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# GROUND STUDIES FOR PILOTS
# FLIGHT PLANNING

**Sixth Edition**

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**Blackwell**
Science

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# Preface

In the past, the Flight Planning examination, when set by the UK Civil Aviation Authority, required the completion of an airways flight plan and a fuel plan together with supplementary questions in three hours. The Joint Aviation Authority (JAA) version of this examination, first set in July 1999, no longer requires the completion of these plans but sets a total of 60 unrelated questions drawn from the charts contained in the Jeppesen Student Pilot Manual and the graphs and tables in the CAP 697 in the same time period. It is therefore essential that anyone studying for this examination be in possession of both these documents.

There are three levels of examination: the Instrument Rating (IR), the Commercial Pilot's Licence (CPL) and the Airline Transport Pilot's Licence (ATPL). The IR and the CPL Flight Planning examinations are virtually identical. The main differences the syllabuses for these examinations have from the syllabus for the ATPL examination are that the following are not required for IR or CPL:

- Fuel planning calculations for the Medium Range Jet Transport (MRJT) aeroplane
- Multi-track points of equal time (PETs)
- Multi-track points of equal fuel (PEFs)
- Multi-track points of safe return (PSRs)

This book has been written to the level of the ATPL syllabus. Those studying for either of the other two examinations should omit the above topics from their studies. The syllabus incorporated in this book is JAR-FCL 033 01 00 00 to 033 061 01 07. The main reference documents for the syllabus are:

- JAR-OPS1
- JAR-1 Definitions and Abbreviations
- The Jeppesen Student Pilot Manual
- CAP 697

I would like to express my thanks to Dave Webb who willingly gave of his time and expertise to convert my hand drawn sketches to become excellent diagrams. I am also grateful to the Civil Aviation Authority, the Joint Aviation Authority, Jeppesen GmbH and the Meteorological Office for their permission to utilise information from their various publications in the text of this book.

P. J. Swatton

## Weight and Mass

Most of us know what we mean when we use the term weight and become confused when the term mass is used in its place. In all of its documents the JAA insist on using the term mass, whereas the majority of aviation documents produced by the manufacturers use the term weight. The following are the definitions of each of the terms and should help clarify the situation:

*Mass* – The quantity of matter in a body as measured by its inertia is referred to as its mass. It determines the force exerted on that body by gravity, which is inversely proportional to the mass. Gravity varies from place to place and decreases with increased altitude above mean sea level.

*Weight* – The force exerted on a body by gravity is known as its weight and is dependent on the mass of the body and the strength of the gravitational force for its value. Weight = mass in kilograms x gravity in Newtons. Thus, the weight of a body varies with its position and elevation above mean sea level but the mass does not change for the same body.

The change of weight of an object due to its changed location is extremely small, even at 50 000 ft above mean sea level; however, it is technically incorrect and the term mass should be used. For the sake of simplicity I have retained the colloquial term weight throughout this book wherever it has been used in the CAP 697 and retained the word mass whenever the JAA documents refer to such. *IEM OPS 1. 605.*

## Figure Acknowledgements

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# List of Abbreviations

| | |
|---|---|
| ACC | Area Control Centre |
| ACS | Air Conditioning System |
| ADF | Automatic Direction Finding |
| AFIL | Filed whilst Airborne |
| AFIS | Aerodrome Flight Information Service |
| AFM | Aeroplane Flight Manual |
| AFTN | Aeronautical Fixed Telecommunications Network |
| agl | above ground level |
| AIP | Aeronautical Information Publication |
| amsl | above mean sea level |
| AOC | Air Operator's Certificate |
| APU | Auxiliary Power Unit |
| ATA | Actual Time of Arrival |
| ATC | Air Traffic Control |
| ATFM | Air Traffic Flow Management |
| ATIS | Automatic Terminal Information Service |
| ATS (U) | Air Traffic Service (Unit) |
| AUW | All Up Weight |
| CA | Correcting Angle |
| CAP | Civil Aviation Publication |
| CF | Fuel Cost |
| CFMU | Central Flow Management Unit |
| CI | Cost Index |
| CP | Critical Point |
| CRP | Compulsory Reporting Point |
| CT | Flight Time Cost |
| CTA | Control Area |
| CTR | Control Zone |
| DA | Decision Altitude |
| DCT | Direct |
| DH | Decision Height |
| DME | Distance Measuring Equipment |
| EAT | Expected Approach Time |
| EGT | Exhaust Gas Temperature |

| | |
|---|---|
| EOBT | Estimated Off Block Time |
| EROPS | Extended Range Operations |
| ETA | Estimated Time of Arrival |
| ETOPS | Extended Twin Operations |
| FAF | Final Approach Fix |
| FIR | Flight Information Region |
| FL | Flight Level (Pressure Altitude) |
| FMS | Flight Management System |
| fpm | feet per minute |
| GMT | Greenwich Mean Time |
| G/S | Ground speed |
| GPH | Gallons Per Hour |
| HF | High Frequency (3–30 MHz) |
| HJ | Sunrise to Sunset |
| HN | Sunset to Sunrise |
| HO | Hours of Operation |
| hPa | hectopascal (1hPa = 1 millibar) |
| IAF | Initial Approach Fix |
| IAS | Indicated Airspeed |
| ICAO | International Civil Aviation Organization |
| IF | Intermediate Fix |
| IFPS | Integrated Flight Planning System |
| IFR | Instrument Flight Rules |
| ILS | Instrument Landing System |
| IMC | Instrument Meteorological Conditions |
| INS | Inertial Navigation System |
| ISA | International Standard Atmosphere |
| JAA | Joint Aviation Authority |
| kg | kilograms |
| kHz | kilohertz |
| KIAS | Knots Indicated Airspeed |
| kmh | kilometres per hour |
| kts | knots (nautical miles per hour) |
| lb | pounds |
| LPD | Last Point of Diversion |
| LRC | Long Range Cruise |
| (M) | Magnetic |
| MAP | Missed Approach Point or Manifold Absolute Pressure |
| MAPSC | Maximum Approved Passenger Seating Capacity |
| mbs | millibars |
| MDA | Minimum Descent Altitude |
| MDH | Minimum Descent Height |
| MEA | Minimum En-route Altitude |

| | |
|---|---|
| MEL | Minimum Equipment List |
| MEP | Multi-engine Piston |
| METAR | Meteorological Actual Report |
| MGAA | Minimum Grid Area Altitude |
| MHz | megahertz |
| MLM | Maximum Landing Mass |
| MLS | Microwave Landing System |
| MOCA | Minimum Obstruction Clearance Altitude |
| MORA | Minimum Off-Route Altitude |
| mph | statute miles per hour |
| mps | metres per second |
| MRJT | Medium Range Jet Transport |
| MSA | Minimum Safe Altitude |
| msl | mean sea level |
| MTCA | Minimum Terrain Clearance Altitude |
| MTOM | Maximum Take-off Mass |
| MTOW | Maximum Take-off Weight |
| NAM | Nautical Air Miles |
| NDB | Non-Directional Beacon |
| NLST | New List |
| nm | nautical mile |
| NOTAM | Notice to Airmen |
| OCA(H) | Obstacle Clearance Altitude (Height) |
| OM | Outer Marker |
| (P) | Port |
| PANS-OPS | Procedures for Air Navigation Services - Aircraft Operations |
| PAR | Precision Approach Radar |
| PEF | Point of Equal Fuel |
| PET | Point of Equal Time |
| PIC | Pilot In Command |
| PNR | Point of No Return |
| PPH | Pounds Per Hour |
| PSR | Point of Safe Return |
| QDR | Magnetic bearing from the facility |
| QFE | The altimeter sub-scale setting which causes the altimeter to read zero elevation on the ground |
| QNE | The indicated height on the altimeter at the aerodrome datum point with the altimeter sub-scale set at 1013.2 hPa |
| QNH | The altimeter sub-scale setting which causes the altimeter to read the elevation above mean sea level, when on the ground |
| RLST | Revised list |
| ROC | Rate of Climb |
| RPL | Repetitive Flight Plan |

| | |
|---|---|
| RPM | Revolutions Per Minute |
| RTF | Radio Telephony |
| RVR | Runway Visual Range |
| (S) | Starboard |
| SAR | Specific Air Range |
| SEP | Single-engine Piston |
| SID | Standard Instrument Departure |
| SIGMET | Significant Meteorological Report |
| SLP | Speed Limit Point |
| STAR | Standard Terminal Arrival |
| SVFR | Special Visual Flight Rules |
| (T) | True |
| TAF | Terminal Aerodrome Forecast |
| TAS | True Airspeed |
| TCH | Threshold Crossing Height |
| TEA | Track Error Angle |
| TMA | Terminal Control Area |
| TMG | Track Made Good |
| TOC | Top Of Climb |
| TOD | Top Of Descent |
| TOW | Take-off Weight |
| UHF | Ultra High Frequency (300–3000 MHz) |
| UTC | Co-ordinated Universal Time |
| VFR | Visual Flight Rules |
| VDF | VHF Direction Finding |
| VHF | Very High Frequency (30–300 MHz) |
| VIMD | Velocity of Minimum Drag |
| VMC | Visual Meteorological Conditions |
| VMO | Maximum Operating Speed |
| VOR | VHF Omnidirectional Range |
| WCA | Wind Correction Angle |
| WGS | World Geodetic System |
| WMO | World Meteorological Office |
| ZD | Zone (leg) Distance |
| ZT | Zone (leg) Time |

# Chapter 1
# Navigation Revision

## The triangle of velocities

Unless the air is still (i.e., there is no wind), the path of an aeroplane through the air differs from that which it travels over the ground. In addition, the speed at which it moves through the air is different from that at which it moves over the ground. There are, therefore, three directions and three speeds always present when an aeroplane is airborne. Together they form what is colloquially known as the *triangle of velocities*.

### *Definitions*

- **Track**, sometimes referred to by the Americans as *course*, is the path of the aeroplane over the ground. It is measured clockwise in degrees up to 360° from a specified datum. At the point of measurement, if the datum is the local meridian, which defines true north, then the direction measured is true and will have the abbreviation (T) after the value. If the datum used is the magnetic meridian, it will have (M) after the value. The difference between the true meridian and the magnetic meridian is *variation*.

  $$\text{magnetic direction} + \text{east variation (or} - \text{west variation)} = \text{true direction}$$

  Track Made Good (TMG) is the path over the ground that an aeroplane **has** followed.
- **Ground speed** is the speed at which an aeroplane travels over the ground; usually it is specified in *knots* (kts or nautical miles per hour). Alternative units of speed measurement that may be used are kilometres per hour (kmh) or statute miles per hour (mph).
- **Heading** is the path of the aircraft through the undisturbed air. It is measured in the same manner and from the same data as track.
- **True airspeed**, abbreviated as TAS, is the true rate of movement through the undisturbed air, normally expressed in knots. This speed can be derived from the Aeroplane Flight Manual (AFM) or calculated using the navigation computer and the indicated airspeed.
- **Wind direction** is the direction **from** which the wind is blowing and

related to true north with the following exceptions. If it is broadcast on the Automatic Terminal Information Service (ATIS), or when Air Traffic Control (ATC) gives take-off or landing clearance, it is then related to magnetic north but in extremely high latitudes it may be related to grid north.

- **Wind speed** is the rate of movement of the air over the surface of the earth, usually expressed in knots; however, at many continental aerodromes it is stated in kilometres per hour (kmh) or metres per second (mps).
- **Drift** is the angle subtended between the heading and the track. It is referred to as starboard (S) when the track is to the right of the heading and as port (P) when the track is to the left of the heading. In Flight Planning, drift is sometimes referred to as the Wind Correction Angle (WCA). It is the correction made to the track (course) to obtain the heading and is labelled + or –, (i.e., plus for port drift and minus for starboard drift).
- **Velocity** is a direction and speed stated together.
- **The triangle of velocities** is a triangle constructed from the three velocities, heading/TAS, track/ground speed and wind direction/wind speed.

If any four of the six elements of the triangle of velocities are known then the remaining two can be found by plotting or by use of the navigation computer. In solving the triangle of velocities, it is important to ensure that the same units of speed measurement and the same datum for direction measurement are used for all velocities.

### *Example 1.1*

An aircraft is heading 090°(T) at a TAS of 300 kts. The wind velocity is 000°(T) at 60 kts (usually written 000/60). Determine the Track Made Good (TMG), the drift and the ground speed.

### *Solution 1.1*

**Plotting solution (Figure 1.1)**

- Draw a line at 90° from the datum, true north. This represents the heading. By convention, this is marked with one arrow.
- Determine the scale to be used for the diagram. Measure one hour's worth of true airspeed to scale along the heading. This point is referred to as the air position after one hour and is shown by a vertical cross.
- From the air position, plot the wind vector for one hour to the same scale and the same directional datum. Mark this line with three arrows. This point is then the ground position after one hour.
- Now join the start position to the ground position. At the start point measure the direction from the same datum as the heading. This is the true track and is marked with two arrows, in this example 101.5°(T).

- The distance measured, using the same scale, from the start point to the ground position is the distance travelled in one hour over the ground and is, therefore, the ground speed. In this example, it is 304 kts.
- The angle between the heading and the track is the drift, and in this case is 11.5°(S).

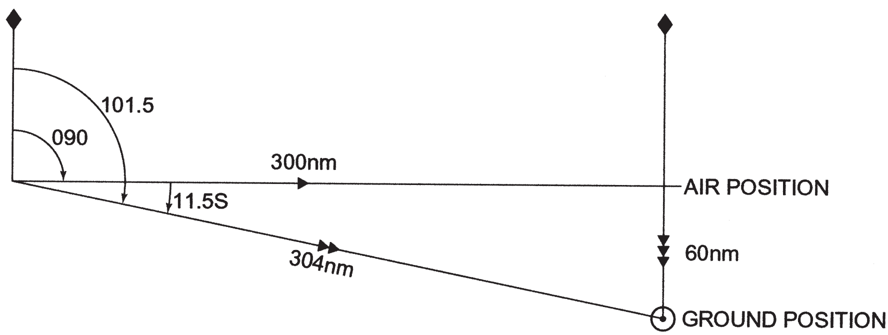



**Figure 1.1** The triangle of velocities.

### Navigation computer solution

On the face of the navigation computer the centre dot (or circle) is the air position after one hour, commonly referred to as the *TAS dot*. The sliding scale has speed circles and drift lines drawn from the start point. There are two sides to the slider, a low-speed scale and a high-speed scale. The rotating inner scale on the face of the instrument is the *bezel*. The index mark at the top of the instrument is the heading index.

- Select the sliding scale appropriate to the TAS. Move the slider until the TAS is under the TAS dot.
- Rotate the bezel until the wind direction is next to the heading index. From the TAS dot measure the wind speed downward and mark with a dot or cross.
- Rotate the bezel until the heading is next to the heading index. The marked dot or cross will now have moved.
- At the dot or cross read the drift against the drift-lines and the ground speed against the speed scale.
- On the outer scale at the top of the instrument, against the drift value read the track on the inner scale.

**Navigation calculators are not permitted in the examination.**

In Flight Planning, the problem is not normally to derive the track and ground speed but to determine the heading to fly to maintain a given track and the ground speed along that track. The ground speed is then used to calculate the time taken to fly between the start and finish points of the track, commonly called a leg of the route. By joining the successive points along a given route, the tracks and distances can be measured for each leg of the route. The TAS can be obtained from the AFM or by calculation using the Indicated Airspeed (IAS) and the reverse side of the navigation computer. The wind velocity is obtained from the route weather forecast.

Although this type of problem can be solved by plotting, it is more normal to use the navigation computer to rapidly obtain the heading and ground speed for each leg of the route.

### *Example 1.2*

The track between *A* and *B* is 135°(T). The distance from *A* to *B* is 200 nm. The aircraft's TAS is 160 kts. The wind velocity is 090/30. Calculate the heading (T), the ground speed and the leg time in minutes.

### *Solution 1.2*

- Select the low-speed sliding scale on the navigation computer. Position 160 kts beneath the TAS dot.
- Rotate the bezel to position the wind direction against the heading index. Mark the wind speed downward from the TAS dot. Mark this point with a dot (referred to as the *wind dot*).
- Rotate the bezel until the track 135°(T) is against the heading index (it cannot remain there, but it enables an approximation of the drift to be determined). Read the approximate drift as 8.5°(S).
- Now move the bezel to position 135°(T) at 8.5°(S) on the outer scale. The drift on the face of the instrument has now changed to 7.5°(S). Adjust the bezel to set 135°(T) against 7.5° drift on the outer scale. This time the drift barely changed and has therefore *equalised*. Read the heading against the heading index as 127.5°(T) and the ground speed under the wind dot, using the scale of the slider, as 137 kts.
- The leg time can be calculated on the reverse side of the navigation computer. Position the 60-minute index against 137 on the outer scale. Against 200 nm on the outer scale read the leg time in minutes. (Alternatively, using a pocket calculator set (200 ÷ 137) × 60 = 87.6 min).

It is important to be able to make this type of calculation rapidly and accurately because there will be many of them in the examination paper. Complete Exercise 1.1 for practice. The answers are at the end of the book.

## Exercise 1.1

**Table 1.1**

| Wind velocity | Track (T) (°) | Drift (°) | Heading (T) | TAS (kts) | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|---|---|---|---|
| 080/40 | 240 | | | 180 | | 213 | |
| 250/50 | 330 | | | 220 | | 176 | |
| 350/30 | 020 | | | 300 | | 242 | |
| 170/60 | 130 | | | 420 | | 315 | |
| 030/30 | 176 | | | 110 | | 94 | |
| 120/50 | 218 | | | 256 | | 135 | |

Fill in the blank spaces in the table.

## The Point of Equal Time (PET)

The *Point of Equal Time* (PET), previously known as the *Critical Point* (CP), is the point along track at which it will take equal time, in the prevailing conditions and specified configuration, to reach either of two nominated points, which do not necessarily have to be on track. Note the calculations depend only on time, not on the fuel available; the only occasion on which fuel has any bearing on the solution is when no reserve fuel is carried. The exact position of the PET may be determined by calculation, by plotting or by using the flight progress chart (which is fully described in Chapter 9).

The purpose of determining the PET is to enable the Captain to make a sound, rational decision when confronted with unforeseen circumstances. Examples of these range from the serious illness of a passenger requiring hospitalisation as soon as possible, to an engine failure necessitating an emergency landing, or a pressurisation failure compelling a descent to continue the flight below 10 000 ft.

A PET can be predetermined for any circumstance or configuration between the departure and destination aerodromes. (Other types of example are dealt with later.) In the event of the emergency accounted occurring before the PET is reached, the aircraft should turn around and return to the departure point; however, if it occurs after the PET has been reached the aircraft should continue to the destination point.

A PET is normally calculated before flight for the all-engines-operating condition and the one-engine-inoperative condition. There are two types of PET, the single-track case, often referred to as the simple case, and the multi-track case.

In still-air conditions the PET will be exactly at the mid-position between the departure point and the destination. However, the PET will always move from that position into wind for any wind component. The greater the wind component the further it will move away from the mid-point.

## *The single-track, constant TAS, constant wind velocity case*

### Calculated solution

This is the simple case of a PET and must be thoroughly understood because it is the basis of the multi-track solution when the factors are more variable. Assume that *A* is the departure aerodrome, referred to as *Home*, and that *B* is the destination aerodrome, referred to as *On*. Then the time taken to reach either *A* or *B* from the PET is the same. Time is equal to distance divided by ground speed. Therefore, the distance from the PET to the departure aerodrome divided by the ground speed home (H) is equal to the distance from the PET to the destination aerodrome divided by the ground speed on (O).

In Figure 1.2: D is the total distance from A to B; X is the distance from A to the PET; H is the ground speed home from the PET to A; and O is the ground speed on from the PET to B.

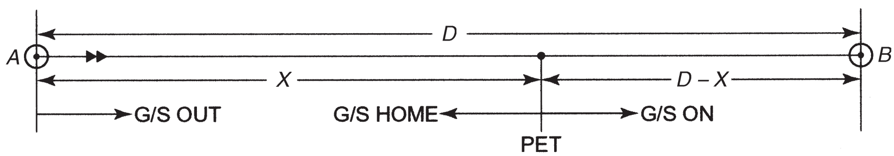



**Figure 1.2** The single-track point of equal time.

The time from the PET to $A = X \div H$

The distance from the PET to $B = (D - X)$

The time from the PET to $B = (D - X) \div O$

By definition, therefore,

$$X \div H = (D - X) \div O$$

By transposition,

$$XO = H(D - X)$$

By multiplication,

$$XO = DH - XH$$

By transposition,

$$XO + XH = DH$$

By isolation,

$$X(O + H) = DH$$

By division,

$$X = DH \div (O + H)$$

This is the PET formula. To calculate the time taken to reach the PET from the departure point, the distance to the PET, $X$, is divided by the ground speed out from the departure point. The result will be the time in hours and decimals of an hour. This may be converted to minutes by multiplying by 60. The ground speed out from the departure point and onward from the PET will be the same if all engines are operating, the cruise altitude is the same and the wind velocity is the same.

### *Example 1.3*

Given: wind velocity 240/50; track 270°(T); TAS 300 kts. The distance from the departure point to the destination is 1000 nm. Calculate the distance and time to the all-engines-operating PET.

### *Solution 1.3*

- Calculate the ground speed for track 270°(T) and for track 090°(T) using the navigation computer. On track 270°(T) it is 256 kts and on track 090°(T) it is 340 kts.
- The distance to the PET from the departure point using the formula $X = DH \div (O + H)$ is $1000 \times 340/(256 + 340) = 340\,000 \div 596 = 570.47$ nm.
- The time to the PET = $(570.47 \div 256) \times 60 = 133.7$ min = 2 hr 13.7 min.

In this solution, it has been assumed that all engines are operating and that the altitude and ambient temperature are the same in both directions from the PET. Therefore, the TAS will be the same in both directions. If, however, the PET is for the one-engine-inoperative configuration or for the pressurisation failure case then the outbound ground speed and the onward ground speed will be different. *The speeds to be used in the formula to determine the distance to the PET must be the ground speeds for the case under consideration.* Thus, if the PET is to be for the one-engine-inoperative case the ground speeds to be used in the PET formula must be those with one engine inoperative. However, the ground speed to be used to calculate the time taken to reach the PET from the departure point is always the all-engines-operating ground speed out from the departure point.

### *Example 1.4*

In Example 1.3, if the TAS with one-engine-inoperative is 200 kts. Calculate the distance and time in minutes to the one-engine-inoperative PET.

### *Solution 1.4*

- Ground speed on track 270°(T) with one-engine-inoperative is 156 kts. Ground speed on track 090°(T) with one-engine-inoperative is 240 kts. Ground speed on track 270°(T) with all-engines-operating is 256 kts.
- Distance to the PET using the formula is 1000 × 240 / (156 + 240) = 240 000 ÷ 396 = 606 nm.
- Time to the PET = (606 ÷ 256) × 60 = 142 min = 2 hr 22 min.

### Exercise 1.2

**Table 1.2**

| Q | Leg distance (nm) | All-engine G/S out (kts) | One-engine-inoperative G/S out (kts) | All-engine G/S home (kts) | One-engine-inoperative G/S home (kts) | All-engine PET distance and time | One-engine-inoperative PET distance and time |
|---|---|---|---|---|---|---|---|
| 1 | 1420 | 420 | 370 | 350 | 300 | | |
| 2 | 879 | 380 | 330 | 350 | 300 | | |
| 3 | 1250 | 320 | 270 | 370 | 320 | | |
| 4 | 2323 | 295 | 245 | 330 | 280 | | |
| 5 | 1952 | 250 | 200 | 300 | 250 | | |

Fill in the blank spaces in the table.

### *The multi-track, variable TAS, variable wind velocity case*

To determine the position and time to reach the PET for a multi-track case it is necessary to calculate the ground speed and leg time, both outbound and inbound, for each leg of the route for the configuration being considered. Then, by a process of elimination, it is possible to determine on which leg the PET is located. When this has been determined, the PET can be exactly located on that leg by the application of the formula already discussed.

### *Example 1.5*

Given the following completed flight plan determine the distance and time to reach the PET from *A*.

**Table 1.3**

| Leg | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *A–B* | 235 | 180 | 46.0 |
| *B–C* | 260 | 240 | 55.4 |
| *C–D* | 210 | 130 | 37.1 |
| *D–E* | 290 | 210 | 43.4 |
| *E–D* | 250 | 210 | 50.4 |
| *D–C* | 190 | 130 | 41.0 |
| *C–B* | 230 | 240 | 62.6 |
| *B–A* | 250 | 180 | 43.2 |

## *Solution 1.5*

- Draw a straight-line diagram of the route showing each of the turning points. This is to show the time between each of the turning points outbound (above the line) and the times inbound (above the line but in the opposite direction). Not all of the times are required, only those needed to effect a balance of times need to be shown. Bear in mind that the time onward to the destination must equal the time home to the departure point. See Figure 1.3(a).

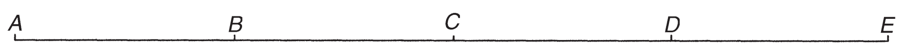



**Figure 1.3(a)** The basic route diagram.

- Insert time *D* to *E* first as 43.4 min. Now insert time *B* to *A* as 43.2 min. See Figure 1.3(b).

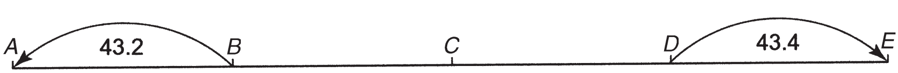



**Figure 1.3(b)** The first time insertions.

- Next, insert time *C* to *D* as 37.1 min. Thus, the total time from *C* to *E* is 43.4 + 37.1 min = 80.5 min.
- Now insert time *C* to *B* as 62.6 min. The total time from *C* to *A* is, therefore, 43.2 + 62.6 min = 105.8 min. See Figure 1.3(c).
- Clearly, the time from *C* to *A* does not balance the time from *C* to *E*. An

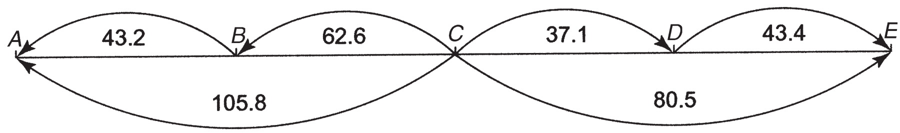



**Figure 1.3(c)** The second time insertions.

interim balance point must be introduced to reduce the larger time to equal the smaller time. This point should be labelled *Z*. Now *Z* to *A* is equal to *C* to *E* at 80.5 min. Therefore, the portion *Z* to *C* has to be time balanced by using the PET formula. See Figure 1.3(d).

