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AUS OPERATIONS, FLIGHT PLANNING AND PERFORMANCE

CHAPTER 14
RANGE AND PAYLOAD

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SECTION 7 – RANGE AND PAYLOAD

7.1 CRUISE CONTROL

7.1.1 Flying for maximum endurance

To fly for endurance means to remain in the air for the longest time possible on the available fuel. To do this requires the amount of fuel used in a set time to be as low as possible, ie. minimum fuel flow (minimum gph).

Maximum endurance may be required when holding at a destination aerodrome or carrying out a search in a specific area. In both these cases it is required to stay in the air for as long as possible and ground distance covered is not a consideration.

Fuel flow for a piston engine / propeller driven aircraft is dependent on power. Maximum endurance will therefore be achieved using minimum power. The lowest power setting published for the Echo Mk IV is 35%. Wherever endurance is required in the Echo Mk IV, set 35% lean. However, when operating at a high Density Height, 35% is unavailable (as indicated by the dashes in the chart) and 45% lean must be used. Echo MK IV fuel flow at 35% is 17.2 gallons per hour and at 45% is 20.4 gallons per hour.

The Echo Mk IV chart shows that when flying for endurance, the airspeed will be very low, between 114 kt and 120 kt at all weights and altitudes.

Maximum endurance is achieved at low altitude because the higher a piston engine propeller aircraft flies, the greater the power required to maintain the best endurance IAS. However, this increase in fuel flow as height increases is not shown in the Echo Mk IV tables to simplify doing exam questions.

In summary, to fly for maximum endurance a pilot should:

a. fly as low as legally and safely possible.

b. set the lowest RPM and highest MP permitted.

c. use the least gross weight.

d. fly at low airspeed and higher angle of attack.

e. operate the engine using a lean mixture.

7.2 RANGE

7.2.1 Flying for maximum range

When flying for maximum range, the distance travelled with the fuel available is the important factor. The time taken is not important. To get maximum range, the maximum possible NAUTICAL MILES PER GALLON needs to be achieved.

To fly for maximum range a pilot should:

a. fly at full throttle height for the selected power setting.

b. set the lowest RPM and highest permitted MP.

c. fly the aircraft at the lowest possible gross weight and the best L/D ratio IAS.

d. use a lean mixture in accordance with engine operating instructions.

This principle is true for aircraft powered by normally aspirated, supercharged or turbocharged engines.

7.2.2 Specific Range

The Specific Range for an aircraft is the number of nautical miles available from each gallon. This can be the ANM / Gal which is the Specific Air Range (SAR) or the GNM / Gal which is the Specific Ground Range (SGR). If other units of fuel are used, the SGR is the ratio of GNM covered in relation to the fuel used.

SPEED is measured in knots (nm / hr) and FUEL FLOW is measured in gallons / hour (other units may be used). If the aircraft has a TAS of 150 kt and a FF of 15 gal / hr it can be seen that while burning 15 gallons the aircraft has travelled 150 nm. The time period for both is one hour.

150 nm for 15 gal = 150 nm / 15 gal = 10 nm / gal. Because TAS has been used, this is stated as 10 ANM (AIR nautical miles) for each gallon travelled, the SAR (Specific Air Range) is 10 ANM / Gal.

SAR is found in ANM/Gal by dividing: $\frac{TAS}{FF}$

Alternatively: $\frac{FF}{TAS}$ = gal / ANM

Specific ground range (SGR) is found by dividing: $\frac{G/S}{FF}$ in $\frac{GNM}{gal}$

Alternatively: $\frac{FF}{G/S}$ = gal / GNM

Most aircraft will exceed the MTOW or MZFW if they are loaded with full fuel and all compartments are loaded to their maximum capacity. If there is a need to carry maximum payload then the aircraft will need to be configured for maximum range to minimise the fuel requirement.

The aircraft should be flown for maximum range if there is a requirement to either:

a. carry maximum payload, *or….*

b. use the least fuel for a given distance.

7.2.3 Finding the Power Setting for Max. Range

Follow the steps below showing the procedure for finding the power setting to achieve the maximum range.

Example 1

An Echo Mk IV is to carry maximum payload under the following conditions. Find the TAS, MP, RPM and total FF.

