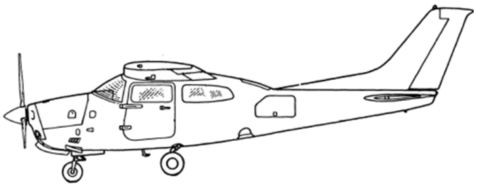
ANNEX A

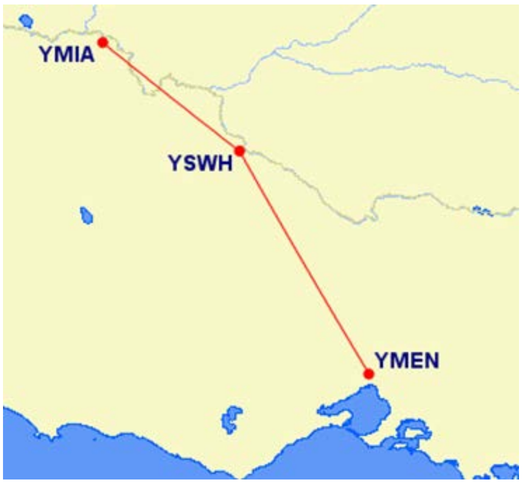
Sample fuel calculations – Single-engine piston aeroplane (Cessna 210)

Cessna 210 – Sample fuel planning



Scenario and conditions

Flight Route Scenario is from Essendon to Swan Hill. Mildura is selected as the destination Alternate for the scenario development where a destination alternate is required.



Flight Distance:	161 Nm
Alternate Distance:	100 Nm
Aircraft Take-off weight:	3750 lbs
Usable Fuel Capacity:	543 lbs
Climb wind and temp:	20 kt headwind, ISA +15deg
Cruise wind and temp:	20 kt headwind, ISA +15deg

For calculations climb wind and temperature is taken at 2/3 of the climb height. Where a descent wind is needed for calculation, the value used is taken at ½ descent altitude.

Performance data – from AFM/POH

Extracted from Cessna 210 AFM/POH Section 5.

Units of Measure

The units of measure for fuel values used in the following examples are based on pounds (lbs) as provided from the C210 AFM/POH. Fuel delivery and uplift information may be provided using units of measure other than lbs, such as litres, gallons or kilograms.

Although the C210 AFM/POH provided unit of measure is fuel pounds (lbs), the often-used unit of Litres (L) is provided in the fuel table examples. The conversion of AVGAS (specific gravity 0.720 at sea level ISA conditions) from lbs to L uses a conversion factor of 1.58.

Note: Where fuel values contain varied units of measure, care must be taken to ensure that the conversion of those values is based on correct information and accurately performed.

Start, taxi and take-off

From AFM/POH Section 5 (5-7 and 5-15/16 Note 1) 12 lbs for engine start, taxi and take-off allowance. This should be taken as the minimum figure. In situations where extended taxi or ground delay after starting can be anticipated value should be increased accordingly.

As Take-off fuel is a constituent of trip fuel, a simple proportional estimate can be used to determine the start and taxi (and run-up if required) and take-off.

- Start and Taxi: 6 lbs

Note: This is NOT part of trip fuel)

Item	**Fuel calculation**	Min	lbs, L or kg	Min	lbs, L or kg
a	**Taxi fuel**	0	6	0	4

Figure 1 - Taxi Fuel

- Take-off: 6 lbs

Note: Take-off fuel IS part of trip fuel.

Climb data

Data for Maximum Rate of climb and Normal climb (100KIAS) are provided in AFM/POH Section 5 (5-15 and 5-16). The tabulated data is entered at the anticipated take-off weight. The time, fuel and distance (nil wind) are provided for the ISA (standard) temperature. Tabulated data is provided for 2000 ft intervals. Given the visual flight rules (VFR) nature of the flight, the planned cruising level is 8500 ft, it is suggested that the data be interpolated to achieve an accurate figure.

For Example: 3800 lbs TOW, ISA+15, climbing to 8500 ft (from Sea Level departure aerodrome)

- Normal Climb (2550RPM/25"MP): Interpolated figures from 8000ft and 10 000 ft lines gives:
  - Time: 14 mins (13.75 rounded up)
  - Fuel: 25 lbs (25.0)
  - Distance: 25 Nm (25.5 rounded down).
- Temperature adjustment: ISA plus 15 degrees requires adding 15% to the time, fuel and distance:
  - Time: 16 mins (15.8 rounded up)
  - Fuel: 29 lbs (28.75 rounded up)
  - Nil Wind Distance: 29 Nm (29.3 rounded down).
- Wind adjustment: the climb wind is then used to adjust the top of climb position (TOPC):
  - Distance/Time will give TAS: 29.3 Nm/15.8 mins=111 KTAS
  - Wind adjustment is made to this NIL WIND TAS to calculate GS: (111-20 KT=91 GS)
  - 91kts for 16 mins = 24Nm.

