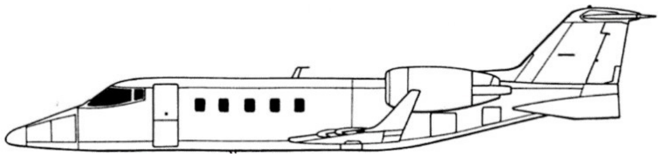
ANNEX C

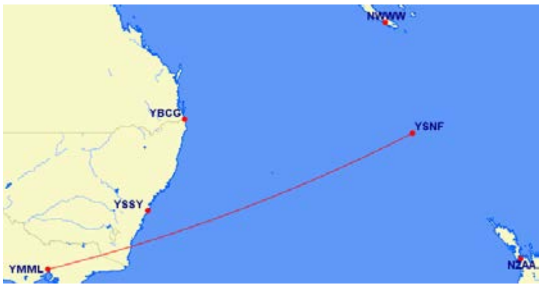
Sample fuel calculations – Multi-engine turbojet aeroplane (Learjet 60)

Learjet 60 - Sample fuel planning



Scenario and conditions

Flight Route Scenario is from Melbourne Essendon to Norfolk Island. Noumea is the destination Alternate for the scenario development where a destination alternate is required.



- Flight Distance: 1295 Nm
- Alternate Distance: 431 Nm
- Take-off weight (TOW): 21 500 lbs (15 500 lbs ZFW)
- Usable Fuel Capacity: 7 910 lbs (6000 lbs fuel at start)
- Climb wind & temp: 270/40 (35 kt tailwind), ISA temp
- Cruise wind and temp: 270/80 kt (64 kt tailwind), ISA temp
- 10 000 ft wind and temp: 270/40 (35 kt tailwind), ISA temp
- Descent wind and temp: 270/40 (35 kt tailwind), ISA temp.

For the scenario the aircraft and operation are RVSM approved. The aircraft is unable to land/depart Lord Howe Island (YLHI).

Performance data – from Learjet 60 Pilot's manual

Performance data is drawn from the Learjet 60 Pilot's Manual (PM) Section VIII, Flight Characteristics & Operational Planning.

Start and taxi

An allowance of 100lbs for engine start and taxi up to the commencement of take-off is applied. This should be taken as the minimum figure, added to where extended taxi or ground delay after starting is anticipated.

- Start and taxi: 100 lbs.

Take-off and Climb Data

21 400 lbs TOW, ISA, climbing from take-off to 41 000 ft (values from sea level departure aerodrome and TOW rounded up to 22 000 lbs.) PM Section VIII 8-23

- Climb Performance – Two Engine:
  - Time: 15.6 mins

  - Fuel: 597 lbs
  - Distance: 93.8 Nm
  - TAS: 361 kts.
- Top of climb position (TOPC):
  - Wind adjusted 101 Nm from departure.

Cruise data

Cruise data is provided in the PM Section VIII. As described in the PM planning preamble, it is appropriate to determine a mid-sector weight and use that value for the cruise segment.

Having determined the position of both TOPC and TOPD, the cruise segment data can be determined.

- Cruise Performance – Normal Cruise:
  - Time: 134 minutes
  - Fuel: 2624lbs (Average F/Flow 1175lbs per hour)
  - Distance: 1115Nm
  - TAS: 435kts. (Average GS: 499kts).

Descent data

The calculations of the descent distance, time and fuel are taken from PM Section VIII, Descent Performance Schedule – Normal Descent (PM 8-104):

- Descent Data – From F410:
  - Time: 11.9 minutes
  - Fuel: 107lbs
  - Distance: 72nm
  - TAS: 360kts.
- Top of descent position (TOPD);
  - Wind adjusted 79nm from destination.

Approach fuel

For this operation an approach to the destination aerodrome is anticipated to consume more fuel than would be used to follow the planned cruise and descent.

In this case, an anticipated value not exceeding 5 minutes, with a conservative value of 100lbs based on holding fuel rate of 1,200lbs/hr, is used.

- Approach fuel allowance: 100lbs/5 minutes.

