MD-80 maintenance analysis

The MD-80's durability is reflected in its low total maintenance costs.

There are several elements to the MD-80/-90's maintenance requirements: line maintenance; hangar checks; heavy components; line replaceable components; engine maintenance; and the provision of technical support for the aircraft in operation.

This analysis considers these elements, and provides a maintenance cost budget for the MD-80 and -90 based on an annual utilisation of 2,500 flight hours (FH) and 1,900 flight cycles (FC) per year. This is for an average FC time of 1.33FH. It is also assumed the aircraft is operational for 350 days per year, and so achieves an average of 7.1FH and 5.4FC per day of operation.

Maintenance programme

The MD-80 was certified as a variant of the DC-9. The MD-80 therefore has a maintenance programme based on maintenance steering group 2 (MSG2) principles. The MD-90 was, however, conceived on MSG3 principles, where maintenance tasks can be grouped according to the convenience of each operator.

It is technically possible for MD-80s to be bridged from a MSG2 to a MSG3 maintenance programme. Most operators, however, find this uneconomic given the probability that they will not continue to operate the MD-80 for much longer. "Our MD-80 maintenance programme could be described as being between MSG2 and MSG3," explains Paul Burakoff, maintenance engineer for heavy aircraft maintenance at Finnair Technical Services. "Our programme is based on the original MSG2 programme and has extended intervals. This involves the normal pre-flight check at the start of each day's operation, a transit check before all other flights during the day, daily checks every 24-48 hours and A checks every 600 flight hours (FH) in the line maintenance programme.

"Our base maintenance programme is the standard pattern of three C checks, followed by an intermediate heavy (I) check, followed by another three C checks and then completed with a full heavy (D) check," continues Burakoff. This is the MSG2 programme followed by most MD-80 operators. The C check interval is 4,800FH or 18 months, whichever is first. The I check interval is 16,000FH or 66 months, and the D check interval is 30,000FH or 120 months. All checks are zeroed when the D check is performed. Our aircraft have an annual utilisation of about 2,300FH per year, meaning they accumulate about 3,500FH in the 18 month C check interval."

While many MD-80 operators have remained with a MSG2 programme, a few airlines have elected to adopt the MSG3 programme for their fleets. SAS Technical Services (STS), a maintenance subsidiary of Scandinavian Airlines System (SAS), has implemented the MSG3 programme on SAS's fleet of 56 MD-80s. "The MD-80's MSG2 programme has equalised A and C checks which have FH limits, and I and D checks that are calendar limited by corrosion prevention and control programme (CPCP) requirements," explains Harrald Petersen, manager of engineering at STS. "As the MD-80 ages it requires more structural maintenance. Some items have high initial thresholds and so start being added to the maintenance programme. There is also the issue of the CPCP, ageing aircraft programme and structural inspection document. A MSG3 maintenance programme incorporates all of these into a common maintenance schedule. Moreover, future owners and operators of MD-80s are likely to prefer aircraft with a MSG3 programme. One reason is that less bridging maintenance is required when changing an aircraft between operators. We have therefore decided to develop a MSG3 maintenance schedule for our MD-80s and are in the process of bridging the aircraft from the MSG2 maintenance system.

"A MSG3 system basically allows an operator to package individual tasks and inspections into the checks that best suits its operation," continues Petersen. "Tasks have to be organised to achieve a compromise between small and frequent checks and large, infrequent checks. STS has created its own MSG3 job cards from Boeing's task cards, and hard-time items have been removed from the programme. The environmental deterioration (ED) tasks in the MSG3 maintenance programme are basically the CPCP tasks from the MSG2 programme. Overall, this has resulted in a new maintenance schedule with a C check interval of 21 months and 4,800FH. There are 1C items and multiples of these: that is 2C, 3C, 4C, 5C, 6C and 8C tasks, which are grouped with 60-month, 72-month and 120-month ED tasks and arranged to form block checks. The C2 check, for example, consists of the 1C and 2C items.