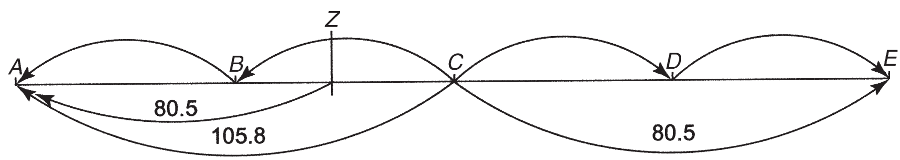



**Figure 1.3(d)** The interim time balance point, *Z*.

- The total distance *D* in the PET formula is the distance *Z* to *C* in Figure 1.3(e). The ground speed on from the PET is the ground speed on leg *B* to *C*. The ground speed home from the PET is the ground speed on leg *C* to *B*.
- The distance *Z* to *C* is equal to the time difference (105.8 – 80.5) = 25.3 min multiplied by the ground speed on the leg in which it fell in the direction of the arrow (i.e., ground speed *CB* = 230 kts). Therefore, distance *ZC* = (230 ÷ 60) × 25.3 = 97 nm. See Figure 1.3(e).

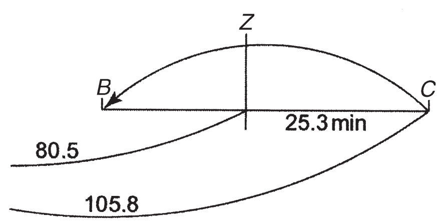



**Figure 1.3(e)** The unbalanced distance.

- In the PET formula, $X = DH / O + H$, the distance *X* is the distance from *Z* to the PET, which always falls in the unbalanced portion of the route, in this case *ZC*, and *X* is always to the left of the PET. Therefore, in this example *X* = 97 × 230 ÷ (260 + 230) = 45.5 nm. In addition, the time from *Z* to the PET = (45.5 ÷ 260) × 60 = 10.5 min. See Figure 1.3(f).
- To determine the distance and time to the PET from *A* it is necessary to calculate the distance from *B* to *Z* = *BC* – *ZC* = 240 – 97 = 143 nm. The time

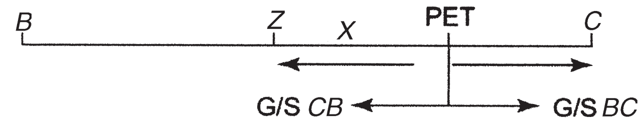



**Figure 1.3(f)** The exact location of the PET.

from *B* to *Z* is equal to the distance divided by the outbound ground speed on that leg (i.e., (143 ÷ 260) × 60 = 33 min).

- Therefore, the distance from *A* to the PET = 180 + 143 + 45.5 = 368.5 nm and the time from *A* to the PET = 46 + 33 + 10.5 = 89.5 min. See Figure 1.3(g).

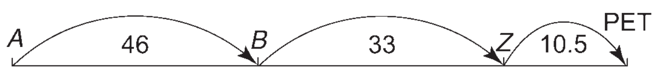



**Figure 1.3(g)** The PET related to *A*.

In the following exercise, determine the distance and the time to the PET from the departure point. It is essential to draw a diagram to solve each of the problems.

## Exercise 1.3

### *Question 1*

**Table 1.4**

| Leg | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *A–B* | 235 | 180 | 46.0 |
| *B–C* | 260 | 240 | 55.4 |
| *C–D* | 210 | 130 | 37.1 |
| *D–C* | 190 | 130 | 41.0 |
| *C–B* | 230 | 240 | 62.6 |
| *B–A* | 250 | 180 | 43.2 |

*Question 2*

**Table 1.5**

| Leg | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *P–R* | 300 | 200 | |
| *R–S* | 320 | 300 | |
| *S–T* | 350 | 400 | |
| *T–S* | 320 | 400 | |
| *S–R* | 290 | 300 | |
| *R–P* | 270 | 200 | |

*Question 3*

**Table 1.6**

| Leg | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *H–J* | 200 | 300 | |
| *J–K* | 300 | 320 | |
| *K–L* | 400 | 350 | |
| *L–K* | 370 | 350 | |
| *K–J* | 270 | 320 | |
| *J–H* | 170 | 300 | |

## The Point of Equal Fuel (PEF)

The *Point of Equal Fuel* (PEF) is the point along track at which an equal amount of fuel would be used, in the prevailing conditions and specified configuration, to reach either of two nominated points. The exact position of the PEF may be determined by calculation or by using the flight progress chart.

The purpose of determining the PEF is to enable the Captain, when confronted with unforeseen circumstances, to make a sound, rational decision regarding the future conduct of the flight when the fuel available is limited.

A PEF can be predetermined for any circumstance or configuration between the departure aerodrome and the destination. Should an emergency occur before the PEF is reached then less fuel would be consumed returning to the departure point than continuing to the destination, but if it occurred after reaching the PEF it would be more economical to continue to the destination.

A PEF is usually calculated before take-off for the all-engines-operating condition. There are two types of PEF, the single-track case, referred to as the simple case, and the multi-track case. In still-air conditions, if the ambient temperature, altitude and fuel flow remain constant for the whole flight both outbound and inbound, then the PEF will be exactly half way between the departure and destination aerodromes.

## *The single-track, constant TAS, constant wind velocity case*

### Calculated solution

This is the simple case of the PEF and must be thoroughly understood because it is the basis of the multi-track solution when all the factors are variable. Assume *A* is the departure aerodrome, referred to as *Home*, and *B* is the destination aerodrome, referred to as *On*. Then the fuel required travelling from the PEF back to *A* is equal to the fuel used travelling on from the PEF to *B*. The fuel used is equal to the fuel flow multiplied by the leg time in hours. In Figure 1.4: *D* is the total distance from *A* to *B*; *Y* is the distance from *A* to the PEF; *D*–*Y* is the distance from the PEF to *B*; *H* is the ground speed home from the PEF to *A*; *O* is the ground speed on from the PEF to *B*; *FH* is the fuel flow home from the PEF to *A*; and *FO* is the fuel flow on from the PEF to *B*.

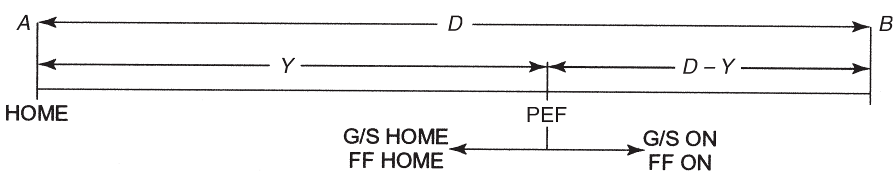



**Figure 1.4** The single-track Point of Equal Fuel.

Time home = $Y / H$

Fuel home = $FH \times Y / H$

Time on = $(D - Y) / O$

Fuel on = $FO \times (D - Y) / O$

By definition, then,

$$FH \times Y / H = FO \times (D - Y) / O$$

By cross multiplication,

$$O\,(FH \times Y) = H\,[FO \times (D - Y)]$$

Therefore,

$$O \times FH \times Y = H \times FO \times (D - Y)$$

By transposition,

$$OY(FH) + HY(FO) = DH(FO)$$

By isolation,

$$Y[O(FH) + H(FO)] = DH(FO)$$

By division,

$$Y = DH(FO) \ / \ [O(FH) + H(FO)]$$

This is the PEF formula. In plainer language, the distance from *A* to the PEF = (total distance × ground speed home × fuel flow on) ÷ the sum of (the ground speed on × fuel flow home) and (the ground speed home × fuel flow on).

### *Example 1.6*

Given: total distance 1420 nm; ground speed on 420 kts; ground speed home 350 kts; fuel flow on 4800 kg/hr; fuel flow home 4200 kg/hr. Calculate the distance to the PEF.

### *Solution 1.6*

Distance to the PEF = 1420 × 350 × 4800 / (420 × 4200) + (350 × 4800)
= 692.7 nm

Proof:

Fuel home from the PEF = 692.7 ÷ 350 × 4200 kg = 8312 kg

Fuel on from the PEF = (1420 – 692.7) ÷ 420 × 4800 = 8312 kg

### Exercise 1.4

**Table 1.7**

| Q | Leg distance (nm) | All-engine G/S out (kts) | Fuel flow out (kg/hr) | All-engine G/S home (kts) | Fuel flow home (kg/hr) | All-engine PEF distance (nm) |
|---|---|---|---|---|---|---|
| 1 | 1420 | 420 | 4200 | 350 | 4800 | |
| 2 | 879 | 380 | 3600 | 350 | 3100 | |
| 3 | 1250 | 320 | 5200 | 370 | 4600 | |
| 4 | 2323 | 295 | 6000 | 330 | 5000 | |
| 5 | 1952 | 250 | 4700 | 300 | 5500 | |

Complete the table.

### *The multi-track, variable TAS, variable wind velocity case*

To determine the position of the PEF for a multi-track case it is necessary to calculate the fuel used on each leg of the entire route, both outbound and inbound, for the configuration being considered. Then, by a process of elimination, it is possible to determine the leg on which the PEF is located. The exact position of the PEF on that leg can be found by the application of the formula already discussed. An example will show the process.

### *Example 1.7*

Given a completed flight plan (Table 1.8) determine the distance to reach the PEF from *A*.

**Table 1.8**

| Leg | Ground speed (kts) | Distance (nm) | Fuel flow (kg/hr) | Fuel used (kg) |
|---|---|---|---|---|
| *A–B* | 235 | 250 | 5500 | 5851 |
| *B–C* | 260 | 300 | 5300 | 6115 |
| *C–D* | 210 | 130 | 5100 | 3157 |
| *D–E* | 290 | 210 | 4900 | 3548 |
| *E–D* | 250 | 210 | 4700 | 3948 |
| *D–C* | 190 | 130 | 4500 | 3077 |
| *C–B* | 230 | 300 | 4300 | 5609 |
| *B–A* | 250 | 250 | 4100 | 4100 |

### *Solution 1.7*

- Draw a straight-line diagram of the route showing each of the turning points. This is to show the fuel used between each of the turning points outbound (above the line) and the fuel used inbound (above the line but in the opposite direction). Not all of the values are required; only those needed to effect a balance of fuel need to be shown. Remember the PEF is the point at which the fuel used onward to the destination is equal to the fuel used homeward to the departure that has to be located. Insert the fuel used values on the diagram in the same manner as the multi-track PET. Firstly, insert the fuel used from *D* to *E* as 3548 kg, then insert the fuel used from *B* to *A* as 4100 kg. Next, insert the fuel used from *C* to *D* as 3157 kg. Thus, the total fuel used from *C* to *E* is 3157 + 3548 = 6705 kg. Now insert the fuel used from *C* to *B* as 5609 kg. The total fuel used from *C* to *A* is, therefore, 5609 + 4100 = 9709 kg. See Figure 1.5(a).
- Clearly, the fuel used from *C* to *A* does not balance the fuel used from *C* to *E*. An interim balance point must be introduced to reduce the larger fuel

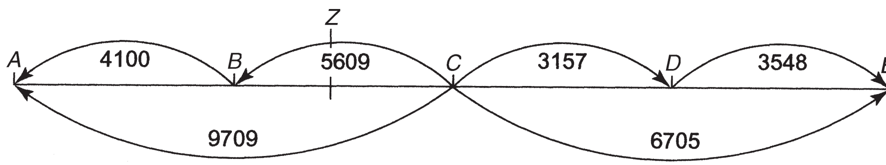



**Figure 1.5(a)** The basic route fuel used diagram.

used to equal the smaller. This point should be labelled *Z*. Now the fuel used from *Z* to *A* is equal to the fuel used from *C* to *E* at 6705 kg. Therefore, the portion *Z* to *C* has to be fuel balanced by using the PEF formula. Before this can be done, the unbalanced fuel must be converted to a distance to be used as *D* in the formula. See Figure 1.5(b).

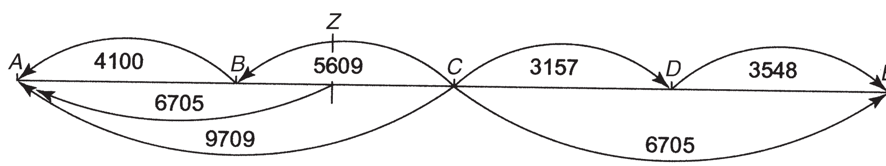



**Figure 1.5(b)** The complete fuel used diagram.

- To determine distance *D*, the difference in fuel used, 9709 – 6705 = 3004 kg, is divided by the fuel flow indicated by the arrow on the leg on which the interim balance point, *Z*, occurs, which is fuel flow *CB* (i.e., 4300 kg/hr) and then multiplied by the ground speed *CB* (i.e., 230 kts). Thus, *D* = (3004 ÷ 4300) × 230 = 160.7 nm.
- The distance from *Z* to the PEF, *Y*, is determined by the formula *D* × *H* × *FO* ÷ [(*O* × *FH*) + (*H* × *FO*)] = 160.7 × G/S *CB* × *FF BC* ÷ [(G/S *BC* × *FF CB*) + (G/S *CB* × *FF BC*)] = 160.7 × 230 × 5300 ÷ [(260 × 4300) + (230 × 5300)] = 83.8 nm. See Figure 1.5(c).

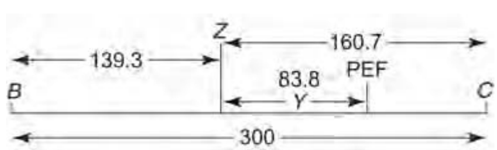



**Figure 1.5(c)** The exact location of the PEF.

- Therefore, the distance of *Y* from *A* = 250 + (300 – 160.7) + 83.8 = 473.1 nm.

## Exercise 1.5

Given the following flight plan details calculate the distance of the PEF from the departure point.

**Table 1.9**

| Leg | Ground speed (kts) | Distance (nm) | Fuel flow (kg/hr) | Fuel used (kg) |
|---|---|---|---|---|
| *A–B* | 320 | 180 | 6500 | |
| *B–C* | 335 | 200 | 6300 | |
| *C–D* | 350 | 350 | 6100 | |
| *D–E* | 360 | 450 | 5900 | |
| *E–D* | 370 | 450 | 5700 | |
| *D–C* | 390 | 350 | 5500 | |
| *C–B* | 400 | 200 | 5300 | |
| *B–A* | 410 | 180 | 5100 | |

# The Point of Safe Return (PSR)

The *Point of Safe Return* (PSR), previously known as the *Point of No Return* (PNR), is the furthermost point from which an aeroplane can safely return to the departure point using all the fuel available, but excluding the safety reserve. The precise position of the PSR can be determined by calculation or by using the flight progress chart.

The purpose of determining the PSR is that in the event of an emergency, when no diversion or alternate aerodrome is available, the Captain can rapidly determine whether returning to the departure aerodrome is a viable option. If the emergency occurs before the PSR is reached then it is, but once the aeroplane is beyond this point, it is not.

Usually the PSR is calculated for the all-engines-operating configuration. It could be calculated for the one-engine-inoperative condition, assuming all engines are operating until the PSR is reached and that the return journey is with one engine inoperative. However, the difference between the two is not very much and the assumption that an engine fails at the PSR is a most unlikely event. Therefore, it is normal to determine only the all-engines-operating configuration PSR. However, there are two cases, as with the PET; the simple, single-track case in which the TAS, altitude and fuel flow remain constant, and the multi-track case, in which the TAS, fuel flow and altitude are all variable.

The greatest distance from the departure point to the PSR occurs in still air. Any wind component, no matter whether it is head or tail, will cause the PSR to be closer to the departure point than its still-air position. The greater the wind component the nearer is the PSR to the departure point.

***The single-track, constant TAS, constant altitude, constant fuel flow case.***

**Calculated solution**

The simple case assumes that the TAS, fuel flow, altitude, and wind velocity remain constant throughout the flight along a single track. By definition, the time taken to reach the PSR from the departure aerodrome plus the time taken to reach the departure aerodrome from the PSR is equal to the safe endurance of the aeroplane. Time is equal to distance divided by ground speed. In Figure 1.6: *X* is the distance of the PSR from the departure aerodrome; *O* is the ground speed out from the departure aerodrome; *H* is the ground speed home to the departure aerodrome; and *E* is the safe endurance of the aeroplane in hours.

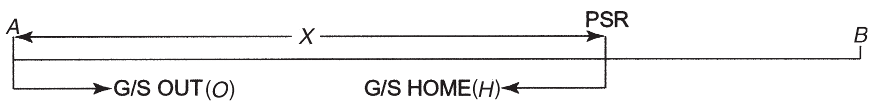



**Figure 1.6** The single-track point of safe return.

By definition,

$$X / O + X / H = E$$

By cross multiplication,

$$XO + XH = EOH$$

By division,

$$X = EOH / (O + H)$$

The time to reach the PSR from the departure aerodrome is equal to the distance *X* divided by the ground speed out, which is assumed to be the same as that onward from the PSR. Therefore,

Time to the PSR = $EOH / O\,(O + H) = EH / (O + H)$

## *Example 1.8*

Given: wind velocity 240/50; track 270°(T); TAS 300 kts, safe endurance 8 hr. Calculate the distance and time to reach the PSR.

### *Solution 1.8*

- Calculate the ground speed for track 270°(T) and for track 090°(T) using the navigation computer. On track 270°(T) it is 256 kts and on track 090°(T) it is 340 kts.
- The distance to the PSR from the departure point using the formula is

$$EOH / (O + H) = 8 \times 256 \times 340 / (256 + 340) = 1168.3 \text{ nm}$$

- The time to the PSR from the departure point using the formula is

$$EH / (O + H) = 8 \times 340 / (256 + 340) = 2720 / 596 = 4.56 \text{ hr} = 4 \text{ hr } 33.6 \text{ min.}$$

### Exercise 1.6

**Table 1.10**

| Q | W/V | Track (T) (°) | TAS (kts) | Endurance (hr) | G/S out (kts) | G/S home (kts) | PSR distance (nm) | PSR time (hr) |
|---|---|---|---|---|---|---|---|---|
| 1 | 240/50 | 180 | 260 | 7.5 | | | | |
| 2 | 090/40 | 030 | 210 | 6.0 | | | | |
| 3 | 320/30 | 120 | 310 | 9.5 | | | | |
| 4 | 110/45 | 240 | 290 | 8.2 | | | | |
| 5 | 190/55 | 280 | 380 | 7.2 | | | | |

Calculate the distance and time in hours to the PSR.

### *The multi-track, variable TAS, variable altitude, variable fuel flow case*

The multi-track PSR case can be solved only by completing a full flight and fuel plan for both the outbound and inbound legs of the entire route. From the total fuel available, the sum of the fuel required for each leg both outbound and inbound, starting at the departure point, is subtracted until the leg is reached on which there is insufficient fuel available to complete the return leg. The PSR occurs on this leg. The fuel available from the last turning point to the PSR is then divided by the sum of the outbound and inbound gross fuel flows on that leg to determine its exact location. The gross fuel flow is the fuel flow in kilograms per hour divided by the ground speed in knots. This produces the number of kilograms of fuel used per nautical mile. An example will clarify the method.

### *Example 1.9*

Fuel available 20 000 kg.

### *Solution 1.9*

**Table 1.11**

| Leg | G/S (kts) | Fuel flow (kg/hr) | Leg distance (nm) | Leg time (hr) | Fuel used (kg) |
|---|---|---|---|---|---|
| *A–B* | 250 | 3300 | 180 | 0.72 | 2376 |
| *B–C* | 270 | 3100 | 220 | 0.81 | 2526 |
| *C–D* | 235 | 3000 | 300 | 1.28 | 3830 |
| *D–E* | 255 | 2900 | 250 | 0.98 | 2843 |
| *E–D* | 280 | 3100 | 250 | 0.89 | 2768 |
| *D–C* | 250 | 3200 | 300 | 1.20 | 3840 |
| *C–B* | 300 | 3400 | 220 | 0.73 | 2493 |
| *B–A* | 280 | 3500 | 180 | 0.64 | 2250 |

Fuel required from *A* to *B* and back to *A* = 2376 + 2250 = 4626 kg.
Fuel required from *A* to *C* and back to *A* = 4626 + 2526 + 2493 = 9645 kg.
Fuel required from *A* to *D* and back to *A* = 9645 + 3830 + 3840 = 17 315 kg.
Fuel required from *A* to *E* and back to *A* = 17 315 + 2843 + 2768 = 22 926 kg.

The fuel available is insufficient to reach *E* and return to *A*. However, there is enough fuel to reach beyond *D* and to return to *A*. The distance that the PSR is beyond *D* now has to be determined. The fuel available from *D* to the PSR and to return to *D* is 20 000 – 17 315 = 2685 kg. To determine the distance that this will enable the aeroplane to travel outbound and to return to *D*, the fuel available must be divided by the total gross fuel flow for both legs.

The gross fuel flow on from *D* = fuel flow *D* to *E* divided by the ground speed from *D* to *E* = 2900 ÷ 255 = 11.37 kg/nm. For the return leg, the fuel flow *E* to *D* must be divided by the ground speed *E* to *D* = 3100 ÷ 280 = 11.07 kg/nm. Therefore, the total gross fuel flow = 11.37 + 11.07 = 22.44 kg/nm.

The distance from *D* to the PSR is, therefore, equal to 2685 ÷ 22.44 = 119.7 nm.
The time from *D* to the PSR is equal to 119.7 ÷ 225 = 0.532 hr.
The total distance from *A* to the PSR = 180 + 220 + 300 + 119.7 = 819.7 nm.
The total time from *A* to the PSR = 0.72 + 0.81 + 1.28 + 0.53 = 3.34 hr = 3hr 20.4 min. (See Figure 1.7.)

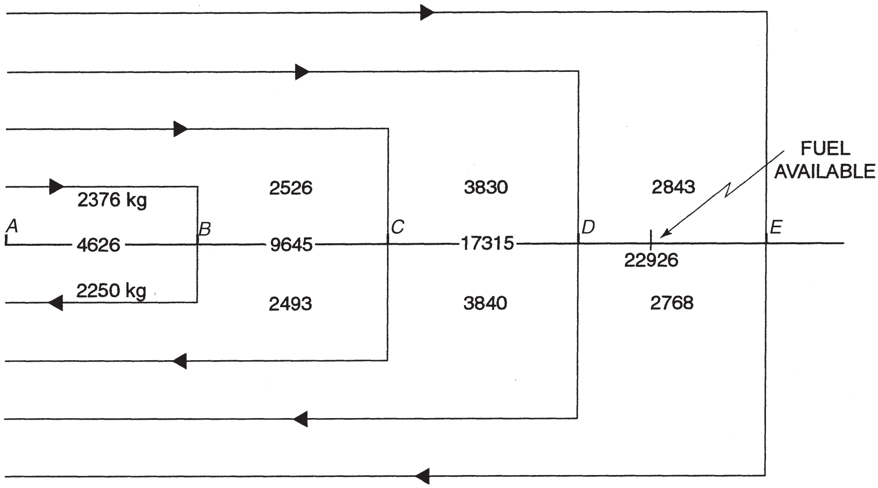



**Figure 1.7** Multi-track PSR.

## Exercise 1.7

Fuel available 30 000 kg. Calculate the time and distance from A to the PSR.

**Table 1.12**

| Leg | G/S (kts) | Fuel flow (kg/hr) | Leg distance (nm) | Leg time (hr) | Fuel used (kg) |
|---|---|---|---|---|---|
| *A–B* | 300 | 6500 | 200 | | |
| *B–C* | 320 | 6400 | 230 | | |
| *C–D* | 350 | 6300 | 180 | | |
| *D–E* | 330 | 6200 | 250 | | |
| *E–D* | 290 | 6100 | 250 | | |
| *D–C* | 310 | 6000 | 180 | | |
| *C–B* | 280 | 5900 | 230 | | |
| *B–A* | 260 | 5800 | 200 | | |

## Summary

| | |
|---|---|
| **Navigation computer** | Be capable of determining the heading and ground speed using the navigation computer when given track, wind velocity and TAS. |
| **The PET** | A point of equal time can be calculated for any given configuration. |
| **PET distance formula** | • Commit to memory the formula to determine the distance to the PET, $DH / (O + H)$.<br>• Remember the ground speeds to be used in the formula are those for the configuration under consideration. |
| **Time to the PET** | The time, in hours, to the PET is the distance divided the all-engines-operating ground speed out. |
| **Wind effect on the PET** | • The PET will always move away from the route mid-position into wind.<br>• The stronger the wind the further it will move. |
| **Multi-track PETs** | • Introduce an interim point, *Z*, to effect a balance of times onward and homeward to equal the smaller of the two.<br>• Apply the PET distance formula for the unbalanced portion of the route.<br>• The PET will always fall in the unbalanced portion and *X* will always be to the left of the PET, if *home* is to the left. |
| **The PSR** | • The PSR is the furthermost point, along track, from which an aeroplane can return to a nominated point, within the safe endurance of the aeroplane.<br>• It is usually calculated for the all-engines-operating configuration. |
| **Wind effect on the PSR** | • If there is any wind component the PSR will always be closer to the departure point than its still-air position, no matter whether it is a headwind or a tailwind.<br>• The greater the wind component the further it moves towards the departure point. |

| | |
|---|---|
| **PSR formulae** | The distance from the departure point to the PSR is equal to *EOH* / (*O* + *H*) and the time in hours is equal to *EH* / (*O* + *H*). |
| **Multi-track PSR** | • The PSR for a multi-track route can be solved only by employing the gross fuel flow method.<br>• It is first necessary to determine the track on which it will fall and how much fuel is available from the last turning point. |

## Sample questions

1. Given: track 240°(T); wind velocity 180/50; TAS 210 kts; leg distance 397 nm. Calculate:
   a. Heading (T)
   b. Ground speed in knots
   c. Leg time in minutes
2. Given the details as in Question 1, determine the distance and time in minutes to the Point of Equal Time from the departure point.
3. If in Question 1 the fuel flow on is 6000 kg/hr and the fuel flow home is 5500 kg/hr, calculate the distance and time to the Point of Equal Fuel (PEF).
4. If the one-engine-inoperative TAS in Question 1 is 150 kts, calculate the distance in nautical miles and the time in minutes of the Point of Equal Time for this configuration from the departure point.
5. Given the details in Table 1.13 determine the PET distance and time from *A*.

**Table 1.13**

| Leg | G/S (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *A–B* | 480 | 325 | |
| *B–C* | 450 | 276 | |
| *C–D* | 430 | 405 | |
| *D–E* | 410 | 370 | |
| *E–D* | 480 | 370 | |
| *D–C* | 500 | 405 | |
| *C–B* | 520 | 276 | |
| *B–A* | 550 | 325 | |

6. Given: track 180°(T); wind velocity 240/50; TAS 310 kts; endurance 8.2 hr. Calculate the distance and time from the departure point of the PSR.
7. Fuel available 30 000 kg. Given the route details in Table 1.14, calculate the time and distance from *A* to the PSR.

