PW4000-112 fuel burn performance

The fuel burn performance of three PW4000-112 powered 777 variants are analysed on a range of routes varying in length from 784nm to 5,332nm. This analyses the PW4000-112 across several 777 family members and different types of operations.

The PW4000-112 series of engines powers three main variants of the 777 family: the 777-200, -200ER and -300.

This analysis looks at the fuel burn performance of 777 variants powered by a range of PW4000-100 variants. Fuel burn is analysed per sector, per passenger seat and per passenger seat-mile for three variants over various routes ranging in length from 784nm to 5,332nm.

The airframe-engine combinations examined are: the 777-200, powered by the PW4077, which has a take-off thrust rating of 79,960lbs; the 777-200ER powered by the PW4090, with a take-off thrust rating of 91,790lbs; and the 777-300, powered by the PW4098 with a take-off rating of 98,000lbs thrust.

Flight profiles

Aircraft performance has been analysed both inbound and outbound for each route to illustrate the effects of wind speed, and its direction, over the tracked distance flown. The resulting distance is referred to as the equivalent still air distance (ESAD), or nautical air miles (NAM).

Average weather for the month of June has been used, with 85% reliability winds and 50% reliability temperatures used for that month, in the flight plans produced by Jeppesen. The flight profiles in each case are based on International Flight Rules, which include standard assumptions on fuel reserves, diversion fuel and contingency fuel. Having said that, the fuel burn used for the analysis of each sector only includes the amount of fuel used for the trip and taxiing. The optimum routes and levels have been used for every flight, except where it has been necessary to limit the levels because of airspace or airway restrictions and to comply with standard routes and Eurocontrol restrictions.

A total taxi-in and taxi-out time of 25 minutes has been factored into the fuel burns and added to the flight times to provide block times. The flight plans have all been calculated using a long-range cruise (LRC) speed of Mach 0.84. Although other speeds are more likely on shorter routes, LRC has been chosen so that all routes can be equally compared for all variants without the need to adapt payload figures. Using LRC means that an aircraft consumes less fuel per nautical mile, and longer block times, but this is considered the economical and operational compromise between fuel consumption and flight times by most carriers.

The aircraft being assessed are assumed to have passenger loads of: 360 in a two-class configuration on the 777-200; 301 in a tri-class layout on the 777-200ER; and 390 in a two-class layout on the 777-300. The 777-200 and 777-300 have been analysed on short- and medium-haul routes in a regional type of operation. The 777-200ER has been analysed on medium- and long-haul services on an intercontinental type of operation.

The standard weight for each passenger and their luggage is assumed, on all flights, to be 220lbs per person. No additional cargo is carried in the hold. The payload carried is therefore: 79,200lbs for the 777-200; 66,220lbs for the 777-200ER; and 85,800lbs on the 777-300.

Route analysis

Seven routes of varying lengths were analysed with tracked distances of 784-5332nm. The 777-200 has been analysed on the shortest four routes, the 777-300 on three routes of medium length, and the 777-200ER on the longest three routes *(see table, page 9)*. This will show the performance of the 777 variants on route lengths that are typical of their utilisation, and the fuel burn performance of the PW4000-112 engines.

The first route is Bangkok (BKK) to Singapore (SIN), using the 777-200 with the PW4077 engine. For this route there was a slight headwind in both directions, causing the tracked distance of 784nm outbound (OB) to increase to an ESAD of 789nm, and the tracked distance of 827nm inbound (IB) to increase slightly to an ESAD of 832nm.

The second route is BKK to Jakarta (CGK) using the 777-200 and 777-300,

The 777-200ER with PW4090 is one of the most popular PW4000-powered 777 variants. The aircraft burns about 12% less fuel per seat than the 747-400 on long-haul routes.