If the departure includes extended departure tracking, or airborne holding during the departure is anticipated, allowance should be made to the fuel and time for those anticipated conditions.

Cruise data

Cruise data is provided in the AFM/POH Section 5. Tabulated data is again provided for 2000 ft intervals for 3800 lbs aircraft weight. The table has %power, TAS and fuel flow for standard temperature and at 20 degrees above and below. Given the VFR planned cruising level is 8500 ft, the data be interpolated to achieve an accurate figure, alternatively the 8000 ft table can be used rounding down from 8500 ft as the approximation will be conservative regarding fuel usage.

For the example we will use a cruise power setting of 2400RPM/22"MP, with ISA +15deg.

- From the 8000 ft Table. Interpolated:
  - % Power: 63%
  - KTAS: 164
  - Fuel Flow: 80 lb/hr (AFM/POH Note – 6 lb/hr reduced fuel flow).
- Wind correction: 164-20=144 kt GS
- Distance: Route distance 161 Nm minus TOPC distance 24 = cruise distance 137 Nm
- 137 Nm at 144 kt GS = 57 mins
- 57 mins at 80 lb/hr = 76 lbs.

Approach fuel

Cruise fuel planning from the previous section is conducted to overhead the destination aerodrome at cruise level. If the descent and approach to the destination aerodrome is anticipated to consume more fuel than would be used to overhead at cruise level, then it would be prudent to include an approach allowance to the cruise fuel. This may be calculated at an intermediate level and at an appropriate power setting for the anticipated circumstances. If holding is anticipated, the holding fuel consumption rate can also be used.

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:

- Take-off (6 lbs), Climb (29 lbs), Cruise (76 lbs), Descent and Approach (0lbs) = 111 lbs
- Time 73 mins (16+57).

Item	Fuel calculation	Min	**lbs**, L or kg	Min	lbs, **L** or kg
b	**Trip fuel**	73	111	73	70

Figure 2 - Trip fuel

Fixed fuel reserve

The fixed fuel reserve for private VFR flight by day is 30 mins[1], calculated at the anticipated weight at holding speed 1500 ft above the destination aerodrome in ISA conditions. For the scenario we will calculate holding at 3800 lbs at 2000 ft, ISA conditions using a power setting of 2200 RPM/20"MP.

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

From the AFM/POH Section 5 (5-17) gives 130 KTAS and 58 lb/hr fuel flow rate. The calculated fixed fuel reserve would be:

- 58 lb/hr for 30 mins = 29 lbs (consider rounding up to 30 lbs for ease of recall).

Item	Fuel calculation	Min	lbs, L or kg	Min	lbs, L or kg
e	Fixed fuel reserve	30	30	30	19

Figure 3 - Fixed Fuel Reserve

WARNING: The amount of fuel that results from the 30 min calculation under the conditions above **DOES NOT ASSURE 30 MINS FLIGHT TIME IN ALL CONDITIONS**. Should the actual aircraft fuel consumption rate exceed the rate calculated, such as for repeated circuits or approaches, somewhat less than 30 mins of flight time may be available. For example: continuous application of full power at 2000 ft would result in a fuel flow of greater than 100 lbs/hr (e.g. would consume 29 lbs in approximately 17 mins at full power).

Minimum fuel to commence flight (Private Day VFR)

Having calculated the fuel elements in the previous section, the minimum fuel required to conduct the flight, in this instance is shown in Figure 4.

Item	Fuel calculation	Min	lbs, L or kg	Min	lbs, L or kg
a	Taxi fuel	0	6	0	4
b	Trip fuel	73	111	73	70
c	Variable fuel reserve (% of b)	0	0	0	0
d	Alternate fuel	0	0	0	0
e	Fixed fuel reserve	30	30	30	19
f	Additional fuel	0	0	0	0
g	Holding fuel	0	0	0	0
h	Fuel required (a+b+c+d+e+f+g)	103	147	103	93

Figure 4 - Fuel required

Margin fuel and endurance

Having determined the fuel and time for the planned flight, a calculation of the fuel that is in excess of the fuel quantity required allows endurance to be calculated. The starting point for this calculation is the known or planned start state of aircraft fuel, up to full capacity. In this example we will use full tanks, for the scenario C210, that is 543 lbs of usable fuel.

Having determined the various elements required by the nature of the flight, 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 given parameter) such as at cruise fuel consumption or holding consumption. By convention (for flight plan endurance calculation) the margin fuel is converted to time at the last en-route cruise consumption rate.

