PW4000-94 fuel burn performance

The PW4000-94 powers many 1980s-generation widebodies. The fuel burn performance of the major aircraft types is analysed.

The PW4000-94 series powers a large number of widebody aircraft types and variants. The fuel burn performance of the most popular types is analysed. This engine family has various applications which include the A300-600, A310, 767 family, 747-400 and MD-11 *(see PW4000-94 specifications, page 10)*.

The applications analysed here include: the 767-200, 767-300 and 747-400 all powered by the PW4056; the 767-300ER with the PW4060; the A300-600R with the PW4158; the A310-300 with the PW4156A; and the MD-11 with the PW4460. The fuel burn performance of these airframe-engine combinations has been analysed on sample routes.

Aircraft analysed

There are several weight and fuel capacity specifications of each aircraft type with different variants of the PW4000-94, and these are summarised for the aircraft analysed *(see table, page 17)*.

The A300-600R with the PW4056 engine has been analysed with a maximum take-off weight (MTOW) of 378,533lbs and a fuel capacity of 16,124 US Gallons (USG). It has been analysed with a 266-seat configuration.

The A310-300 model analysed has an MTOW of 361,558lbs, a fuel capacity of 18,030USG and PW4156 engines *(see table, page 17)*. This is the highest gross weight and fuel capacity version of the A310-300. The aircraft has been analysed with 220 seats, which is typical of a European-style, two-class configuration.

The 767-200 and -300 models analysed have MTOWs of 351,000lbs and 350,000lbs respectively. Both have fuel capacities of 16,700USG, and are powered by the PW4056 engine. The -200 has been analysed with 230 seats, and the -300 with 260 seats. This is typical for a two-class configuration.

The 767-200ER aircraft was not included in this study, since there is only a small number in service powered with PW4000-94 engines.

The 767-300ER has an MTOW of 412,000lbs, the highest gross weight version of the -300ER, and a fuel capacity of 24,140USG, and is equipped with PW4060 engines. It has been analysed with 215 seats for long-haul operations and 230 seats for medium-haul operations. The 747-400 has the highest MTOW available of 870,000lbs, a fuel capacity of 57,065USG, and is equipped with PW4056 engines *(see table, page 17)*. It has been examined with a 390-seat configuration. The passenger variant of the MD-11 has an MTOW of 630,500lbs, the highest available for the aircraft, a fuel capacity of 38,615USG, PW4460 engines, and an interior layout of 298 seats.

Routes analysed

All airframe-engine combinations have been analysed on routes with lengths typical for their gross weight and range capability. The performance of each aircraft has been examined with a payload of a full complement of passengers. All routes used do not limit the aircraft's payload-carrying performance below its maximum passenger capacity. Aircraft performance has been examined in both directions on a route to reveal the effect of headwinds and tailwinds on fuel burn performance and flight time.

It should be noted that the tracked distances as listed *(see table, page 17)* vary between different aircraft on a given route, and also according to the direction flown. This is because two sources for the aircraft flight plan data were used: Airbus computed the flight plans for the A300-600 and A310, while plans for all the other aircraft were provided by Jeppesen. Furthermore, for the latter, the multiple waypoints and climb segments used in each flight plan would have influenced the actual tracked ground distance covered, as well as the winds encountered en route. Moreover, the waypoints used by Jeppesen could not match those provided by Airbus.

The low-weight and short-range aircraft, the A300-600R, 767-200 and 767-300, have been analysed on the intra-European route of Rome, Fiumicino (FCO) - Athens (ATH) whose stage length is similar to many US and Japanese domestic city-pairs where many of these aircraft operate. The route has an approximate tracked distance of 600nm and a flight time of 100 minutes for most types when flying at optimum long-range cruise. The alternate airport for Rome is Naples, and for Athens it is Crete.