**Table 1.14**

| Leg | G/S (kts) | Fuel flow (kg/hr) | Leg distance (nm) | Leg time (hr) | Fuel used (kg) |
|---|---|---|---|---|---|
| *A–B* | 260 | 6500 | 200 | | |
| *B–C* | 280 | 6400 | 230 | | |
| *C–D* | 310 | 6300 | 180 | | |
| *D–E* | 290 | 6200 | 250 | | |
| *E–D* | 330 | 6100 | 250 | | |
| *D–C* | 350 | 6000 | 180 | | |
| *C–B* | 320 | 5900 | 230 | | |
| *B–A* | 300 | 5800 | 200 | | |

8. Determine the distance and time to the Point of Equal Fuel for the route details given in Question 7.

Chapter 2
# Meteorology Revision

## Introduction

In Flight Planning, the main sphere of interest with regard to meteorology is the practical interpretation of meteorological actual reports (METARs), terminal aerodrome forecasts (TAFs), significant meteorological reports (SIGMETs), flight forecast weather charts and wind charts.

All of these can be divided according to the geographical region of the world. The flight forecast weather and wind charts are subdivided into low-level and high-level charts. The Joint Aviation Authority (JAA) tend to concentrate on the UK and European charts.

## METARs, TAFs and SIGMETs

The abbreviations used in METARs, TAFs and SIGMETs are the same. It is important to note that all times are UTC (GMT) and all wind directions are true directions. Wind speeds are stated in knots or metres per second. All temperatures and dew points are in degrees Celsius (centigrade) and all QNHs are in hectopascals (hPa) (i.e., mbs). Visibility is stated in metres or kilometres.

It should be noted that in the USA the units of measurement may differ from those used in Europe. The wind speed may be in miles per hour (mph), the visibility may be in statute miles and the temperature and dew point may be in Fahrenheit.

The abbreviations and their meaning in the following tables must be memorised.

**Table 2.1** Thunderstorm or cumulonimbus abbreviations

| Abbreviations | Meaning | Abbreviations | Meaning |
|---|---|---|---|
| FRQ | Frequent | SQL | Appear as a line squall |
| EMBD | Embedded within another cloud | OBSC | Hidden by other clouds or haze |

**Table 2.2** SIGMET, METAR and TAF abbreviations

| Abbreviations | Meaning | Abbreviations | Meaning | Abbreviations | Meaning |
|---|---|---|---|---|---|
| ACT | Active | AMD | Amended | ASSW | Associated with |
| BKN | Broken, 5 to 7 oktas | BLW | Below | BTN | Between |
| CAT | Clear air turbulence | CNS | Continuous | COR | Correction |
| COT | At or on the coast | EMBD | Embedded | FCST | Forecast |
| FEW | 1 or 2 oktas | FPM | Feet per minute | FRQ | Frequent, little or no separation |
| GR | Hail | GRN | Ground | HVY | Heavy |
| ICE | Icing | INC | In cloud | INTSF | Intensifying |
| INTST | Intensity | ISOL | Isolated or individual | LAN | Inland or overland |
| LOC | Locally | LSQ | Line squall | LYR | Layer or layered |
| MAR | At/over sea | MAX | Maximum | MNM | Minimum |
| MOD | Moderate | MON | Above or over mountains | MOV | Moving |
| MTW | Mountain waves | NC | No change or not changing | OBS | Observed |
| OBSC | Obscured | OCNL | Occasional or well separated | OVC | Overcast, 8 oktas |
| SCT | Scattered, 3 or 4 oktas | SEV | Severe | SKC | Sky clear, no oktas |
| SLW | Slow | STNR | Stationary | TDO | Tornado |
| TRS | Tropical cyclone | TURB | Turbulence | VAL | In valleys |
| VERVIS | Vertical visibility | VRB | Variable | VSP | Vertical speed |
| WDSPR | Widespread | WKN | Weakening | WS | Wind shear |

## *Turbulence reports*

Any reports regarding turbulence may include any of the words shown in Table 2.3, which are interpreted as shown.

**Table 2.3** Turbulence reports

| Description | Interpretation |
|---|---|
| OCCASIONAL | Less than ⅓ of the time. |
| INTERMITTENT | ⅓ to ⅔ of the time. |
| CONTINUOUS | More than ⅔ of the time. |
| LIGHT TURBULENCE | Slight erratic changes in altitude/attitude. The IAS fluctuates between 5 and 15 kts. |
| LIGHT CHOP | Slight rapid rhythmic bumpiness with no change in altitude, attitude or IAS. |
| MODERATE TURBULENCE | Changes to altitude and/or attitude but the aircraft remains in positive control. The IAS fluctuates between 15 and 25 kts. |
| MODERATE CHOP | Rapid bumps or jolts with no change in altitude or attitude but with slight fluctuations to the IAS. |
| SEVERE TURBULENCE | Large abrupt changes in altitude and/or attitude, which may result in the aircraft being momentarily out of control. The IAS may fluctuate more than 25 kts. |

## *Icing reports*

If any report contains a description of icing it should be interpreted as shown in Table 2.4.

**Table 2.4** Icing reports

| Description | Interpretation |
|---|---|
| TRACE | Barely perceptible. The accumulation is not dangerous unless encountered for more than **one hour**. |
| LIGHT | Accumulation may be hazardous if experienced for more than **one hour** and anti-icing/de-icing equipment is not used. |
| MODERATE | The rate of accumulation is hazardous even for **short periods**. The use of de-icing/anti-icing equipment is essential to prevent it becoming dangerous. |
| SEVERE | The rapid rate of accumulation is **extremely dangerous** even with the use of de-icing/anti-icing equipment and it necessary to evacuate the area immediately. |

## *SIGMETs*

A SIGMET is a warning passed to aircraft in flight of any adverse weather which is of significance and could affect the conduct of the flight. It is normally passed only if the significant weather is within two hours flight time or 500 nm of the aircraft's dead reckoning position.

### *Example 2.1*

**SIGMET messages**

BMDA57 AFTN 300700
300700
GG EGRHYMYX EGRAYMYX
300700 EGGYYBYA
WSUK31 EGGY 300700
EGPX **SIGMET 03** VALID 300715/301115 EGRR-
SCOTTISH FIR SEV MTW VSP 700FPM FCST FL080 OVER AND LEE OF HILLS S OF 58N STNR NC=

WSUK31 AFTN 301113
FF EGZZWPXX
301113 EGRRYMYX
WSUK31 EGGY 301113
EGPX **SIGMET 04** VALID 301115/031515 EGRR-
SCOTTISH FIR SEV MTW VSP 700FPM FCST FL080 OVER AND LEE OF HILLS S OF 58N STNR WKN FROM NW=

### *Decode of example 2.1*

The interpretation of the SIGMETs is as follows:

- The first four lines identify the method and time of transmission and the transmitting agency. SIGMET 03 was transmitted using the Aeronautical Fixed Telecommunications Network (AFTN) on the 30th day of the month at 0700 UTC by the UK weather office at Bracknell. The fifth line identifies the area to which the message applies, in this case UK area 31. The interpretation so far is not required in the JAA examinations.
- The interpretation of the rest of the message is required by the JAA. The sixth line states the International Civil Aviation Organisation (ICAO) identifier of that area, EGPX, and that the message is SIGMET number 3 for that day. Following that, the validity period of the warning is stated; for this message it is from 0715 UTC until 1115 UTC.
- The contents of the warning are that severe mountain waves with a vertical speed of 700 fpm are forecast in the Scottish Flight Information Region (FIR) at Flight Level (FL) 080 over and in the lee of hills south of 58N. They will be stationary during the period and no change is expected during the period.
- This SIGMET is followed at 1113 UTC by number 4, which updates the information that number 3 contained. Whilst the position, altitude and severity of the mountain waves are unchanged, they are now expected to weaken from the north-west.

## *The interpretation of METARs*

The abbreviations used in METARs are shown in Table 2.5.

**Table 2.5** Abbreviations used in METARs

| Abbreviations | Meaning | Abbreviations | Meaning |
|---|---|---|---|
| *Intensity or proximity* | | | |
| – | Light | + | Heavy or well-developed |
| VC | In the vicinity. Within 8 km (5 nm) of the aerodrome boundary. | | |
| *Description of weather* | | | |
| BC | Patches | BL | Blowing |
| DR | Drifting | FZ | Super-cooled |
| MI | Shallow | PR | Partial |
| SH | Shower(s) | TS | Thunderstorm |
| *Precipitation* | | | |
| DZ | Drizzle | GR | Hail |
| GS | Small hail (less than 5 mm diameter) and/or snow pellets | IC | Diamond dust |
| PE | Ice pellets | RA | Rain |
| SN | Snow | SG | Snow grains |
| *Obscuration* | | | |
| BR | Mist | DU | Dust |
| FG | Fog | FU | Smoke |
| HZ | Haze | SA | Sand |
| VA | Volcanic ash | | |
| *Other* | | | |
| DS | Dust storm | FC | Funnel cloud(s) (Tornado or waterspout) |
| PO | Well developed dust/sand whirls | SS | Sandstorm |
| SQ | Squall(s) | | |
| *Cloud* | | | |
| CB | Cumulonimbus | TCU | Towering cumulus |

Meteorological Actual Reports are transmitted with the information in a specific sequence. The sequence is:

- Report type
- ICAO Location Identifier
- Date and time of the observations
- Surface wind direction and speed
- Visibility
- Runway Visual Range (RVR)
- Present weather
- Cloud
- Temperature and dew point
- QNH
- Recent weather
- Wind shear
- Trend
- Runway state.

Some of these items are conditional and, therefore, require further explanation:

**Report type**

This will always be specified as a METAR.

**ICAO Location Identifier**

The four letter ICAO identifier.

**Date and time of the observations**

This is a six-figure group followed by the letter Z to indicate UTC. The first two numbers are the day of the month and the last four are the time.

**Surface wind velocity (W/V)**

The first three numbers are the mean true wind direction over the last ten minutes. The next two or three digits are the mean wind speed over the same period. This is followed by letters to indicate the units of measurement, KT for knots, kmH for kilometres per hour, or MPS for metres per second. If the highest speed during the past ten minutes exceeded the mean speed by 10 kts or more, then the mean wind will be followed by the letter G and the maximum speed during that period. For example, 22021G32KT.

- If the wind direction during the ten minutes before the report varied by 60° or more, **and** the mean speed was 4 kts or more, then the two extreme directions separated by a V will be stated after the details of the wind, for example, 22021G32KT 190V260. This decodes as the mean wind was 220°(T) at 21 kts, with the maximum-recorded speed of 32 kts and a direction which varied between 190°(T) and 260°(T) during the ten minutes before the report.

- Calm is indicated by 00000. If the wind is 3 kts or less the wind direction is replaced by the letters VRB, which will be used for speeds of 4 kts or more when the variation of direction exceeds 180°.

**Visibility**

If there is no marked variation in the surface visibility throughout the 360° surrounding the observer then a four-digit number will be stated, which is the lowest visibility expressed in metres. If the number is 0000 then this is a visibility of less than 50 m and if it is 9999, this indicates that the visibility is 10 km or more.

- When there is a marked variation in visibility, the minimum quoted will be followed by one of cardinal point abbreviations, for example, 3000NE. This also indicates that the visibility is at least 50% better in other directions. However, when the minimum visibility is less than 1500 m and the maximum in another direction is greater than 5000 m, then both values have the appropriate cardinal point abbreviation after them, for example, 1000SW 6000NW.

**Runway Visual Range**

The runway visual range (RVR) group is always prefixed by the letter R, which is followed by the runway designator. Parallel runways have the designator suffix L, R or C. If the visibility down the runway is greater than the maximum measurable the value will have the prefix P, or if it less than the minimum measurable it will have the prefix M, for example, R24L/M0050, which decoded means the RVR on runway 24 left is less than 50 m.

- If, during the ten minutes before the report, the RVR value indicated a distinct change taking place in the visibility then the value would have a suffix of U for increasing, D for decreasing or N for no significant change, for example, R24L/2000D, which decoded means the RVR on runway 24 left is 2000 m decreasing.
- Whenever there is a significant variation in the RVR along a particular runway during the ten minute period before the report, and the difference from the mean value for the period is more than 50 m or 20%, then two RVRs will be quoted separated by a letter V, for example, R24L/0700V1200.

**Present weather**

This will always be given by one or any combination of the abbreviations in Table 2.5. Note the abbreviations BR, DU, FU, IC and HZ are not reported when the visibility is greater than 5000 m.

### Cloud

A six-character group will be stated for each layer of cloud. The first three characters are letters, which indicate the amount of sky covered, and the next three characters are figures that indicate the base of the cloud above aerodrome level in hundreds of feet. Only significant convective cloud is mentioned by type and is represented by a suffix of CB for cumulonimbus or TCU for towering cumulus. The first cloud group is the lowest layer of any amount of cloud, the second is the next highest layer having more than two oktas and the third group is the next highest layer having more than four oktas, for example, BKN018TCU indicates a layer of 5–7 oktas of towering cumulus with a base height of 1800 ft above aerodrome elevation.

### Temperature and dew point

Both temperature and dew point are stated in degrees Celsius, temperature being before the oblique line. If either value is below zero it will have a prefix of M.

### QNH

The unit of measurement for the mean sea level pressure derived from the aerodrome surface pressure is shown by the prefix Q for hectopascals (hPa) or A for inches and hundredths of inches of mercury.

### Recent weather

Weather that has occurred in the last hour, but not at the time of observation, will have one or more of the abbreviations from Table 2.5 prefixed by the letters RE. In the sequence of the METAR information, it always follows the QNH.

### Wind shear

Wind shear is not reported in UK METARs at present. For other aerodromes it is only quoted if it occurs below 1600 ft with reference to the runway and the report will state whether it is at the landing or take-off end of the runway, for example, WS LDG RWY24L, which decoded indicates that there is wind shear at the landing end of runway 24 left.

### Trend

A *trend* is a short-term forecast for the two hours following the time of the report. Certain abbreviations will be used to indicate the time of the occurrence.

- BECMG (becoming) is used to indicate a permanent change to the main conditions and is followed by a four-figure time group to indicate the earliest and latest times between which the change will take place. A deterioration is assumed to happen at the earliest time but an improvement is not assumed to have taken place until the latest time.

- TEMPO (temporarily) indicates a temporary variation to the main conditions which will last for a total of less than half of the period (i.e., less than one hour).
- FM (from) or AT (at) specifies the exact time at which a change will occur by a suffix of four figures.
- TL (until) indicates the latest time to which a change may extend by a four-figure group.
- NOSIG (no significant change) means that no significant change is expected in the next two hours.

## CAVOK

The visibility, RVR, weather and cloud groups can be replaced by the abbreviation CAVOK if the following conditions exist:

- visibility 10 km or more, and
- no cloud below 5000 ft above aerodrome elevation or below Minimum Sector Altitude (MSA), whichever is the higher, and
- no cumulonimbus, and
- no precipitation, thunderstorms, shallow fog or low drifting snow.

### Runway state

If the runway state is quoted it will be shown by an additional eight-figure group at the end of the METAR. The figures decode as follows:

- The first two digits are the runway designator, for example, 27 means runway 27 (or 27L for parallel runways). Where two parallel runways exist the number 50 is added to signify the right-hand runway, so 77 is 27R. If the information applies to all runways, it will be indicated by 88.
- The third digit indicates the type of contaminant, for example, 4 is dry snow.
- The fourth digit indicates the extent of the runway contamination expressed as a percentage of the runway surface area, for example, 5 means 26% to 50% is covered.
- The fifth and sixth digits detail the depth of the contaminant in millimetres.
- The seventh and eighth digits show either the coefficient of friction or the braking action. The coefficient of friction is indicated by numbers up to 60, for example, 30 indicates a coefficient of friction of 0.30. Above 90, the figures indicate the braking action.

**Table 2.6** Decode of last two figures of runway state

| Code | Meaning | Code | Meaning |
|---|---|---|---|
| 29 | Friction coefficient 0.29 | 94 | Braking action: **Medium/Good**<br>Friction coefficient 0.36–0.39 |
| 36 | Friction coefficient 0.36 | 95 | Braking action: **Good**<br>Friction coefficient 0.4 and above |
| 91 | Braking action: **Poor**<br>Friction coefficient 0.25 and below | 99 | Readings unreliable |
| 92 | Braking action: **Medium/Poor**<br>Friction coefficient 0.26–0.29 | // | Braking action: **Not reported** |
| 93 | Braking action: **Medium**<br>Friction coefficient 0.3–0.35 | | |
| If contamination has been cleared the abbreviation CLRD will be used | | | |

## Remarks

Many European and American METARs include a remarks section at the end of the message, although the UK does not. The World Meteorological Office (WMO) manual of codes states 'the indicator RMK denotes the beginning of a section containing information included by national decision which shall not be disseminated internationally'. Italy, for instance, uses QUK followed by a number to indicate the sea state and QUL followed by a number to indicate the sea swell. Details of the American decode of the remarks can be found on the website at http://205.156.54.206/oso/oso1/oso12/fmh1/fmh1toc.htm.

**Table 2.7** Additional abbreviations used in METARs

| Abbreviations | Meaning | Abbreviations | Meaning |
|---|---|---|---|
| NSC | No significant cloud, i.e., no cloud below 5000 ft above aerodrome elevation or MSA, whichever is the higher, and no cumulonimbus. | NSW | No weather of significance to aviation. |
| NOSIG | No significant change to the conditions is expected in the period stated. | SKC | Sky clear. No cloud at any height. |

## *Example METARs Europe for 30 October 2001*

EGHI 301550Z 20015KT 170V240 8000 FEW009 SCT011 BKN018 16/14 Q1013=
EGPD 301550Z 21016KT 9999 FEW017 SCT044 BKN 080 14/11 Q0991 TEMPO 7000 BKN015=
EGPH 301550Z 23018KT 9999 -RA FEW022 BKN028 14/12 Q0994 REDZ=
EDDB 301550Z 22009KT CAVOK 15/11 Q1014 NOSIG=
LOWG 301550Z VRB01KT 3200 BR MIFG FEW050 SCT140 BKN290 12/12 Q1024 NOSIG=
LIPZ 301550Z 00000KT 1500 R04/P1500N BR SCT003 BKN015 14/12 Q1027=
EPWA 301550Z 27008MPS 250V350 9999 BKN030 13/10 Q1008 TEMPO 28009G14MPS=
ULLI 301550Z 11005MPS 4400 -RA OVC011 05/03 Q0990 NOSIG RMK ALL RWYS CLEAR and DRY 51–100 PCT LESS THAN 1 MM BA72=



## *Decode of METARs*

All the METAR examples given are for the 30th day of the month and the observations were made at 1550 UTC.

**EGHI**

- W/V: 200°(T)/15 kts, the wind direction varied in the previous ten minutes between 170°(T) and 240°(T).
- Visibility: 8000 m.
- Cloud: 1–2 oktas base 900 ft above aerodrome elevation. 3–4 oktas base 1100 ft above aerodrome elevation. 5–7 oktas base 1800 ft above aerodrome elevation.
- Temperature/Dew Point: 16°C/14°C.
- QNH: 1013 hPa.

**EGPD**

- W/V: 210°(T)/16 kts.
- Visibility: 10 km or more.
- Cloud: 1–2 oktas base 1700 ft above aerodrome elevation. 3–4 oktas base 4400 ft above aerodrome elevation. 5–7 oktas base 8000 ft above aerodrome elevation.
- Temperature/Dew Point: 14°C/11°C.
- QNH: 991 hPa.
- TREND: For less than a total of one hour during the next two hours, the visibility will be 7000 m and the cloud will be 5–7 oktas at 1500 ft above aerodrome elevation.

**EGPH**

- W/V: 230°(T)/18 kts.
- Visibility: 10 km or more.
- Weather: Light rain.
- Cloud: 1–2 oktas base 2200 ft above aerodrome elevation. 5–7 oktas base 2800 ft above aerodrome elevation.
- Temperature/Dew Point: 14°C/12°C.
- QNH: 994 hPa.
- Recent weather: There has been moderate drizzle in the last hour but not at the time of observation.

**EDDB**

- W/V: 220°(T)/09 kts.
- Visibility: 10 km or more.
- Weather: There is no precipitation, thunderstorms, shallow fog or low drifting snow.
- Cloud: No cloud below 500 ft above aerodrome elevation or below MSA and there is no cumulonimbus.
- Temperature/Dew Point: 15°C/11°C.
- QNH: 1014 hPa.
- TREND: No significant change expected in the next two hours.

**LOWG**

- W/V: Variable/01 kts.
- Visibility: 3200 m.
- Weather: Mist and shallow fog.
- Cloud: 1–2 oktas base 5000 ft above aerodrome elevation. 3–4 oktas base 14 000 ft above aerodrome elevation. 5–7 oktas base 29 000 ft above aerodrome elevation.
- Temperature/Dew Point: 12°C/12°C.
- QNH: 1024 hPa.
- TREND: No significant change expected in the next two hours.

**LIPZ**

- W/V: Calm.
- Visibility: 1500 m.
- RVR: Runway 04 RVR greater than 1500 m not changing.
- Weather: Mist.
- Cloud: 3–4 oktas base 300 ft above aerodrome elevation. 5–7 oktas base 1500 ft above aerodrome elevation.
- Temperature/Dew Point: 14°C/12°C.
- QNH: 1027 hPa.

**EPWA**

- W/V: 270°(T)/08 mps. The direction varied between 250°(T) and 350°(T) in the previous ten minutes.
- Visibility: 10 km or more.
- Cloud. 5–7 oktas base 3000 ft above aerodrome elevation.
- Temperature/Dew Point: 13°C/10°C.
- QNH: 1008 hPa.
- TREND: For less than a total of one hour during the next two hours the wind will be 280°(T)/09 mps with a maximum gust strength of 14 mps.

**ULLI**

- W/V: 110°(T)/05 mps.
- Visibility: 4400 m.
- Weather: Light rain.
- Cloud: 8 oktas base 1100 ft above aerodrome elevation.
- Temperature/Dew Point: 05°C/03°C.
- QNH: 990 hPa.
- TREND: No significant change expected in the next two hours.
- Remarks: All runways dry and clear of contamination with a coefficient of friction between 0.51 and 1.00. Less than 1 mm of standing water.

## *The interpretation of TAFs*

There are two types of TAF. They can usually be differentiated in the preamble by a prefix attached to the area code. For example, FCUK31 indicates that it is a 9-hour forecast for UK area 31, whereas ftUK31 would indicate that it is an 18-hour TAF for the same area. The abbreviations used are the same as those used for METARs. The main differences between the METAR and the TAF are that a validity period is stated immediately after the transmission date/time group and any change to the forecast, such as BECMG or TEMPO, will have a time period quoted after the abbreviation, during which the change is expected to occur. However, in a TAF, TEMPO means a variation to the main forecast for a total of less than half of the period quoted. Additionally, the likelihood of an occurrence can be quoted as a PROB. This is the percentage probability of the forecast condition occurring. The forecaster is not permitted to use 50% or above because it would then become the main forecast. Usually only 30% or 40% probabilities are used, because 20% is too low a probability with which to bother.

## *Example TAFs*

EGHI 301512Z 301623 21012KT 8000 SCT 012 BKN020 TEMPO 1623 20016G27KT 9999 BKN010 PROB30 TEMPO 1723 4000 BR BKN005=

EGPD 301506Z 301623 21017G27KT 9999 SCT015 BKN030 TEMPO 1623 7000 -RA BKN012 PROB40 RA BKN007 BECMG 1719 25008KT=

EDDB 301000Z 301812 24010KT CAVOK TEMPO 0712 23015G25KT=

LOWG 301000Z 301812 VRB03KT 4000 BR NSC 2022 3000 MIFG BECMG 2224 0200 BCFG PROB30 TEMPO 0006 0100 FG VV001 BECMG 0710 3500 BR FEW050 BECMG 1012 23010KT 9999=

ULLI 301000Z 301212 16009G14MPS 5000 BR RA BKN007 TEMPO 1220 1500 SHRA BKN004 BKN010CB BECMG 2224 VRB03MPS TEMPO 2006 1000 SHRA BKN003 BKN010CB BECMG 0608 23006G11MPS TEMPO 0612 1600 SHRA BKN005 BKN010CB=



## *Decode of TAFs*

**EGHI**

- Transmitted on 30th day of the month at 1512Z.
- Validity period: 30th day of the month from 1600Z to 2300Z.
- W/V: 210°(T)/12 kts.
- Visibility: 8000 m.
- Cloud: 3–4 oktas base 1200 ft above aerodrome elevation. 5–7 oktas base 2000 ft above aerodrome elevation.
- Temporarily: For less than half the period between 1600Z and 2300Z the forecast is W/V 200°(T)/16 kts with a maximum speed of 27 kts, the visibility 10 km or more, the cloud 5–7 oktas with a base at 1000 ft above aerodrome elevation.
- Probability: There is a 30% probability that for less than half the period between 1700Z and 2300Z the visibility will be 4000 m in mist with 5–7 oktas of cloud having a base at 500 ft above aerodrome elevation.

**EGPD**

- Transmitted on 30th day of the month at 1506Z.
- Validity period: 30th day of the month from 1600Z to 2300Z.
- W/V: 210°(T)/17 kts with a maximum speed of 27 kts.
- Visibility: 10 km or more.
- Cloud: 3–4 oktas base 1500 ft above aerodrome elevation. 5–7 oktas base 3000 ft above aerodrome elevation.
- Temporarily: For less than half the period between 1600Z and 2300Z the

forecast is visibility 7000 m in light rain, the cloud 5–7 oktas with a base at 1200 ft above aerodrome elevation.

- Probability: There is a 40% probability that for less than half the period between 1600Z and 2300Z there will moderate rain with 5–7 oktas of cloud having a base at 700 ft above aerodrome elevation.
- Becoming: Between 1700Z and 1900Z the W/V will change for the rest of the forecast period to become 250°(T)/08 kts.

**EDDB**

- Transmitted on 30th day of the month at 1000Z.
- Validity Period: 30th day of the month from 1800Z to 1200Z on the 31st day of the month.
- W/V: 240°(T)/10 kts.
- Visibility: 10 km or more.
- Cloud: No cloud below 5000 ft above aerodrome elevation or MSA, whichever is the higher. No thunderstorms.
- Temporarily: For less than half the period between 0700Z and 1200Z on the 31st day of the month the forecast is W/V 230°(T)/15 kts with a maximum speed of 25 kts.

**LOWG**

- Transmitted on 30th day of the month at 1000Z.
- Validity Period: 30th day of the month from 1800Z to 1200Z on the 31st day of the month.
- W/V: Wind direction variable at speed 3 kts.
- Visibility: 4000 m.
- Weather: Mist.
- Cloud: No cloud below 5000 ft above aerodrome elevation or MSA, whichever is the higher. No thunderstorms.
- Temporarily: For less than half the period between 2000Z and 2200Z, the visibility will be 3000 m in shallow fog.
- Becoming: Between 2200Z and 2400Z, the visibility will fall to 200 m in banks or patches of fog. This is a deterioration, assume it to occur at 2200Z.
- Temporarily: During the period 0000Z and 0600Z on the 31st day of the month there is a 30% probability that for less than half the period the visibility will fall to 100 m in fog with a vertical visibility of 100 ft.
- Becoming: Between 0700Z and 1000Z the visibility will improve to 3500 m in mist with 1–2 oktas of cloud base 5000 ft above aerodrome elevation. This is an improvement, assume it to occur at 1000Z.
- Becoming: Between 1000Z and 1200Z on the 31st day of the month, the W/V will be 230°(T)/10 kts and the visibility will be 10 km or more. This is an improvement, assume it to occur at 1200Z.