"Every third C check is like a MSG2 I check, and the 1C items are combined with the 3C, 4C and 5C tasks. The 60-month and 72-month ED inspections are also added," continues Petersen. "This is followed by another two C checks, the C4 and C5 checks, and then followed by the C6 check, which is the heaviest check in the cycle. This means there are structural inspections every third check. The basic interval is 21 months. We estimate that by converting to a MSG3 programme there will be a 30-40% reduction in routine man-hours (MH) across the C check cycle, mainly because duplication of tasks in the C3 and C6 checks will be avoided. This will also result in a reduction in non-routine MH, although it is too early to estimate what the magnitude of the saving will be."

"There is also a stream of A checks, which operates independently of the C checks," says Petersen. "These will have an interval of 600FH."

MD-90 programme

The MD-90 was certified with a MSG3 maintenance programme. STS has arranged tasks into checks for SAS's fleet of MD-90s that are not too dissimilar from its MD-80's maintenance schedule.

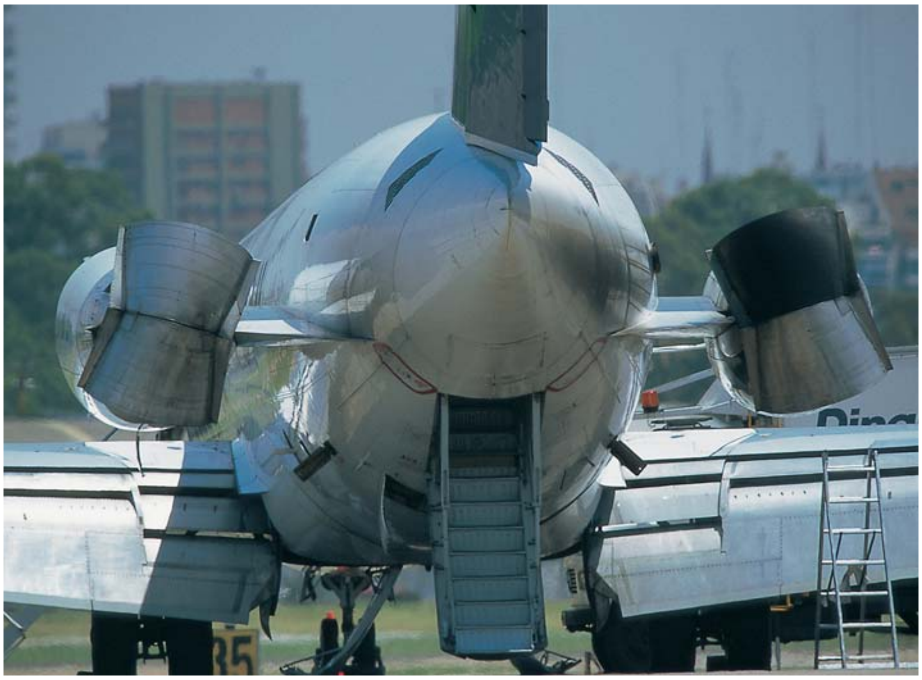
There are A checks with an interval of 550FH and P checks, or C checks, with a 4,000FH and flight cycle (FC) interval. There is also a separate group of structural tasks. These have initial intervals of 60, 90 and 120 months. Most MD-90s were delivered between 1995 and 1999, and so only the oldest aircraft will have had their tasks with an initial interval of 120 months completed. The same structural tasks then have repeat intervals of 30, 45 and 120 months.

SAS groups the structural tasks with the C checks, depending on when each one is performed. The aircraft accumulate about 2,500FH per year, and so have a C check every 18-20 months.

Line maintenance

Like all other aircraft types, the MD-80 has a basic line maintenance schedule of pre-flight checks prior to the first flight of the day, a transit check before all other flights in the day and a daily check performed overnight every 24-48 hours. On this basis, and the assumed level of utilisation, an aircraft will require about

The MD-80 is durable, and enjoys stable and low maintenance costs. This is attributable to its low base maintenance-related costs and engine reserves. This makes the MD-80's direct operating costs predictable, and so a strong aircraft candidate for start-up airlines.



