PW2000 & RB211-535 fuel burn performance

The fuel burn performance of the main RB211-535E4 & PW2000 variants powering passenger- and freighter-configured aircraft are analysed.

The 757-200 and -300 aircraft were each offered with four engine options. The 757-200 options were the RB211-535E4, -535E4B, PW2037 or PW2040 engines. The 757-300 was offered with the RB211-535E4C, PW2037, PW2040 or PW2043 engines. The 757-200 also briefly had the RB211-535C, but only a small number of aircraft have this engine.

This means there are eight main different official airframe-engine combinations. If all the various freighter variants are considered, then there are another eight variants that could be analysed.

The 757-300 series is equipped with the PW2040, and the -E4B and -E4C variants of the RB211-535.

The 757-200 series is operated using the two lower-thrust-rated engines in the both the PW2000 series and RB211-535E4 series.

This analysis studies the performance of the passenger variants of the -200 and -300 series, and the freighter-converted variants of the 757-200. For the passenger-configured 757-200, the lower-thrust-rated engines from both engine manufacturers have been used. For the -300 the high-thrust-rated RB211-535E4B has been used. The freighter-configured versions of the 757-200 have been studied with the RB211-535E4, PW2037 and PW2040.

There are many thrust and maximum take-off weight (MTOW) options used by different airlines. The basic specification weights, as stated by the engine manufacturers, have been used for these calculations.

Sectors analysis

The 757 has been a workhorse for both the international scheduled airlines and the European carriers involved in the leisure and all-inclusive charter markets. Most, if not all, of the big American carriers and the European charter airlines have recently operated 757s, and many still have them in their fleets. The 757-200 is economically viable on a variety of routes, which vary from short-haul domestic to long-haul inter-continental.

Two routes have been used to analyse the fuel burn of three of the most numerous airframe-engine combinations. The first route is representative of the US domestic market: Houston (IAH) to Denver (DEN) *(see table, page 16)*. There are 184 seats on the 757-200 and 216 on the 757-300, reflecting the two-class cabins the US majors typically operate.

The second route is representative of the type of flight that UK charter airlines would use the 757 for: London Gatwick (LGW) to Larnaca, Cyprus (LCA) *(see table, page 16)*. The 757-200 will carry up to 235 passengers and the -300 up to 280 on this route. This, again, reflects the typical single-class charter configuration for these two aircraft.

The standard weight for each passenger and their baggage is assumed to be 220lbs with no additional cargo carried. The payload for the US domestic route will therefore be 40,480lbs for the 757-200 and 47,520lbs for the 757-300 *(see table, page 16)*. For the longer charter route the payload will be 51,700lbs for the -200, and 61,600lbs for the -300.

Aircraft performance has been analysed in both directions on each route to illustrate the effects of wind speed and direction on the actual distance flown, also referred to as Equivalent Still Air Distance (ESAD). 85% reliability winds and 50% reliability temperatures for the month of August have been used in the flight plans performed by Jeppesen. Flight times are 110 minutes for the US sectors and 270 minutes for the charter sectors.

The alternate airport for the IAH-DEN route is City of Colorado Airport, Colorado (COS). The tracked distance of 756nm on IAH-DEN increases to an average ESAD of 798nm due to a head-wind of 28-30 knots *(see table, page 16)*.

The return sector has a slightly longer tracked distance of 794nm. Due to a smaller headwind of 4 knots, the ESAD increases by a small amount to an average of 800nm, only 2nm more than the first sector. This return sector uses San

The PW2000-powered variants of the 757-200 and -300 have the best fuel burn performance. The difference with RB211-powered aircraft is only a few percent, however.

FUEL BURN PERFORMANCE OF PASSENGER-CONFIGURED 757-200 & 757-300 SERIES

City-pair variant	Aircraft	Engine model	MTOW lbs	TOW lbs	Fuel burn USG	Block time mins	Passenger payload	ESAD nm	Fuel per seat	Wind speed
IAH-DEN	757-200	PW2037	240,000	186,034	2,357	130	40,480	798	12.81	-30
IAH-DEN	757-200	RB211-535E4	240,000	187,435	2,409	130	40,480	799	13.09	-29
IAH-DEN	757-300	RB211-535E4B	272,500	211,860	2,775	130	47,520	797	12.85	-28
DEN-IAH	757-200	PW2037	240,000	188,491	2,202	134	40,480	801	11.97	-4
DEN-IAH	757-200	RB211-535E4	240,000	189,894	2,308	134	40,480	799	12.54	-4
DEN-IAH	757-300	RB211-535E4B	272,500	214,480	2,646	132	47,520	800	12.25	-4
LGW-LCA	757-200	PW2037	240,000	219,045	5,239	281	51,700	1,937	22.29	4
LGW-LCA	757-200	RB211-535E4	240,000	221,118	5,461	280	51,700	1,936	23.24	4
LGW-LCA	757-300	RB211-535E4B	272,500	252,532	6,385	281	61,600	1,937	22.80	4
LCA-LGW	757-200	PW2037	240,000	221,018	5,571	297	51,700	2,063	23.71	-44
LCA-LGW	757-200	RB211-535E4	240,000	223,134	5,805	295	51,700	2,063	24.70	-44
LCA-LGW	757-300	RB211-535E4B	272,500	254,756	6,763	294	61,600	2,054	24.16	-43

Source: Jeppesen

Antonio International Airport, Texas (SAT) as an alternate.