**ULLI**

- Validity Period: 30th day of the month from 1200Z to 1200Z on the 31st day of the month.
- W/V: 160°(T)/09 mps maximum gust speed 14 mps.
- Visibility: 5000 m.
- Weather: Mist and moderate rain.
- Cloud: 5-7 oktas base 700 ft above aerodrome elevation.
- Temporarily: For less than half the period between 1200Z and 2000Z, the visibility will be 1500 m in moderate rain showers with 5–7 oktas of cloud base 400 ft above aerodrome elevation and 5–7 oktas of cumulonimbus base 1000 ft above aerodrome elevation.
- Becoming: Between 2200Z and 2400Z, the wind velocity will become variable at 03 mps.
- Temporarily: During the period 2000Z and 0600Z on the 31st day of the month for less than half the period the weather will become moderate rain showers with a visibility of 1000 m with 5–7 oktas of cloud base 300 ft above aerodrome elevation and 5–7 oktas of cumulonimbus base 1000 ft above aerodrome elevation.
- Becoming: Between 0600Z and 0800Z the wind velocity will become 230°(T)/06 mps with a maximum gust speed of 11 mps.
- Temporarily: For less than half of the period between 0600Z and 1200Z on the 31st day of the month the visibility will become 1600 m in moderate rain showers with 5–7 oktas of cloud base 500 ft above aerodrome elevation and 5–7 oktas of cumulonimbus base 1000 ft above aerodrome elevation.

## Weather and wind charts

Weather and wind charts can be divided into low-level and high-level charts and are produced for all areas of the world by the Meteorological Office. The symbols and abbreviations used are the same on all of these charts. They are shown and described in Tables 2.8–2.11.

### *The UK Low-level Forecast Chart (Form 215)*

The UK Low-level Forecast Chart is valid for a period of six hours. The time of issue and the validity period is stated at the top of the chart. The form contains two charts, the left chart is the forecast weather for the time at the middle of the validity period and the right chart is the outlook chart for the time at six hours after the end of the validity period. The text to the left of the charts specifies that all heights on the chart and in the textual descriptions are above mean sea level.

Beneath the chart is a descriptive table of the weather, visibility, cloud, turbulence and icing in each of the weather zones. These are numbered

**Table 2.8** Cloud type abbreviations

| Abbreviations | Cloud type |
|---|---|
| AC | Altocumulus |
| AS | Altostratus |
| CB | Cumulonimbus |
| CC | Cirrocumulus |
| CI | Cirrus |
| CS | Cirrostratus |
| CU | Cumulus |
| NS | Nimbostratus |
| SC | Stratocumulus |
| ST | Stratus |
| The datum used for the cloud base is dependent on the chart | |

**Table 2.9** Significant weather symbols

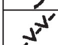
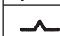
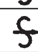
| Symbol | Meaning | Symbol | Meaning |
|---|---|---|---|
|  | Thunderstorms |  | Drizzle |
|  | Tropical cyclone |  | Rain |
|  | Severe line-squall |  | Snow |
|  | Moderate turbulence |  | Shower |
|  | Severe turbulence |  | Widespread high blowing snow |
|  | Mountain waves |  | Severe sand or dust haze |
|  | Moderate icing |  | Widespread sand or dust storm |
|  | Severe icing |  | Widespread haze |
|  | Widespread fog |  | Widespread mist |
|  | Hail |  | Widespread smoke |
|  | Volcanic eruption |  | Freezing precipitation |
|  | Visible ash cloud | | |

**Table 2.10** Other weather symbols

| Symbol | Meaning | Symbol | Meaning |
|---|---|---|---|
|  | Surface cold front |  | Surface warm front |
|  | Surface occluded front |  | Surface quasi-stationary front |
|  | Intertropical convergence zone |  | Convergence line |
|  | Tropopause level |  | Tropopause high point |
|  | Tropopause low point |  | Freezing level |
|  | State of the sea |  | Sea surface temperature |
|  | Wind pennant – 50 kts |  | Wind feather – 10 kts |
|  | Half wind feather – 5 kts |  | ±20 kts or ±3000 ft |

**Table 2.11** Depicting lines or symbols

| Type of line | Meaning |
|---|---|
| Scalloped | Demarcation of significant weather area. |
| Heavy broken | Demarcation of clear air turbulence area (CAT). |
| Heavy solid | Position of the core of a jet stream with arrow indicating its direction, symbol for its speed and labelled with its flight level. |
| Figures on arrows | Speed, usually in knots, and direction of movement of weather area or frontal system. |
| Small rectangles | Inside the symbol is the flight level of the tropopause at that position. If the symbol has an upward pointing arrow it indicates a locally high point of the tropopause and a downward pointing arrow a locally low point of the tropopause. |
| X | This indicates the position of a centre of pressure, the value of which is stated beside the symbol. |
| L | Centre of a low-pressure system. |
| H | Centre of a high-pressure system. |
| Feathered arrow | The direction from which the wind is blowing and the number of pennants and/or feathers indicates its strength. A pennant represents 50 kts (93 kmh), a feather represents 10 kts (18 kmh) and a half feather represents 5 kts (9 kmh). |
| Boxed 0°C | This only appears on the low or medium level charts and states the height above mean sea level of the 0°C isotherm. |

scalloped areas on the left chart. At the bottom of the table is a description of the weather outlook relating to the right chart. Figure 2.1 is such a form issued by the Met Office for 30 October 2001.

In the left chart of Figure 2.1, there are four weather areas denoted by numbers enclosed within circles. Zone 1 in the north-west of the chart is moving south-east at 15 kts. Zone 2 in the north-east of the chart is moving to the north-east at 10 kts. The centre of the low pressure in Zone 2, which is denoted by L, has a pressure of 994 hPa and is moving north-east at 25 kts. The southernmost cold front in Zone 2 is moving south-east at 20 kts and the warm front is travelling north-east at 10 kts. On the scalloped line separating Zones 3 and 4 is written the word SLOW, this indicates that weather Zone 3 is moving east at less than 5 kts.

The freezing level in each of the zones is shown in large rectangles that enclose 0°C, followed by the appropriate height above mean sea level in 1000s of feet. The latitude and longitude are barely discernable but are shown with faint dots at every degree and a small cross at every five degrees. The 50°N, 55°N and 60°N parallels and the 0° and 10°W meridians are appropriately labelled.

The right chart shows the isobars at even four hectopascal intervals together with the surface position of the fronts and the centre of the low pressure.

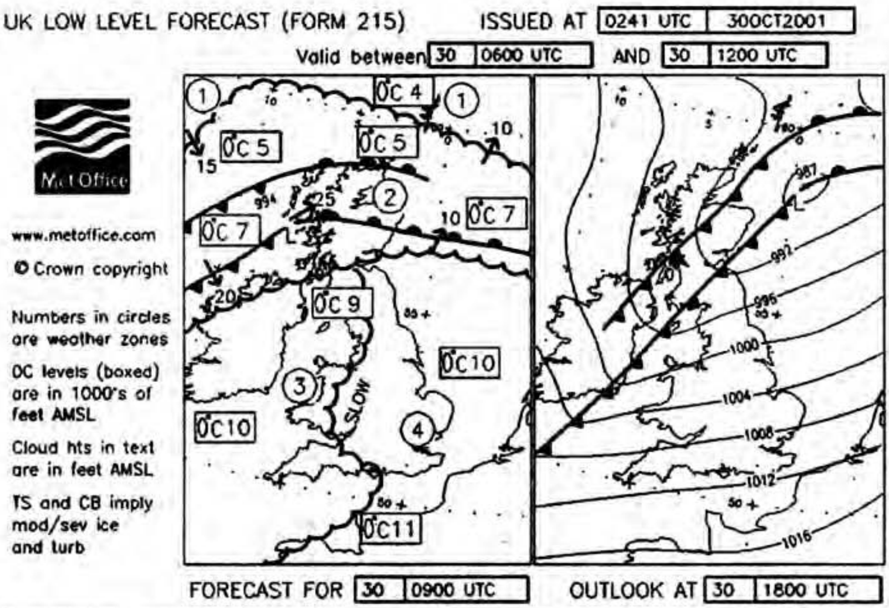
Below the charts there is a table that describes the weather, visibility, cloud, turbulence and icing in each of the zones on the left chart. Each zone in the table is divided in four columns. The first column states the location within the zone, the second quotes the visibility for each of the locations, the third gives the weather in each location and the final column describes the cloud, turbulence and icing for those locations.

## *Interpretation of the zone weather*

It is only necessary to interpret the first two Zones as an example, the remainder can be interpreted in a similar manner:

### Zone 1

- Generally: the visibility is 30 km and there is no weather. The cloud is 3–6 oktas of cumulus and stratocumulus between 2500 ft and 6000 ft above mean sea level.
- Isolated in the east and occasionally in the west of the zone: the visibility is 10 km in rain showers from 7 oktas of cumulus, which extends between 1800 ft and 10 000 ft above mean sea level.
- Isolated in the west of the zone: the visibility is 4000 m in heavy rain showers from 7 oktas of cumulonimbus between 1500 ft and 16 000 ft above mean sea level. There will be moderate icing above the freezing level, which is 4000 ft above mean sea level, in cloud except in cumulonimbus cloud where moderate or severe icing can be expected at any




| | | | |
|---|---|---|---|
| ZONE 1 GEN | 30KM | NIL | 3–6/8CUSC 2500/6000. |
| ISOL E, OCNL W | 10KM | RA SH | 7/8CU 1800/10000. |
| ISOL W | 4000M | HEAVY RA SH | 7/8CB 1500/16000. |
| | | | MOD ICE AND MOD TURB IN CLD. |
| ZONE 2 GEN | 8KM | RA | 5/8SC 2000/6000, 8/8LYR 6000/20000. |
| OCNL E OF HILLS | 15KM | NIL | 2/8SC 3000/6000, 6–8/8LYR 8000/20000. |
| WDSPR W, OCNL E FRONTS AND S | 5000M | RA | 3–6/8ST 1000/1500, 8/8LYR 1800/22000. |
| ISOL MAINLY NEAR AND SE OF LOW | 3000M | HEAVY RA | 6/8ST 500/1500. 8/8NS 1500/24000. |
| | | | CLD ON HILLS. MOD ICE AND MOD TURB IN CLD. OCNL SEV ICE IN NS. MOD ISOL SEV TURB BLW 6000 S OF MORE S'LY FRONTS. MTW MAX VSP 500FPM NEAR 8000, S. |
| ZONE 3 GEN | 4000M | MIST | 3–6/8ST 500/1200, 2–6/8SC 1800/3000. |
| ISOL BEC OCNL MAINLY LAND E | 10KM | NIL | 5/8SC 1800/3000. |
| ISOL N | 8KM | RA | 3–6/8ST 800/1500. 6/8AC 9000/16000. |
| OCNL SEA/COT S | 400M | FOG | 7/8ST SFC/1000. |
| | | | CLD ON HILLS. MOD ICE AND MOD TURB IN AC. MOD, ISOL SEV IN N. TURB BLW 6000. |
| ZONE 4 GEN | 12KM | NIL | 2–5/8SC 2000/5000. |
| OCNL | 7KM | HAZE | 3/8ST 1200/1500, 2–5/8SC 2000/5000. |
| ISOL MAINLY LAND S | 4000M | MIST | 5/8ST 800/1500. |
| ISOL CONTINENT TO 10Z | 200M | FOG | 6/8ST SFC/500. |
| | | | CLD ON HILLS. MOD TURB N OF 50N, AND ISOL SEV TURB N OF 53N, BLW 6000. MTW MAX VSP 500FPM NEAR 8000, N. |
| OUTLOOK UNTIL 301800Z: SH IN NW, SOME HEAVY WITH RISK TS OR HAIL. LITTLE CHANGE ELSEWHERE | | | |

**Figure 2.1** UK Low-level Forecast Chart (Form 215). (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

height. Moderate turbulence can be expected in cloud except in cumulonimbus where it may be severe.

**Zone 2**

- Generally: 8 km visibility in moderate rain with 5 oktas of stratocumulus between 2000 ft and 6000 ft and an 8 oktas layer between 6000 ft and 20 000 ft.
- Occasionally east of hills in the zone: the visibility is 15 km with no weather and 2 oktas of stratocumulus between 3000 ft and 6000 ft and a further layer of 6–8 oktas between 8000 ft and 20 000 ft.
- Widespread in the west of the zone and occasionally east of fronts and in the south of the zone: the visibility is 3000 m in heavy rain with 6 oktas of stratus extending between 500 ft and 1500 ft and 8 oktas of nimbostratus extending between 1500 ft and 24 000 ft.
- General warnings: cloud on hills in which the visibility will be less than 200 m. There will be moderate icing above the freezing level in cloud but severe icing is forecast in nimbostratus. Moderate turbulence is expected in cloud at any height. Below 6000 ft above mean sea level, south of the more southerly fronts in the zone, turbulence is expected to be moderate but severe in isolated areas. Near 8000 ft in the south of the zone mountain waves are forecast with a maximum vertical speed of 500 feet per minute.
- Outlook: until 1800 UTC showers are forecast in the north-west of the chart, some heavy with a risk of thunderstorms or hail. Elsewhere there will be little change.

## *The UK Low-level Spot Wind Chart (Form 214)*

The issue of a Low-level Forecast Chart (Form 215) is always accompanied by the issue of a Low-level Spot Wind Chart (Form 214). The chart covers the UK and some of the north-west of Europe. The parallels of latitude are spaced at 2°30´ intervals which are labelled every 5°. The interval and labelling of the meridians is the same. Figure 2.2 is the chart that accompanied the Low-level Forecast Chart shown in Figure 2.1.

This chart contains boxes in which the wind velocity and ambient temperature at fixed heights above mean sea level are printed. The boxes are at fixed positions on the chart. At the top of every box the latitude and longitude of the centre of the box is specified. Unfortunately, because of congestion on the chart very few of the boxes are sited in the correct position, but the contents of the box apply to the position as detailed. The heights for which the wind velocity is given are fixed and are 1000, 2000, 5000, 10 000, 18 000 and 24 000 ft. The wind directions are true directions and the temperatures are in degrees Celsius.

To obtain precise values for a specific height and/or position it may be necessary to interpolate between the listed values. For example, if the W/V

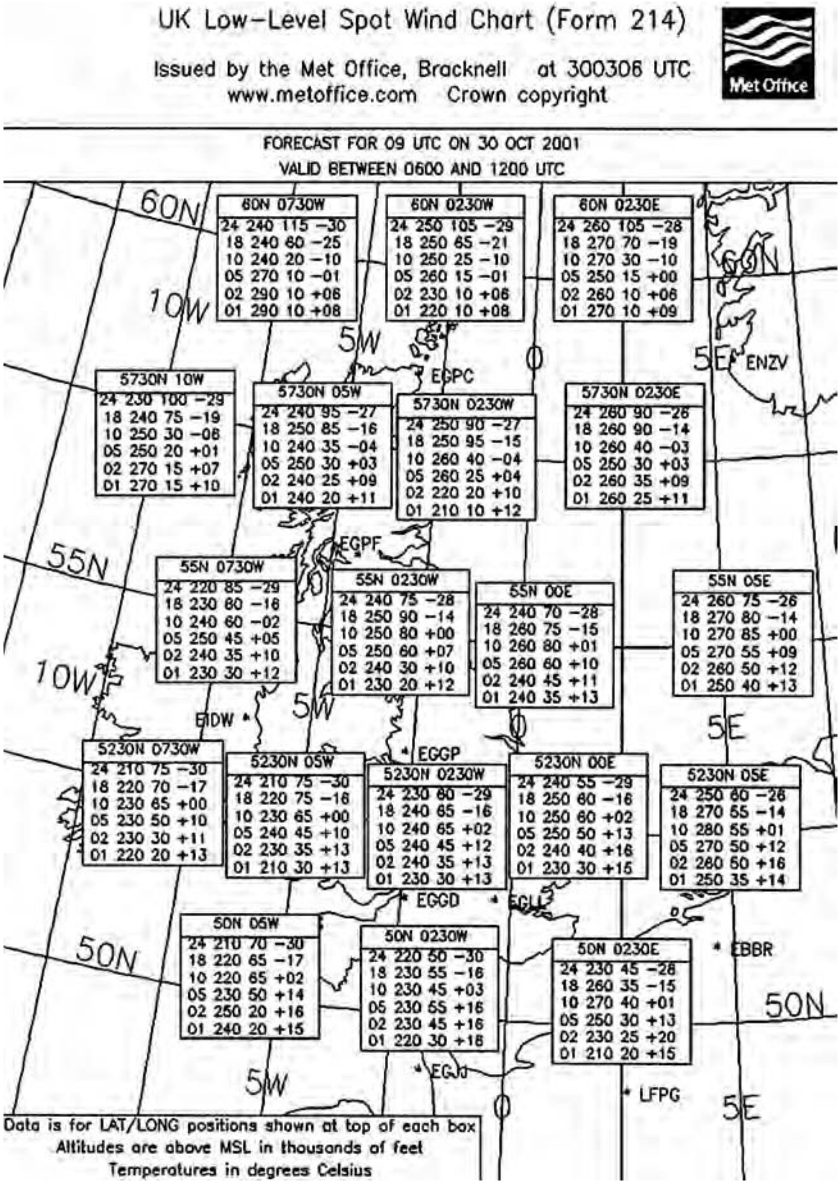



**Figure 2.2** UK Low-level Spot Wind Chart (Form 214). (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

and temperature are required for 50°N 02°30'W at a height of 10 000 ft it would be read directly from the chart as 230/45 +03°C. However, if the same details were required for the same height but at 50°N 00°00'W it would be necessary to interpolate between the details given at 50°N 02°30'W and 50°N 02°30'E. The required information would then be 250/42½ and +02°C. Similarly if the details were needed for a height of 14 000 ft above mean sea level for the same location then the details would have had to have been interpolated for altitude as well as position. At 50°N 02°30'W at 14 000 ft the details are 230/50 –6½°C and at 50°N 02°30'E they are 265/37½ –7°C. The result would therefore be 247½/44 –7°C. Most times the JAA select the exact position of one of the boxes and require only the height to be interpolated.

The European version of Form 215 is Form 415, which is shown in Figure 2.3(a), with the accompanying text in Figure 2.3(b). The interpretation of the chart and text is the same as that of the UK chart.

The example chart in Figure 2.3(a) is valid at 1500 UTC on 30 October 2001 and was issued at 0923 UTC on the same day. The interpretation of Zone 4, given in Table 2.12, shows that all abbreviations and symbols are the same as those used on the UK chart Form 215.

**Table 2.12**

| Area within the zone | Visibility (km) | Weather | Cloud |
|---|---|---|---|
| Generally | 12 km | No weather | 2–5 oktas of stratocumulus between base 2000 ft and tops 5000 ft. |
| Occasionally | 7 km | Haze | 0–3 oktas of stratus between base 1200 ft and tops 1500 ft. 2–5 oktas of stratocumulus between base 2000 ft and tops 5000 ft. |
| Isolated over the continent until 1300UTC | 4 km | Mist | 5 oktas of stratus between base 800 ft and tops 1500 ft. |
| Cloud on hills in which the visibility will be less than 200 m. There will be moderate turbulence north of 49°N below 6000 ft, but there will be isolated patches of severe turbulence in the same area. The freezing level is mainly 10 000 ft but will be 11 000 ft in the west of the zone. | | | |

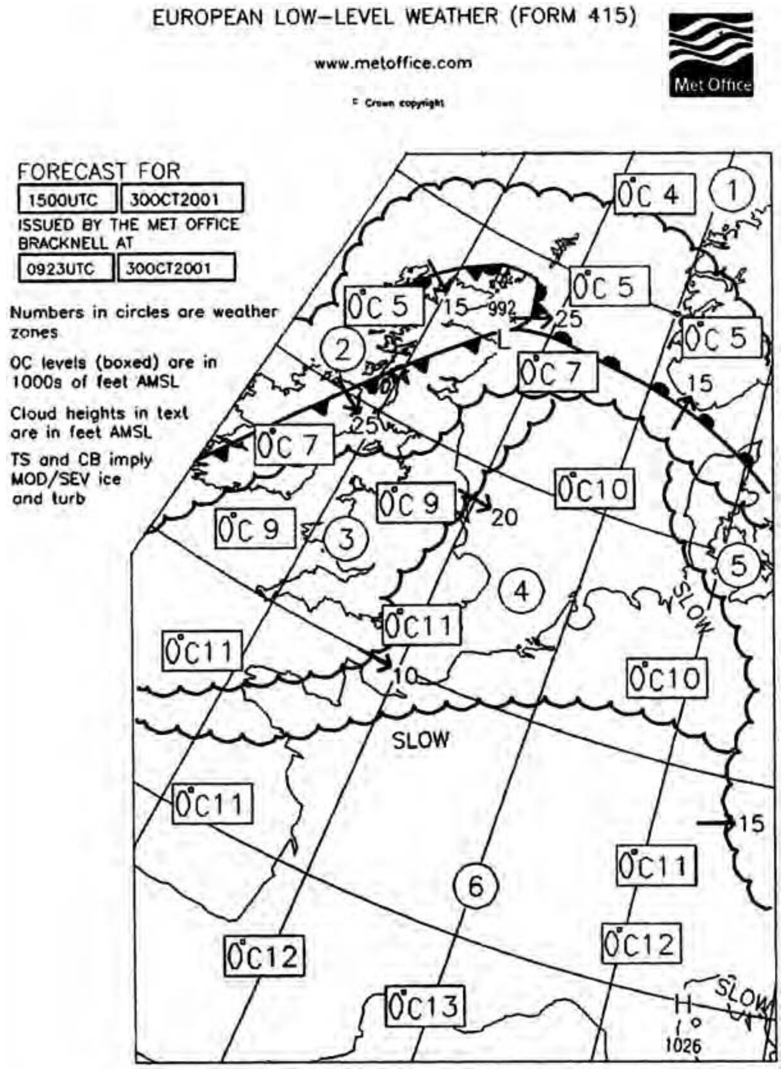



Figure 2.3(a) European Low-Level Weather Chart. (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

## *World Upper Weather Charts*

The World Area Forecast Centre at Bracknell issue fixed time forecast charts for most regions of the world at selected Flight Levels. In the legend is a statement of the area and altitude coverage. The same text area contains a statement regarding the time of validity of the chart.

The chart may be a Lambert Conical Orthomorphic, a Polar Stereographic or a Mercator projection. On all types of chart, degrees of latitude are shown by dots along meridians and degrees of longitude by dots along parallels of

METFAX AVIATION

EUROPEAN LOW LEVEL WEATHER CHART. F415
ISSUED BY THE MET OFFICE, BRACKNELL
SUITABLE FOR INITIAL DEPARTURES AND FLIGHTS BETWEEN 301200 AND 301800

NOTE: PILOTS ARE ADVISED TO OBTAIN LATEST TAFS AND METARS BEFORE
TAKE-OFF. AMENDMENTS, IF INCLUDED, FOR F215 AREA – UK ONLY.

| | | | |
|---|---|---|---|
| ZONE 1 GEN | 30KM | NIL | 3–6/8CUSC 2500/6000. |
| ISOL E, OCNL W | 8KM | RA SH | 7/8CU 1800/10000. |
| ISOL W | 3000M | TS/HEAVY RA SH | 7/8CB 1500/18000. |
| | | | CLD ON HILLS. MOD ICE AND MOD TURB IN CLD. |
| ZONE 2 GEN | 12KM | RA | 5/8SC 2000/6000, 8/8LYR 6000/18000. |
| OCNL N AND NW | 25KM | NIL | 2–5/8CUSC 2500/7000, 6–8/8LYR 7000/14000. |
| OCNL FRONTS, WDSPR SE OF COLD FRONT | 5000M | RA | 3–6/8ST 1000/1500, 8/8LYR 1800/22000. |
| ISOL MAINLY W SCOTLAND | 3000M | HEAVY RA | 6/8ST 200/1500, 8/8NS 1500/24000. |
| | | | CLD ON HILLS. MOD ICE AND MOD TURB IN CLD. OCNL SEV ICE IN NS. MOD ISOL SEV TURB BLW 6000 WARM SECTOR. MTW MAX VSP 500FPM NEAR 8000 WARM SECTOR. |
| ZONE 3 GEN | 7KM | HAZE | 2–5/8ST 1000/1500, 4–7/8SC 1800/5000. |
| OCNL E | 10KM | NIL | 5/8SC 2500/5000. |
| ISOL | 8KM | RA | 3–6/8ST 800/1500, 6/8AC 9000/16000. |
| OCNL SEA/COT W AND S | 2000M | MIST | 6/8ST 300/1200, 4–7/8SC 1800/5000. |
| | | | CLD ON HILLS. MOD ICE AND MOD TURB IN AC. MOD, ISOL SEV N OF 52N, TURB BLW 6000. MTW MAX VSP 500FPM NEAR 8000. |
| ZONE 4 GEN | 12KM | NIL | 2–5/8SC 2000/5000. |
| OCNL | 7KM | HAZE | 0–3/8ST 1200/1500, 2–5/8SC 2000/5000. |
| ISOL CONTINENT TO 13Z | 4000M | MIST | 5/8ST 800/1500. |
| | | | CLD ON HILLS. MOD ISOL SEV TURB N OF 49N, BLW 6000. |
| ZONE 5 GEN | 15KM | NIL | 6/8CUSC 2000/3500. |
| OCNL | 8KM | HAZE | 8/8SC 1500/5000. |
| | | | CLD ON HILLS. MOD OCNL SEV TURB BLW 6000, N OF 52N. |
| ZONE 6 GEN | 8KM | HAZE | NIL. |
| LOC MON | 20KM | NIL | NIL. |
| ISOL BUT WDSPR PO VALLEY | 2000M | MIST | 3/8ST 400/700. |
| ISOL MAINLY PO VALLEY | 200M | FOG | 6/8ST SFC/500. |
| | | | ISOL CLD ON HILLS. |

**Figure 2.3(b)** Text of the European Weather Chart. (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

latitude. Only every ten degrees are labelled as such. All charts show the position and initial letter of major cities on the chart. Of particular significance to the JAA examiners are the charts issued for Europe and the Mediterranean together with the associated upper wind charts.

Directly beneath this area of the legend it states that all height indications are Flight Levels and all speeds are in knots. It also specifies that the thunderstorm symbol or CB indicate moderate or severe icing and turbulence. Tropopause heights for the general area are shown as Flight Levels in rectangular boxes; however, locally high or low points are shown in arrow-shaped boxes.