350 pre-flight checks, 1,550 transit checks and 300-350 daily checks per year.

Estimation of man-hour (MH) and material cost inputs are approximate. Pre-flight and transit checks each use about one MH, and can be performed by flightcrew. A budget of $15 for materials should be allowed. Daily checks are larger, and use about two MH and $40 for materials. Some airlines, such as SAS, have weekly checks and use up to 20MH and $200 of materials. The largest line checks are the A checks. These vary in size, and STS has divided them into two halves, each with an interval of 275FH. Interval utilisation is relatively low for line checks, and this analysis assumes an actual interval of 200FH. The MH used varies between 65 and 100, and an average of 85 is taken. Material cost can also vary widely, and a conservative average of $700 is used.

Over one year's operation, line maintenance will use about 4,600MH and $60,000 in materials. At an average assumed labour rate of $70 per MH, the labour cost for this would be $322,000. This takes the total labour and material cost for line maintenance to about $383,000. When amortised over the annual utilisation of 2,500FH, it is equal to a rate of $153 per FH *(see table, page 20)*.

Airframe checks

The maintenance budget analysis assumes a MSG2 maintenance schedule for the MD-80. Similar to Finnair's maintenance programme, this is a C check with an interval of 4,800FH and 18 months, and a sequence of base checks terminating with a D check with an interval of 30,000FH and 120 months. This D check coincides with the eighth C check in the cycle.

At an annual utilisation of 2,500FH, an aircraft will accumulate about 3,750FH in the 18-month interval. The actual C check interval achieved will be about 15 months in the case of most operators. This will be equal to about 3,100FH. The eighth C/D check will thus be performed at about a 120-month interval, its actual maintenance programme interval, and 25,000FH.

"The non-routine ratio for base checks has changed little with age. We have performed second D checks on 20-year old aircraft," explains Burakoff. "C checks are similar in size. We use an average of about 1,500MH for C checks, including our own originated tasks for cleaning and cabin refurbishment. This is a total that includes about 1,000MH for routine tasks, another 400MH for non-routine corrections, and about another 200MH for cabin work. This would take the total for all items to 1,700-1,800MH. Modifications would add additional MH. This is actually less MH than we use for a C check on an A320, which has a lot of system inspection requirements. C checks also use about $11,000 for materials for routine work, and a further $17,000-30,000 for materials for defects."

Rune Marthinsen, head of marketing, sales and purchasing at STS heavy maintenance makes a similar estimate of up to 1,500MH for C checks for MD-80s kept on a MSG2 programme.

A base maintenance labour rate of $50 per MH takes total cost for the check to $120,000-130,000.

I checks are heavier, and are the smaller of the two structural checks. "The I checks have about 200 different items. The routine inspections use about 12,000MH to complete, with about 45% of this being used for non-routine and cabin work. About another 5,000MH are required for large modifications, such as the installation of insulation blankets, but these are one-off items and these will not affect the subsequent heavy checks. ADs, SBs and interior work also have to be considered, and so the total MH consumption for a mature aircraft will go up to 16,000-18,000. Materials for routine inspections and defects will be about $150,000, while the additional cost for major modifications and interior work and cabin refurbishment will add up to another $330,000. Material cost can reach about $450,000-500,000."

This compares to Marthinsen's estimate of 15,000-20,000MH and $600,000 for materials for this check.

A labour use of 18,000MH charged at a rate of $50 per MH and a further $550,000 for materials will take the total for the check to about $1.45 million.

Routine and non-routine D check tasks consume about 26,000MH. "This is split into about 15,000MH for the routine items and 11,000MH for the non-routine tasks. This also includes about 5,000MH for interior work for cleaning and refurbishment, as well as labour for CPCP and ageing aircraft tasks," says Burakoff. "Another 2,000MH could be used for stripping and repainting, while a further 2,000MH can be used for modifications, so that the total for the check can approach 30,000MH. The check will also use about $800,000 in materials for routine inspections, defects, modifications, cabin refurbishment and painting. The downtime for the check is up to five weeks." The standard labour rate would take the total cost of the check to about $2.3 million.