The maximum usable fuel capacity of 543 lbs is known. The required fuel from the scenario is 147 lbs. The margin is therefore 396 lbs, which at a cruise fuel flow of 80 lbs/hr gives a time margin of 297 mins.

Item	Fuel calculation	Min	lbs, L or kg	Min	lbs, L or kg
h	**Fuel required** (a+b+c+d+e+f+g)	103	147	103	93
i	**Discretionary fuel**	0	0	0	0
j	**Margin fuel**	297	396	297	251
k	**Endurance** (h+i+j)	400	543	400	344

Figure 5 – Margin Fuel and Endurance

Scenario Development: IFR vs VFR

If the flight was to be conducted under the Instrument Flight Rules (IFR), the cruising level would be selected at an appropriate IFR level such as 8000 ft. (for a magnetic track from 180^0 through West to 359^0) and the climb and cruise data would be determined. Consideration of applying an approach fuel would also be advised.

A notional approach fuel based on an anticipated 10 mins would to require 15 lbs.

The Fixed Fuel Reserve for private IFR operations is 45 mins[2]; so 45 lbs would be an appropriate value for the scenario.

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

The fuel analysis is shown in Figure 6:

Item	Fuel calculation	Min	lbs, L or kg	Min	lbs, L or kg
a	**Taxi fuel**	0	6	0	4
b	**Trip fuel**	83	126	83	80
c	**Variable fuel reserve** (% of b)	0	0	0	0
d	**Alternate fuel**	0	0	0	0
e	**Fixed fuel reserve**	45	45	45	28
f	**Additional fuel**	0	0	0	0
g	**Holding fuel**	0	0	0	0
h	**Fuel required** (a+b+c+d+e+f+g)	128	177	128	112
i	**Discretionary fuel**	0	0	0	0
j	**Margin fuel**	275	366	275	232
k	**Endurance** (h+i+j)	403	543	403	344

Figure 6 - Fuel Analysis: IFR (no ALTERNATE)

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, we assume the destination alternate is 100 Nm from the destination. The alternate fuel would be 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.

Alternate - climb distance, time and fuel

Although the weight would be less than 3800 lb, the climb chart weight is conservative.

For the example we will assume the missed approach point is at 2000 ft and the selected alternate cruising level is 6000 ft.

- Normal Climb (2550RPM/25"MP): from 2000 ft to 6000 ft gives:
  - Time: 9 mins to 6000 ft minus 3 mins to 2000 ft = 6 mins
  - Fuel: 17 lbs to 6000 ft minus 5 lbs to 2000 ft = 12 lbs
  - Distance: 16 Nm to 6000 ft minus 5 Nm to 2000 ft = 11 Nm.
- Temperature adjustment: ISA plus 15 requires adding 15% to the time, fuel and distance:

  - Time: 7 mins
  - Fuel: 14 lbs
  - Nil Wind Distance: 12 Nm (12.65 rounded down).
- Wind adjustment: the climb wind is then used to adjust the top of climb position (TOPC):
  - Distance/Time will give TAS: 12.65 Nm/6.9 mins=115 KTAS
  - Wind adjustment is made to this NIL WIND TAS to calculate GS: (115-20 KT=95 GS)
  - 95kts for 7 mins = 11 Nm.

Alternate - Cruise distance, time and fuel

For the example we will again use a cruise power setting of 2400 RPM/22"MP, with ISA +15deg.

- Cruise Distance = total (100 Nm) minus TOPC (11 Nm) = 89 Nm
- From the 6000 ft Table. Interpolated for ISA +15:
  - % Power: 61%
  - KTAS: 159
  - Fuel Flow: 78 lb/hr (AFM/POH Note – allow for a 6 lb/hr reduced fuel flow)
- Wind correction: 159-20=139 kt GS
- 89 Nm at 139 kt GS = 38 mins
- 38 mins at 80 lb/hr = 51 lbs.

No extra descent or approach fuel, on account of the anticipated arrival conditions and approach direction. Anticipated or known descent and approach requirements (fuel and time) at the completion of the alternate leg are required to be included in the alternate fuel calculation.

Alternate fuel:

- Fuel (14 + 51) 65 lbs
- Time (7 + 38) 45 mins

Item	Fuel calculation	Min	lbs, L or kg	Min	lbs, L or kg
a	**Taxi fuel**	0	6	0	4
b	**Trip fuel**	83	126	83	80
c	**Variable fuel reserve** (% of b)	0	0	0	0
d	**Alternate fuel**	45	65	45	41
e	**Fixed fuel reserve**	45	45	45	28
f	**Additional fuel**	0	0	0	0
g	**Holding fuel**	0	0	0	0
h	**Fuel required** (a+b+c+d+e+f+g)	173	242	173	153
i	**Discretionary fuel**	0	0	0	0
j	**Margin fuel**	226	301	226	191
k	**Endurance** (h+i+j)	399	543	399	344

Figure 7 - Fuel Analysis: IFR (with ALTERNATE)

Variable fuel reserve

For a private operation of a small aeroplane (piston or turboprop) variable fuel reserve is not a legislative requirement[3]. The pilot-in-command may choose to apply variable fuel reserve if they see fit, they may alternatively include this value as discretionary fuel, neither is compulsory.