Weather areas have a scalloped outline, in which a boxed abbreviated text of the weather is enclosed, or positioned nearby with an arrow indicating the area to which it applies. Standard abbreviations are used and are the ones already described. On the chart the surface position of all fronts are shown at the time of the chart. Across each front there is usually a small arrow with a number; this shows the direction and speed of movement of the front. If the symbol xxx is printed below the Flight Level shown for a particular feature it indicates that the lowest level or base level of that feature is below the lower limit of the chart.

Clear air turbulence areas are shown by a pecked outline, within which is a number in a small square box. In the legend of the chart against the same numbered symbol will be a statement of the severity and altitude limits of the turbulence within that area.

The cores of jet stream are shown by heavy black lines on which the appropriate wind symbol is attached to represent the mean speed of the core in that area and will comprise pennants, feathers and half-feathers to the nearest five knots. Two parallel lines may be across the heavy black line main core if the value of the speed varies from the mean by ±20 kts or the altitude varies by ±3000 ft.

Volcanic activity is notified under the appropriate volcano symbol by the date and time (UTC) of any activity during the month of issue of the chart. Specific mention is made in the legend that SIGMETs must be checked for the whereabouts of any volcanic ash clouds. Often they are shown on the appropriate chart, depicting the plume and its direction and speed of movement.

Figure 2.4 depicts the forecast chart for the north-west of Europe and the Mediterranean area, on a Lambert Conical Orthomorphic Chart, between FL100 and FL450 at 1800 UTC on 10 April 2000. Figure 2.5 shows the forecast weather for the North Atlantic on a Transverse Mercator Chart for the same time and day but between FL250 and FL630. Figure 2.6 depicts the forecast weather at 1800 UTC on 18 April 2001 for the whole of Europe, the Mediterranean, the Middle East and the whole of Africa on a Mercator Chart, between FL250 and FL630. Figure 2.7 shows the forecast weather for the whole of Europe, the Mediterranean, the Middle East and the Far East on a Transverse Mercator Chart, between FL250 and FL630 on 19 April 2001.

An interpretation of some of the weather symbols on each chart will suffice to enable more detailed analysis to be made. On Figure 2.4, notice the volcano symbol for Mount Etna is positioned over the English Channel but investigation of the latitude and longitude stated will show a similar symbol correctly positioned. Table 2.13 gives the interpretation of some of the areas on Figure 2.4.

**Table 2.13** Interpretation of Figure 2.4

| **Position** | **65° N 20° W Iceland** | **60° N 10° W** | **60° N 02° E Norway** | **53° N 00° E East Spain** |
|---|---|---|---|---|
| Cloud | Broken layer of cumulus, stratocumulus and alto cumulus | Broken overcast layer of cumulus, stratocumulus and altocumulus | Broken overcast layer | Overcast layer |
| Turbulence | Moderate turbulence from below FL100 up to FL160 | Moderate turbulence from below FL100 up to FL140 | Moderate turbulence from below FL100 up to FL150 | Moderate turbulence from below FL100 up to FL200 |
| Icing | Moderate icing from below FL100 up to FL100 | Moderate icing from below FL100 up to FL140 | Moderate icing from below FL100 up to FL150 | Moderate icing from below FL100 up to FL150 |
| CB | Nil | Nil | Nil | Isolated, embedded from below FL 100 to FL 230 |
| Surface fronts | Occluded front moving south at 15 kts | Nil | Occluded front moving south-east | Occluded front moving west at 10 kts |
| Tropopause | FL250 | FL250 | FL310 | FL300 |
| CAT areas | Area 6: Moderate turbulence between FL190 and FL380 | Area 6: Moderate turbulence between FL190 and FL380 and Area 3: Moderate turbulence between FL190 and FL380 | Area 3: Moderate turbulence between FL190 and FL380 | Nil |
| Jet streams | At 60°N 12°W 320/150 at FL290. The core values may vary by ±20 kts or ±3000 ft | Nil | At 65°N 10°E 260/90 at FL290 | Nil |

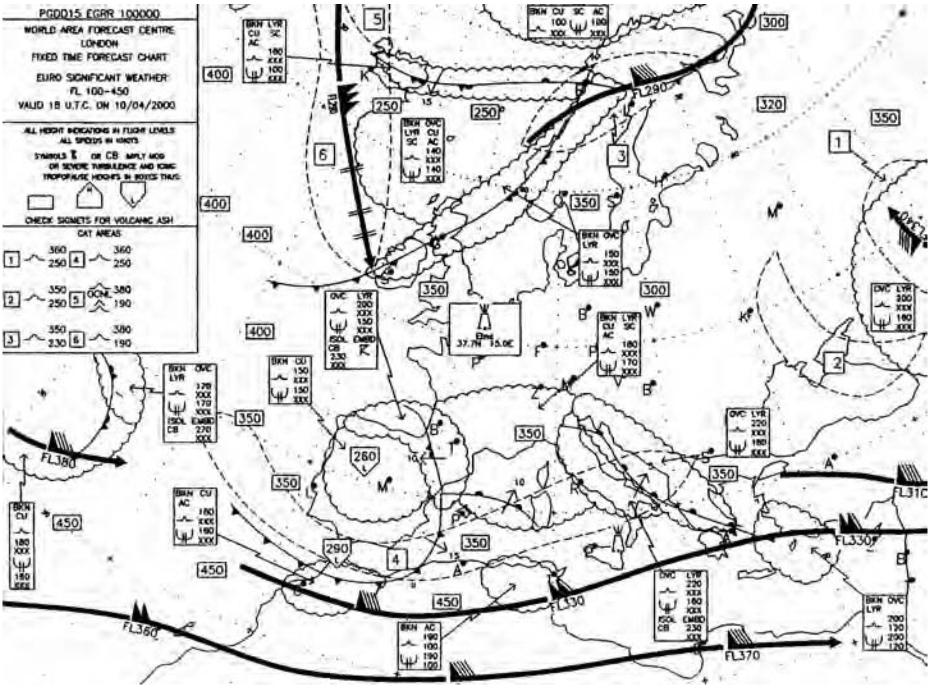



**Figure 2.4** Europe and the Mediterranean. (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

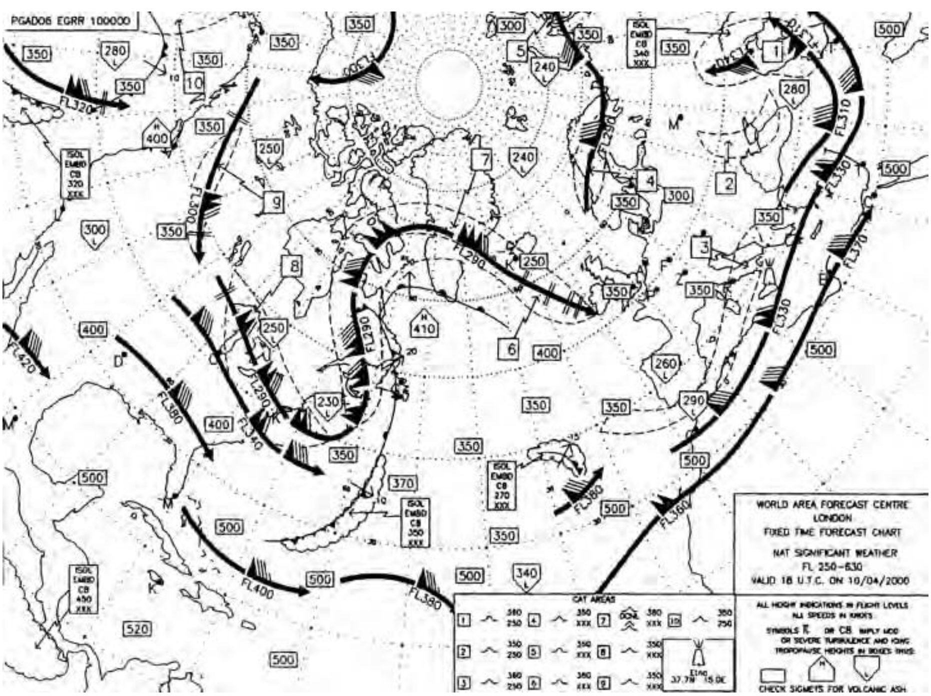



**Figure 2.5** North Atlantic. (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

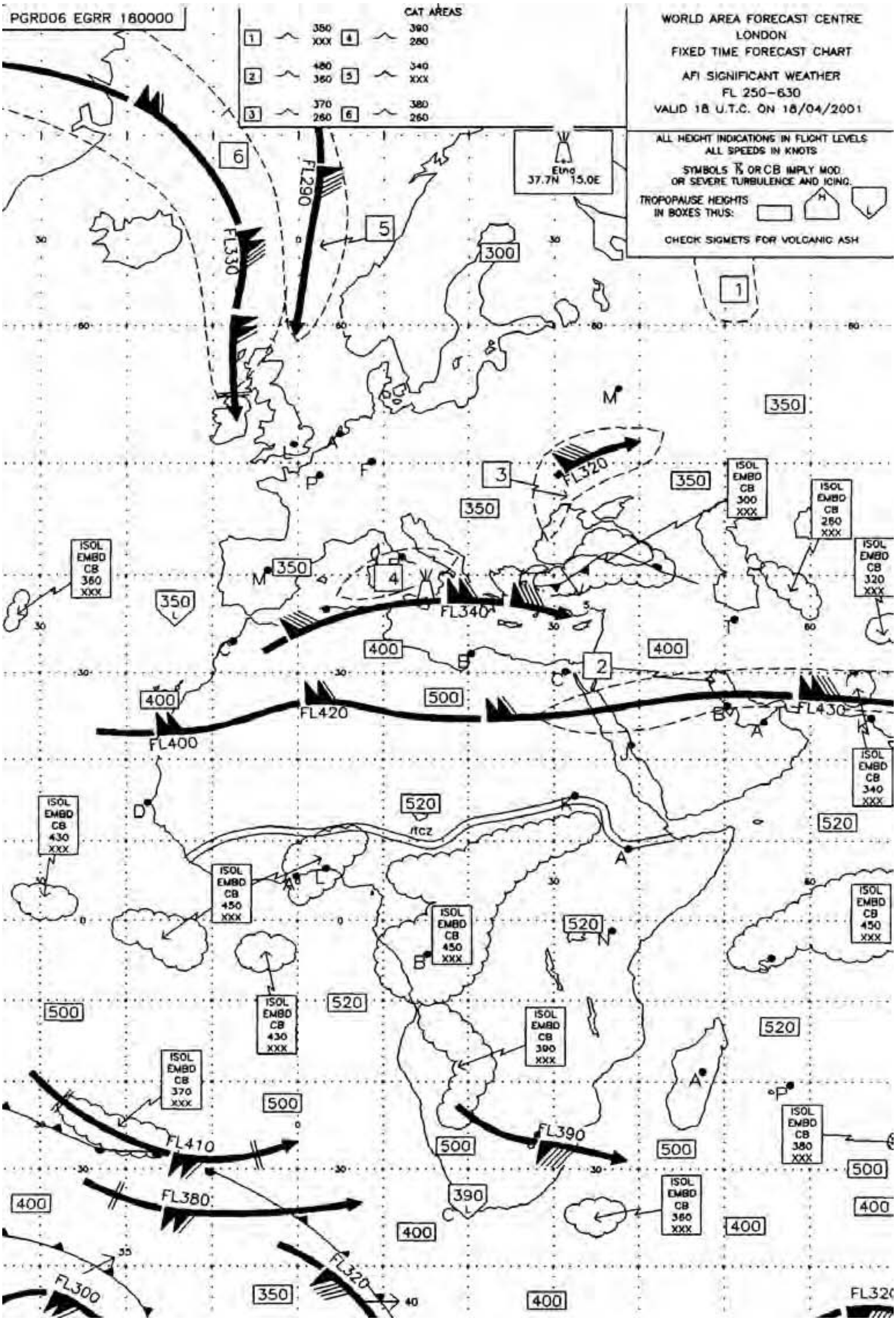



**Figure 2.6** Europe, Middle East and Africa. (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

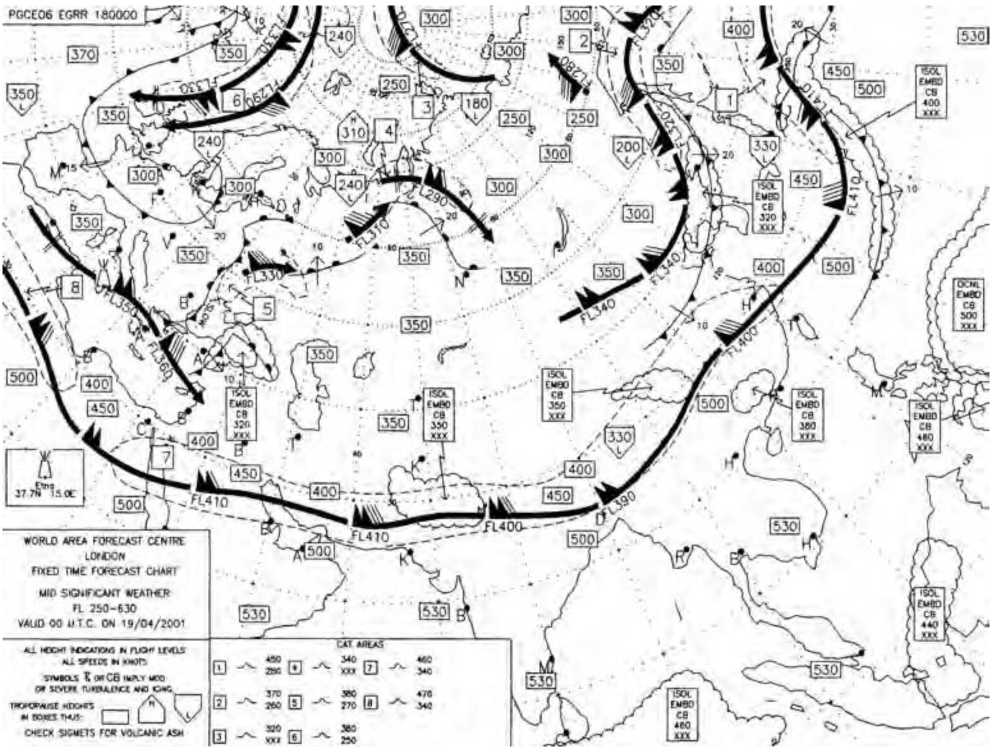



**Figure 2.7** Europe, Middle East and Far East. (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

Particularly note on the previous charts the Intertropical Convergence Zone shown in Figure 2.6 as two parallel lines at approximately 10°N over Africa (tropical thunderstorms and associated bad weather are likely to occur here) and the jet stream at 25°N. The jet stream is shown the next day at approximately the same latitude and extending on Figure 2.7 from North Africa to Japan.

## *Upper Wind Charts*

Issued with each Upper Weather Chart is a series of Upper Wind Charts for specific Flight Levels. The winds and temperatures are shown in the same manner on all charts. The direction from which the wind is blowing is shown by the shaft of an arrow pointing into an exact intersection of a meridian of longitude and a parallel of latitude. They will be depicted at a set interval, which is dependent on the chart scale and the latitude, along specific meridians and parallels. At low latitudes, it is usually 5° and at high latitudes, it is normally 10°. The speed is shown by the combination of pennants and feathers appended to the shaft of the arrow.

The temperature at each 5° or 10° interval of position is printed beside the wind

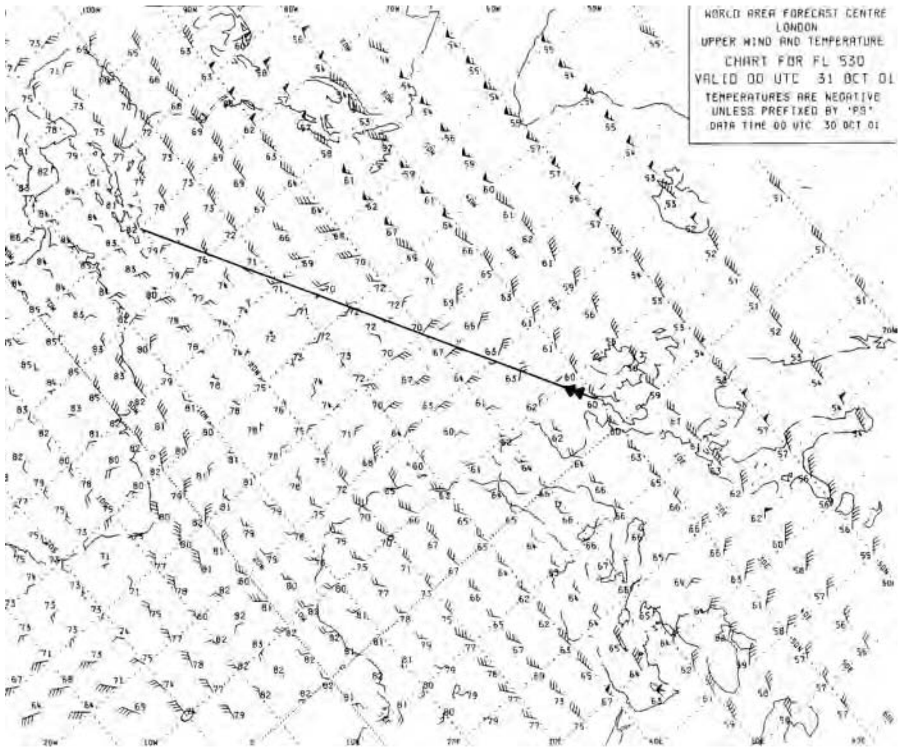



**Figure 2.8** Upper Winds for FL530 (North Atlantic). (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

arrow. All temperatures are in degrees Celsius and are negative unless prefixed by the letters 'ps'. The greatest difficulty, when using the charts, is identifying the latitude and longitude. For instance the chart shown in Figure 2.8, which covers the North and South-west Atlantic, only details the latitude and longitude for each 10° around the edge of the chart. A second problem is that the shafts of the arrows depicted are very short and makes the determination of the exact true direction of the wind at any specific position very difficult. A protractor and straight edge should be used to improve the accuracy of any reading.

Before it is possible to determine the mean wind velocity and temperature for any route, it is essential that accurate spot readings are made. A route will rarely track along a parallel or a meridian so it becomes necessary to interpolate between adjacent values either side of track. As an example, the route is depicted from 50°N 005°W and 20°N 070°W. To determine the mean value of the wind velocity and temperature the on track spot values must first be read.

For any particular position along the route if a spot wind and temperature is not available then it must be interpolated from the values either side of track. At 50°N 005°W there is a spot wind and temperature available which is 260/25 and –60°C. However, at the next position of 48°N 010°W no spot values are available so they must be interpolated between those at the same longitude at 50°N and at 45°N, which were 275/30 –60 and 310/15 –62, respectively. Five degrees of latitude separate the values and the interpolation will therefore be 3/5 of the difference from 45°N; which results in the values 289/24 –61. This procedure must be carried out whenever a spot value is not available.

To calculate the average values for a route the on-track values are added and the total is divided by the number of inputs. However, two considerations must be accounted. First it is essential to determine the predominant wind direction along the route. In the example shown in Table 2.14, most of the wind directions are from the west or north-west.

The first problem to be addressed is caused when the calculator is used to determine the mean wind velocity instead of solving the problem by plotting a vector diagram. It only occurs if the winds included in the predominant direction include values that lie either side of north. A simple example will demonstrate the problem. If there were two wind velocities 340/20 and 020/20 it is easy to realise that the mean wind direction is from the north. However, if a calculator were used to determine the mean then the result would be a direction from the south, that is, $(340 + 020) \div 2 = 180$. To correct this error it is necessary to adjust one of the wind directions by the value of 360. If the predominant wind

**Table 2.14** Route mean wind velocity and temperature

| Position on track | Off track north | | Off track south | | On track | |
|---|---|---|---|---|---|---|
| | W/V | Temp. | W/V | Temp. | W/V | Temp. |
| 50°N 005°W | — | — | — | — | 260/25 | –60 |
| 48°N 010°W | 275/30 | –60 | 310/15 | –62 | 289/24 | –61 |
| 46°N 015°W | 300/30 | –61 | 320/20 | –63 | 316/22.5 | –62 |
| 44°N 020°W | 330/30 | –63 | 350/25 | –64 | 334/29 | –63 |
| 42°N 025°W | 330/30 | –66 | 000/30 | –67 | 348/30 | –66.5 |
| 40°N 030°W | — | — | — | — | 350/30 | –70 |
| 37°N 035°W | 310/15 | –72 | 060/10 | –72 | 016/12 | –72 |
| 35°N 040°W | — | — | — | — | 150/15 | –72 |
| 33°N 045°W | 200/20 | –70 | 160/10 | –71 | 184/16 | –70.5 |
| 30°N 050°W | — | — | — | — | 200/15 | –71 |
| 28°N 055°W | 260/20 | –71 | 270/15 | –74 | 264/18 | –72 |
| 25°N 060°W | — | — | — | — | 270/25 | –76 |
| 22°N 065°W | 290/25 | –77 | 330/15 | –79 | 314/19 | –78 |
| 20°N 070°W | — | — | — | — | 280/10 | –82 |
| TOTALS | | | | | 3401/202.5 | –976 |
| ROUTE MEAN VALUES | | | | | 309/14.5 | –69.7 |

direction is from the west or north-west then 360 is added to those directions from the north-east, so 020 becomes 380 and the solution becomes (340 + 380) ÷ 2 = 360. If the predominant direction had been from the east or north-east then 360 is subtracted from the north-west direction the solution becomes (–020 + 020) ÷ 2 = 000. In Table 2.14 the wind direction at 37°N is 016, which becomes 376 for the calculation of the mean value.

The second consideration is necessary when individual wind directions are the reciprocal or approximately the reciprocal of some of the predominant directions. If such is the case then the wind direction of the reciprocals are omitted from the total and are not accounted. However, the associated wind speeds are negated and included in the total wind speeds. In Table 2.14 the wind velocities at 35°N, 33°N and 30°N are those that require this treatment. 150 opposes 334, 184 opposes 350 and 200 opposes 016. The associated speeds become –15, –16 and –15, which must be included in the total.

The mean wind direction for Table 2.14 is calculated as (260 + 289 + 316 + 334 + 348 + 350 + 376 + 264 + 270 + 314 + 280) ÷ 11 = 309. The mean wind speed is calculated as (25 + 24 + 22.5 + 29 + 30 + 30 + 12 – 15 – 12 – 15 + 18 + 25 + 19 + 10) ÷ 14 = 14.5 kts. The mean temperature is –976 ÷ 14 = –69.7°C.

A further consideration, which does not arise in Table 2.14, is that of a light and variable wind velocity. Such a wind velocity has no direction and therefore is not included as a value when calculating the mean wind direction, but the wind speed is zero and must be included as an input value when calculating the mean wind speed for the route.

## Summary

| | |
|---|---|
| **METARs, TAFs and SIGMETs** | Memorise the codes so that any of the messages can be decoded. In particular, remember the runway state codes. Ensure that the correct sequence of items for a METAR is known. |
| **Weather and Wind Charts** | Be able to recognise and interpret the significant weather chart symbols and abbreviations. |

## Sample questions

Answer Questions 1–5 on the following METARs. Select a, b, c, or d.
EGNT 301550Z 22012G24KT 9999 FEW020 SCT025 SCT035 15/12 Q0999=
LCLK 301600Z 32010KT 9999 FEW030 FEW040TCU 20/08 Q1017 NOSIG=
EPGD 301530Z 28008MPS 250V320 9999 BKN018 12/10 Q1006=
EHBK 301550Z 19017KT CAVOK 18/10 Q1017 TEMPO 21018G30KT=

1. At EGNT the wind velocity is reported to be:
   a. Mean W/V over the past 10 min 220°(M) 12 kts with a maximum speed of 24 kts in the past 10 min
   b. Mean W/V over the past 10 min 220°(T) 12 kts
   c. Mean W/V over the past 10 min 220°(M) 12 mps
   d. Mean W/V over the past 10 min 220°(T) 12 kts with a maximum recorded speed during that period of 24 kts

2. The cloud reported at LCLK is:
   a. 3–4 oktas base 3000 ft and 3–4 oktas base 4000 ft
   b. 3–4 oktas base 3000 ft and 3–4 oktas base 4000 ft of towering cumulus
   c. 1–2 oktas base 3000 ft and 1–2 oktas base 4000 ft
   d. 1–2 oktas base 3000 ft and 1–2 oktas base 4000 ft of towering cumulus

3. The meaning of the trend NOSIG at LCLK is:
   a. No significant cloud
   b. No significant weather
   c. No significant change expected in the next hour
   d. No significant change expected in the next two hours

4. The wind velocity at EPGD is reported as:
   a. 280°(T)/8 kts
   b. 280°(M)/8 kts, the direction varied over the last 10 min between 250°(M) and 320°(M)
   c. 280°(T)/8 mps, the direction varied over the last 10 min between 250°(T) and 320°(T)
   d. 280°(M)/8 mps, the direction varied over the last 10 min between 250°(M) and 320°(M)

5. At EHBK the visibility is:
   a. Not reported
   b. 10 nm
   c. 10 km or more
   d. 10 km

Answer Questions 6–10 on the following TAFs. Select a, b, c, or d.
LFML 301400Z 301524 25006KT 9999 FEW040 BECMG 1618 14008KT CAVOK BECMG 1821 VRB03kt 4000 BR SCT001 T21/15Z T14/24Z=
LIME 301524Z VRB05KT 2500 MIFG SCT020 BECMG 1517 1000 FG NSC=
UMKK 301400Z 301524 26014G19MPS 5000 BR BKN015CB TEMPO 1524 2000 SHRA BKN007=

6. At LFML, the temperature at 1800Z is forecast to be:

   a. +23°C
   b. +19°C
   c. +17°C
   d. +15°C

7. At LFML, the group 301524 means:

   a. The time of transmission was 1524Z on the 30th day of the month
   b. The forecast becomes operative at 1524Z on the 30th day of the month
   c. The forecast is valid between 1500Z and 2400Z on the 30th day of the month?
   d. The forecast is valid between 1500 local time and 2400 local time on the 30th day of the month

8. At LIME, the forecast cloud after 1700Z is likely to be:

   a. 3–4 oktas base 2000 ft
   b. No significant cloud
   c. No cloud below 5000 ft or MSA, whichever is the lowest
   d. No cumulonimbus or towering cumulus

9. At UMKK, the weather after 1500Z is forecast to be:

   a. Moderate rain showers or mist
   b. Mist
   c. Heavy rain showers
   d. Thunderstorms

10. At UMKK, the lowest visibility at 1500Z is forecast to be:

    a. 5000 m
    b. 2000 m
    c. 1524 m
    d. 1500 m

Answer Questions 11–15 using the Significant Weather Chart shown in Figure 2.9. Select a, b, c, or d.

