The 777 is unique in that the MPD does not group tasks into checks. While airlines are free to devise their own checks, maintenance programmes of different airlines are similar. The 777 is light in man-hour consumption, providing it with lower costs than its competitors.

Modern design gives the 777 an edge in maintenance cost

The 777 has won a reputation for high reliability and low maintenance costs, while many of its operators regarding it as superior to other widebodies. The earliest delivered 777s have been in operation for six years, and the first aircraft have been put through heavy checks where appropriate according to the operator's maintenance programme. The 777 seems to have required few modifications after introduction into service, and has high technical despatch reliability (TDR). In addition it is expected to consume few man-hours (MH) per flight hour (FH) relative to similar sized aircraft. While many aircraft are still young, the 777-200's airframe and component maintenance costs are analysed across the aircraft's full airframe check cycle in terms of cost per FH.

777 in operation

Like the 767-300, most 777 operations fall into two categories: high-density medium-haul sectors of about 3FH; or long-haul missions of 8-9FH. Many aircraft are also certified for extended range operations (Etops). The average sector length, FH per flight cycle (FC) and annual utilisation will affect the aircraft's maintenance programme and maintenance cost per FH.

United, which operates the world's largest fleet of 57 777s, uses some of its fleet for trans-Continental US routes and high gross weight aircraft on long-haul transatlantic and trans-Pacific routes.

"Our fleet averages about 6.1FH per FC," explains Tom Edwards, principal engineer at United Services. "All our aircraft are Etops certified. Annual utilisation is about 4,750FH and 785FC per year."

Delta, with a small fleet of seven aircraft, operates the 777 on transatlantic routes plus a few high-density US domestic sectors. "Our aircraft achieve an average FC time of 5.4FH, and generate 4,900FH and 910FC per year," says Tom Cooper, director programs and planning at Delta TechOps.

Air France uses the 777 exclusively for long-haul operations from France to the Americas and the Asia Pacific. "The aircraft generate about 5,300FH and 630FC per year, with an average FC time of 8.4FH," says Raymond Topin, 777 engineering and maintenance manager at Air France. "The shortest route is 6FH, while we operate the aircraft on flights up to 13FH. Our aircraft are certified for 180 minutes Etops, and the 777's TDR is more than 99%, one of the highest of all 777 global fleets."

Airlines in the Asia Pacific provide many examples of the 777 operating shorter average sectors. The 777 is used extensively on regional routes in the Asia Pacific. Air China and Cathay Pacific provide two examples. Ameco Beijing is Air China's maintenance provider. "Air China aircraft operate average flights of 2.6FH per FC, since the aircraft flies regional routes from Beijing. A few exceptions are routes to Moscow and Paris. Utilisation is about 2,900FH and 1,100FC per year," says Michael Keller, manager production engineering and planning department at Ameco Beijing.

Cathay Pacific uses the aircraft on routes from Hong Kong to the Asia Pacific, the Middle East and Australia. As a consequence the aircraft achieves average FC lengths of 2.8FH, and generates about 3,400FH and 1,200FC per year.

The maintenance cost analysis is based on two operations: medium-haul and long-haul with respective average FC times of 3FH and 8FH. Aircraft utilisation for medium-haul missions is assumed to be 2,900FH and 970FC per year, and 4,800FH and 600FC per year for long-haul operations.

Maintenance schedule

The 777 is unique in that the maintenance planning document (MPD) does not specify limits. Operators are free to group and package individual tasks into their own tailor-made checks. There are therefore no traditional maintenance checks, such as A or C checks. Some operators, nevertheless, still use the generic terms of A, B and C checks and heavy maintenance visits in their maintenance programmes.

The number and type of checks in the 777's maintenance programme vary widely between operators. The most influential effect on any maintenance schedule structure is the effect of system-related tasks, with FH and calendar intervals; and structure-related tasks, with FC and calendar intervals. Depending on average FC time, airlines will group these separately or together in the heavier airframe checks. Although operators are free to devise their own maintenance programmes, the intervals and MH requirements for checks are not dissimilar between operators.