The total for the six C checks, I check and D check in the full base check cycle will be an expenditure of $4.5 million, including about 58,000MH. This compares to 45,000-50,000MH used for an A320 in its first base check cycle with a similar interval of 25,000FH.

The MD-80's total costs amortised over an interval of about 25,000FH, and 120 months, results in a reserve of about $182 per FH *(see table, page 20)*.

All MD-90s are young and no aircraft have yet completed a heavy check cycle. STS has a system of C or 'P' checks every 4,000FH/FC, and only has experience of the first four or five 'P' checks in the heavy maintenance cycle. Marthinsen estimates that MH inputs for the lighter

'P' checks are in the region of 1,200-1,500MH, while the heavier P4 check uses 10,500-12,000MH. Cost of materials for the lighter check would be $10,000-18,000, and $400,000-450,000 for the heavier P4 check. Using an assumed labour rate of $50 per MH would take total cost for these first four checks to about $1.25 million.

This would be over an interval of about 14,000FH, considering typical interval utilisation rates. The cost would be equal to a reserve of $90 per FH. This compares favourable to the MD-80's base maintenance reserve under a MSG2 programme, and indicates the savings that can be accrued from operating an an with a MSG3 philosophy.

Heavy components

Heavy components, which are maintained on a separate schedule from the airframe checks and on an on-condition basis, include the auxiliary power unit (APU), wheels and brakes, landing gear and thrust reverser units. The maintenance cost of these components is related to a FC interval. Maintenance cost should therefore be examined on a per FC basis, and then converted to a rate per FH according to the average FC time.

The MD-80 is powered by the GTCP85-98 APU. The cost per FC is determined by the average shop visit cost, the APU hours interval between shop visits and the ratio of APU hours to FCs.

The number of APU hours per FC depends on each airline's operation. The APU is typically used between landing and arrival at the terminal gate, and may either be kept running while the aircraft is on the ground or stopped and re-started prior to engine start and pushback. On the basis of the assumed daily utilisation, the aircraft will spend five to six hours on the ground between flights with an average of just over an hour between each flight. Most airlines will switch off the APU and use ground power for some of this downtime. In this case the APU may be switched on twice for a total time of about 30 minutes per aircraft cycle. The APU time per FC would exceed one hour if it was kept on for the entire downtime between flights. In the former case, the average APU utilisation would be 950 APU hours per year. This is a ratio of about 30 APU minutes per FC. The average shop visit interval for the GTCP 85-98 is about 3,000-4,000APU hours, and average shop visit cost in the region of $125,000. This is thus equal to a rate of $35-40 per APU hour, and $17 per FC *(see table, page 20)*.

Thrust reversers for the JT8D-200 are an old generation type. Although maintained on-condition, operators have established average or 'soft' removal intervals. Since they are used at most landings, removal intervals are related to number of FCs. Average removal intervals are partially related to weight of the aircraft, with the MD-83s and -88s having harder braking at landing and so shorter removal intervals. Typical intervals for MD-80 thrust reversers are 7,000-8,000FC.

The average shop visit cost for each reverser unit is in the region of $170,000, similar to the reverser on the JT8D Standard series. The cost for a shipset of two is thus $340,000, and so the reserve for thrust reverser repair is $45 per FC *(see table, page 20)*.

The total cost for wheels and brakes is broken into several elements. The first of these is tyre remoulding and replacement. Intervals are on-condition, and operating climate affects removal intervals, as does aircraft weight and pilots' treatment at landing. Like thrust reversers, the heavier MD-83s and -88s will have shorter tyre remould intervals than the -81 and -82.

In Finnair's experience, main wheel tyres have an average removal interval of 500FC between retreads and are remoulded twice on average before replacement at the third removal, thus not exceeding the life limit of 1,800FC. "A main tyre re-tread costs about $400," says Koskentalo. "Nose tyres are remoulded about every 350FC at an average cost of $170. These are remoulded about four times before being replaced after a total life of 1,750FC."