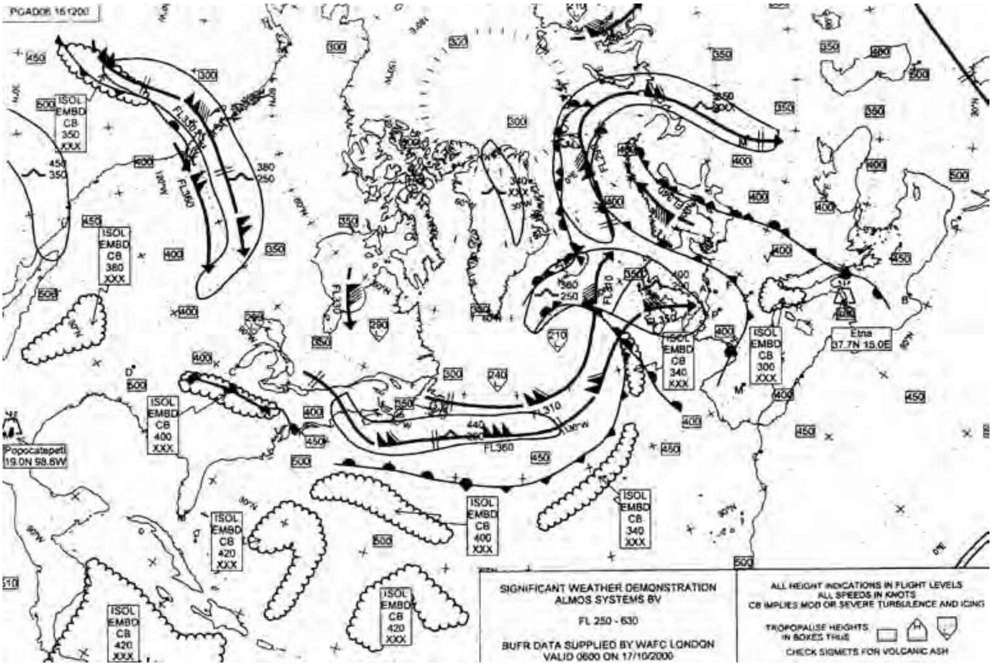



**Figure 2.9** Chart for sample questions. (*Reproduced by kind permission of the Met Office © Crown Copyright*.)

11. The height of the tropopause at 50°N 43°W is:

    a. 30 000 ft
    b. FL300
    c. 24 000 ft
    d. FL240

12. The direction, speed and pressure altitude of the jet stream at 44°N 53°W are:

    a. 260°(T)/110 kts; FL360 ±3000 ft
    b. 260°(T)/110 kts; FL360 ±2000 ft
    c. 260°(T)/150 kts; FL360 ±3000 ft
    d. 260°(T)/110 kts ±20 kts; FL360 ±3000 ft

13. The front shown at 60°N 19°E is:

    a. A surface cold front moving east
    b. A quasi-stationary front moving east
    c. A surface occluded front moving east
    d. An upper occluded front moving east

14. The clear air turbulence at 53°N 120°W is described as:

    a. Moderate between FL250 and FL380
    b. Moderate between FL360 and FL380
    c. Moderate or severe between FL350 and FL380
    d. Moderate or severe between FL250 and FL380

15. The type of cloud and its extent at 38°N 30°W is:

    a. Isolated, embedded cumulonimbus from FL250 to FL340
    b. Individual, embedded cumulonimbus from below FL250 to FL340
    c. Isolated, embedded cumulonimbus from below FL100 to FL340
    d. Individual, embedded cumulonimbus from below FL100 to FL340

Answer Questions 16–20 using the Upper Wind Chart shown in Figure 2.8.

16. The wind velocity at FL530 at 00°N 30°W is:

    a. 310/35
    b. 130/35
    c. 300/40
    d. 120/40

17. The ambient temperature at FL530 at 00°N 30°W is:

    a. –79°C
    b. –80°C
    c. –81°C
    d. –82°C

18. The mean temperature at FL530 between 60°N 00°W and 30°N 00°W is:

    a. 62°C
    b. 60°C
    c. –62°C
    d. –60°C

19. The mean wind velocity between 20°S 10°W and 20°N 10°W is:

    a. 210/22
    b. 230/25
    c. 240/20
    d. 210/20

20. The wind velocity at 35°N 35°E is:

    a. 260/55
    b. 270/50
    c. 280/40
    d. 290/30

# Chapter 3
# VFR Flight Planning

## Introduction

Flight planning in VMC must be executed with the same diligence as for an IMC flight. Due consideration must be given to the route and altitude selection. The avoidance must be planned of all prohibited, danger and restricted areas. If possible, the route should be planned to avoid all areas of high air traffic density. Turning points should be easily identifiable visually, preferably from a long distance. High ground and obstacles should be avoided by an adequate vertical separation or by re-routing.

## The topographical chart

The route must be planned on a topographical chart. There is such a chart included in the Jeppesen student pack entitled *VFR + GPS Chart*, which is of Southern Germany and numbered ED6. This is used in the JAA examination. The importance of being thoroughly familiar with this chart (in particular, with the symbology, layout and legend information) cannot be over emphasised. **You must be in possession of this chart to be able to follow the rest of this chapter.**

### *Position*

The position of anywhere on the chart can be located by latitude and longitude. This is printed at 10' intervals around the edge of the chart. Individual minutes of latitude or longitude are etched along meridians and parallels valued at 30' and whole degree. The geodetic datum used for this grid is WGS 84.

### *Direction and distance measurement*

The chart is a Lambert Conical Orthomorphic type with standard parallels at 37°N and 65°N. Therefore, it can be considered a constant scale chart. Distance can be measured either in nautical miles along any meridian with the appropriate etchings or on the scale provided at the top of the legend positioned at the bottom of the chart.

True north is shown by the meridians, whereas magnetic north is indicated at intervals across the chart by small winged symbols. An example of such a symbol is at 48°17'N 013°34'E. The variation for all of the radio navigation aids on the chart is listed in the legend in the bottom right corner of the chart. Magnetic north is also indicated on every VOR symbol by half an arrowhead. Isogonals are depicted by thin broken blue lines on which the value of the variation is printed, and were correct for the year 1999. An example can be found along the bottom of the chart at 012°06'E; the line continues to the top of the chart at 012°15'E.

## *Height, elevation and altitude*

No matter which chart is being used it is most important to be aware of the units used for height measurement because an error can have serious consequences. *All heights, elevations and altitudes on this chart are in feet.* High ground is shown on the chart by layer tinting and contours ranging from green (low elevation) to dark brown (high elevation) and can be decoded by using the diagram in the legend at the bottom left of the chart. The highest elevation on each topographical chart in this series is boxed and located in its correct position; for ED6 it is 12 028 ft and is located at 47°07N 012°21'E. Natural high points have a dot in the exact position and the height above msl (elevation) stated beside it. Some cableways have the height above ground level stated in brackets beside the symbol. See Figure 3.1.

### Minimum Grid Area Altitude

In the centre, or approximately the centre, of each half-degree of latitude and longitude is a large red number. This figure is in hundreds of feet and is the Minimum Grid Area Altitude (MGAA). It is calculated to provide 1000 ft vertical separation from the highest terrain or obstacle in that area, provided the highest point is 5000 ft or less. If the highest point in the area is 5001 ft or more above msl then the MGAA has been calculated to ensure a vertical separation of 2000 ft. It is the equivalent of the Grid Minimum Off-route Altitude (MORA) on the Jeppesen airways charts and is referred to as the Jeppesen formula. *IEM OPS 1.250 paragraph 3*. If the MGAA is too restrictive and unrealistic a route value may be calculated by determining the elevation of the highest ground or obstacle within an area extending 10 nm either side of track and including a 10 nm radius beyond the end of leg turning point. To this elevation is added 1000 ft or 2000 ft as appropriate and the result is then rounded up to the next whole hundreds of feet. See Figures 3.1 and 3.2.

### VFR semicircular cruising altitudes

The semicircular cruising altitudes for VFR flights are shown by two diagrams in the bottom legend of the chart (see Figure 3.3). The left diagram shows those levels applicable to all countries on the chart except France. The right diagram depicts the VFR cruising levels for France. For Germany and Austria,

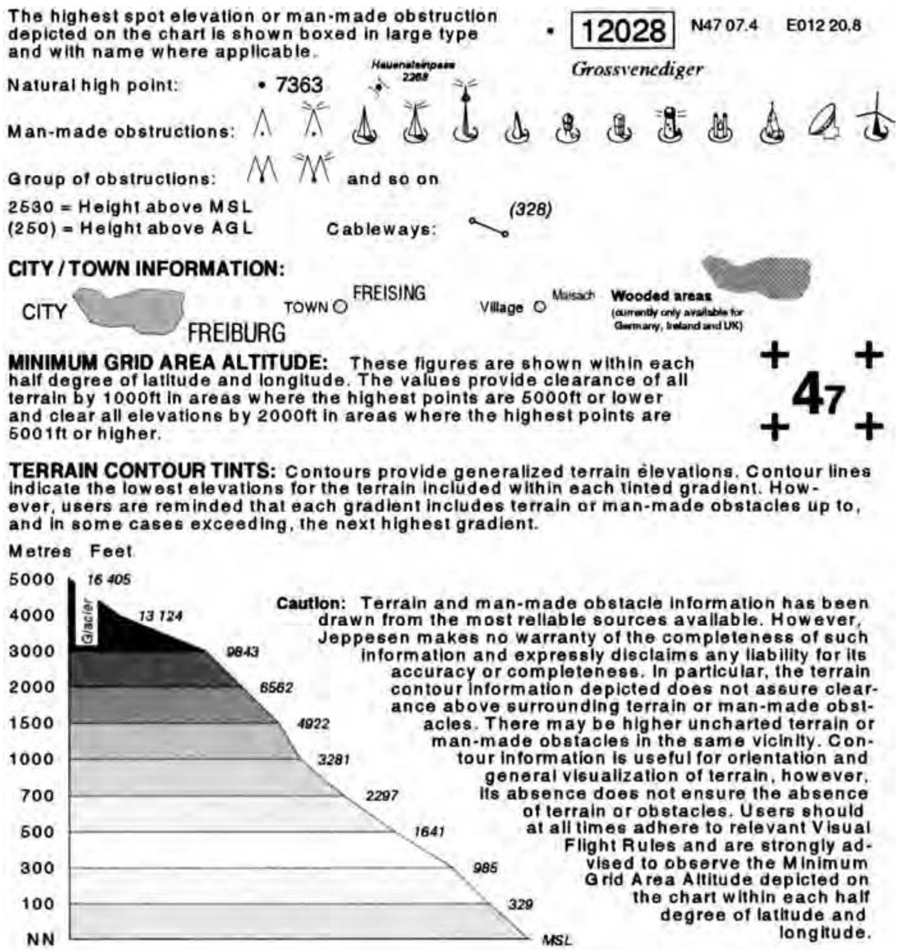



**Figure 3.1** Topographical information symbols. (*Reproduced with permission of Jeppesen GmbH.*)

the VFR cruising levels for magnetic tracks between 000° and 179° are odd thousands of feet plus 500 ft from 3500 ft to 19 500 ft. For magnetic tracks between 180° and 359° over Germany and Austria the VFR cruising levels are even thousands of feet plus 500 ft from 4500 ft to 18 500 ft.

When planning or conducting a flight under VFR, the cruising altitude used for each leg of the flight should be above the highest MGAA or route MORA for the leg and comply with the semicircular cruising level rules for VFR flights. However, the cruising level should never be less than 2000 feet above ground level, because of the possible confliction with military low-level flights. In some countries, this rule is mandatory.

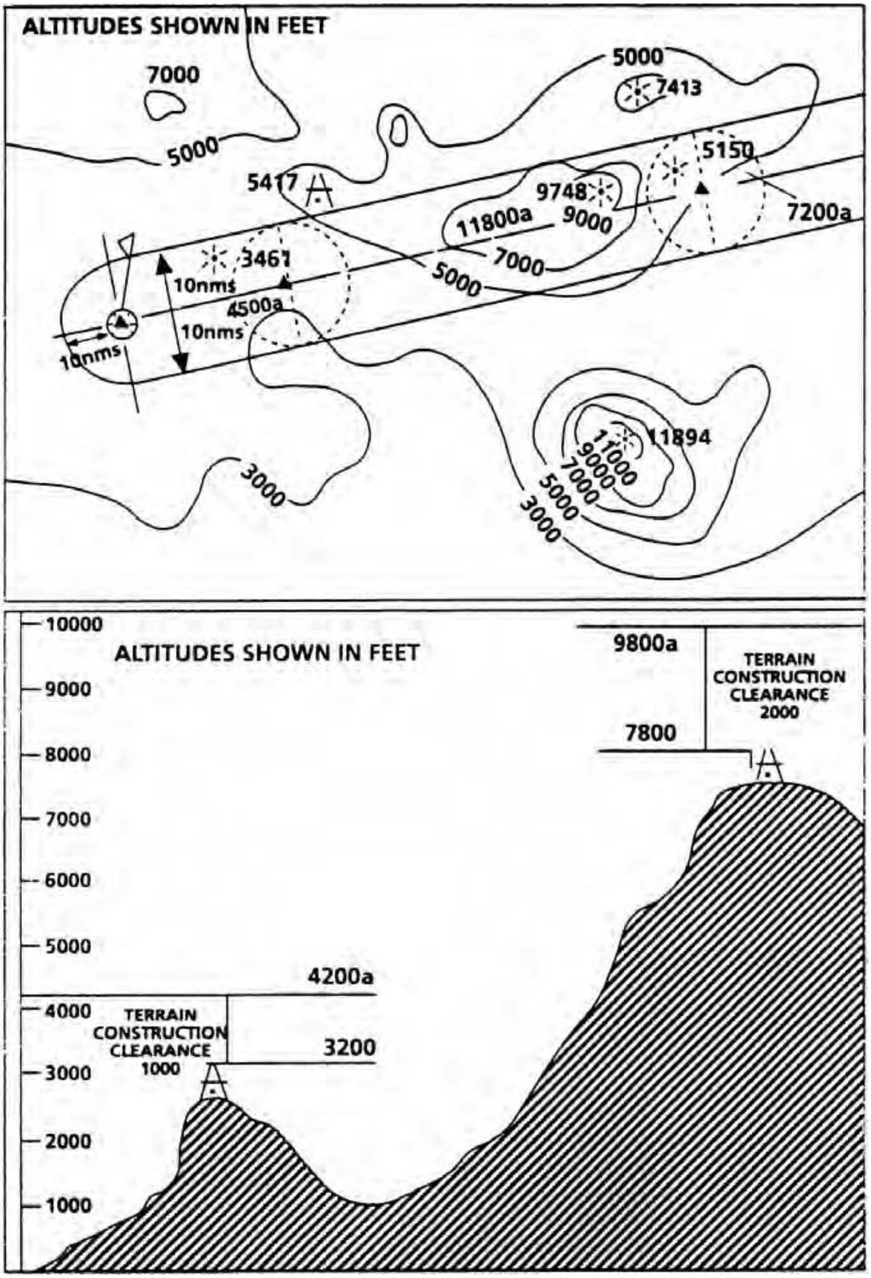



**Figure 3.2** MORA and MGAA clearance diagram.

## *Controlled airspace*

The designators used for airspace classification are the letters from A to G. The conditions pertaining to each classification regarding separation, ATC clearance, radio communication, Air Traffic services provided, speed

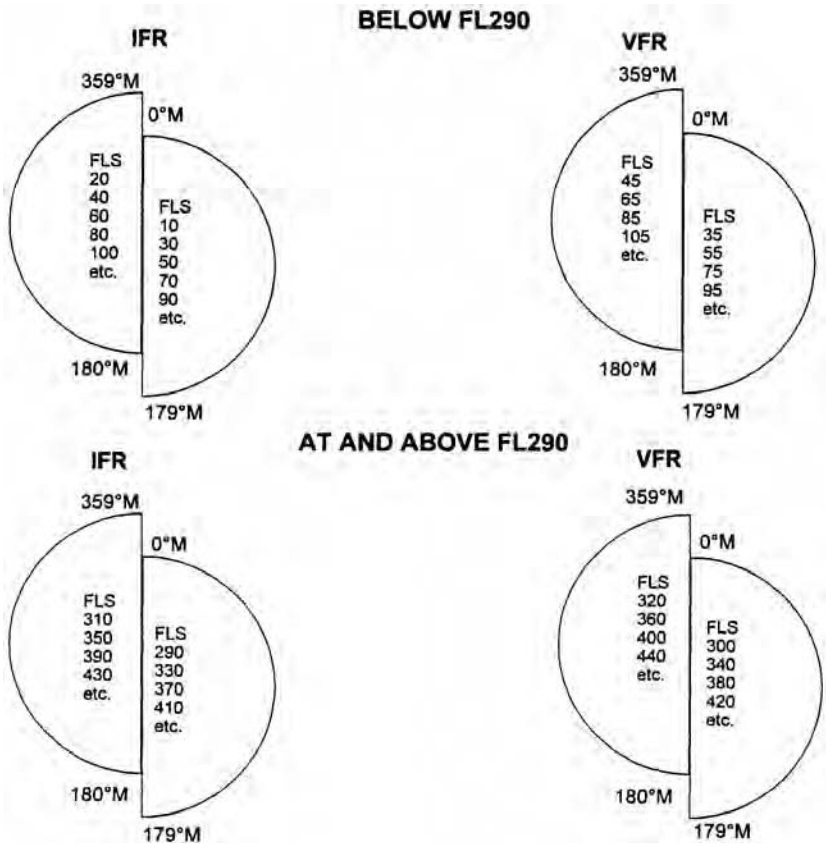



**Figure 3.3** ICAO standard semicircular cruising levels.

limitations and VMC minima are all listed in the legend at the bottom of the chart. It should be noted that VFR flights are prohibited in any airspace classified as A. See Figures 3.4 and 3.5.

The controlled airspace will be depicted on the chart bounded by a magenta line for areas B, C and D, and by a blue boundary for areas E, F and G. The lower and upper limits of the area are printed within the boundary. Those having no lower limit stated commence at ground level. If the letter designator is preceded by an asterisk, it means that the area is operating part-time and the Aeronautical Information Publication (AIP) should be consulted to determine the hours of operation.

A table of the Airspace Designators and Control Frequencies is also provided in the bottom legend of the chart. These are identified on the chart by black ball symbols labelled with a number that indicates the airspace in the table. The table is subdivided in such a manner that the controlling authority is listed alphabetically in each country covered by the chart. In the legend to the right of the chart is a list of all VFR reporting points on the chart with their titles and exact positions. Beneath this is a further list, which

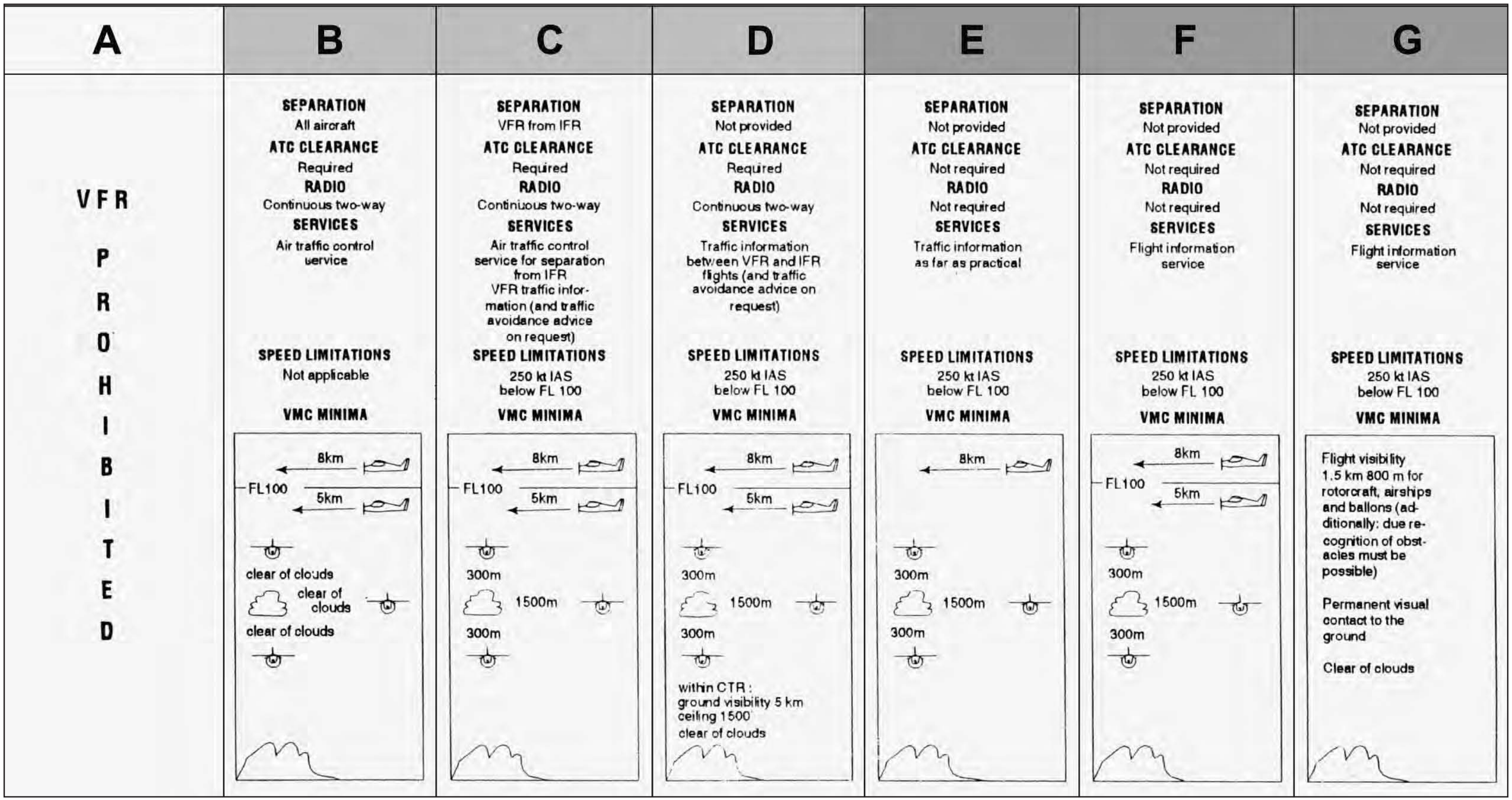



**Figure 3.4** Controlled airspace classification for VFR. (*Reproduced with permission of Jeppesen GmbH.)*

includes all of the aerodromes on the chart, their ICAO identifiers and precise location.

## *Symbology*

Many different symbols are used on the chart to identify various features and include airports, waypoints, navigation aids, man-made obstructions, cities/towns and wooded areas. Beside each aerodrome/airfield symbol, printed in black, is the ICAO identifier, the name of the aerodrome, the elevation in feet, the length of the longest runway in metres and the radio frequency. It is essential that all of the symbols depicted in the legend, and shown in Figure 3.5, should be recognised, but they need not be committed to memory.

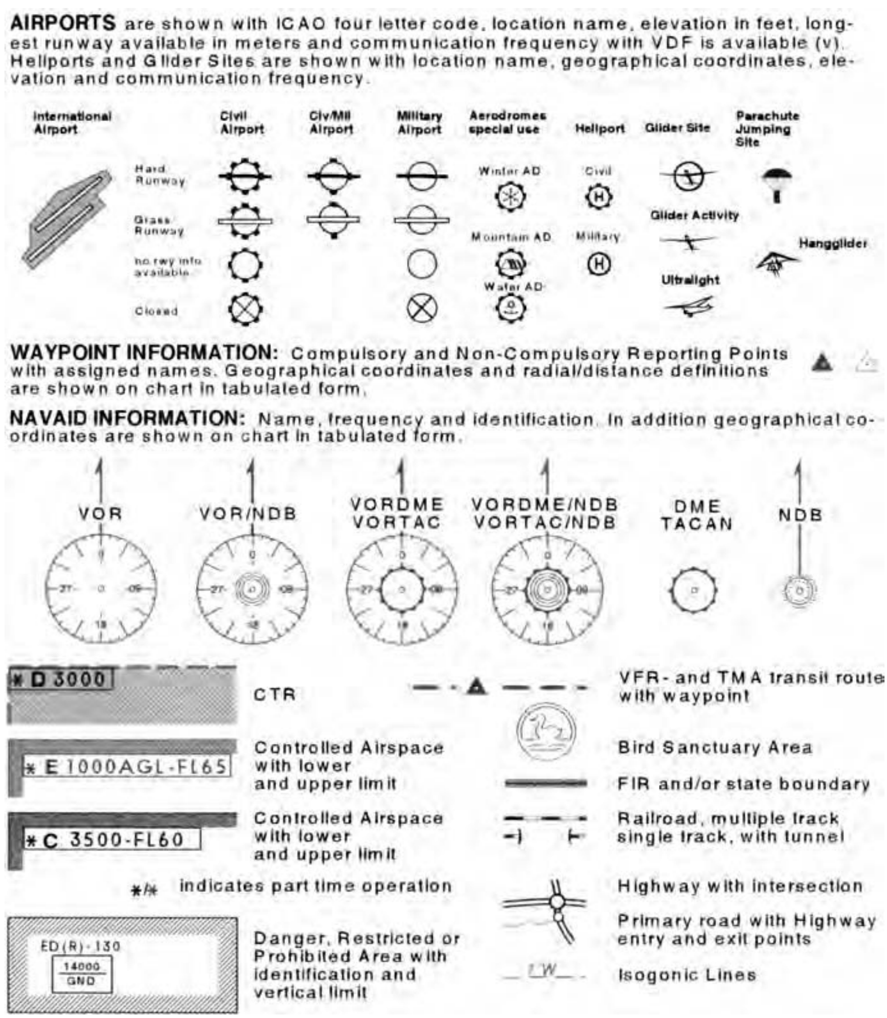



**Figure 3.5** Aeronautical information symbols. (*Reproduced with permission of Jeppesen GmbH.*)

## Example route plan

To illustrate the process to be adopted when planning a VFR flight, follow the reasoning for a flight from Salzburg/Glasenbach (47°47'N 013°01'E) to Stuttgart (48°41.5'N 009°12'E). The most direct route would be a straight line; however, this would be through the high-density air traffic area of Munich. This could be avoided by flying due west to Kempten and then to Stuttgart, but this would require a high cruising level because of the mountainous terrain to the south. It would be more advantageous to fly north from Salzburg away from the high ground and avoid the controlled airspace at Munich. Using readily identifiable turning points and accounting the departure and arrival procedures then the route must be via Salzburg VOR (48°00'N 012°53.6'E), Regensburg (49°01.5'N 012°06'E) and Schwaebisch Gmuend (48°48'N 009°47.5'E). The alternate aerodrome is Friedrichshafen (47°40'N 009°31'E).