Trip fuel

Having calculated the climb, cruise, descent and approach fuel, the elements of trip fuel are known and can be summed. In the scenario presented, the trip fuel would now be:

- Climb (597lbs), cruise (2624lbs), descent (107lbs) and approach (100lbs) = 3428lbs
- Climb (16 mins), cruise (134 mins), descent (12 mins) and approach (5 mins) = 167 mins

Item	Fuel Calculation	Min	lbs, L or kg
a	Taxi fuel	0	100
b	Trip fuel	167	3428

Figure 1 – Trip fuel

Fixed fuel reserve

The fixed fuel reserve legislated for a private IFR flight in a large or turbojet aeroplane is 30 minutes[1], calculated at the anticipated weight at holding speed 1500 ft above the destination aerodrome in ISA conditions.

Holding Operations (PM 8-109) provides holding speeds and fuel flows for weights and altitudes. As the table does not provide a value for 1500 ft, it is prudent to use the information provided in the Long Range Cruise performance tables for the anticipated holding conditions to give the most accurate value available.

For an arrival weight of 18 000 lbs (500 lbs above MZFW), at 1500 ft, ISA, based on interpolating the Sea Level and 5000 ft values at long range cruise (232 KIAS/236KTAS) of 1290 lbs/hr. As the holding speed at 18 000 lbs at 5000 ft is 185KIAS, substantially lower than the 232KIAS maximum range speed, we can conservatively use a holding fuel rate of 1200 lbs/hr. This rounds the calculated fixed fuel reserve to an easily rememberable figure of 600 lbs.

The calculated fixed fuel reserve would be:

- 30 minutes at 1200 lb/hr = 600 lbs

Variable fuel reserve

For a private operation of a large or turbojet aeroplane (Learjet 60) as defined in the Civil Aviation (Fuel Requirements) Instrument 2018, variable fuel reserve is required[2].

In this instance trip fuel of 3428 lbs requires a variable fuel reserve of:

- 5% of trip fuel (3428 lbs) = Variable fuel reserve of 172 lbs (8 mins).
- Note: The Variable Fuel Reserve calculation does not apply to the alternate fuel, only to trip fuel.

Additional fuel

The additional fuel requirements prescribed in the Civil Aviation (Fuel Requirements) Instrument 2018, are such that the flight must also be planned so that fuel is available to enable the aircraft if engine failure or loss of pressurisation (if applicable), whichever results in the greater subsequent fuel consumption, occurs at the most critical point to enable the aeroplane to:

- Proceed to an alternate aerodrome; and

[1] *Civil Aviation (Fuel Requirements) Instrument 2018, 5(6) and Table 1 (Item 3)*
[2] *Civil Aviation (Fuel Requirements) Instrument 2018, 5(6) and Table 1 (Item 3)*

- Fly for 15 minutes at holding speed at 1500 feet above aerodrome elevation in ISA conditions; and
- Make an approach and landing.

The quantity required for 15 mins and an approach and landing would be 400 lbs, comprising 300 lbs for 15 minutes holding and a 100 lbs conservative value for the approach and landing.

In determining which of the two contingency cases is most limiting, many factors must be considered. For this scenario, the One Engine Inoperative OEI case is assumed to be less limiting than the depressurised case, although a more thorough analysis of the aircraft capabilities in relation to emergency oxygen provision supporting flight at higher levels than 10 000 ft may influence the decision as to which contingency is most limiting.

Critical point YMEN to YSNF (En-route alternate: YSSY)

An illustrative example to assist in understanding the additional fuel calculation is as follows. In the case of the Essendon to Norfolk Island flight (with no destination alternate required) which overflies Sydney en-route, in the simplest form there are two available aerodromes for the flight; Sydney and Norfolk Island

The wind adjusted critical point between the two aerodromes is the point from which the flight must have sufficient fuel to fly depressurised or on or back and conduct an approach and landing with 15 mins fuel reserve remaining. If the planned fuel at that point is less than the critical fuel, an amount of additional fuel must be uplifted. The CP in this instance is the ETP between Sydney and Norfolk Island.

Critical point - planned cruise level - all engines operating (CPA)

At the planned cruise level of F410 the distance to the equi-time point (ETP) between Sydney and Norfolk Island is calculated with the formula:

$$\frac{Total\ Distance \times Ground\ Speed\ Back}{Ground\ Speed\ Back + Ground\ Speed\ Forward} \qquad \frac{908 \times 384\ (435TAS - 51HW)}{384 + 486}$$

The calculation returns an ETP (CPA) 401 Nm from SY (507 Nm distance to run to NF).

