747-400 fuel burn performance

The fuel burn & operating performance of passenger- and freighter-configured aircraft are analysed on ultra long-haul missions.

The fuel burn and operating performance of the passenger and freighter variants of the 747-400 are analysed. Each of these two main groups has aircraft powered by CF6-80C2, PW4000 and RB211-524 engines.

The performance of three maximum take-off weights (MTOW) variants of the 747-400 passenger aircraft powered by the CF6-80C2 have been examined. Passenger-configured aircraft powered by PW4056 and RB211-524 engines with an MTOW of 870,000lbs have also been examined. Their performance has been examined at Mach 0.84.

Only GE- and P&W-powered freighter aircraft have been analysed. The performance has been examined at Mach 0.84.

Passenger routes

The performance of passenger-configured aircraft has been examined on a typical ultra-long-haul route: Hong Kong (HKG) -Vancouver (YVR). This has a great circle distance of about 5,500NM.

Performance of the aircraft has been analysed in both directions to illustrate the effects of wind speed and direction on the actual distance flown and the aircraft's performance. Headwinds and tailwinds increase or reduce the equivalent still-air-distance (ESAD), compared with the tracked distance.

The HKG-YVR route has a flight time of 11-12 hours, depending on the direction and wind speed, and is close to the edge of the 747-400's payload-range performance. The fuel the aircraft are legally required to carry to operate the route in either direction is influenced by the choice of suitable diversion and alternate airports. These are Calgary (YYC) when operating to YVR, and Macau (MFM) when operating to HKG.

The flight plans, performed by Jeppesen/Boeing, have used 50% reliability winds and 50% reliability temperatures for the month of June.

The aircraft have been assumed to carry a full passenger payload of 400 passengers in three classes. The standard weight for each passenger plus baggage is 220lbs. No additional underfloor cargo is carried. Each aircraft therefore carries a payload of 88,000lbs.

The flight profiles in each case are based on domestic FAR flight rules, which include standard assumptions on fuel reserves, standard diversion fuel (for the alternate airports mentioned above), plus contingency fuel.

In an easterly direction to YVR, the aircraft is assisted by a 45-knot tailwind. This results in a flight time of 681 minutes and a shorter ESAD of 5,503nm compared with a tracked distance of 5,971nm.

Meanwhile, for the YVR-HKG route, where there is a headwind component of 18 knots, the 5,768nm tracked distance compares with an increased ESAD of 5,990nm. This route has a flight time of 738 minutes.

Freighter route

The freighter aircraft are examined on a shorter route: Seattle (SEA) - Shanghai (PVG). The aircraft performance has been analysed in both directions to illustrate the effects of wind speed and direction on the ESAD and aircraft performance. The chosen city-pair is typical of many 747-400 long-range freight operations, since it has a block time of 10-11 hours depending on the direction of travel. The diversion and alternate airports chosen are Fuzhou (FOC) when operating to PVG, and Portland (PDX) when operating to SEA. Again, 50% reliability winds and 50% reliability temperatures for the month of June have been used.

The aircraft have been analysed carrying the maximum possible freight payload in both directions on this route. The freight payloads are 173,797-203,000lbs for the respective sectors. The flight plans have therefore calculated the payload that can be carried without the aircraft exceeding its MTOW, and carrying all the legally required trip, contingency, diversion and taxi fuel.

When operating in a westerly direction to PVG, the aircraft encounter a headwind component of 3 knots which results in an ESAD of 5,356nm compared with a tracked distance of 5,322nm. This route has a flight time of 655 minutes.

The aircraft experience a tailwind component of 51-53 knots when operating in an easterly direction operating to SEA. This results in an ESAD of 4,825nm compared with a tracked distance of 5,310nm. This route has a flight time of 591 minutes.

Aircraft powered by CF6-80C2B1F engines have lower rates of fuel burn per passenger and per ton-mile than aircraft equipped by PW4056 and RB211-524 engines. These differences are only in the order of 1-3%.

FUEL BURN PERFORMANCE OF PASSENGER-CONFIGURED 747-400

City-pair variant	Aircraft	Engine model	MTOW lbs	TOW lbs	Fuel capacity USG	Fuel burn USG	Flight time mins	Passenger payload	ESAD nm	Fuel per seat	Wind speed
HKG-YVR	747-400	CF6-80C2B1F	850,000	788,132	53,757	38,222	680	400	5,503	96	45
HKG-YVR	747-400	CF6-80C2B1F	870,000	788,782	57,057	38,290	680	400	5,503	96	45
HKG-YVR	747-400	CF6-80C2B1F	875,000	788,782	57,057	38,290	680	400	5,503	96	45
HKG-YVR	747-400	PW4056	870,000	792,960	57,277	38,731	681	400	5,503	97	45
HKG-YVR	747-400	RB211-524G/H	870,000	803,981	57,277	39,783	681	400	5,503	99	45
YVR-HKG	747-400	CF6-80C2B1F	850,000	798,767	53,757	41,703	738	400	5,990	104	-18
YVR-HKG	747-400	CF6-80C2B1F	870,000	798,752	57,057	41,701	738	400	5,990	104	-18
YVR-HKG	747-400	CF6-80C2B1F	875,000	798,753	57,057	41,701	738	400	5,990	104	-18
YVR-HKG	747-400	PW4056	870,000	802,493	57,277	42,090	739	400	5,990	105	-18
YVR-HKG	747-400	RB211-524G/H	870,000	811,222	57,277	42,664	739	400	5,990	106	-18