Having decided on the most practical route it is now necessary to accurately draw the tracks on the chart and then to measure the true track and the distance for each leg. These should be entered in the appropriate columns of a flight plan form similar to that shown in Figure 3.6. Now extract the highest MGAA for each leg of the route. These will help decide which cruising altitude is the most practical for the route. The practical aspect of the flight plan calculations will be dealt

**SEP FUEL PLAN**

| STAGE FROM | STAGE TO | TEMP °C | FL | SAF ALT | WIND DIR'N | WIND SPEED | TR (M) | IAS kts | TAS kts | G/S kts | GND DIST nm | TIME mins | FUEL FLOW lbs/hr | START OF LEG AUW lbs | FUEL USED lbs | END OF LEG AUW lbs | FUEL REMAINING lbs | ETA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GLASENBACH | TOC | — | ↗ | 8500 | | | 339 | | | | 14 | | | 3650 | | | | |
| TOC | SBG | | | 8500 | | | 339 | | | | | | | | | | | |
| SBG | REGENSBERG | | | 3100 | | | 332 | | | | 69 | | | | | | | |
| REGENSBERG | SCHWAEBISCH | | | 3900 | | | 261 | | | | 92 | | | | | | | |
| SCHWAEBISCH | STUTTGART | | | 3900 | | | 253 | | | | 24 | | | | | | | |
| | TOTALS | | | | | | | | | | 199 | | | | | | | |
| SY | FREIDRICHSCHAFEN | | | 4300 | | | 164 | | | | 62 | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | | |

| DEPARTURE A/F | | DESTINATION A/F | | ALTERNATE A/F | | ROUTE CLEARANCE | ROUTE FUEL | |
|---|---|---|---|---|---|---|---|---|
| RUNWAY (M) | 346 | RUNWAY (M) | 263 | RUNWAY (M) | 242 | POWER 25.0 Hg 2100 rpm | CONTINGENCY FUEL | |
| W/V | | W/V | | W/V | | | ALTERNATE FUEL | |
| ELEVATION | 1411' | ELEVATION | 1267' | ELEVATION | 1367' | | FINAL RESERVE | |
| QNH | | QNH | | QNH | | | PLANNED TAKE-OFF FUEL | |
| PRESSURE ALT | | PRESSURE ALT | | PRESSURE ALT | | | EXTRA FUEL | |
| TAKE-OFF MASS | 3650 | ALT T/O MASS | | | | | TAKE-OFF FUEL | |
| ROUTE FUEL | | ALTERNATE FUEL | | | | | TAXI FUEL | |
| LANDING MASS | | LANDING MASS | | | | | BLOCK FUEL | 444 |

**Figure 3.6** Example skeleton flight plan form.

with in Chapter 6 for the single-engined piston aeroplane, Chapter 7 for the multi-engined piston aeroplane and in Chapter 8 for the jet-engined aeroplane.

## *Route analysis*

### Leg 1 Glasenbach to Salzburg VOR

See Figure 3.7. The measured track is 340°(T) and distance is 14 nm. The variation in the Radio Navigation list at the bottom right of the chart quotes the variation as 1°E at Salzburg; therefore, the track is 339°(M). The aerodrome details are shown to the east of the symbol and are ICAO identifier LOWS, name Salzburg, elevation 1411 ft, longest runway 2510 m, tower frequency 118.1 MHz and VDF is available.

Before take-off, although this is a visual flight, both the Salzburg VOR, listed in the legend as being on frequency 113.8 MHz with call sign SBG, and the NDB on frequency 382 KHz with the same call sign, should be selected on the appropriate equipment and identified. After setting heading and during the climb there are some good visual clues to assist in track keeping: there is a railway under the left wing and the River Salaach under the right wing both running parallel to track. At a distance of 4 nm from the SBG VOR, the track crosses an S-bend in the river. The VOR can be used to home on to the turning point but it should be visible as a circular arrangement of aerials on the ground, after passing the NDB on the left.

The hazards to be aware of on this leg are that to the east of the aerodrome on take-off there are two hang-glider sites, one glider site and several groups of pylons with heights above msl of between 1605 ft and 4537 ft. The highest MGAA for the leg is 11 400 ft. This will not affect the flight because it is caused to be so high by the terrain in the south-east corner of the grid. The highest terrain along a corridor 5 nm either side of track is less than 3000 ft.

The leg lies totally within the Salzburg TMA, which is a class D airspace from ground level to 7000 ft above msl. ATC clearance is required, continuous two-way communication must be maintained, and traffic avoidance advice can be requested. The listed frequencies are Radar 123.72 MHz or 134.97 MHz.

The maximum speed below FL100 is 250 kts IAS. The VMC minima below FL100 are 5 km visibility, 300 m (1000 ft) vertical separation from cloud and 1500 m (5000 ft) horizontal separation from cloud. In the CTR, the cloud ceiling must not be below 1500 ft.

### Leg 2 SBG VOR to Regensburg

See Figures 3.7 and 3.8. The track measures 333°(T) and the distance is 69 nm. The track is, therefore, 332°(M). The highest MGAA is 3800 ft on this leg and the highest ground within 10 nm of track is 2201 ft.

After passing over SBG VOR at a distance of approximately 3 nm a man-made obstruction, height 1890 ft amsl, should pass under the port wing. The

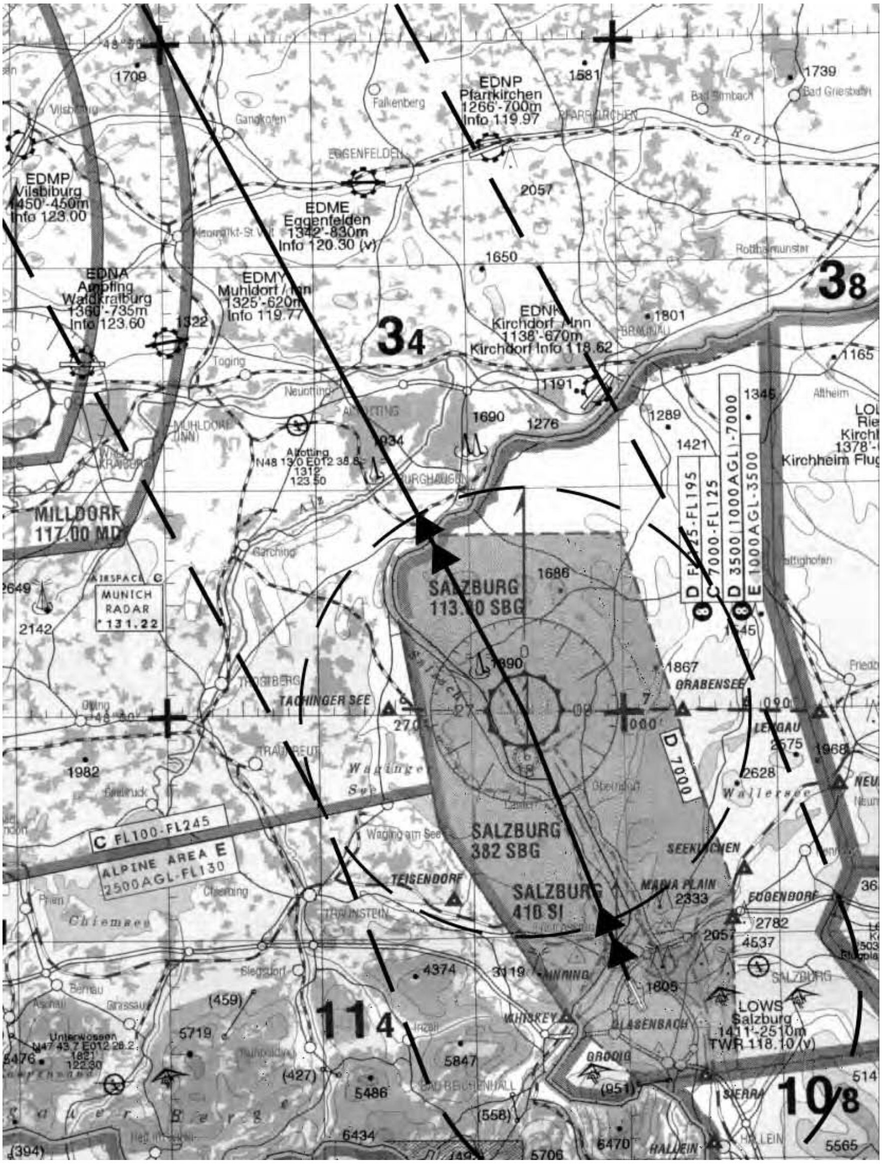


Figure 3.7 Leg 1. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

River Salaach continues to roughly parallel track until at a distance of 9 nm from SBG it crosses track at 90°. This signifies the boundary of the Salzburg TMA. It would now be wise to contact Munich Radar on frequency 131.22 MHz and to maintain a listening watch on this frequency for any conflicting traffic.

A railway now parallels the track from about 3 nm before diverging to the west. The track now passes over the eastern edge of Neuotting. Keep a lookout for gliders to the west and for light aircraft coming from Muhldorf/Inn (Information

119.77 MHz) and Eggenfelden (Information 120.30 MHz). A railway now crosses track at approximately 90° to a junction 3 nm left of track; this will provide a useful ground speed and ETA check. The track now passes almost over the village of Gangkofen and the railway that parallels track for a short distance.

The track passes just outside of the Munich controlled airspace; it is advisable to maintain a listening watch on 131.22 MHz for conflicting traffic. The River Isar, a railway and autobahn, all crossing track at Dingolfing, provide another ground speed and ETA check, 25 nm from the turning point. Be aware there may be light aircraft activity to the east. Seven nautical miles after the checkpoint there is a mast located in woods to the east at 1848 ft amsl.

After crossing the railway at Hagelstadt, which leads to the turning point, there is an airfield on which there may be gliding activity. The city of Regensburg

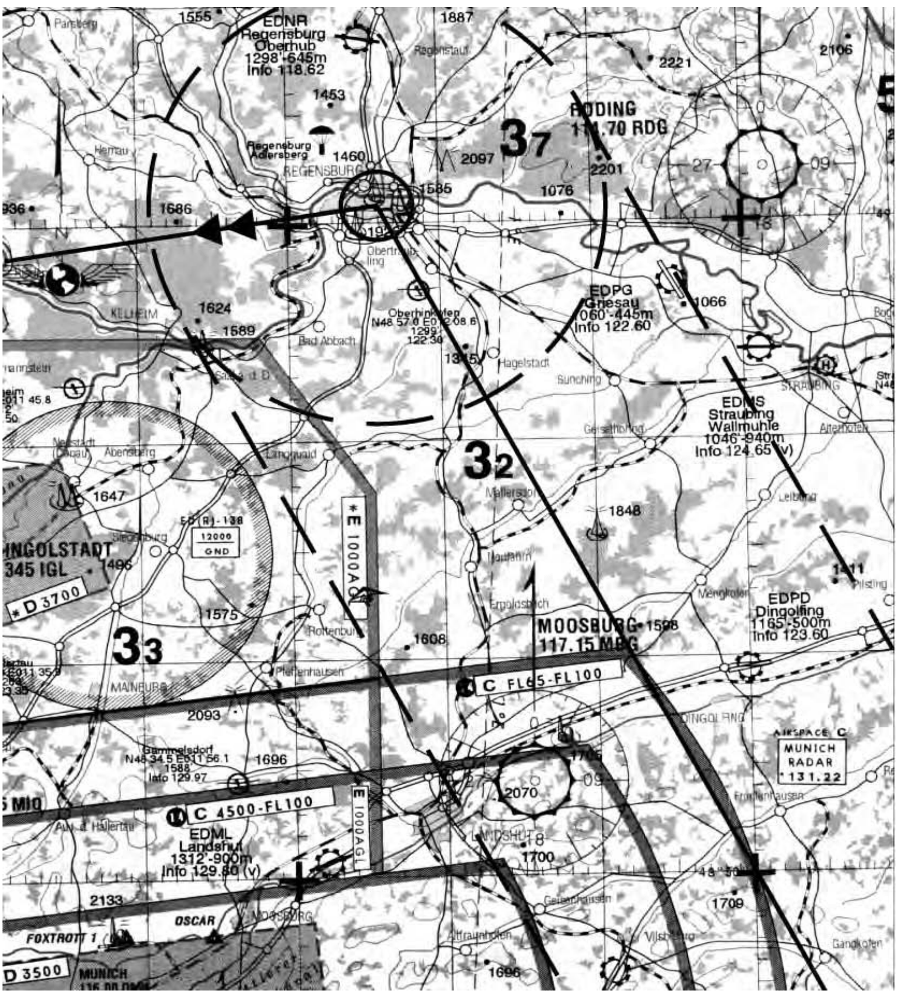


**Figure 3.8** Leg 2. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

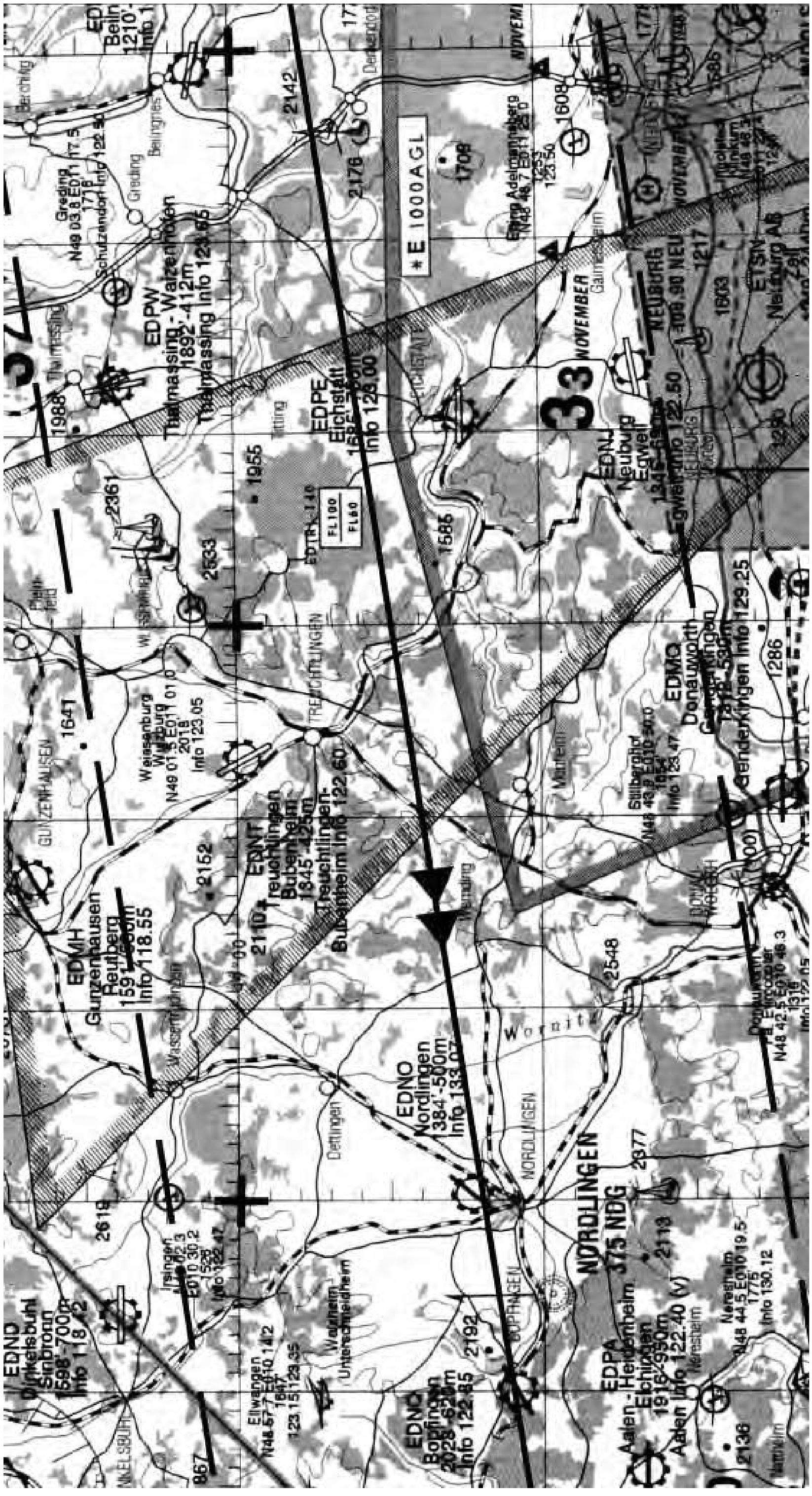


Figure 3.9 Leg 2. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

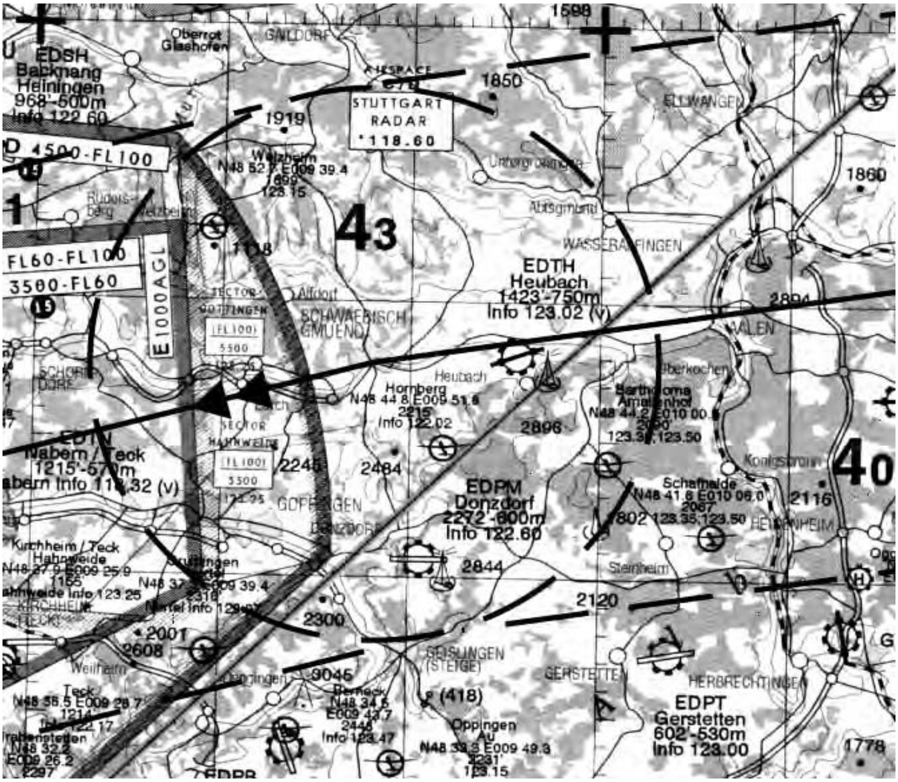


**Figure 3.10** Leg 3. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

should now be visible, surrounded by a dual carriageway bypass; it has a cathedral at the centre, which should be easily visible from a considerable distance.

### Leg 3 Regensburg to Schwaebisch Gmuend

See Figures 3.8–3.10. The measured track is 262°(T), which converts to 261°(M), and the distance is 92 nm. This next turning point was selected because it is directly in line with the main runway at Stuttgart and provides a good checkpoint to line up for the approach and landing. The highest MGAA on this leg is 4300 ft.

There are two hazards of which to be aware along the leg. First, the turn at Regensburg must not be too wide because there is a parachute-dropping zone north of the city. Second, the track passes through a restricted area. ED(R) 140 extends from FL60 to FL100 and may restrict the cruising altitude.

There are three masts of significant elevation. The first is on track a distance of 27 nm from Regensburg and extends to an elevation of 2142 ft. The second, 14 nm from the next turning point, is 2 nm north of track, and extends to an elevation of 2894 ft. Finally, 6 nm before reaching the turning point there is a mast 1 nm south of track extending to an elevation of 2896 ft.

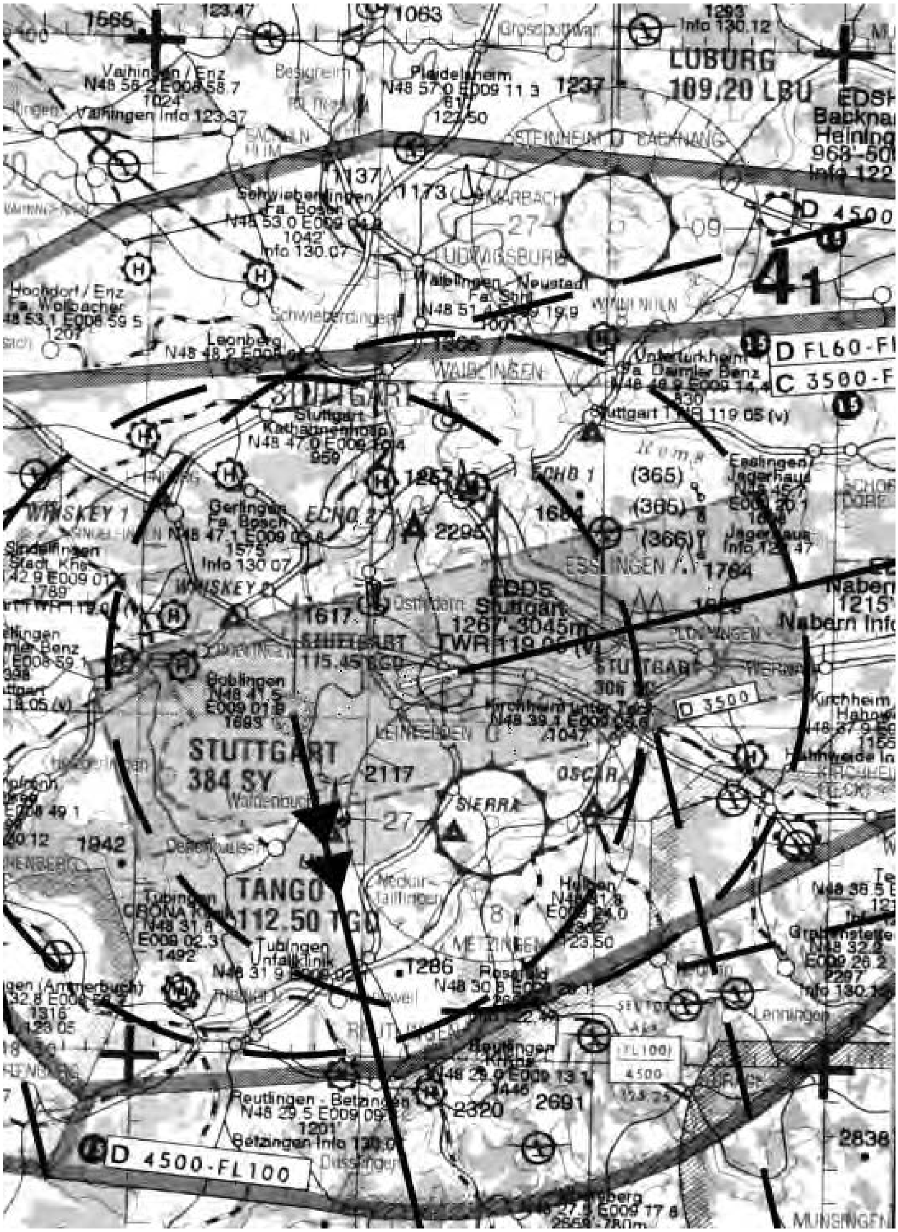


**Figure 3.11** Leg 4. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

On the chart, 14 nm from Regensburg you will notice the winged symbol which indicates magnetic north in that area. After a further 2 nm the track passes over an S-bend in the River Donau. The track now passes over a scattered wooded area before reaching the autobahn, which provides a ground speed and ETA check. Continuing over the woods, the track passes north of Eichstatt where there could be light aircraft activity to the south. Further air activity could take place 4 nm north of track at Treuchtlingen. The railway coming south from the town will provide a further ground speed check. Thirty-eight nautical miles from the turning point a railway parallels track into the town of Nordlingen. The track passes directly over the light aircraft airfield here, traffic information on frequency 133.07 MHz, and over another airfield 7 nm further along track at Bopfingen, traffic information on frequency 122.85 MHz.

See Figure 3.10. The track now passes over a densely wooded area, passing south of Wasseralfingen from which a road leads directly to the turning point. This is a good lead-in feature, keeping Heubach light aircraft aerodrome to the left. Just before reaching the aerodrome, the listening watch frequency should be changed to Stuttgart Radar on 118.6 MHz. The turning point can be identified as a town on a bend in the River Rems.

### Leg 4 Schwaebisch Gmuend to Stuttgart

See Figure 3.11. Clearance must be obtained on the appropriate frequency before entering Stuttgart controlled airspace. The Stuttgart NDB, SG 306 KHz, and the VOR SGD 115.45 MHz, should be selected on the radio navigation equipment in case visual contact with the ground is lost. The track is 254°(T), which is 253°(M), and the distance is 24 nm.

The first half of the track passes over dense woodland before reaching the autobahn leading to the city of Stuttgart, a distance of 6 nm from the airport. Beware of descending too early because there are masts on track, just before the autobahn, extending to an elevation of 1629 ft. The visual approach charts must be considered and adhered to when planning the approach. The aerodrome information is tabulated as ICAO identifier EDDS, name Stuttgart, elevation 1267 ft, longest runway 3045 m, tower frequency 119.05 MHz and VDF is available.

### Diversion route Stuttgart to Friedrichshafen

See Figures 3.11 and 3.12. The direct track is 169°(T), which is 168°(M), and the distance is 62 nm. However, the departure procedure requires a climb straight ahead to the SY NDB (on Figure 3.11) and then to turn left on track to the destination. The track from SY is 165°(T) or 164°(M) and the distance is the same, 62 nm. The highest MGAA is 5900 ft. On leaving the Stuttgart controlled airspace a listening watch should be maintained on 118.6 MHz for any conflicting traffic.

There are no hazards along the route. Caution must be observed, because the track passes directly over Mengen light aircraft aerodrome at 48°03'N 009°22'E. There is an NDB MEG 401 KHz on the aerodrome, which will be of great assistance in maintaining track. It will also provide a good check on the ground speed and the ETA.