EMZW	2,500 kg
Cruise at	FL 150
QNH	1012 hPa
TOAT at FL 150	ISA

Solution

Because the power setting is not known, the SAR for all possible power settings must be investigated. High power settings and very low power settings are uneconomical, so the SAR for 35%, 45%, 55%, and 65% will all need to be checked.

In nil wind conditions 45% will usually yield the best SAR.
In a headwind check 45% and 55% (if the wind is very strong also check 65%)
In a tailwind check 35% and 45% power settings.

Method

a. Find the cruise DH:

PH= 15,000 ft at ISA. Therefore DH = 15,000 ft.

b. Make a table extracting the TAS and FF values from the charts at the end of this section.

% POWER	TAS (kt)	FF (Gal / h)	SAR (ANM / gal)
35	116	17.2	6.477
45	154	20.4	7.549
55	176	23.6	7.458

A LEAN mixture is used. It can be seen that 45% power gives the MOST ANM / gal (7.549).

c. Now extract the TAS for the power setting of 45%. This is 154 kt.

d. Use the LOWEST RPM within the recommended range:
This is 2,200 RPM.

e. Select the required MP:
45% power at 15,000 ft, lean mixture, MP = 25.6" Hg

Answers -	**TAS**	**154 kt**
	FF	**20.4 Gal / h**
	Power setting	**2,200 RPM and 25.6" MP**.

Once SAR is calculated and nil wind conditions exist, it is possible to calculate the fuel required to fly a given distance.

To find the fuel divide the distance by the SAR (or SGR if there is wind) to get the fuel required:

600 nm / 7.549 nm / Gal = 79.48 gal.

Answer - **79.48 gal**

7.3 PAYLOAD

Payload is anything (passengers and/or cargo) for which payment will be received. In commercial operations, payload is usually maximised.

Maximum payload may be limited by:

a. Take-Off Weight
The lower of the structural MTOW and the performance limited take-off weights.

b. Landing Weight
The lower of the structural MLW and the performance limited landing weights.

c. Maximum Zero Fuel Weight

d. Station load limits such as seat and compartment limits or floor loading capacity.

7.3.1 Finding Maximum Payload

The following shows the correct method of finding maximum payload for a flight from **A** to **B.**

a. Draw a simple diagram of the flight, with take-off and landing limitations.

b. Calculate fuel burn-off (flight fuel) and the total fuel required for the flight.

c. Find the maximum payload from the least of:

- Payload = TOW - (BEW + pilot + FOB at take-off).
- Payload = LW - (BEW + pilot + fuel remaining at landing).
- Payload = MZFW - (BEW + pilot)

c. Check that this payload does not exceed station load limits.

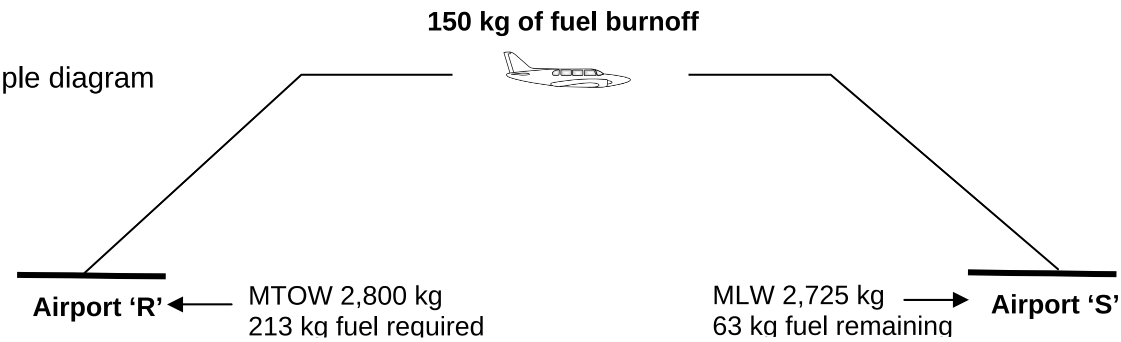
d.

Example 1

An Echo Mk IV aircraft is to fly from **R** to **S**. The burn off for the flight is 150 kg and there is no performance limit on landing. Due to runway length, the 'P chart' MTOW is 2800 kg. If the BEW is 1950 kg and the pilot weighs 80 kg, what is the maximum payload for the flight?