"The interval on each task card has been determined by Boeing, according to whether FH, FC or calendar time affects deterioration," explains Keller. "Each has its own FH, FC or calendar interval. Some tasks cards have two limits. Operators decide which tasks to combine into a check. The airline can therefore have a large number of small checks or smaller number of large checks. Compromises have to be made, since items with long intervals have to be combined with ones with shorter intervals. The grouping of tasks into checks is done by a computer, and the packaging is affected by the FH:FC ratio. There are many different possible permutations for the packaging of airframe checks, although airlines will use the same generic designations for checks.

777 OPERATORS' LINE CHECKS & INTERVALS

United	Delta	Air France	Cathay Pacific	Air China
	Pre-flight & Trip checks Every flight	Pre-flight check Every flight	Transit check Every landing	Pre-flight & Transit check
Daily check Every 24 hours	Layover/daily checks Every 24 hours	Daily check Every 24 hours	Daily check Every 24 hours	Daily check Every 24 hours
Service check 75 FH		V check 130 FH	Weekly check 85 FH/8 days	Weekly check
		K check 400 FH		
A-odd check 250 FH	Service/A check 500 FH	A-odd check 600 FH	A check 500 FH	A-odd check 500 FH
A-even check 250 FH		A-even 1,200 FH		A-even 500 FH
			B check 150 days	

"The grouping of tasks is not perfect," explains Keller. "This is because some items have odd intervals and drop out and are performed on their own. As with other aircraft, these tasks are called out-of-phase items."

Line & light checks

Line and light maintenance is accounted for checks up to B check level. The biggest influence on the maintenance programmes airlines derive for 777 line/light maintenance is certification for Etops missions. Many operators with Etops capability have engine-related items grouped with tasks performed during maintenance checks. Since it is necessary to avoid performing these engine tasks for both left and right engines in the same check, they are alternated between checks.

Since airlines can design their own maintenance schedules, the type of check varies. Examples of different line maintenance programmes are shown *(see table, this page)* for United, Delta, Air France, Cathay Pacific and Air China.

Most airlines have a pre-flight or transit check, performed every flight. One exception to this is United. Although its smallest check is a daily check, it performs a walkround inspection for each flight, but few MH are consumed.

Some operators have both pre-flight and transit checks. "We perform a pre-flight or Etops check prior to an international departure at a gateway city, but a trip check if the aircraft is at a maintenance station and about to operate a non-Etops flight," explains Cooper. "Either way a check is performed prior to a flight." Cooper puts labour at 1.5MH for a trip check and 2.5MH for a pre-flight check.

Topin explains the pre-flight check is mandatory because monitoring of Etops-related items is required, but not for non-Etops flights. "We consider all of our routes Etops, so this makes planning simple. The check has to be done within two hours before the flight during the turnaround at the gate," says Topin. "This check only consumes one or two MH."

Cathay Pacific's and Air China's aircraft do not require Etops items to be performed as on long-haul fleets operated by other carriers. "The transit check, which we perform at every landing, is the only one defined in the maintenance planning document," says Elvis Ho, manager engineering planning at Cathay Pacific. "The check is basically a visual inspection and servicing at turnaround. It can consume up to 5MH."

Air China performs either pre-flight or transit checks every flight. Keller estimates labour consumption of about 5-6MH for these checks.

All airlines have a daily check, most with a limit of 24 hours. "We have to complete this before 23:59 the day after completing the previous check, but the average interval works out to be about 24 hours," says Edwards.

Delta has a layover check, which Cooper likens to a daily check, and only performs it if the aircraft is on the ground at a maintenance station for more than five hours. Cooper estimates labour consumption in the region of 12MH.

Air France performs daily checks every time the aircraft returns to the main base. "In addition to routine items, we complete some out-of-phase items plus defects reported by the flight crew. Routine daily check items consume about 2MH, but the out-of-phase items and defects take the total to about 18MH," says Topin.

Cathay uses a 24-hour interval as a planning framework for daily checks, and Ho says labour consumed is in the region of 12MH. This is similar to MH estimated by Keller for Air China's aircraft, the maintenance of which follows a similar pattern to Cathay Pacific's.