Critical point depressurised (CPD)

For the depressurised ETP, the position will change based on the change in cruise level required for the depressurised cruise (10 000 ft) and the TAS at that level. For the scenario the depressurised performance setting chosen is the Maximum Range Cruise (PM 8-50) for an approximate cruise weight of 19 000 lbs. 253 KTAS and fuel flow of 1142 lbs/hr.

10 000 ft wind results in a 35 kt TW on to NF, 35 kt HW back to SY. At the depressurised cruise level of 10 000 ft the distance to the equi-time point (ETP) between Sydney and Norfolk Island is calculated with the formula:

$$\frac{Total\ Distance \times Ground\ Speed\ Back}{Ground\ Speed\ Back + Ground\ Speed\ Forward} \qquad \frac{908 \times 218\ (253TAS - 35HW)}{218 + 288}$$

The calculation returns an ETP (CPD) 391 Nm from SY (517 Nm distance to run to NF).

From CPD fuel back to Sydney: 391 Nm at 218GS, results in flight interval of 108 mins, which at a burn rate of 1142 lb/hr, results in diversion fuel of 2048 lbs. The required 15 mins holding of 300 lbs is then added to the approach and landing value of 100 lbs, culminates in a total fuel value required at 391 Nm from Sydney of 2448 lbs.

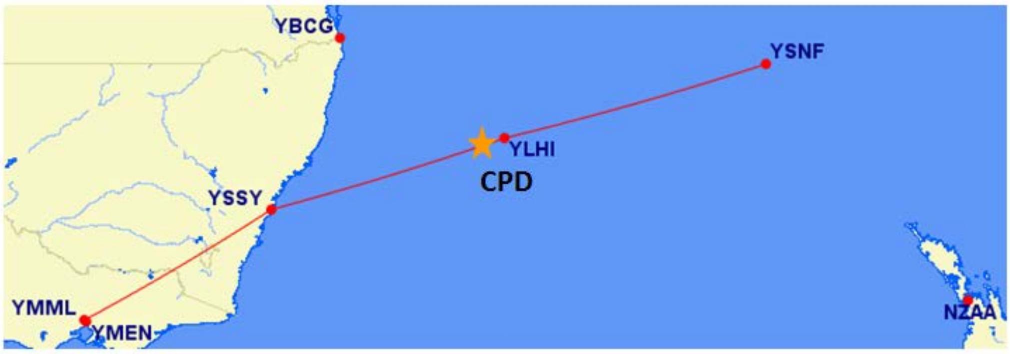


Figure 2 – Critical point depressurised (CPD) SY to NF

Fuel onward to Norfolk Island: 517 Nm at 288GS, flight interval of 108 mins, burn rate of 142 lb/hr, results in diversion fuel of 2048 lbs. As above, culminates in a total fuel value required at 517 Nm from Norfolk Island of 2448 lbs. (This verifies the ETP calculation).

To determine whether additional fuel is required, the basic calculation value is compared to the value required for flight to the CP under planned conditions added to the fuel from the CPD to the ERA under the conditions for the critical fuel case.
Based on the basic flight fuel required for the planned flight from Essendon to Norfolk Island of 4300 lbs, the planned fuel remaining at CPD is 2290 lbs (Fuel used to CPD is 2010 lbs). As the basic fuel calculation returns a value 158 lbs less than the 2448 lbs of fuel required at CPD for the critical fuel case, 158 lbs of additional fuel must be uplifted. This is graphically illustrated in Figure 4.

Minimum fuel to commence flight (private IFR – no destination alternate)

In light of the additional fuel requirement of 158 lbs to meet the critical fuel scenario, based on the available aerodromes being Sydney and Norfolk Island, the minimum fuel to commence the flight is 4458 lbs shown below in Figure 3.