Method

a. Draw a simple diagram



b. Fuel burn-off (flight fuel) of 150 kg is given.
Fuel required on takeoff = burn off + variable reserve (15% of flight fuel) + fixed reserve (15 gallons or 40 kg)

= 150 + (150 x 15 /100) + 40

= **213 kg**

c. Find the maximum payload from the lower of:

- Payload = TOW - (BEW + pilot + FOB at take-off).
- Payload = LW - (BEW + pilot + fuel remaining at landing).
- Payload = MZFW - (BEW + pilot)

Payload = TOW - (BEW + pilot + FOB at take-off).

PL = 2800 - (1950 + 80 + 213)

PL = **557 kg**

Payload = LW - (BEW + pilot + fuel remaining at landing).

PL = 2725 - (1950 + 80 + 63)

PL = **632 kg.**

Payload = MZFW - (BEW + pilot)

PL = 2630 - (1950 + 80)

PL = **600 kg**

d. Check that this payload does not exceed station load limits. For this flight the maximum payload is limited to 557 kg (by take-off weight).

Check 557 kg can be carried in the aircraft.
Maximum load for Echo Mk IV cargo compartments = 320 kg
On 5 seats in the cabin 385 kg can be carried.

320 kg + 385 kg = 705 kg

Answer - **557 kg** can be carried provided some is carried in the cabin.

7.3.2 Calculating Fuel Burn Off from SGR

Sometimes fuel burn off will not be given for the flight but the distance and SGR are known. Fuel burn off is found using the following:

$$\text{Fuel Burn Off} = \frac{\text{Distance}}{\text{SGR}}$$

If SGR is not given, the following method should be used to find it:

a. Find estimated Fuel Burn Off by multiplying the distance by 0.4 kg per nm (which is the approximate fuel used per nm in the Echo Mk IV).

b. Find the estimated MZW.

c. From Density Height, power setting and MZW, find TAS (Chart on P7-12).

d. Find the fuel flow and the TAS. Apply the wind component (GS), to find SGR. (Chart on P7-12).

7.3.3 Maximum payload / multiple legs

A pilot often flies multiple legs, using intermediate airfields to refuel, take on and put off payload or for other operational reasons. The pilot must know the maximum payload for each leg and for the whole journey.

The method used to find this information, is to divide the flight into legs finding a separate maximum payload for each of the legs.

Method

a. Draw a diagram of the flight, adding fuel burn off for each leg and writing take-off and landing weights.

b. Calculate total fuel required and then write the fuel on board on the diagram for each take-off and landing.

c. Check that the fuel remaining at the final destination is equal to the required reserves and any other allowance.

d. Find the maximum payload for the first leg.

e. Find the maximum payload for the second and subsequent legs.

f. The maximum payload for the total flight is lower of from d) and e) above.

Example 1

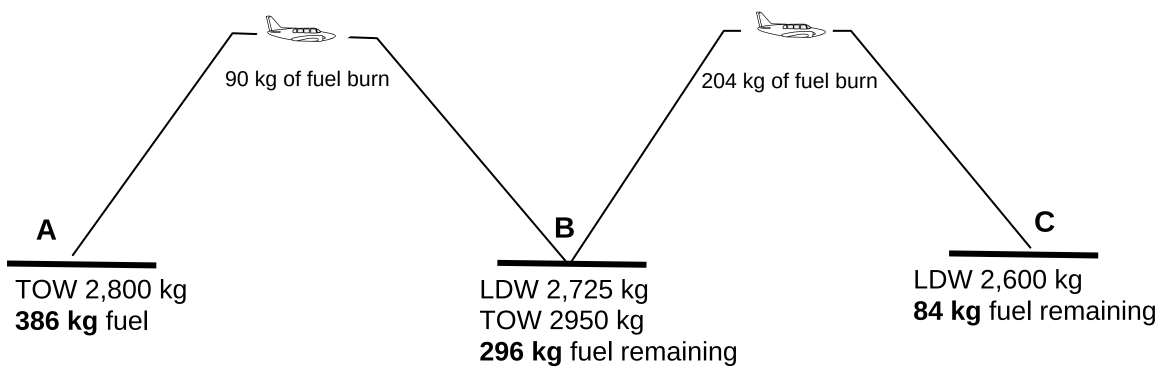
An Echo Mk IV aircraft is to fly from **A** to **B** to **C**. There is no refuelling at **B**.
Given the following information, what is the maximum payload that can be carried?