New main wheel tyres cost about $1,400 and new nose wheel tyres about $250. Overall, the total cost for tyre remoulding and replacement is about $9-10 per FC *(see table, page 20)*.

Wheel inspections are made at the same time as tyre remoulds. Nose wheels are thus put through the shop about every 350FC, and main wheels about every 500FC. Nose wheel inspection shop visits cost about $600, and main wheel inspections about $650. Main wheel brake units are steel and have an interval about every 1,000FC; in the case of the MD-80 about every second wheel removal. Brake inspections have a cost of about $10,000. Overall, the wheel inspections and brake repairs have a total cost of about $48 per FC *(see table, page 20)*.

Landing gear overhaul intervals are the same for all other types; eight to 10 years. Koskentalo says shop visit exchange fees are in the region of $350,000, and an interval of nine years is equal to about 17,000FC. The cost for landing gear overhaul and exchange is thus about $21 per FC *(see table, page 20)*.

The total for all four categories of heavy components is thus about $140 per FC. At an average FC time of 1.33FH, this is equal to $105 per FH *(see table, page 20)*.

Line replaceable components

Many major MD-80 operators own their own inventories of line replaceable units (LRUs) and have their own in-house repair facilities and shops. Identifying the direct cost of this and separating it from overheads is difficult or impossible.

One way of analysing probable costs of having access to enough LRUs to maintain a reliable operation and paying for their associated repair and management is to examine the costs a small operator has to bear by acquiring this service from a third party supplier. An airline with a fleet of 10-15 aircraft can have access to sufficient LRUs by leasing a homebase stock and pay a power-by-the-hour (PBH) rate for access to a pool of inventory of the remaining parts. These would be items that have lower failure rates or do not have such an impact on the aircraft's operation when they fail. The airline would then pay a third fee, as a PBH rate, to the supplier for the management and repair of the components.

Koskentalo quotes a PBH rate of about $27 per FH for the lease of homebase stock. The access fee for the pool stock of remaining parts would be in the region of $34 per FH. The PBH fee for the repair and management of all parts would be the largest element: Koskentalo quotes in the region of about $125 per FH. Overall, the total for all three elements would be about $186 per FH *(see table, page 20)*.

Engine maintenance

MD-80 operators manage their engines in different ways. Some take an on-condition approach to engine maintenance, while others try to manage removal intervals and shop visit workscopes to match LLP life expiry and achieve the lowest possible cost per engine flight cycle (EFC) and engine flight hour (EFH).

The average interval between scheduled removals is 4,000-6,000EFC, equal to about 6,000-8,000EFH for an average EFC time of 1.33EFH. Some operators, however, manage to achieve

DIRECT MAINTENANCE COSTS FOR MD-80/-90

Maintenance Item	Cycle cost $	Cycle interval	Cost per FC-$	Cost per FH-$
Line checks	$383,000	2,500FH		153
Hangar checks	$4,500,000	25,000FH		182
Heavy components:				
Landing gear	$350,000	17,000FC	21	
Tyre remould & replacement	$16,000	1,750FC	9	
Wheel inspections	$4,000	500FC	8	
Brake inspections	$40,000	1,000FC	40	
Thrust reverser overhauls	$340,000	7,500FC	45	
APU	$125,000	7,500FC	17	
Total heavy components			140	105
LRU component support				186
Engine maintenance				316
Spare engine coverage				40
Total				**990**

Based on an annual utilisation of 2,500FH and 1,900FC.

scheduled removals every 8,000-9,000EFH.

EGT margins are 15-25 degrees centigrade after an overhaul, and these are low compared to modern engine types. Erosion rates are 3-4 degrees per 1,000, but allow long removal intervals and do not affect rates of removal.

Most JT8D-200s conform to an alternating pattern of hot section inspection and overhaul shop visits. Some operators try to match this pattern with LLP replacement. LLP lives that are currently saleable have uniform lives of 20,000EFC, and heavier shop visits are more appropriate for LLP replacement, which is targeted for every second overhaul shop visit. In this pattern of four shop visits, however, there is also usually a smaller unscheduled shop visit making a total of five shop visits every LLP replacement cycle.