Item	Fuel Calculation	Min	lbs, L or kg
a	Taxi fuel	0	100
b	Trip fuel	167	3428
c	Variable fuel reserve (% of b)	9	172
d	Alternate fuel	0	0
e	Fixed fuel reserve	30	600
f	Additional fuel	8	158
g	Holding fuel	0	0
h	Fuel required (a+b+c+d+e+f+g)	214	4458

Figure 3 – Fuel analysis: minimum fuel required

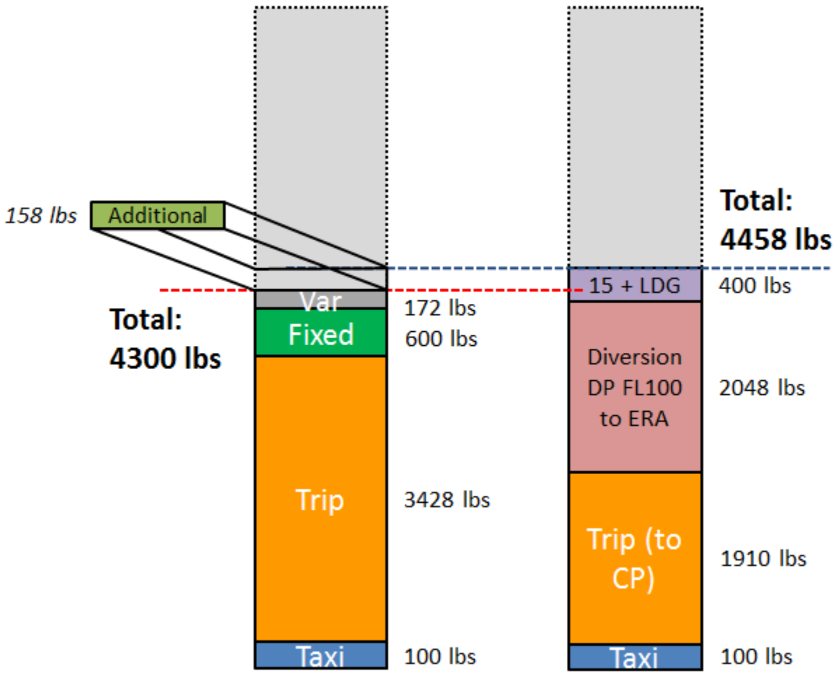


Figure 4 – Basic fuel quantity and critical fuel scenario quantity

Protecting variable fuel reserve

It is apparent from the graphical depiction that both variable fuel reserve and the additional fuel quantity are both required at the CPD to meet the critical fuel scenario. In this instance all the variable fuel reserve must be present at the critical point and as such cannot be consumed prior without compromising the ability to execute the critical fuel scenario if needed. The variable fuel reserve would need to be protected until it is no longer required to meet the critical fuel scenario diversion.

Destination alternate fuel

If the flight was conducted under such conditions that a destination alternate was required, the alternate fuel would need to be calculated. This is done in a manner similar to the calculation of trip fuel (without the take-off element).

For the scenario, the destination alternate Noumea (NWWW) is 431 Nm from the destination (actual flight distance under real conditions, via required routing, may differ). The alternate fuel is the fuel required from the missed approach point, to climb to an appropriate cruising altitude, cruise to the destination alternate, descend and conduct an approach at the destination alternate as required.

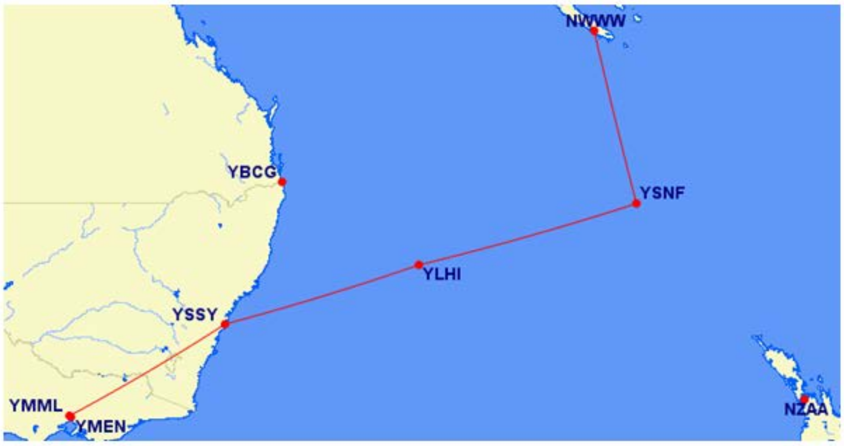


Figure 5 – Flight Route and Destination Alternate NWWW

Alternate - climb distance, time and fuel

Conditions assumed for the scenario are at ISA temperature and a 20 kt headwind for the climb alternate fuel calculation. Real-world values would be used in actual planning. F430 selected as the alternate leg cruising level.