- from **A** to **B**
- from **B** to **C**
- from **A** to **C**

Distance **A** to **B**	= 184 nm.
Distance **B** to **C**	= 520 nm.
SGR **A** to **B**	= 5.5 gnm per gallon
SGR **B** to **C**	= 6.86 gnm per gallon
'P' Chart MTOW at **A**	= 2800 kg.
'P' Chart MLW at **C**	= 2600 kg.
BEW	= 1920 kg

Method

a. Draw a diagram



b. Calculate fuel burnoff for each leg. Write on the diagram.

FBO **A** to **B** = 184 / 5.50
= 33.45 US Gal
= **90 kg**

FBO **B** to **C** = 520 / 6.86
= 75.80 US Gal
= **204 kg**.

Flight Fuel **A** to **C** = (204 + 90) x 115 / 100 + 40 + 8
= **386 kg**

Note: 8 kg must be added to fuel required for start up and taxi at **B**.

On the diagram, write the fuel on board at each take off and landing.

c. Fuel remaining at the final destination (**C**) should be the variable reserve plus fixed reserve (for this flight no other allowances are to be taken).

The fuel remaining = 294 x 15 / 100 + 40
= **84 kg**. This checks with the diagram.

d. Find maximum payload for **A** to **B**.

PL = TOW - (BEW + pilot + FOB at T/O)
= 2800 - (1920 + 77 + 386)
PL = **416kg**

PL = LW - (BEW + pilot + FOB at land)
= 2725 - (1920 + 77 + 296)
PL = **432 kg**

PL = MZFW - (BEW + pilot)
= 2630 - (1920 + 77)
PL = **633 kg**

The aircraft is TOW limited causing the maximum payload to be limited to **416 kg** A to B.

e. Find maximum payload for **B** to **C**.

PL = TOW - (BEW + pilot + FOB at T/O)
=2950 - (1920 + 77 + 288)
PL = **665 kg**

PL = LW - (BEW + pilot +FOB at land)
=2600 - (1920 + 77 + 84)
PL = **519 kg**

f. Find MZFW as above in Step d. PL = **633 kg**

Answers -

- Maximum payload **A** to **B** = **417 kg**.
- Maximum payload **B** to **C** = **519 kg**.
- Maximum payload **A** to **C** = **417 kg**.

7.3.4 Operating Weights

Most large commercial aircraft have an operating weight.
Operating Weight (OW) = BEW + Crew

Because the aircraft will not be flown without crew, the use of an OW rather than BEW is more practical.
The three equations to find maximum payload using OW are:

- PL = TOW - (OW + FOB at take off)
- PL = LW - (OW + fuel remaining at landing)
- PL = MZFW - (OW)

7.3.5 Diverting

When an aircraft is to fly from **A** to **B** but needs a diversion airfield **E**, the maximum payload must be the lower of **A** to **B** or **A** to **E** (via **B**). This is because on take off, it is not known whether the aircraft will land at **B** or **E**.

7.4 ECHO MK LV CRUISE PERFORMANCE CHART (TWO ENGINES)

TAS (Kt)																
Press Ht.	Temp	Gross Weight														
		2950 Kg					2500 Kg					2000 Kg				
		Maximum continuous power														
		75%	65%	55%	45%	35%	75%	65%	55%	45%	35%	75%	65%	55%	45%	35%
SL	ISA - 20	177	165	156	142	116	180	168	159	145	118	184	171	161	149	120
5,000		185	172	160	145	116	188	172	163	147	119	192	178	166	151	121
10,000		193	179	165	147	117	196	182	168	150	119	201	185	171	153	122
15,000		201	185	169	149	116	204	189	173	152	117	209	193	177	155	120
20,000		209	193	174	150	-	213	197	178	154	-	217	201	182	157	-
SL	ISA	181	168	158	144	116	184	171	161	146	118	188	174	164	149	121
5,000		189	175	162	146	117	192	178	165	148	119	198	181	169	152	122
10,000		197	182	166	148	117	200	185	170	151	119	205	189	174	154	122
15,000		205	189	171	150	114	208	192	176	154	116	213	196	184	156	118
20,000		213	198	177	151	-	217	201	180	154	-	221	208	189	157	-
SL	ISA + 20	185	171	160	145	116	187	174	163	147	119	191	177	166	151	121
5,000		192	178	166	147	117	195	181	166	150	119	200	185	171	153	122
10,000		200	185	170	149	116	204	188	173	152	118	208	192	175	155	121
15,000		209	193	173	151	-	212	196	178	154	-	217	200	182	157	-
20,000		216	201	179	149	-	221	205	183	152	-	225	209	186	155	-