The next largest check all airlines have is generically similar to an A check performed on other types. Some carriers, however, have smaller checks. United, for example, has a 'service check' with an interval of 75FH, similar to a weekly check, which gets performed about once every six days. Therefore while some airlines have pre-flight and daily checks, United consumes a large number of MH in its weekly checks. "About 80% of the work in this check is non-routine," says Edwards, "since we use the check to rectify deferred items."

Air France has a series of 'V' and 'K' checks with intervals of 130FH and 400FH, which are performed about every week and month. "The content of these is similar to daily checks, but just a few additional items," explains Topin. "They are also performed at the gate, and consume about 19MH and 20MH, similar to daily checks."

Both Cathay Pacific and Air China have weekly checks in their programmes, limited by intervals of seven or eight days. "This is really an extended transit check, which clears deferred items," says Ho.

A checks & Etops

Most airlines have opted for an 'A' check interval in the region of 500FH. This is the case with United, Delta, Air China and Cathay Pacific. Air France has been permitted an extension to 600FH.

The content of A checks is affected by aircraft that are used for Etops missions. "Our aircraft used for Etops flights have engine-related items performed in the A check. To avoid work being done on both engines in the same check, which could pose a safety risk, the engine-related items

on the left and right engines have to be performed in separate checks," explains Edwards. "We also split the other A check items equally between these alternating checks. That is, we perform a half-A check about every 250FH, although the interval for A check items is 500FH *(see table, page 26)*. The left engine items are done during the first, third and then subsequent odd numbered checks every 500FH. The right engine items get performed at the second, fourth and then each even-numbered A check, also every 500FH. Thus A check items are performed at their interval of 500FH, but we have a half-A check every 250FH. About 65% of A check MH consumption is routine."

Delta records 75MH for its A or 'service' checks'.

Like United, Air France alternates Etops-related items in its A checks between odd and even numbered A checks *(see table, page 26)*. "We perform left-engine items on the odd-numbered checks and right-engine items on the even-numbered checks," says Topin. "We have an A check every 600FH, so the odd- and even-numbered checks are both performed every 1,200FH *(see table, page 26)*. The odd-numbered A checks (A1, A3, A5, A7, A9 and A11) are lighter than the even-numbered A checks (A2, A4, A6, A8, A10 and A12), because the odd-numbered checks only have the left engine-related items, whereas all other items and right-engine items are done in the even-numbered checks. The odd-numbered A checks consume only about 20MH in total for routine, non-routine and cabin cleaning, while the heavier even-numbered A checks consume about 220MH. There are also some A check items which have multiple intervals, so we complete the A check cycle at the A12 check, at about 7,200FH. About another 25MH could be added for service bulletins (SBs)".

Although Air China does not operate Etops missions, it also has a system of alternating light and heavy and A check intervals similar to United's. "The basic A check items are performed every 500FH. We separate left and right engine related items. We have AL checks, with just left-engine items," says Keller. "These start with the AL1 checks at 250FH and repeat every 500FH with the AL3 at 750FH, AL5 at 1,250FH and so on. The right-engine items, in the AR checks, and main A check tasks start at the AR1 check at 500FH, and repeat every 500FH with the AR2 check at 1,000FH. The A check cycle is completed at the AR12 check, after 6,000FH. There are also items with multiple intervals of the basic A check interval, so this means there are differences in A check package sizes." Keller puts routine MH for the A-odd and A-even checks at 45MH and 150MH. Non-routine labour in addition is 6-10MH for the A-odd checks and 6-80MH for the A-even checks, plus about 36MH for handling and both cases. This takes average MH consumption to 80MH for the A-odd checks and 225MH for the A-even checks.

Cathay Pacific has an A check every 500FH. It is also the only carrier to have a B check in its light maintenance programme. Ho says this requires about 24 hours' downtime and about 750MH to complete, and comprises extensive operational checks. Labour input is about 150MH.

777 OPERATORS' HANGAR CHECKS & INTERVALS

United	Delta	Air France	Cathay Pacific	Air China
C check every 12 months	PSV check every 12 months	Light C1 check at 12 months	Light C1 check at 12 months	C check every 24 months/5,800FH
Heavy C4 check at 48 months	Light PSV-odd checks alternate with Heavy PSV checks	Heavy C2 check at 24 months	Heavy C2 check at 24 months	Heavy C4 check at 96months/23,200FH
	PSV8 check after 96 months	SC check every 4 years		
		SC6 check at 24 years		
		Cabin refurbishment every 5 years		

A check cycle costs

The cost of MH and materials for line, light and hangar maintenance is summarised in terms of MH and $ cost for materials per FH. Since line and light maintenance is independent of hangar checks the costs for these inputs are analysed separately.