The A310-300 and 767-300ER with 220 and 230 seats respectively have been analysed on Larnaca (LCA) - Paris (CDG), and Paris-Larnaca. The alternate airport for Larnaca is Paphos, and for Paris it is Brussels. This is typical of a medium-haul route, with a tracked distance of 1,700nm and flight time close to four hours, depending on the waypoints chosen for each calculation.

The 767-300ER configured with 215 seats and the 295-seat MD-11 have been examined on Copenhagen (CPH) - Tokyo, Narita (NRT). This is a typical long-haul route of 5,100nm, with a flight time of over 10 hours.

The 747-400's performance has been examined on Auckland (AKL) - Los Angeles (LAX), which has a tracked distance of 5,800nm and flight time of 12-13 hours, depending on the direction of travel.

The performance of all aircraft has been examined using 85% reliability winds for the month of July, a 15-minute taxi time (10 minutes out and five minutes in), and the optimum long-range cruise for each type. The standard weight for each passenger is given as 220lbs.

Aircraft fuel burns

As described, the aircraft have been split into groups, with two or three airframe-engine combinations being analysed on a specific city-pair that would be typical of airline deployment. The A300-600R, 767-200 and 767-300 have been examined on FCO-ATH. Travelling eastwards to Athens, aircraft experience an 18-21 knot tailwind. The tracked distance is either 616nm or 701nm (depending on whether the flight plans are supplied by Jeppesen or Airbus). With the tailwind, the resultant equivalent still air distance (ESAD) is between 590nm and 685nm *(see table, page 17)*. The 767-200/-300 both have a block time of 104 minutes, while the A300-600R missions take 103 minutes block time. On this sector, both 767 models burn similar amounts of fuel per passenger-mile. It should be noted that using the ESAD in this calculation of fuel burn per passenger-mile enables a like-for-like comparison between the aircraft in terms of quantifying the fuel required to transport a given payload over a given distance. Using tracked distance instead would skew the result because of the

FUEL BURN PERFORMANCE OF PW4000-94-POWERED PASSENGER AIRCRAFT

City-pair	Aircraft variant	Engine type	Seats	Payload lbs	MTOW lbs	Actual TOW lbs	Fuel burn USG	Flight time mins	ESAD nm	USG per pax-nm
FCO-ATH	767-200	PW4056	230	50,600	351,000	254,809	2,348	104	608	0.0150
FCO-ATH	767-300	PW4056	260	57,200	350,000	284,483	2,550	104	685	0.0143
FCO-ATH	A300-600R	PW4158	266	58,520	378,533	289,902	2,586	103	590	0.0165
ATH-FCO	767-200	PW4056	230	50,600	351,000	254,422	2,492	111	732	0.0148
ATH-FCO	767-300	PW4056	260	57,200	350,000	283,983	2,690	110	730	0.0142
ATH-FCO	A300-600R	PW4158	266	58,250	378,533	290,617	2,996	120	717	0.0157
CDG-LCA	767-300ER	PW4060	230	50,600	412,000	295,361	5,539	228	1,652	0.0146
CDG-LCA	A310-300	PW4156A	220	48,400	361,558	275,670	5,338	241	1,647	0.0147
LCA-CDG	767-300ER	PW4060	230	50,600	412,000	303,344	6,346	256	1,872	0.0147
LCA-CDG	A310-300	PW4156A	220	48,400	361,558	283,662	6,210	272	1,895	0.0149
CPH-NRT	767-300ER	PW4060	215	47,300	412,000	379,948	17,586	652	4,931	0.0166
CPH-NRT	MD-11	PW4460	298	65,560	630,500	52,267	24,866	630	4,925	0.0169
NRT-CPH	767-300ER	PW4060	215	47,300	412,000	381,279	18,332	675	5,140	0.0166
NRT-CPH	MD-11	PW4460	298	65,560	630,500	545,219	25,837	653	5,123	0.0169
AKL-LAX	747-400	PW4056	390	85,800	870,000	759,233	38,531	702	5,735	0.0172
LAX-AKL	747-400	PW4056	390	85,800	870,000	801,084	42,936	750	6,164	0.0179

variations in the figures, thereby making a meaningful comparison impossible.