ZULU MK XV ENGINE PERFORMANCE CHART

Pressure Height	Power %	3200	3000	2800 RPM		2600 RPM		2400 RPM		2200 RPM		Power %	Fuel flow	
		Rich	Rich	Rich	Lean	Rich	Lean	Rich	Lean	Rich	Lean		Rich	Lean
		“Hg	“Hg	“Hg	“Hg	“Hg	“Hg	“Hg	“Hg	“Hg	“Hg		GPH	GPH
Zero	100	34.5	-	-	-	-	-	-	-	-	-	100	31.7	-
	75	26.5	26.9	28.7	28.7	29.3	30.2	31.8	32.7	-	-	75	19.7	16.3
	65	23.1	23.5	24.9	24.9	25.9	26.4	28.4	28.9	-	-	65	16.9	14.0
	55	19.9	20.3	21.2	21.5	22.7	23.0	25.2	25.5	29.9	30.2	55	14.1	11.8
	45	-	17.4	18.3	18.4	19.8	19.9	22.3	22.4	27.0	27.1	45	11.8	10.2
	35	-	-	-	-	16.4	16.5	18.9	19.0	23.6	23.7	35	9.3	8.6
5,000 feet	100	34.5	-	-	-	-	-	-	-	-	-	100	31.7	-
	75	26.0	26.4	27.3	28.2	28.8	29.7	31.3	32.2	-	-	75	19.7	16.3
	65	22.6	23.0	23.9	24.4	25.4	25.9	27.9	28.4	-	-	65	16.9	14.0
	55	19.4	19.8	20.7	21.0	22.2	22.5	24.7	25.0	29.4	29.7	55	14.1	11.8
	45	-	-	17.8	17.9	19.3	19.4	21.8	21.9	26.5	26.6	45	11.8	10.2
	35	-	-	-	-	15.9	16.0	18.4	18.5	23.1	23.2	35	9.3	8.6
10,000 feet	100	34.5	-	-	-	-	-	-	-	-	-	100	31.7	-
	75	25.5	25.9	26.8	27.7	28.3	29.2	-	-	-	-	75	19.7	16.3
	65	22.1	22.5	23.4	23.9	24.9	25.4	27.4	27.9	-	-	65	16.9	14.0
	55	18.9	19.3	20.2	20.5	21.7	22.0	24.2	24.5	28.9	29.2	55	14.1	11.8
	45	-	-	-	-	18.8	18.9	21.3	21.4	26.0	26.1	45	11.8	10.2
	35	-	-	-	-	15.4	15.5	17.9	18.0	22.6	22.7	35	9.3	8.6
15,000 feet	100	34.5	-	-	-	-	-	-	-	-	-	100	31.7	-
	75	25.0	25.4	26.3	27.2	27.8	28.7	-	-	-	-	75	19.7	16.3
	65	21.6	22.1	22.9	23.4	24.4	24.9	26.9	27.4	-	-	65	16.9	14.0
	55	18.4	18.8	19.7	20.0	21.2	21.5	23.7	24.0	-	-	55	14.1	11.8
	45	-	-	-	-	18.3	18.4	20.9	21.0	25.5	25.6	45	11.8	10.2
	35	-	-	-	-	-	-	17.4	17.5	22.1	22.2	35	9.3	8.6
20,000 feet	100	29.0	-	-	-	-	-	-	-	-	-	100	31.7	-
	75	24.6	25.0	-	-	-	-	-	-	-	-	75	19.7	-
	65	21.2	21.7	22.5	23.0	-	-	-	-	-	-	65	16.9	14.0
	55	18.0	18.4	19.3	19.6	20.8	21.1	23.3	23.6	-	-	55	14.1	11.8
	45	-	-	-	-	17.9	18.0	20.5	20.6	-	-	45	11.8	10.2

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