FUEL BURN PERFORMANCE OF FREIGHTER-CONFIGURED 747-400

City-pair variant	Aircraft	Engine model	MTOW lbs	TOW lbs	Fuel capacity USG	Fuel burn USG	Flight time mins	Freight payload lbs	ESAD nm	Fuel per ton-mile	Wind speed
SEA-PVG	747-400	CF6-80C2B1F	870,000	865,164	57,057	40,638	655	175,219	5,356	0.098	-3
SEA-PVG	747-400	PW4056	870,000	868,971	57,277	41,130	655	173,797	5,356	0.100	-3
PVG-SEA	747-400	CF6-80C2B1F	870,000	832,564	57,057	35,856	590	189,024	4,825	0.080	51
PVG-SEA	747-400	PW4056	870,000	860,203	57,277	37,558	591	203,000	4,825	0.078	51

Source: Jeppesen

Fuel burn performance

The fuel burn for each aircraft-engine combination and the consequent burn per passenger or ton-mile of freight are summarised *(see table, this page)*.

The first comparison is between three different MTOW versions (850,000lbs, 870,000lbs and 875,000lbs), all with CF6-80C2B1F engines, and a cruise speed of Mach 0.84 for consistency.

The data shows that for the respective models, the fuel burn per passenger increases in relation to actual take-off weights, regardless of the aircraft's MTOW capability *(see table, this page)*. This is because the MTOW capabilities of the aircraft are not actually reached, and the actual take-off weights of the three aircraft analysed are almost identical. The aircraft with MTOWs of 870,000lbs and 875,000lbs have exactly the same take-off weights, and are required to carry (and burn) exactly the same amount of fuel. The lighter aircraft with an MTOW of 850,000lbs has just a 650lbs lighter take-off weight and burns 68USG less fuel during the trip.

The differences between the fuel burns of the three CF6-80C2-powered 747-400 examples are thus small. The requirement for aircraft with a higher MTOW is that they are able to carry higher payloads on longer routes than aircraft with a lower MTOW capability.

A single variant of PW4056-powered aircraft with an MTOW of 870,000lbs has been analysed. This has a higher fuel burn compared with the CF6-80C2-powered aircraft. The PW4056-powered aircraft burns 442USG more fuel than its counterpart when operating to YVR, and 389USG more when operating to HKG.

This is a more significant difference than the above example, and is mainly a result of the PW4056-powered aircraft having a 4,178lbs higher actual take-off weight and a 572lbs higher operating empty weight (OEW). The higher OEW is due to the PW4056s being heavier than the CF6-80C2B1F engines.

The difference in fuel burn between aircraft powered with RB211-524G/HT and CF6-80C2B1F engines is larger, at 1,493 USG *(see table, this page)*. There are several reasons for this. The OEW of the RR-powered aircraft is 2,196lbs greater. The actual take-off weights show a larger difference, with the RR-powered aircraft being 15,284lbs heavier for the same mission to YVR sector.

The ESAD differs by 487nm for the two missions. This is matched by a difference of 58 minutes in flight time between the two directions of travel, which results in differences in fuel burns. Aircraft with PW4056 engines burn 3,359USG more fuel in a westerly direction to HKG compared to operating in an easterly direction to YVR. The aircraft burns 3,350-3,400USG per hour in the cruise.

Freighter fuel burn

The SEA-PVG and PVG-SEA missions are close to the 747-400F's payload-range performance. The easterly operation to PVG has a 519nm longer ESAD than the westerly leg to SEA, so the aircraft carries 13,805lbs less payload when operating to PVG for it to carry enough fuel to operate the 519nm longer ESAD.

Moreover, the aircraft's actual take-off weight is at 865,000-868,000lbs; just 2,000-5,000lbs less than the MTOW of 870,000lbs when operating to PVG *(see table, this page)*.

The tailwind in the reverse direction to SEA reduces the ESAD to 4,825nm, and the aircraft have to take off at 832,564lbs and 860,203lbs *(see table, this page)*. These lower take-off weights and lighter fuel loads allow the aircraft to carry more payload.

It is worth noting the differences in the engine-related fuel burns between the PW- and GE-powered 747-400F. As previously evidenced with the passenger version, the CF6-80C2-powered freighter is slightly more fuel efficient than the PW-powered aircraft *(see table, this page)*. The installed engine weight difference is certainly a factor, and the two engines also differ in propulsive efficiency. AC