Shortly after departing the SY NDB the track passes over the visual

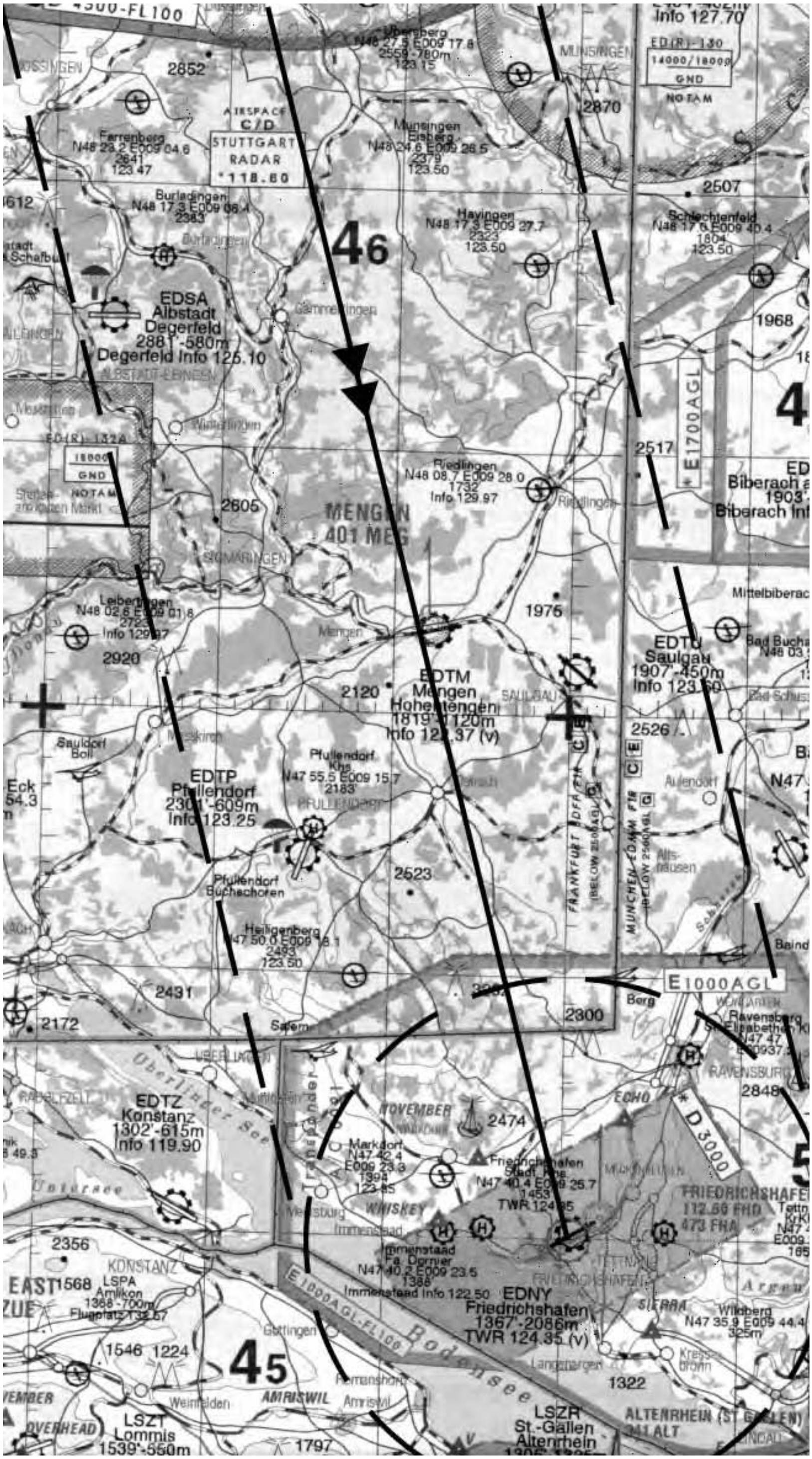


**Figure 3.12** Leg 5. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

reporting point LIMA, which is a mast extending to 2117 ft amsl. The track then passes over an autobahn 1 nm west of a right angle bend. After a short distance Reutlingen is reached, at which there are two helicopter landing areas. Three nautical miles to the south-east there is a glider site. There is little of navigational value from this point until Mengen aerodrome is reached, because it is mostly scattered woods and hills. A railway line, 11 nm past Reutlingen, could be useful because it parallels track for a short distance.

Six nautical miles beyond Mengen, the village of Ostrach should be 1 nm right of track. A road leads from this village parallel to track for a distance of 8 nm. The radio should now be set to the destination arrival frequency. At a distance of 11 nm before reaching the alternate aerodrome is the Friedrichshafen CTA, an E class airspace, which extends from 1000 ft agl to FL100. Permission should be sought to enter the area and the transponder should be set A/C 0021. The aerodrome information is tabulated as ICAO identifier EDNY, name Friedrichshafen, elevation 1367 ft, longest runway 2086 m, tower frequency 124.85 MHz and VDF is available. Instructions will be given how to approach the aerodrome.

**Selection of cruising level**

All tracks are westerly, therefore the cruising level must be even thousands of feet plus 500 ft between 4500 ft and 18 500 ft. The cruising level must not be below 2000 ft agl. The next consideration must be that of the safety altitude for each leg (i.e., the Route MORA for each leg).

## *Altitude considerations*

The altitude considerations are detailed in Table 3.1.

**Table 3.1**

| Leg | Route MORA (ft) | MGAA (ft) | Highest ground (ft) | Highest ground + 2000 (ft) | Lowest cruise altitude (ft) |
|---|---|---|---|---|---|
| 1 | 8500 | 11 400 | 6470 | 8470 | Climbing |
| 2 | 3100 | 5000 | 1887 | 3887 | 3900 |
| 3 | 3900 | 4300 | 2484 | 4484 | 4500 |
| 4 | 3900 | 4300 | 2608 | 4608 | Descending |
| 5 | 4300 | 4600 | 2852 | 4900 | 4900 |

The lowest cruise altitude for the whole route, taking into account all of these considerations, must be 4500 ft. Should a diversion be necessary then the cruising altitude would have to be 5500 ft. To convert these altitudes to pressure altitudes use the formula:

Pressure Altitude = Altitude + [(1013.2 – QNH) × 28]

## *Chart preparation*

After drawing the tracks and completing the flight plan, it is necessary to prepare the chart in such a manner that visual navigation is made as easy as possible. Although some people recommend drawing time marks at 10-minute intervals along each track, this method has two disadvantages; first they are only correct for that particular flight plan and second they are of no assistance in revising the ground speed in flight. The better option would be to draw *distance to go* marks at 10 nm intervals from each turning point. To facilitate recovery to the next turning point, for any track error that may occur, converging lines at 5° intervals should be drawn to that turning point. Although not absolutely essential the determination of any alteration of heading required could be further enhanced by drawing diverging lines at 5° intervals from the last turning point and distance gone markers at 10 nm intervals. The application of the '1 in 60 rule' is unnecessary because the track error angle (TEA) is that from *A* and the correcting angle (CA) is that to *B*. To calculate the heading to steer to reach the next turning point add the TEA and the CA and apply the correction in the opposite direction to the drift experienced. The ground speed in knots is equal to the distance gone in nautical miles divided by the time in minutes multiplied by 60. The time to the next turning point is the distance to go in nautical miles divided by the ground speed in knots multiplied by 60.

Figure 3.13 illustrates the practical application of this method for a leg between *A* and *B*, distance of 150 nm. The example shows an aeroplane set heading from *A* at 1000 hrs and obtaining a pinpoint after 20 minutes. The track error angle is 10° and the correcting angle is 7°; therefore, the alteration of heading to reach the turning point is 17° to the right. The ground speed can be calculated as 60 nm in 20 minutes = 180 kts. The ETA is therefore is 1020 + 30 min = 1050 hrs.

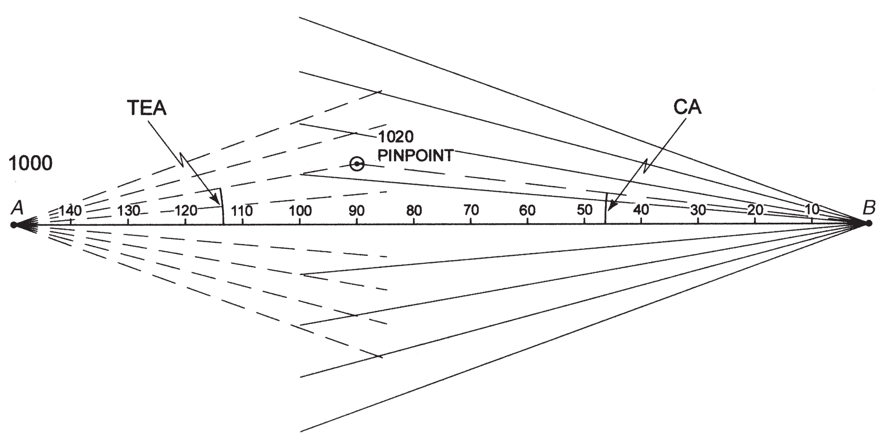


**Figure 3.13** Chart preparation.

## Summary

Become familiar with the Jeppesen topographical chart, in particular the symbology and the contents of the legend. There is no need to learn them, just know what they contain.

Be aware of the amount of clearance given by the Minimum Grid Area Altitude of obstacles and high ground. Know how to calculate the route value of the MGAA.

Remember all the considerations to be made when deciding on the cruising altitude.

## Sample questions

1. The separation from the highest obstacle within each half-degree of longitude and latitude provided by the MGAA is:

   a. 10% of the obstacle height
   b. 2000 ft for obstacles of 5000 ft or less
   c. 1000 ft for obstacles of 5000 ft or less
   d. 1500 ft for obstacles of 5000 ft or less

2. Which of the following is a VFR semicircular cruising level for a magnetic track of 270°?

   a. 5000 ft
   b. 5500 ft
   c. 6000 ft
   d. 6500 ft

3. Because of the possibility of military low-flying activity the cruising level should never be less than:

   a. 500 ft agl
   b. 1000 ft agl
   c. 1500 ft agl
   d. 2000 ft agl

4. The figure shown beside a cableway on the VFR chart is the:

   a. Height above mean sea level
   b. The elevation

c. The height above ground level
d. The altitude above mean sea level

5. The MGAA for an obstacle 9000 ft elevation would be shown as:

a. 11 000 ft
b. 10 000 ft
c. 9000 ft
d. 10 500 ft

6. In which of the following airspace classifications are VFR flights prohibited over Germany?

a. A
b. B
c. C
d. D

7. What does the symbol * signify when positioned next to an airspace classification designator on the VFR chart?

a. Prohibited between dusk and dawn
b. Prohibited between dawn and dusk
c. Prohibited at all times
d. Part-time operation

8. The information printed against an aerodrome symbol on the VFR chart gives:

a. The length of the longest runway in metres and the elevation in feet
b. The length of the longest runway in feet and the elevation in metres
c. The length of the longest runway in metres and the elevation in metres
d. The length of the longest runway in feet and the elevation in feet

9. From Figure 3.7, the vertical limits of Alpine Area E are:

a. FL25 to FL130
b. 2500 m agl to FL130
c. 2500 ft amsl to 13 000 ft amsl
d. 2500 ft agl to FL130

10. Using Figure 3.9, the symbol shown at Greding, 49°03.8'N 011°17.5'E indicates that it is:

a. A hang glider site
b. A glider site
c. A glider activity area
d. An ultralight aeroplane site

# Chapter 4
# IFR Flight Planning

## Introduction

The selection of the route and the aerodromes to be used is most important. They must be compatible with the aeroplane type to be used by the operator, and, in certain circumstances, additional considerations must be made.

## Aerodrome selection

### *Take-off alternate aerodrome(s)*

The operator must select and specify on the ATC Flight Plan (CA 48) a take-off alternate aerodrome for use if an aeroplane is unable to return to the departure aerodrome after take-off because of meteorological or performance reasons. It must be located within the still-air distance that would be covered at the one-engine-inoperative speed, according to the AFM, at the actual take-off weight in a period for:

- Non-ETOPS twin-engined aeroplanes – one hour
- ETOPS twin-engined aeroplanes – the approved ETOPS diversion time, up to a maximum of two hours, subject to any MEL restriction
- Three- and four-engined aeroplanes – two hours.

*JAR-OPS 1.295(b)*

If the AFM does not contain a one-engine-inoperative speed then the speed to be used is that which would be obtained with the live engine(s) set at maximum continuous power. *JAR-OPS 1.295(b)(3).*

#### Weather minima

For any aerodrome selected as a take-off alternate, the weather reports or forecasts, or any combination thereof, for a period commencing one hour before and ending one hour after the ETA at that aerodrome, must be at least at or above that specified for the type of approach provided both the aircraft and ground equipments are serviceable. If only non-precision and/or circling approaches are available at that aerodrome then the cloud ceiling must be accounted. Any one-engine-inoperative limitation must also be accounted. *JAR-OPS 1.297(a).*

## *Destination alternate aerodrome(s)*

On all IFR flights at least one destination alternate aerodrome must be selected by the operator, unless the flight time is six hours or less **and** the destination has two separate usable runways available, at which the weather reports or forecasts, or any combination thereof, indicate that for the period of the ETA ± 1 hour the cloud ceiling will be at least 2000 ft, or the circling height +500 ft, whichever is the higher, and the visibility will be at least 5 km. The exception to the rule is when the destination is isolated and there is no adequate alternate aerodrome available. *JAR-OPS 1.295(c).*

If there is no meteorological information available or the weather reports or forecasts, or any combination thereof, indicate that for the period of ETA ± 1 hour at the destination that the conditions will be below the planning minima then two destination alternate aerodromes must be selected and specified on the ATC Flight Plan. *JAR-OPS 1.295(d).*

The planning minima for the destination and the destination alternate aerodromes for a period of ETA ± 1 hour are:

- Destination aerodrome, except for an isolated destination aerodrome:
    - RVR/Visibility specified by *JAR-OPS 1.430* for the type of approach, provided both the aircraft and ground equipment are serviceable
    - The cloud ceiling at or above MDH for a non-precision or circling approach
- Destination alternate aerodromes and isolated destination aerodromes:

**Table 4.1** Planning minima – en-route and destination alternates

| Type of approach | Planning minima |
|---|---|
| Cat II and III | Cat I (Note 1) |
| Cat I | Non-precision (Notes 1 and 2) |
| Non-precision | Non-precision (Notes 1 and 2) plus 200 ft/1000 m |
| Circling | Circling |

Notes

1 RVR.

2 The ceiling must be at or above MDH. *JAR-OPS 1.297 Table 1.*

## *En-route alternate aerodromes*

The location of an acceptable en-route alternate aerodrome depends on the method used to calculate the contingency fuel for the flight. If 3% of the trip fuel is to be used as the contingency fuel then the en-route alternate aerodrome must be located within a circle, radius equal to 20% of the total flight plan distance, centred at a distance equal to 25% of the total route distance from the destination or 20% + 50 nm, whichever is the greater. See Figure 4.1.

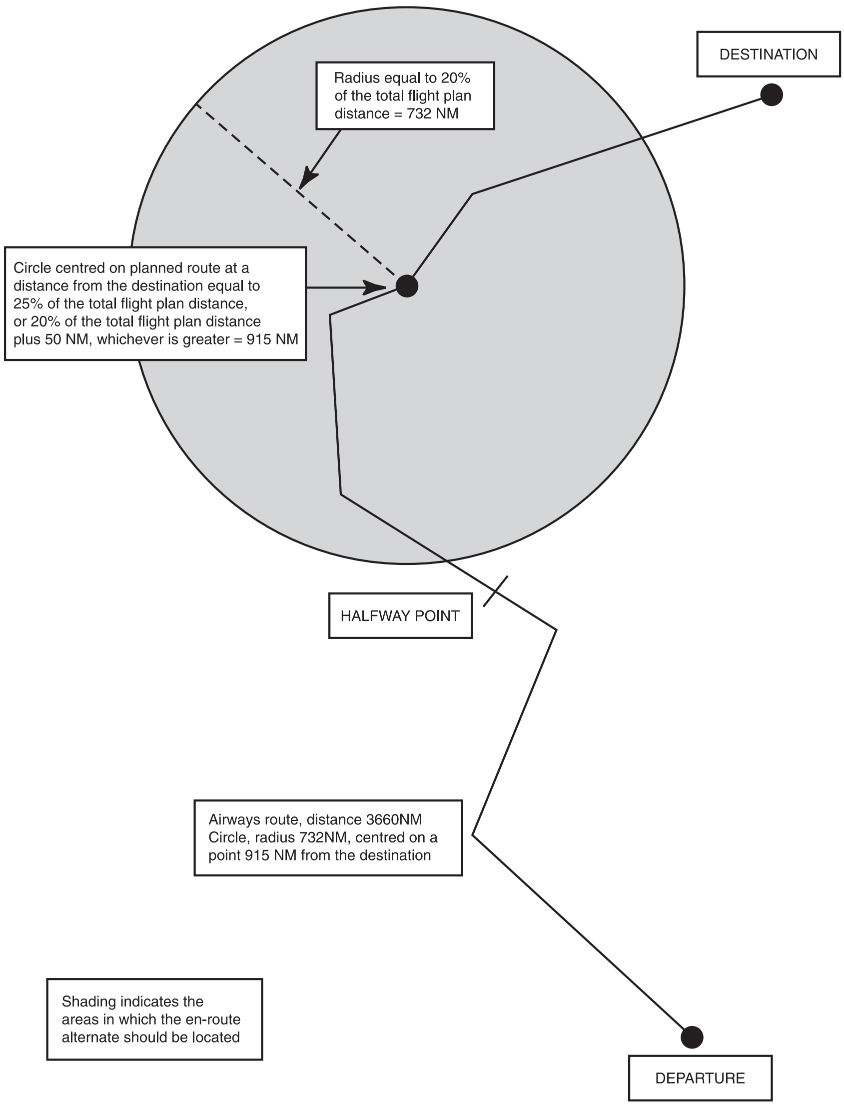


**Figure 4.1** Location of a fuel en-route alternate aerodrome (Appendix to *ACJ-OPS 1.295*).

## Routes and Area of Operation

The route selected must have navigational aids that can be used by the operator to maintain accurate tracking, in compliance with the rules and regulations of the national controlling authority of the airspace through which the route passes. *JAR-OPS 1.240(b).* The aircraft to be used, therefore, must have sufficient equipment on board to meet the minimum navigational en-route and approach requirements stipulated by the appropriate authorities. *JAR-OPS 1.240(a)(1)* and *(3).*

The maps and charts to be carried must be current, appropriate for the route from departure to destination, and onward to the destination alternate aerodrome. Additionally, the appropriate arrival and approach charts must be carried, not only for the planned destination and destination alternate aerodromes but also for all the aerodromes at which a landing may be made. *JAR-OPS 1.240(a)(4)*, *1.135(a)(9)* and *1.290(b)(7).*

The performance of the aeroplane must be sufficient to comply with the take-off, en-route and landing requirements specified in the appropriate subpart of JAR-OPS. Particular mention of its ability to comply with the minimum flight altitude requirements is made in *JAR-OPS 1.240(a)(2)*.

If the aeroplane is twin-engined then adequate aerodromes must be available within the time/distance limitations specified in *JAR-OPS 1.245*. These restrictions are explained in detail later in this chapter. Single-engined aeroplanes may be used only if there are surfaces available along the route on which a safe forced landing may be executed.

### *Twin-engined aeroplane restrictions*

All public transport twin-engined aeroplanes have their routes restricted by one of the following rules:

- Aeroplanes having a maximum take-off mass (MTOM) greater than 8618 kg **or** a maximum approved passenger seating capacity of more than 19 are restricted to routes that remain within a distance that may be reached in *60 minutes at the one-engine-inoperative cruising speed in ISA conditions* from an adequate aerodrome, unless ETOPS approval has been granted by the appropriate licensing authority.
  *CAP 513 paragraph 1.2.1* and *paragraph 1.4.11* and *JAR-OPS 1.245(a).*
- An aeroplane certificated as being in Performance Class B is restricted in a similar manner except that the maximum distance from an adequate aerodrome is equal to *90 minutes at the all-engines maximum-range cruise speed in ISA conditions* ***or*** *300 nm*, whichever is the least.
  *JAR-OPS 1.245(b).*

- Aeroplanes not included in the preceding two points and not ETOPS approved may not be operated on a route that contains any point at a distance greater than that which is equal to *120 minutes at the one-engine-inoperative cruise speed in ISA conditions.*

  *JAR-OPS 1.245(c).*

- If the operator has obtained ETOPS approval, then a suitable en-route alternate aerodrome must be available within *the authorised diversion time* at which the forecast weather is within the prescribed limits and there is an ATC facility and at least one letdown aid (ground radar would so qualify) for an instrument approach.

  *JAR-OPS 1.245(d).*

### *Minimum flight altitude*

An aeroplane is not permitted to be flown below the specified minimum altitudes except for take-off and landing. *JAR-OPS 1.365* and *1.250.* The considerations that must be made are the minimum safe altitude above the ground/obstacles and ATC considerations, such as controlled airspace, danger areas and the semicircular cruising altitude regulations.

A detailed explanation was given in Chapter 3 of the Jeppesen formula for calculating the minimum off-route altitude (MORA), therefore, in this chapter the ATLAS formula will be explained in detail.

### *The ATLAS formula*

The Minimum Safe En-route Altitude (MEA) is based on the elevation of the highest point along the route segment concerned within a specified corridor. The semi-width of the corridor is:

- Ten nautical miles for sector lengths up to 100 nm, which can be reduced to 5 nm within a TMA because of the large number of navigational aids available and the accuracy of the tracking required.
- For sector lengths over 100 nm, the semi-width of the corridor is equal to 10% of the segment length up to a maximum semi-width of 60 nm. However, where this method is impracticable, a special MEA of not less than 10 nm may be imposed. If such is the case, an indication of the actual width of the protected airspace will be given.

The MEA is calculated by adding an increment to the elevation of the highest point in the leg corridor and adjusting the sum to the nearest 100 ft. The increment is given in Table 4.2.

**Table 4.2**

| Highest point elevation | Increment |
|---|---|
| 5000 ft and below | 1500 ft |
| Over 5000 ft up to 10 000 ft | 2000 ft |
| Over 10 000 ft | 10% of elevation +1000 ft |

Note that for the last segment of a route that terminates at an initial approach fix within a TMA the increment may be reduced to 1000 ft because of the high degree of navigational accuracy required. *IEM OPS 1.250.4.*

The ICAO Standard Semicircular IFR cruising levels should be used because all airway flights are conducted under IFR. These are based on the magnetic track (see Figure 3.3) such that:

**Table 4.3**

| Magnetic track | Below FL290 | Above FL290 |
|---|---|---|
| 000–179 | Odd FLs | FL290 + 4000 ft intervals |
| 180–359 | Even FLs | FL 310 + 4000 ft intervals |

Because of the congested airways system within Europe, and the fact that the airways must be coordinated, it is not always possible for an airway to comply with the ICAO semicircular cruising levels. If an airway does not comply then marked along the airway centre line on the chart will be either O> or E>.

Most airways do not pass through danger or prohibited areas. If such is the case the airway will be closed when the area is notified as being active.

Many airways are only open one-way. The en-route charts must be carefully studied before deciding on a particular route. Additionally, the Standard Instrument Departure charts (SIDs), the Standard Terminal Arrival charts (STARs) and Instrument Approach charts must be considered when making this decision. Many airlines have standard routes for which the FMS has the coordinates already in the database. Route preparation is therefore minimised.

## *SIDs, STARs, Instrument Approach and En-route charts*

### General

The charts to be used for a flight under IFR can be broadly divided into the following categories:

- Aerodrome Information charts

- Standard Instrument Departure charts
- En-route charts
- Standard Terminal Arrival charts
- Instrument Approach charts
- Area charts.

**Aerodrome Information charts**

The Aerodrome Information charts are titled ‘Airport’ and include several different types of chart. The quantity of charts for a particular aerodrome will vary according to its size. For instance, Heathrow has 11 ‘Airport’ charts in the Jeppesen Student Pilot Route Manual; however, there are many more in the complete manual. They are:

- Aerodrome layout 1
- Parking positions 2
- INS coordinates 2
- Engine start-up procedure 1
- Taxi and parking procedure 1
- Stand entry guidance 1
- Use of runways for landing 1

**Standard Instrument Departure charts (SIDs)**

Most major aerodromes have produced standard departure routes, from every runway, to join all of the frequently used airways. The runway and route for which the chart is to be used is specified in the title at the top of each chart. The SID chart shows the magnetic track and distance to each reporting, or turning point, together with the altitude to be maintained or reached by specified positions. Navigational aids are shown with their frequency and call sign. The commonly used communications frequencies are stated at the top of the chart.

**En-route charts**

En-route charts are divided into high- and low-level charts. They are navigational charts that have the aeronautical information overlaid on a skeleton-plotting chart, which is a Lambert Conical Orthomorphic, a Mercator, a Transverse Mercator, an Oblique Mercator or a Polar Stereographic type. The type of underlying plotting chart used depends on the area of coverage of the world. The meridians of longitude and parallels of latitude are shown and labelled at intervals determined by the scale of the chart. A scale for measuring distance is provided at the side of each chart.

Usually the charts are printed back to back. On the front fold of each chart is a diagram showing the area of coverage. The chart shows the airways structure, all aerodromes, navigational aids, Flight Information Region (FIR) boundaries, international boundaries, communications area boundaries, together with the controller's identification and frequency. Safety altitude information is stated as either a MORA or an MEA, and the altitude limitations of all controlled airspace are printed on the depicted airway.

### Standard Terminal Arrival charts (STARs)

The route to be followed from a particular airway reporting point to land on a specified runway at the destination aerodrome is depicted on a STAR. Specified in the title at the top of each chart is the runway and route for which the chart is designed. The STAR chart shows the magnetic track and distance to each reporting, or turning point, together with the altitude to be maintained or reached by specified positions. Navigational aids are shown with the frequency and call sign. The commonly used communications frequencies are stated at the top of the chart.

### Instrument Approach chart

For each runway that has an instrument approach aid at an aerodrome there will be a chart depicting the plan and profile view of the approach path for that particular approach aid. The title at the top of the chart will specify the approach aid and runway for which the chart was designed. The communication frequencies to be used will be shown in the same block. Both plan and profile views will show magnetic tracks and distances between reporting points, and altitudes and heights at specified positions. Below the profile view there is a block showing the minimum permissible altitude and height to which the aeroplane may be descended without visual contact with the runway.

### Area charts

For some large aerodromes at which the air traffic is dense, an area chart is available. This chart is a large-scale version of the airways chart for the area surrounding the terminal aerodrome, but it also includes the depiction of high ground using contours, layer tinting and spot heights. The navigational and communications information is the same as that of the en-route chart.

### Chart preparation

Although the charts in the Jeppesen Student Pilot Route Manual do not change with the passage of time, be aware that all charts used for navigation are liable to change at irregular intervals. It is most important that when planning a flight the charts to be used should be checked against the most recent currency checklist. In the pre-flight preparation, it is usual to highlight the route to be followed on all the charts to be used. This will facilitate the rapid location of the route on the chart when in flight.

It is essential that the symbology used on all charts is easily recognised and interpreted. Although there is a comprehensive decode section in the Jeppesen Student Route Manual, there will be insufficient time in the examination to make use of it. Try to learn as many symbols as possible because they are an invaluable source of questions to the examiner.

Some of the decode pages are reproduced here but it is stressed that they are only a sample. It is necessary to study the complete section in the manual from page 51 to page 166 and *New Format* pages 1 to 5.

## *The route plan*

The easiest way to learn about the various charts is to follow through the procedure to formulate a route plan. The example route presented here is from London to Munich, taking off from runway 09 right using the SID to join airways at Dover and travel via airways G1 and B1 to land at Munich on runway 08 left. The aeroplane is multi-engined pistoned (MEP). At this stage, it is only necessary to draw up a skeleton plan, which will be completed in Chapter 7 with the fuel details. