40 FLIGHT HOUR (FH) AIRFRAME AND COMPONENT MAINTENANCE COSTS

Maintenance Item	Interval	MH used	MH cost ($)	Materials used ($)	Rotable repairs ($)	Total cost ($)	Cost per FH ($)
Pre-flight check	5.0 FH						
Daily check	9.6 FH						
Seven-day check	67.2 FH						
Total weekly line checks	67.2 FH	100	4,000	3,000/7,000		7,000/11,000	105/164
MSG2 maintenance programme:							
A check	550 FH	600	30,000	5,000		35,000	64
C check	5,000 FH/17 months	6,800	340,000	70,000		410,000	82
D check-passenger aircraft	20,000 FH	45,000	2,250,000	400,000	400,000	3,050,000	152
D check-freight aircraft	20,000 FH	42,000	2,100,000	400,000	400,000	2,900,000	145
MSG3 maintenance programme:							
A check	450 FH	450	22,500	4,000		26,500	59
C check	5,200FH	6,800	340,000	80,000		420,000	81
Structural check	10,000 FC	44,500	2,225,000	440,000	400,000	3,065,000	61
Landing gear change	8 years	900	45,000			45,000	2
Engine change	1,700 FH	250	12,500			12,500	8
Landing gear	8 years					300,000	11
APU shop visit	8,000 FH					200,000	25
Wheel inspection & tyre remould	130 FC					30,000	46
Tyre replace	520 FC					12,000	5
Wheel replace	8 years					187,000	7
Brake inspection/repair	600 FC					100,000	33
Brake replace	12,000 FC					300,000	5
LRU/rotables-$ PBH rate							360
Non-scheduled rotable repairs							50
Total cost per flight hour							
– Freighter, MSG2							**948**
– Freighter, MSG3							**858**
– Passenger aircraft, MSG2							**1,014**

This table is based on an annual aircraft utilisation of 3,500FH and 700FC and average flight time of five hours.

airline swaps a freshly overhauled gear for its used one at a fixed price. The fixed price has two elements. The first is the exchange fee, which is a cost element to cover ownership of the gear. "In the case of the DC-10 this is $50,000 for the set," says Carmichael.

The second element is cost for overhaul. "This is about $250,000 for the -30/-40," explains Carmichael. These costs do not include an element for scrapped parts. Cylinders and pistons are, however, becoming scarce and if they have to be replaced can cost up to $225,000.

Total exchange fee for the -30/-40 will then be about $300,000. Amortised over the removal interval cost per FH is $11. Other considerations for landing gears can sometimes be the cost of upgrading if the aircraft's operator increases maximum take-off weight. In the case of the DC-10-30/-40 only a few minor parts have to be upgraded.

The wheels, brakes and tyres are inter-related. Like all aircraft, the opportunity to inspect wheels comes when tyres are due for remoulding.

"Nose wheels have an average interval of 130FC between tyre inspections," says Kari Lappalainen, workshop engineer at Finnair. "The main wheels have similar intervals, although aircraft with low gross weights achieve nearer 170FC. Every removal the wheel is inspected and the tyres remoulded. This costs about $2,500 per wheel. The cost for the aircraft is therefore $25,000 for a 10-wheel, tricycle landing gear DC-10-10 and $30,000 for a 12-wheel, quadri landing gear -30/-40".

Tyres are remoulded three or four times before being replaced. The cost of new tyres is $1,000 each, and so $12,000 for the shipset.

"Wheels do not get replaced very often. They are also made of two halves, each of which can be replaced, so it is hard to model wheel costs," says Lappalainen. Wheels can normally last eight to ten years. New nose and main wheels each cost about $8,500 and $17,000. On the basis of an eight-year life, the cost for a new set of wheels amortised over the 28,000FH achieved equals $7 per FH.

"About every five wheel removals or 600FC we remove and inspect brakes, which involves changing the linings. The interval of 600FC is because we know

Despite its age, the DC-10 maintains a low level of defects at routine inspections. The aircraft is also free of expensive modifications. This will keep the aircraft economical to maintain. Other issues that operators should remain aware of is the cost of components. These may start becoming scarce, leading to shortages and high repair costs later in life.

from experience of testing the lining thickness every daily check with calipers," explains Lappalainen.

A full overhaul is made after about ten inspections or every 6,000FC. Inspection for each brake costs about $9,500 and $10,000 for overhaul. Cost for brakes on the main gears on the -10 is about $80,000, while it is $100,000 for the -30/-40.

New brake units cost about $30,000, thus $300,000 for an entire main wheel set for the -30/-40. Brakes might be overhauled once before being replaced. The aircraft utilisation between brake replacement is thus 12,000FC, or 60,000FH. Amortised cost for overhauling and replacing brakes is therefore $25 per FC, or $5 per FH on the basis of a 5.0FH average FC.

The APU is maintained on an on-condition basis. All DC-10 variants were equipped with the Allied Signal TSCP 700-4B. The -4E model was later used on the MD-11. "Reliability of the -4B has been good and bad," explains Jorma Klemola, powerplant engineering at Finnair. "The average on-aircraft time between shop visits is about 4,000APU hours and is used during taxi and ground time".

Since most DC-10s are operating long sectors, ground time can exceed two hours. Assuming an average APU cycle of 2.5 hours, 4,000APU hours will equal about 1,600FCs or 8,000FH.

"APU exhaust gas temperature margin can be monitored during the A check and from the flightdeck. APUs now often get sent to third-party overhaul agencies or the original vendors for maintenance," explains Klemola. "The shop visits are split about 50:50 between hot-section inspections and overhauls. Life limited parts (LLPs) with lives of 11,000–30,000 cycles also have to be considered. An average shop visit cost is about $170,000".

Amortised over the removal interval, a shop visit is equivalent to about $22 per FH. Klemola warns that costs will get higher as shop visits get heavier and as more LLPs are due for replacement. In this case the average shop visit cost could get nearer to $250,000, raising cost per FH to about $32.

Besides landing gear, APU, wheels, brakes and tyres and components maintained during scheduled airframe checks, the remaining components are LRUs and other rotables. These items have on-condition maintenance. Airlines with larger fleets will keep their own inventory and perform repairs. However, it is more economical for smaller fleets to arrange a power-by-the-hour (PBH) agreement with a spare parts vendor.

"A small operator will usually pay for the ownership of the inventory through a lease arrangement and pay for the on-going repair of the items with a PBH arrangement," explains Iain Sturrock, commercial director of AJ Walter Aviation. "This is economic for fleets of up to ten aircraft. The actual cost for a vendor to acquire the required amount of inventory varies. The world's 747 and DC-10 fleets are imploding and inventory can be acquired at low prices".

Ted Anderson, vice president of business development at AAR estimates the cost of inventory for a fleet of five DC-10s will cost about $8.5 million. This would increase to about $12 million for a fleet of ten. "The lease rate to cover ownership will be in the region of 1.2–1.8%, or say $127,000 per month for five aircraft and $180,000 for ten". This equals $85 per FH for a fleet of five or $62 per FH if a larger fleet is operated. "On the basis of a utilisation of 3,500FH per year, the PBH charge for repair will be $260–300 per FH".

Total cost for LRU rotable inventory would then be $345–380 per FH *(see table, page 27)*.

Sturrock explains that once a fleet of more than ten aircraft is operated it becomes more economic for the airline to maintain its own inventory and manage the sub-contracting or repairs themselves.

Although other rotables will have their maintenance scheduled for airframe checks, there will be non-scheduled maintenance required in the event of failures. An additional budget of $50 per FH should be made to cover the cost of these eventualities.

Summary

The difference in FH costs between MSG2 and MSG3 maintenance programmes is about $110 for freighter aircraft, the MSG3 programme costs be ing about $858 per FH.

The line maintenance costs for the aircraft total about $105/164 per FH. Heavy component changes and repairs add another $142 per FH while LRU repairs and ownership equal about $410 per FH.

The total of $858 per FH for a freighter under a MSG3 maintenance programme is extremely economical. This is dependent, however, on the aircraft achieving a high rate of utilisation. The DC-10's despatch reliability should certainly not prevent this, and its long-range performance means 3,500FH per year are achievable. As the aircraft ages then utilisation is likely to decline a bit and more maintenance per FH will be required. The DC-10 is most vulnerable, however, to the costs of access and repair of LRUs, which form a large part of total airframe and component maintenance costs.

Another of the DC-10's weak points is engine shop visit and overhaul costs. The CF6-50's maintenance costs will be analysed in the November/December 2000 issue. AC