Inputs should be analysed over the interval of the A check cycle, since the A check is the heaviest of all line and light maintenance in the case of most operators. United, for example, operates continuous equalised A-even and A-odd checks every 250FH, the cycle being completed every 500FH.

Delta has equalised A checks every 500FH, and so completes the cycle in the same interval. Air France completes its A check cycle at the sixth A-even check, after about 7,200FH. Ameco completes its A check cycle at the AR12 check after 7,200FH, while Cathay Pacific has a simple A check schedule finishing after 500FH.

The total number of line and light checks performed in this A check cycle and the MH used in each check, and consequently full line and light maintenance cycle, will determine the average MH consumption per FH.

Two factors greatly influence the MH used per FH in the cycle. The first is the maintenance programme, and the tasks in each type of check, which is also affected by the airline's policy for deferred items.

The second is the average FH:FC ratio. MH inputs in line and light checks are more related to FC, than FH. Thus, aircraft operating short average FC times will consume more MH per FH.

One operator may only consume 0.5MH for a pre-flight check, while another can use 2.0MH. When multiplied by the number of pre-flight checks in the cycle the difference in MH per FH will be large, and will account for the largest differences between the aircraft's total maintenance costs per FH.

Aircraft operating short-/medium-haul missions will consume in the region of 4.1-4.7MH per FH for line and light maintenance averaged over the A check cycle. Aircraft flying long flight times in the region of 9.0FH per FC will consume 1.3-1.6MH per FH averaged over the A check cycle.

A line and light labour rate of $65 per MH will take labour cost to $265-305 per FH for short-haul operations and $85-105 for long-haul operations *(see table, page 31)*. Actual labour cost for operators varies widely, because of airline remuneration structures and cost of sub-contracted labour at outstations.

Material cost inputs for each check are variable. Daily checks may consume

$200-300, weekly checks $300-500 and A checks $1,000-12,000 depending on workscope. Total material costs combine to $20-35 per FH for long-haul operations, and will be in the region of three times higher at $75 for short-haul missions *(see table, page 31)*.

Heavy checks

Like the 767, the 777 has items grouped into higher checks that are either system-related or structural-related. Most 777 operators have a form of generic 'C' check for hangar checks, and some have even larger checks for the structural items, with the longest inspection intervals, and cabin refurbishment.

United operates a system of a C check every 5,000FH. "There is an overhanging interval of 24 months for structural items," says Edwards. "Therefore if we do a C check within a 12-month frequency no structural items have to be included in the first C check, and all odd-numbered checks thereafter. It is then possible to have a system of alternating light and heavy C checks. The heavy C checks will be the even-numbered ones. We may escalate our C check interval to 15 months, and so structural items would have to be added to every C check. Although this would add about 1,000MH to the equalised C check, there would be an overall saving over our large fleet, because non-routine work and downtime would be reduced." Edwards estimates the routine to non-routine ratio for the light C checks to be about 1.0:0.25, and 1.0:0.40 for the heavy C checks.

United completes its C check cycle with a heavy C4 check. The interval for this is about 19,000FH, considering United's annual utilisation of 4,750FH. "We have done the first heavy visit on most of our 777s, but no second heavy visits," says Edwards. The ratio of routine to non-routine MH is similar to the heavy C checks; 1.0:0.40. "We will increase the interval of this check to five years, in line with our C check interval escalation, and will possibly get a proportionate increase in MH."

Delta also operates a system of annual checks, which it terms PSV checks, or 'packaged service visits'. The visits increase in scope as the aircraft ages. "The actual calendar limit of the PSV check is currently 12 months," says Cooper, "The PSV checks alternate between light and heavy, since most structural items are included only in every second PSV check, the even-numbered ones. The downtime for the PSV-odd checks is only one to three days, while the PSV-even checks use 4-10 days downtime. The PSV2/4/6 checks are smaller than the PSV8/12/16/20 checks. The PSV8 check has the heavy structural inspections that would be included in a D check of an older aircraft type."