- Climb Performance – Two Engine (PM 8-19) at an initial climb weight of 18,000 lbs:
  - Time: 12.4 mins
  - Fuel: 465.4 lbs
  - Distance: 75.2 Nm
  - Calculated TAS 364.
- Top of climb position (TOPC):
  - Wind adjusted 71 Nm from Missed Approach Point.

Alternate - Descent distance, time and fuel

The descent distance, time and fuel from F430 with a 20 kt headwind is then calculated from Performance Schedule – Normal Descent (PM 8-104):

- Descent Data
  - Time: 12.9 mins

  - Fuel: 118 lbs
  - Distance: 80 Nm
  - Calculated TAS 372.
- Top of descent position (TOPD);
  - Wind adjusted 76 Nm from destination alternate.

Alternate - Cruise distance, time and fuel

The cruise distance, time and fuel can now be determined at F430 with a 40 kt headwind:

- Maximum Range Cruise at F430, ISA at 17 5000 lb cruise weight (PM 8-47):
  - TAS: 402 kts
  - Fuel flow: 974 lbs/hr
  - Ground Speed: 362 kts)
- Cruise Distance: 284 Nm (431 Nm – climb 71 + descent 76)
  - Time: 47 mins
  - Fuel: 742 lbs

If the approach and landing anticipated at the alternate aerodrome include extra time and fuel requirements, they should be added to the alternate fuel quantity calculated. In this instance, anticipating no extra requirements the alternate fuel quantity is:

- Climb (466 lbs), cruise (742 lbs), descent (118 lbs) and approach (0 lbs) = 1325 lbs
- Climb (13 mins), cruise (47 mins), descent (13 mins) and approach (0 mins) = 75 mins

Item	**Fuel Calculation**	Min	lbs, L or kg
d	**Alternate fuel**	75	1325

Figure 6 – Alternate fuel

Minimum fuel to commence flight (private IFR – destination alternate required)

Having calculated the fuel elements in the previous sections, the minimum fuel to conduct the flight, in this instance is shown in Figure 7.

Item	Fuel Calculation	Min	lbs, L or kg
a	Taxi fuel	0	100
b	Trip fuel	167	3428
c	Variable fuel reserve (% of b)	9	172
d	Alternate fuel	75	1325
e	Fixed fuel reserve	30	600
f	Additional fuel	0	0
g	Holding fuel	0	0
h	Fuel required (a+b+c+d+e+f+g)	281	5625

Figure 7 – Fuel analysis: private IFR with destination alternate

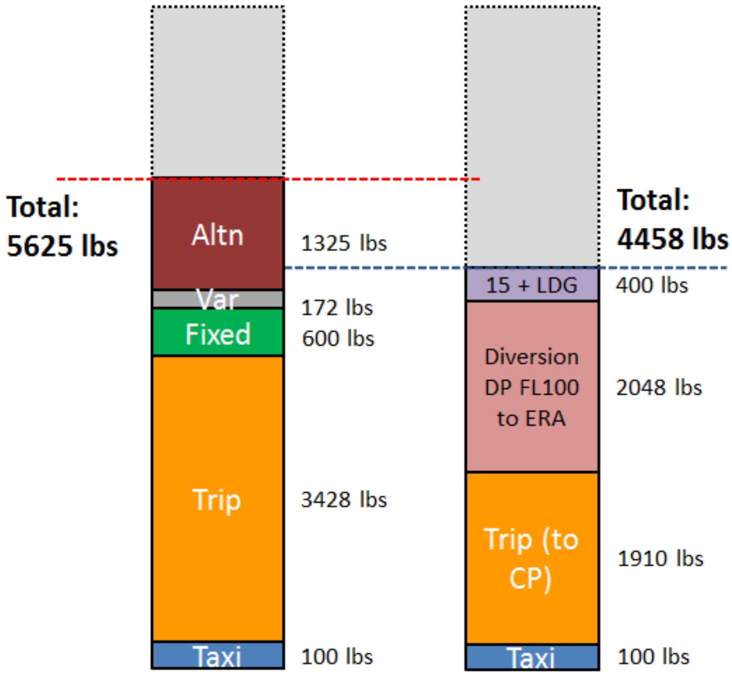


Figure 8 – Fuel analysis

Margin fuel and endurance

Having determined the fuel and time for the planned flight, a calculation of the fuel in excess of requirements allows endurance to be calculated.