FUEL BURN PERFORMANCE OF THE PW4000-100&-112 ENGINES

City-pair	Aircraft variant	Engine model	MTOW lbs	TOW lbs	Fuel burn USG	Block time mins	Seats	Payload lbs	Tracked distance nm	ESAD nm	Fuel per seat	Fuel per seat-mile	Wind speed kts
BKK-SIN	777-200	PW4077	535,000	430,347	4,041	134	360	79,200	784	789	11.22	0.014	-4
SIN-BKK	777-200	PW4077	535,000	431,148	4,193	139	360	79,200	827	832	11.65	0.014	-5
BKK-CGK	777-200	PW4077	535,000	441,928	5976	193	360	79,200	1,262	1,269	16.60	0.013	-4
	777-300	PW4098	660,000	496,634	6,859	191	390	85,800	1,262	1,270	17.59	0.014	-4
CGK-BKK	777-200	PW4077	535,000	445,431	6,222	198	360	79,200	1,312	1,322	17.28	0.013	-4
	777-300	PW4098	660,000	498,252	7,089	198	390	85,800	1,312	1,322	18.18	0.014	-5
BKK-DPS	777-200	PW4077	535,000	456,114	7,750	244	360	79,200	1,655	1,687	21.53	0.013	-11
	777-300	PW4098	660,000	512,378	8,906	242	390	85,800	1,655	1,688	22.84	0.014	-11
DPS-BKK	777-200	PW4077	535,000	454,885	7,564	237	360	79,200	1,654	1,644	22.01	0.013	4
	777-300	PW4098	660,000	509,342	8,664	237	390	85,800	1,654	1,644	22.21	0.014	4
BKK-NRT	777-200	PW4077	535,000	492,660	12,250	362	360	79,200	2,699	2,674	34.03	0.013	5
	777-300	PW4098	660,000	553,824	14,183	362	390	85,800	2,699	2,674	36.37	0.014	4
NRT-BKK	777-200	PW4077	535,000	489,870	12,533	375	360	79,200	2,610	2,768	34.81	0.013	-27
	777-300	PW4098	660,000	550,215	14,469	373	390	85,800	2,610	2,764	37.10	0.013	-28
BKK-DXB	777-200ER	PW4090	632,500	476,296	12,450	373	305	66,220	2,759	2,743	40.82	0.015	4
DXB-BKK	777-200ER	PW4090	632,500	476,805	12,623	378	305	66,220	2,759	2,771	41.39	0.015	-17
BKK-SYD	777-200ER	PW4090	632,500	521,422	18,480	536	305	66,220	4,174	4,092	60.59	0.015	10
SYD-BKK	777-200ER	PW4090	623,500	527,114	19,766	574	305	66,220	4,195	4,409	64.81	0.015	-24
BKK-LHR	777-200ER	PW4090	623,500	578,409	26,860	727	305	66,220	5,314	5,691	88.06	0.015	-33
LHR-BKK	777-200ER	PW4090	623,500	561,975	24,717	685	305	66,220	5,332	5,312	81.04	0.015	2

Source: Jeppesen

with a tracked distance of 1,262-1,312nm depending on the routeing. Again the headwinds are slight, only raising the tracked distance by up to 10nm when looking at the ESAD, which equates to less than 1%.

The third route is BKK to Bali (DPS) using both the 777-200 and -300. This has a tracked distance of 1,655nm. There is a large headwind OB and a small tailwind on the return sector, meaning that the tracked and ESAD distances have a difference of roughly 40nm.

The fourth route is BKK to Narita (NRT) with both the 777-200 and 300. Tracked distance is 2,610-2,699nm depending on the routeing. The small tailwind on the OB sector is changed for a very large headwind on the return, resulting in a 90nm difference in the ESADs.

The next three routes all use a 777-200ER from BKK. The fifth route is to Dubai (DXB) with a tracked distance of 2,759nm, and there is a difference of nearly 30nm with the ESAD due to winds.

The sixth route is to Sydney (SYD), which has a tracked distance of 4,174-4,195nm, depending on routeing. The route has relatively strong tail- and headwinds, OB and IB, resulting in a difference of nearly 400nm with the ESAD.

The last route is BKK to London (LHR), with a tracked distance of 5,314-5,322-nm. This route has strong headwinds OB, and virtually no tailwind on the return. This wind differential results in only a 220nm ESAD difference, which is not too much given the route length.

For most of the routes, flight times in either direction only differ by 5-7 minutes. In the case of NRT-BKK there is a 13-minute lengthening of the flight on the return due to the strongest headwind of 28 knots. The two longest routes also showed strong headwinds on one sector each and, due to the length of the routes, this has resulted in an ESAD increase of up to 377nm and an increase in flight times of 38-42 minutes.

Fuel burn performance

The fuel burn for each airframe/engine combination and the consequent fuel burn per passenger seat are shown *(see table, this page)*, as well as the fuel burn per passenger seat-mile or fuel per seat-mile.

The data shows that for each variant the fuel burn increases as the take-off weights increase. This is still the same when the burn per seat is calculated. The burn per seat-mile, however, takes into account the distances flown. For the same airframe/engine combination, the fuel burn per seat-mile reduces with increased distance.

The burn per seat and per seat-mile increases slightly as the aircraft increases in size, which goes against expectations. This increase is only a few per cent, however.

The burn per seat-mile data also shows that different airframe/engine combinations are better for certain routes. The fuel burn per seat-mile for the BKK-SIN route on the 777-200 is higher than on the BKK-NRT route using either the 777-200 or -300.

From the fuel burn per seat-mile, it can be seen that the optimum route length for the 777-200ER is the BKK-SYD route, which is about 4,000nm.

It is worth remembering that the shorter routes are not likely to be flown with LRC, but at a higher Mach number. Maximum cruise speed is Mach 0.89, which will have the disadvantage of increasing the fuel burn per seat-mile, but will also have the benefit of decreasing the flight time. AC