The PSV-odd checks have routine inputs of 500-800MH, and Cooper expects non-routine work to remain at about 0.66 of routine inputs over the long-term. Routine MH for the PSV-odd checks are relatively consistent. Total MH for routine and non-routine inputs are 800-1,200MH.

PSV-even checks are heavier and more varied in routine inputs. Routine MH are expected to vary between 1,200 and 3,000 over a 20-year period, with PSV8/12/16/20 checks having the largest inputs. Non-routine ratio is also more variable, being as low as 1.5 for the PSV2/4 and lighter PSV-even checks. Heavier PSV6/8/12/16/20 checks are expected to have non-routine ratios of 1.7-2.4.

Cooper projects routine and non-routine MH inputs for the lighter PSV2/4 checks to total 3,000-4,200, and 7,000-10,000 for heavier PSV6/8/12/16/20 checks and their multiples as the aircraft ages beyond 15 years.

Additional MH have to be added for docking, cabin cleaning, SBs, interior

refurbishment and strip/paint.

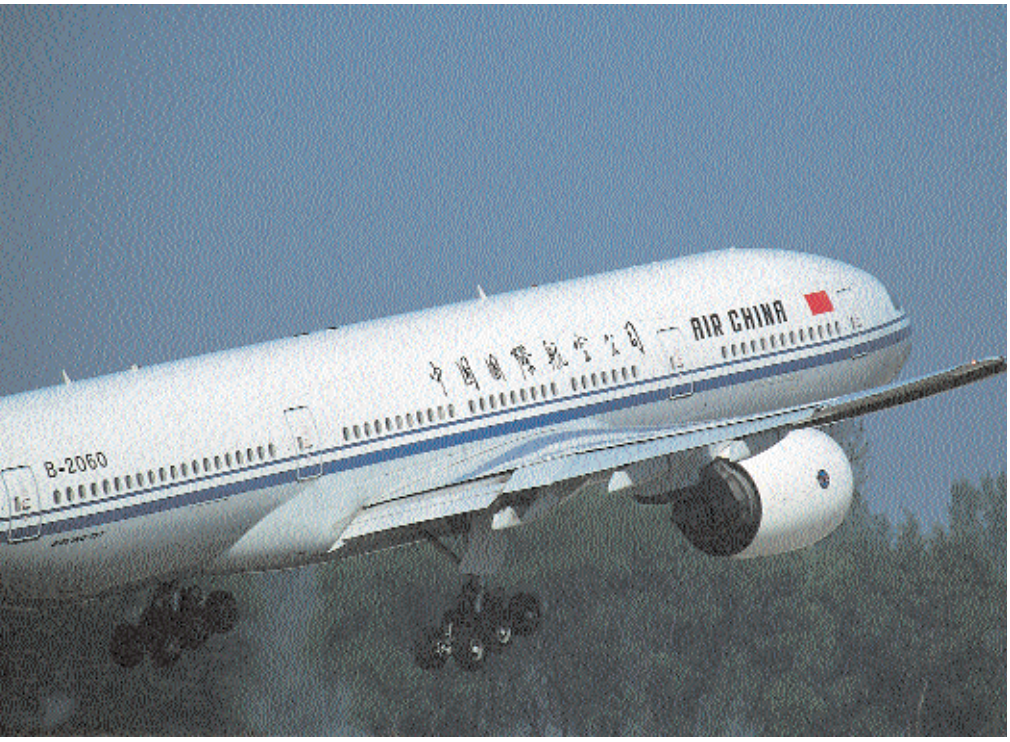
"We expect the 777 to be much better structurally than the 767, and so have a smaller rate of increase in non-routine work as the aircraft ages. Corrosion control is the key to MH inputs in structural checks," says Cooper.