Taking an average scheduled removal interval of 4,500EFC, the cycle would be completed about every 18,000EFC. This compares to LLP lives of 20,000EFC, which have a list price of $990,000. LLP amortisation would therefore be about $55 per EFC.

The inputs for a lighter, hot section inspection are 1,800-2,200MH, about $200,000 for materials and parts, and $100,000 for sub-contract repairs. A standard labour rate of $70 per MH would take total shop visit cost to about $450,000.

Inputs for an overhaul are 3,000-4,500MH, $350,000 for materials and parts and $150,000-250,000 for sub-contract repairs. This would take the total cost for a shop visit to $750,000-900,000.

The average cost for a smaller, unscheduled shop visit would be in the region of $250,000. The total cost for five shop visits over the LLP replacement cycle would thus be about $2.8 million. Amortised over the interval of about 18,000EFC the cost would be equal to $155 per EFC. Added to LLP replacement it would take total reserve for all maintenance to $210 per EFC, equal to $158 per EFH. Maintenance reserve for both engines would be $316 per FH *(see table, this page)*.

Maintenance reserves for the V.2500-D5 powering the MD-90 will be higher. Although the engine has long removals between shop visits, it has higher cost of materials. Reserves therefore tend to be equal or higher to average rates per EFH for the JT8D-200.

Operators also have to consider the costs of spare engine provisioning. Removal intervals of about 7,000EFH and rate of aircraft utilisation means each engine has a scheduled removal about once every three years. An average shop turn time of three months means one spare engine could support about 10 installed units, equal to a fleet of five aircraft. The market value of JT8D-200s varies depending on variant, but Tom MacAleavey, senior vice president of sales and marketing estimates at Willis Lease Finance Corporation the value of -217s or -219s in a good maintenance status to be $1.5-2.0 million.

Airlines can consider leasing spare engines as an alternative to ownership. Some engines will have to be leased as additional cover to owned spare engines. Willis Lease Finance Corporation is the world's largest lessor of JT8D-200s, with a portfolio of 26. MacAleavey says lease rates for JT8D-217s and -219s are about $1,000 per day at current market rates, or about $30,000 per month. A fleet of five MD-80s could be supported year-round with a leased engine, incurring a cost of about $360,000, plus additional cost for leasing other engines on for short periods. Maintenance reserves also have to be considered for the leased engine, and are in the region of $140 per EFH plus $51 per EFC. Considering that the annual cost for single engine may be in the region of $500,000, and so $100,000 per aircraft, an additional rate of $40 per FH could be added to maintenance costs.

Lease rates for V.2500-D5 engines are at about $2,000 per day, or $60,000 per month. Maintenance reserves are high, however, at $266 per EFH plus $97 per EFC. MacAleavey puts market values at about $5.5 million. Removal intervals are longer, meaning a spare unit can support a larger fleet of 12-14 aircraft.

Maintenance cost summary

The total for all maintenance cost elements for the MD-80 is $990 per FH. Aircraft kept under a MSG3 programme may have marginally lower costs because of a reduction in base maintenance-related costs.

While the MD-90 may have lower base maintenance-related costs, it could be expected to have similar line and component maintenance related costs. The MD-90's V.2500 engines, however, will have higher reserves than the JT8D-200, and this will more than outweigh the benefits of lower base maintenance costs. The MD-90 has higher overall maintenance costs per FH than the MD-80.

Technical support

The MD-80 is an ideal aircraft for start-up carriers. Initial operations require a lot of training and development of in-house expertise, and so airlines may seek technical support from a third party provider to assist them. The different types of support an airline could consider include maintenance operations control, management of LRU inventory and logistics, management of aircraft maintenance and maintenance records, and engine condition monitoring and maintenance management. Finnair can provide this type of support to customers and Koskentalo quotes a rate of $20-55 per FH, depending on fleet size and several operational parameters. The higher rate includes having staff on site to assist with the operation. AC