We simply deduct the required fuel quantity from the usable fuel capacity (or payload limited capacity). This margin fuel can then be converted to a useful value of time (for a suitable consumption rate) such as at cruise fuel consumption or holding consumption. By convention (for turbine-powered IFR aeroplanes) the holding fuel rate, in this case 1200 lbs/hr can be used to calculate a fuel margin value of time.

Deducting the known fuel load pre-start of 6000 lbs from the fuel required value of 5625 lbs, returns a margin 375 lbs, which at a holding fuel flow of 1200 lbs/hr gives a time margin of 19 mins.

Item	**Fuel Calculation**	Min	lbs, L or kg
h	**Fuel required** (a+b+c+d+e+f+g)	281	5625
i	**Discretionary fuel**	0	0
j	**Margin fuel**	19	375
k	**Endurance** (h+i+j)	300	6000

Figure 9 – Fuel analysis: margin fuel and endurance

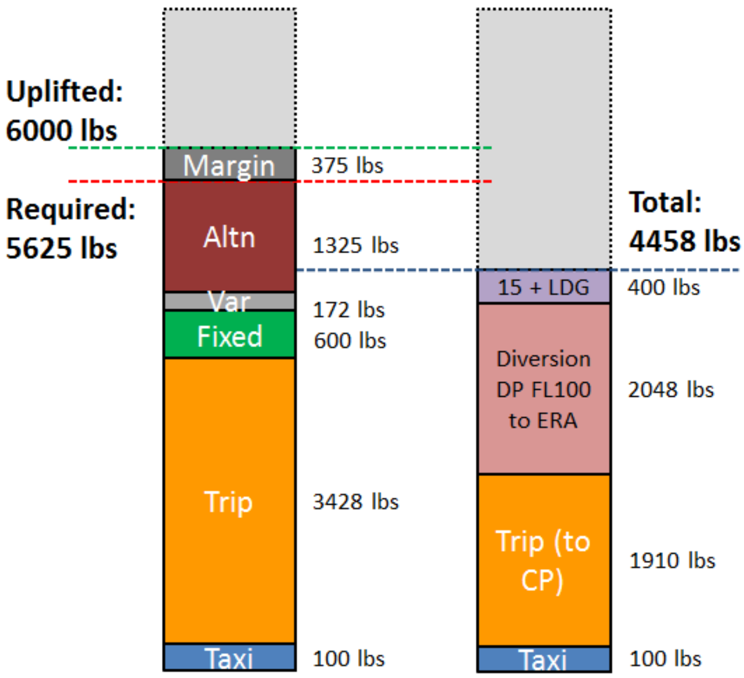


Figure 10 – Fuel analysis

Use of off-track en-route alternates

The availability of en-route alternates that are off-track may reduce the fuel quantity required to meet the critical fuel scenario.

Critical Point YMEN to YSNF (En-route Alternate: YBCG)

Referring to Figure 2, the CPD between YSSY and YSNF is 517 Nm distance to run to YSNF. Using YBCG as the ERA, the wind adjusted critical point (CPD) between the aerodromes YBCG and YSNF occurs along track at a 351 Nm from YBCG (461 Nm distance to run to YSNF).