On this basis, the 767-200 uses 0.015USG per passenger-mile (ESAD); the 767-300ER uses 0.0143USG; and the A300-600R uses the most fuel per passenger mile with 0.0165USG. In the westerly direction to Rome, a headwind of 52-66 knots increases the ESAD to 717-732nm *(see table, this page)*, which increases the fuel required. The fuel burned per passenger-mile (ESAD) is again similar for both 767 models: 0.0148USG for the 767-200; and 0.0142USG for the 767-300. The A300-600R, by comparison, burns 0.0157USG per passenger-mile.

Meanwhile, the A310-300 and 767-300ER are both examined on LCA-CDG, which is a medium-haul route of similar length to that on which many aircraft in this category are operated. In the easterly direction to Larnaca, the aircraft benefit from a small tailwind of 11-12 knots *(see table, this page)*. This results in an ESAD of 1,650nm, which compares to the tracked distance of 1,690nm. The A310-300's block time is 241 minutes, while the 767-300ER is a little faster with 228 minutes. The fuel burns per passenger-mile of the 767-300ER and A310-300 are very close indeed: 0.0146USG for the 767-300ER; and 0.0147USG for the A310-300.

In the westerly direction to Paris, the aircraft face a headwind of 40-51 knots, which increases the ESAD to 1,900nm *(see table, this page)*. This compares to a tracked distance of 100nm shorter. There is a small difference in flight times between the two, with the 767-300ER completing the missions in 256 minutes and the A310-300 in 277 minutes. Again, the 767-300ER has a slightly lower fuel burn per seat-mile, of 0.0147USG, compared to the A310-300's 0.0149USG.

The 767-300ER and MD-11 are examined on CPH-NRT, which is a long-haul route within their full payload-range capability that allows both types to comfortably carry a full passenger load. This is a trans-Siberian routing, so the aircraft face a headwind when operating in both directions. However, this is small at just three knots when travelling east to Tokyo, resulting in an ESAD of about 4,930nm. The actual tracked distance is therefore very similar at 4,902nm. On this long sector the 767's lower long-range-cruise speed gives it a 22-minute longer block time than the MD-11.

Despite having 83 more seats than the 767-300ER, the MD-11 has a higher fuel consumption per passenger-mile because of its much higher structural weight coupled with its lower lift-to-drag ratio. The MD-11 therefore has a fuel burn per seat-mile (ESAD) of 0.0169USG compared to 0.0166USG for the smaller 767-300ER.

In the westerly direction to Copenhagen, the tailwind rises to 27 knots, resulting in an ESAD of 5,130nm. This compares with the actual tracked distance of 4,852nm, giving a difference of 278nm.

The MD-11 has a flight time of almost 11 hours, while that of the slower 767-300ER is 22 minutes longer at 11 hours and 15 minutes *(see table, this page)*. Again, the MD-11 has a higher fuel burn per passenger-mile of 0.0169USG, compared to 0.0166USG for the smaller 767-300ER.

The 747-400 is examined on an ultra-long-haul route: AKL-LAX. Flying to Los Angeles the aircraft has a small tailwind of eight knots which results in an ESAD of 5,735nm compared with the actual tracked distance of 5,820nm, giving a 85nm difference.

The 13-knot headwind in the opposite direction results in an ESAD of 6,164nm compared with the actual tracked distance of 6,003nm, a difference of 161nm. Although the 747-400 is able to carry a full passenger load on Auckland-Los Angeles, its fuel burn performance per passenger-mile is worse than that of all the other aircraft analysed in this study. This is partly due to the 747-400 having a high overall lift-to-drag ratio, and partly due to its lower-than-optimum passenger load (the 747-400 can easily accommodate about 415 passengers in two classes, in contrast to the 390 here). AC