Air France has the same system of alternating light and heavy C checks as United and Delta. Air France had an original interval of 5,000FH/12 months, but this has been escalated to 6,500FH/15 months. "The C-even checks are heavier, and 40% of their content is interior work. These just alternate, so the cycle is completed at the C2 check," says Topin. "We have separated structural items into SC checks, which also alternate between light and heavy. The basic interval is four years/4,000FC; equal to about 21,000FH with our utilisation. Although this coincides closely with the C3 check, the C and SC checks are operated independently. The SC check cycle is completed at the SC6 check, which will be after about 127,000FH if our annual utilisation is maintained at 5,300FH per year. Finally, we are planning cabin refurbishment every five years, which will be done together with a C or SC check. This will take care of sidewall panel and overhead bin refurbishment, and galley and toilet refurbishment on-condition. The labour for this will be sub-contracted. We also plan to strip and re-paint every six years."

Topin puts non-routine ratio as a percentage of routine inputs at 50% for C checks, 100% for C2 checks, and 100% for SC checks. "Inputs for routine, access, non-routine, interior work and SBs will total about 115MH for the C1 checks, in the region of 1,100MH for the C2 checks, 2,000MH for the SC check, 3,000 for the SC2 check, 4,800MH for the five year interior refurbishment and about 2,500MH for strip and paint every six years."

Cathay Pacific has a simple system of alternating light and heavy C checks; C1 and C2. "These are annual checks, so are performed every 3,400FH for us. The structural inspections and corrosion prevention and control programme work are an integral part of the C2 checks. The C2 check has structural items with intervals of 6,000FH or more. Including routine, non-routine and SBs, the C1/3/5 checks consume about 4,000MH, but we expect this to rise to about 5,000MH. The C2 multiples consume in the region of 7,000MH. The cabin panels and decor are attended to in C checks, with work on the galley and toilet refurbishment every C2 check as required. Strip and paint will be done every five years together with a C check. Although the routine:non-routine ratio will increase with age, we do not expect this to happen until the aircraft are about 10 years old. The 777 is better protected than previous Boeing types," says Ho.

Ameco combines system and structural items. The basic interval for the C check is 6,000FH, equal to about two years of operation, which is also equal to the interval of structural tasks. The C check cycle is completed with a C4 check, which is heavier than the preceding C checks. "The system tasks have an interval of 6,000FH/750 days. These reach their intervals at a similar time of two years," explains Keller. "The structural items have intervals of 4,000FC/750 days, and a check at two years reaches the limit of 750 days, but only 2,250FC. The C3 check has more items, and so is heavier, than the C1 check." Non-routine work as a percentage of routine work is about 50% for the C1, 60% for the C2, 80% for the C3 and 100% for the C4. Labour inputs for routine, non-routine and docking are about 1,350MH for the C1, 2,400 for the C2, 2,100MH for the C3 and 5,000 for the C4. Additional MH are required for SBs, cabin refurbishment and strip and paint.



Most 777 utilisation is split between high density medium-haul or long-haul operations. Aircraft operating medium-haul missions will incur the disadvantages the effect of short cycle times have on cycle-related maintenance tasks, but the aircraft is regarded as requiring low MH inputs for light and base checks.

Hangar check cycle & inputs

Hangar check cycles are completed in varying intervals, of 6,800FH in the case of Cathay Pacific, to as long as 127,000FH with Air France. Air France has a long cycle because it does not perform its heaviest SC6 check until after 24 years.

In addition to the inputs for routine, non-routine, docking, SBs and cabin cleaning, MH in hangar check cycles are also used for interior refurbishment and stripping and painting.

Typical interior refurbishment programmes will use in the region of 5,000MH and will be completed every five or six years. Material costs for this process can be in the region of $500,000. Stripping and painting will be done at a similar frequency, and use about 2,500MH and $16,000 in materials.

Material inputs for lighter C checks will be in the region of $50,000-100,000, $100,000-200,000 for heavier C checks and up to $400,000 for C checks with structural inspections.

Unlike line and light maintenance, the MH inputs for C checks are more influenced by FH accumulated than FC. MH per FH over the cycle for hangar checks, or base maintenance, will therefore be similar for aircraft operating short-haul and long-haul missions. Variations still occur between airlines because of different maintenance schedules, non-routine ratios and policies for interior refurbishment.

MH inputs vary between 0.8-1.3 MH per FH over the hangar check cycle. At a labour rate of $55 per MH, this is equal to $44-70 per FH *(see table, page 31)*. Material inputs are in the region of $30-45 per FH.