The variable fuel reserve applicable to a charter or RPT piston aeroplane is the greatest of 10% of the trip fuel or 5 mins[4] (calculated at the holding rate). In our scenario, although not a requirement, the PIC may choose to apply variable fuel reserve in accordance with the following calculation:

- Calculated trip fuel: 126 lbs
- Variable Fuel Reserve: the greater of:
  - 10% of trip fuel = 13 lbs (8 mins)
    or
  - 5 mins at holding fuel rate (58 lbs/hr) = 5 lbs.

Note: Variable Fuel Reserve calculation does not apply to alternate fuel, only to trip fuel.

[3] *Civil Aviation (Fuel Requirements) Instrument 2018, 5(6) and Table 1 (Item 1 & Item 2)*
[4] *Civil Aviation (Fuel Requirements) Instrument 2018, 5(6) and Table 1 (Item 8)*

Item	Fuel calculation	Min	lbs, L or kg	Min	lbs, L or kg
a	**Taxi fuel**	0	6	0	4
b	**Trip fuel**	83	126	83	80
c	**Variable fuel reserve** (% of b)	8	13	8	8
d	**Alternate fuel**	45	65	45	41
e	**Fixed fuel reserve**	45	45	45	28
f	**Additional fuel**	0	0	0	0
g	**Holding fuel**	0	0	0	0
h	**Fuel required** (a+b+c+d+e+f+g)	181	255	181	161
i	**Discretionary fuel**	0	0	0	0
j	**Margin fuel**	216	288	216	182
k	**Endurance** (h+i+j)	397	543	397	344

Figure 8 - Fuel analysis: IFR with alternate (optional PVT Variable)

Putting it all together

The graphical representations in Figure 9, illustrate the various fuel elements calculated in the scenarios described in the preceding sections.

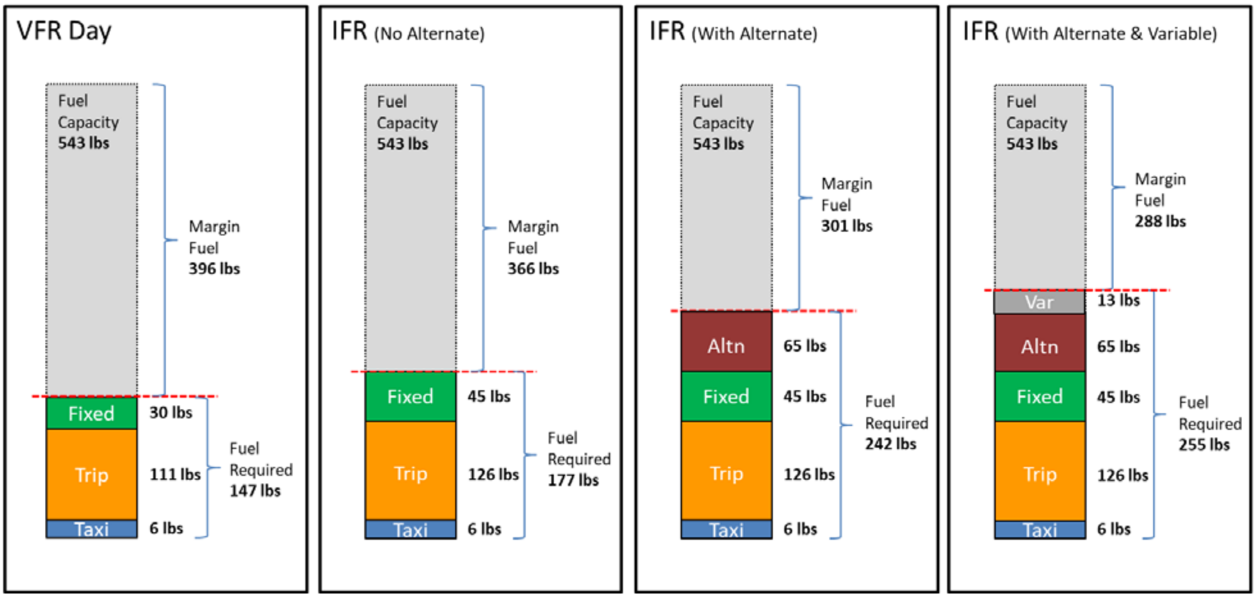


Figure 9 - Fuel analysis comparison