The second route, LGW-LCA, uses Paphos International Airport, Cyprus (PFO) as an alternate. This sector has a tracked distance of 1,954nm, and a shorter ESAD of 1,937nm due to a 4-knot tail wind.

The return sector for this route uses London Stansted, UK (STN) as an alternate. The route has a shorter tracked distance of 1,867nm. With a headwind of about 44 knots, the ESADs are longer than the third sector at 2,054-2,063nm *(see table, this page)*.

To illustrate the effect of hot temperatures on the engines, these two routes were planned with arrival into Larnaca at 1200 local time and departure from Larnaca at 1300 local time.

Flight profiles

The flight profiles in each case include standard assumptions on fuel reserves, diversion fuel (for the alternate airports mentioned above), contingency fuel, and a taxi time of 20 minutes for the whole sector. This is included in block time.

Taxiing typically accounts for a fuel burn of 2,200-2,600lbs for both ends of the sector for the 757-200, and 2,700-3,100lbs for the 757-300. All the sectors are flown using the economy cruise speed of Mach 0.80. Cruise speed affects flight time, but also fuel consumption. The use of economy cruise provides a compromise between speed and fuel burn. If longer distances were needed, a slower long-range-cruise speed would be used that consumes less fuel per nautical mile.

Fuel burn performance

The fuel burn performance of each aircraft/engine combination is shown *(see table, this page)* for both routes along with the associated burn per passenger.

The data show that for each sector, the block fuel burn increases as the actual take-off weight increases. The PW2000-powered aircraft is marginally lighter than the RR-powered aircraft, while the larger -300 is heavier than the -200.

On the IAH-DEN sector, the 757-200 equipped with the PW2037 engine has a fuel burn of 2,357 US Gallons (USG), compared to a burn of 2,409USG for the RB211-535E4-powered -200. This is a difference of 52USG on a 110-minute, 800nm trip, which gives a 2% advantage for the PW2037-equipped aircraft.

The DEN-IAH sector gives a larger advantage to the PW2037 of 4.5%.

On the longer LGW-LCA and LCA-LGW routes, the difference between the two airframe-engine types is 222-234USG. This is a 4% advantage to the PW2037 in either direction, for trips of 260-275 minutes and 1,940-2,060nm.

The block fuel-burn of the 757-300 is more than that of the -200 variant's, but that is due to its longer length, which makes it heavier. With its increase in size, come extra seats and passengers, and more potential revenue.

Economics

The results *(see table, this page)* also show fuel burn per passenger and per passenger-mile, using the ESAD (rather than the tracked distance). As the aircraft size and weight increase, so too does the required engine thrust, and the quantity of fuel burnt. Fuel burn per passenger is nevertheless lowest with the 757-300, on account of its higher seat numbers. Fuel performance is best for the 757-300 in charter configuration, only if there is a full load for each variant, as used in these flight plans.

When the fuel burn per passenger in USG is examined on the shorter route, the PW2037 is the most fuel-efficient. The longer the route, the better the fuel burn per passenger.

The fuel burn per passenger-mile in USG confirms much of what has already been said, in a general ranking order of fuel efficiency. But it also shows that all three main types have close fuel efficiencies.

757 freighters

Over 100 757s are freighters or being converted into freighters. Conversion seems to be an increasingly valid option for 757s that are no longer required by passenger operators. The 757-200 is the only 757 used as a freighter, and there are many freighter variants available, including the factory-built freighter, and several passenger-to-freighter conversion variants. The passenger-to-freighter variant that has won the most orders in recent years is Precision Conversions' (PCF) modification.

The fuel burn and operating performance of the 757-200PCF are analysed here. Not only does it account for the largest number of converted 757-200s, it has also recently increased its

FUEL BURN PERFORMANCE OF 757-200PCF

City-pair	Aircraft variant	Engine model	Fuel USG	Flight time (mins)	Freight payload (lbs)	Tracked distance-nm	ESAD nm	Wind speed factor
MIA-SAL	757-200PCF	RB211-535E4	2,998	133	72,000	975	968	3
MIA-SAL	757-200PCF	PW2037	3,013	138	72,000	975	968	3
MIA-SAL	757-200PCF	PW2040	3,003	138	72,000	975	968	3
MIA-SAL	757-200PCF	RB211-535E4	3,064	133	80,000	975	968	3
MIA-SAL	757-200PCF	PW2037	3,083	138	80,000	975	968	3
MIA-SAL	757-200PCF	PW2040	3,060	138	80,000	975	968	3
SAL-MIA	757-200PCF	RB211-535E4	3,113	135	72,000	978	987	-4
SAL-MIA	757-200PCF	PW2037	3,090	141	72,000	978	987	-4
SAL-MIA	757-200PCF	PW2040	3,073	140	72,000	978	987	-4
SAL-MIA	757-200PCF	RB211-535E4	3,173	135	80,000	978	987	-4
SAL-MIA	757-200PCF	PW2037	3,120	141	75,600	978	987	-4
SAL-MIA	757-200PCF	PW2040	3,128	140	80,000	978	987	-4

gross structural payload to 80,000lbs through an increase in maximum zero fuel weight (MZFW). The performance of the 757-200PCF equipped with the RB211-535E4, PW2037 and PW2040 engines is examined.