Components

Components can be subdivided in many ways for maintenance management and costing. The majority of 777 rotable components are maintained on-condition and are also line replaceable. A small percentage require the deep access of a hangar check for removal, and are still maintained on an on-condition basis. It is therefore convenient to group rotables as one item. Heavy components; wheels, brakes, landing gear, auxiliary power unit (APU) and thrust reverser can be grouped as another category.

Heavy components

The 777 has 12 main wheels and two nose units. The number of tyre retreads vary by operator, but five is typical. FC intervals between removals for retreads are in the region of 250FC for main wheels and 300FC for nose wheels. Tyre remould costs are about $400 per unit. Remould for a main wheel shipset is thus $4,800. New tyres cost about $1,000 for main wheels and $800 for nose wheels. Over five remoulds, the total cost of $42,000 for remoulds of nose and main wheels, and new tyres will be amortised over the tyre replacement life of 1,250-1,500FC, equal to about $35 per FC. This is equal to $12 per FH for aircraft operating 3FH per FC, and $5 per FH for aircraft on 8FH missions *(see table, page 31)*.

The 777 uses carbon brakes. Unlike steel brakes, carbon units have to reattain their original weight and thickness. Pads therefore have to ground to half their original thickness and joined with other halves. Each carbon disc can therefore only be ground once, and half the number of discs have to be replaced at each shop visit. Average brake repair cost is $30,000 per unit. Typical brake removal intervals for repair are 1,500FC, and so $20 per FC. A full shipset of 12 brakes equals $240 per FC, equal to $80 per FH for a 3FH mission and $30 per FH for a 8FH operation *(see table, page 31)*.

Most 777 operators are planning to remove landing gears every 8-10 years. The FC limit for most airlines is 10,000FC. Until the fleet matures exchange and repair fees for a shipset will be in the region of $860,000. This equals $29 per FH for short-haul aircraft, and $19 per FH for long-haul operations *(see table, page 31)*.

Thrust reversers are maintained on an on-condition basis, but removal intervals are expected to be as high as 6,000FC. Aircraft on long-haul operations therefore have FH intervals between shop visits almost three times those of short-haul aircraft. Average shop visit costs are expected to be $240,000 per unit, and so full shipset repair costs will be in the region of $10 per FH for long-haul aircraft; and about $27 per FH for aircraft operating short-haul missions *(see table, page 31)*.

The 777 uses the GTCP 331-500 APU. This is similar to the GTCP 331-350 used by the A330/340. Intervals between APU shop visits are expected to be about 3,500 APU hours. On the basis of 1.7 APU hours per FC, the average APU removal will be about 2,100FC. Shop visit costs may be in the region of $275,000, and so amortised cost per FH will be $16 for aircraft on 8FH missions and $44 for 3FH operations *(see table, page 31)*.

Rotables

The remaining rotables are those that are line replaceable units (LRUs) and ones that have to be removed during airframe checks, otherwise known as deep access components.

With regard to the inventory cost, it is more economic to have pooling or exchange arrangements to get access to replacement units and repair removed parts. One traditional example is the IATP pool where one airline helps the other at remote stations to save inventory.

A modern pooling arrangement goes beyond this traditional back-up solution.

The pool provider will cover as many parts as possible and will ship serviceable parts to an airline in exchange for removed unserviceable parts that require repair. He will also guarantee the interchangeability of parts and the necessary documentation like Joint Airworthiness Authority or Federal Aviation Administration forms. Such arrangement is also known as 'open loop exchange', meaning that different serial numbers will be sent back.

A usual arrangement will be for a customer airline to pay a pool access fee and maintenance repair fee on the basis of a fixed rate per FH or month.

The main benefit of pooling comes out of scale effects from material provisioning where the pooling provider services a virtual larger airline. That is, it services itself and several customer airlines, and passes a part of the savings to the customer. As a direct effect the home base inventory for the airline reduces remarkably and is mainly limited to minimum equipment list (no-go) items and those part numbers which are not poolable.