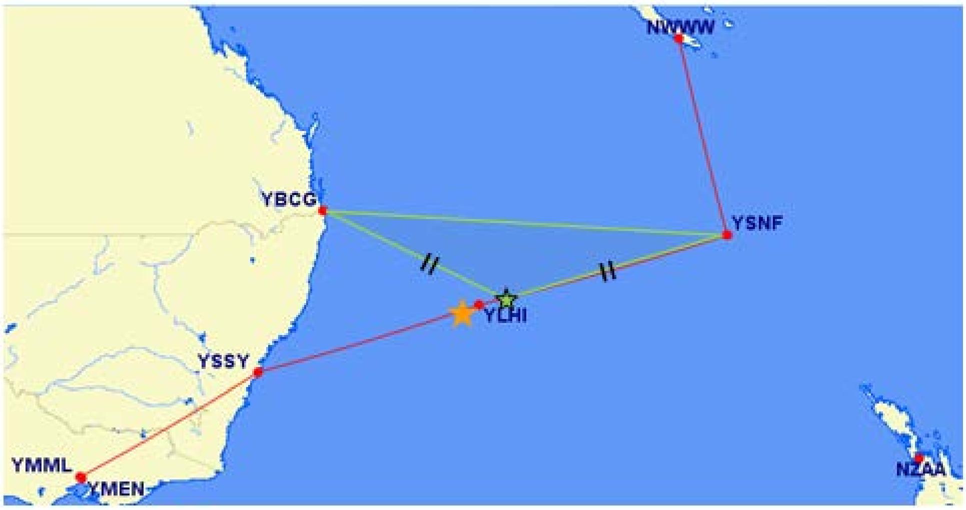


Figure 11 – CPD to Enroute Alternate - YBCG

Fuel from CPD to YBCG: 351 Nm at 218GS, results in flight interval of 96 mins, which at a burn rate of 1142 lb/hr, results in diversion fuel of 1839 lbs. The required 15 mins holding of 300 lbs is then added to the approach and landing value of 100 lbs, culminates in a total fuel value required at 351 Nm from YBCG of 2239 lbs. Fuel from CPD to YSNF: 461 Nm at 288GS, also returns a flight time of 96 mins and a diversion fuel of 1839 lbs plus the approach and landing value of 400 lbs. As above, culminates in a total fuel value required at 461 Nm from Norfolk Island of 2239 lbs. (This verifies the ETP calculation).

Based on the basic flight fuel required for the planned flight of 4300 lbs, the planned fuel remaining at CPD is 2162 lbs (Fuel used to CPD is 2138 lbs). As the basic fuel calculation returns a value 77 lbs less than the 23778 lbs of fuel required at CPD for the critical fuel case, 77 lbs of additional fuel must be uplifted. This is graphically illustrated in Figure 12. As previously discussed, the variable fuel reserve in this scenario is required to be available at the critical point and should be protected.

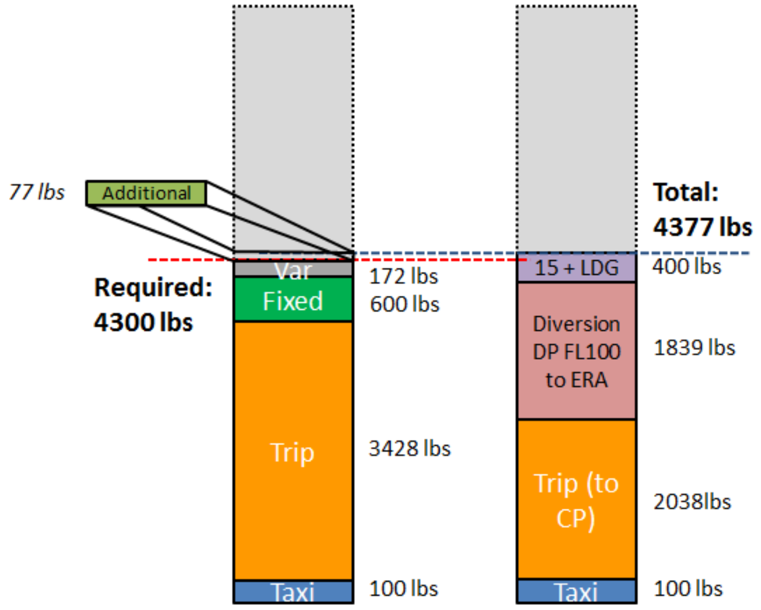


Figure 12 – Fuel comparison basic and additional fuel calculation

Passenger carrying AOC-holder operations to a remote island

If the scenario included the carriage of passengers to a remote island (YSNF) as an operation under an AOC, assuming the operator's AOC and associated operations manual were based solely on the prescriptive provisions of the Civil Aviation (Fuel Requirements) Instrument 2018, there would be some minor changes to the minimum safe fuel required to conduct the operation, when compared to a non-AOC flight.

For a non-AOC holder flight to a remote island (YSNF), the requirement to nominate an alternate is dependent upon normal alternate determination criteria. The CAO 82.0 3A Conditions on all passenger carrying aeroplane operations to remote islands specifies that irrespective of the weather at the destination on the remote island, an alternate, itself not on a remote island must be nominated.

Accordingly, calculation of the minimum safe fuel for the flight is the minimum fuel to satisfy the two fuel cases: the basic fuel case with a destination alternate and the OEI or DP critical fuel scenario case.