The two variants of the aircraft examined are those with the highest MZFW options of 188,000lbs and 196,000lbs. The RB211-powered versions of these variants have gross payloads of 72,000lbs and 80,000lbs. The PW2000-powered versions of the same aircraft have slightly higher payloads because of marginally lighter operating empty weights (OEWs).

Freighters converted by different companies and conversion programmes will have different OEWs. The difference in OEW between the -200PCF and the same aircraft converted by Alcoa-SIE (757-200ACF) is 1,823lbs in favour of the -200PCF. The -200ACF will have a 1.0-1.1% higher fuel burn. The fuel burn shown *(see table, this page)* can therefore be increased by 1% for the equivalent variant of the 757-200ACF.

As already stated, the fuel burn performance for 757 freighters will be assessed using the 757-200PCF. The engines used will be the PW2037, PW2040 and Rolls-Royce RB211-535E4, to make three aircraft/engine variations for each of the two MZFW weights.

The route used to illustrate the fuel burn performance of the freighter is El Salvador (SAL) to Miami (MIA). This is representative of the distance that many 757 freighters are likely to operate.

An average take-off temperature of 25°C has been used at both El Salvador and Miami. Average winds for the area in August have been used, as well as maximum payloads where permitted. The only example where the aircraft have a take-off weight, and therefore payload, limitation is the heavier MZFW aircraft of 196,000lbs with the PW2037 engines. This variant has a payload limitation of 4,400lbs, so it is only able to carry 75,600lbs of its maximum capacity of 80,000lbs.

SAL-MIA has an ESAD distance of 968nm, compared to an actual distance of 975nm. This sector has been helped by a 3-knot tail wind. Flight times are 133-138 minutes, with the RR-equipped aircraft being five minutes faster than the PW-equipped aircraft each time.

The return sector has an ESAD of 987nm, which was longer than the actual distance of 978nm, due to this sector's 4-knot headwind. Flight times are a little longer at 135-141 minutes due to the headwind and a very slightly longer routeing. The flight times were the same for each engine, regardless of which MZFW aircraft it was powering. The RR-powered aircraft was faster than the PW-powered examples.

On the first sector, the aircraft-engine combination with the best fuel burn was the 757-200PCF with the -535E4 engine and a 188,000lbs MZFW. On the second (return) sector, the lower MZFW again, now with the PW2040, had the lowest fuel burn. Generally, the lower MZFW and payload variants on both sectors had the better fuel burn of 1.5-3.15%, equal to 57-70USG in either direction. These additional fuel burns are small in relation to the revenue value of the 8,000lbs higher payload carried.

On the lower MZFW there are differing results on both sectors. On the first sector, the -535E4 has a better fuel burn than that of the PW engines by 0.2-0.5%. On the second sector, the PW2040's fuel burn is 0.55% better than the PW2037's and 1.28% better than the RB211-535E4's.

The fuel burn figures of the higher MZFW aircraft show a different result for each sector. On the first sector, the PW2040 only narrowly beats the -535E4 by 0.13% and the PW2037 by 0.75%. On the second sector, the PW2037 has the better fuel burn figure by 0.255% (PW2040) and 1.67% (RB211-535E4), but that is because of the adjusted TOW and carrying less weight. If like-for-like are compared, the PW2040 is 1.42% more fuel-efficient than the -535E4-powered aircraft on the second sector.

On this route and with these examples, no clear aircraft-engine combination has the better fuel efficiency, so an alternative way of assessing this is in terms of lbs carried per US Gallon used. This shows the higher MZFW aircraft carrying the most, with 26lbs of freight per USG burnt (with the -535E4 and PW2040 doing slightly better than the PW2037).

The lower MZFW aircraft carry 24lbs per USG, with the -535E4 and PW2040 again doing slightly better than the PW2037. On the second sector, the higher MZFW aircraft are again carrying more per fuel load. The PW2040 is the best performer with 25.58lbs per USG, compared to 24.23lbs/USG and 25.21lbs/USG for the PW2037 and -535E4. While the PW2037, with the adjusted TOW, seemed to perform well in fuel efficiency, it is actually last when considering the payload per US Gallon.

There is little difference between each of the engines on this route, with the RB211-535E4 doing fractionally better than the PW2000 engines. The longer the route, however, the more likely it is that the PW2000-powered aircraft, especially the PW2040, will prove better on fuel efficiency. AC