These items are mainly:

- Peculiar parts with no pool/scale effect (for example buyer furnished equipment and passenger seats)
- Parts with limitations in transportation or logistics (for example batteries and oxygen bottles)
- Economically unfeasible parts (wheels and brakes)

These parts also have to be kept in an inventory at an airline's base and line stations and will remain under the airline's material management. Some pool providers offer leasing arrangements for this remaining home base inventory.

The overall cost elements are:

- Component repair and overhaul flatrate, including engine LRUs.
- Pool access fee for pooled components (about 80% of all LRUs, excluding deep access components).
- Capital cost for the home base parts.

Typically this amounts to:

- A charge for the repair and overhaul of the parts of about $175/FH for LRUs, $75/FH for deep access parts and $30/FH for engine LRUs. This is for both poolable and home base parts.
- The pool access fee for all poolable components, which effectively covers their capital cost is in the region of $75/FH, not including line station support or possible extras for logistics and customs duties.
- The capital cost for the home base inventory will depend on fleet size, no-fault found rate and other parameters. As a budget figure an investment of about $10 million is sufficient for a fleet of 10 aircraft, increasing to $16 million for 20 aircraft. The cost of this is calculated as an annual depreciation and interest charge, divided by the number of annual flight hours. Depreciation to zero over 15 years, a 6% interest rate an annual utilisation 4,500FH results in a cost of $25/FH for a fleet of 10 aircraft, and $20/FH for 20 aircraft.
- The total cost is thus $380 for a fleet of 10 *(see table, this page)*, and $375 for a fleet of 20.

PASSENGER 777 FLIGHT HOUR (FH) AIRFRAME & COMPONENT MAINTENANCE COSTS

Maintenance item	$/FH for 3.0FH/FC	$/FH for 8.0FH/FC
Line & light maintenance labour @ $65/MH	265-305	85-105
Line & light maintenance material costs	75	20-75
Hangar check maintenance labour @ $50 per MH	45-70	45-70
Hangar check maintenance material costs	30-45	30-45
5 tyre remoulds every 250-300FC & replacement	12	5
Brake repairs every 1,500FC	80	30
Landing gear removal & exchange every 8-10 years	29	19
Thrust reversers removal & repair every 6,000FC	27	10
APU removal & shop visit every 3,500 APU hours	44	16
Rotable pooling repair & access and home base fee inventory	380	380
Total cost	**990-1,070**	**640-755**

Summary

The 777 has competitive maintenance costs compared to similar sized aircraft. On long-haul missions with sectors of 8.0FH, total airframe and component maintenance is $640-755 per FH *(see table, this page)*. These costs can be broken down into four constituent parts.

The first is line and light maintenance. Actual cost depends on the operator's maintenance schedule and in particular MH and materials spent in the smallest and most frequent checks. Their large number over the full A check cycle can mean a high expenditure on each will increase cost per FH. It is this element of airframe and component maintenance that has the largest influence on overall maintenance costs. This is $105-180/FH for the 777, which is lower than the rate of $155 for the A340 *(see Technology provides A340 with partial gain in maintenance cost, Aircraft Commerce, October/November 2001, page 27)*.

The second element is base maintenance for C and heavy checks. This is $75-115 for the 777, which compares to $155 for the A340. This provides one of the largest differences between the 777 and A340. This is mainly due to the MH consumption in these checks. The 777 has low consumption in relation to the check workscopes and their interval. Airlines operating both types have commented that the 777 is more economic in this respect. Few A340s, however, have been through their first 10-year check, and the 777 is not yet mature. Further experience with operation of both will begin to reveal how much they consume in base maintenance.

Heavy component maintenance costs are similar for both types, but are small differences. The A340, for example, will benefit from having fewer mainwheel brake units, while the 777 has two thrust reversers compared to the A340's four. Both aircraft have a similar APU, which will be expected to have similar intervals between shop visits and shop visit costs.

The cost of rotable provisioning and repair is hard to compare between the two, since there are many methods which can be used to acquire the parts and arrange repair. Similar methods are likely to result in similar costs for the two.

The 777 therefore appears to gain an advantage over the A340 in line and light and base maintenance costs. A comparison between the two, calculating costs on an equal basis will be made in the August/September 2002 issue of *Aircraft Commerce*.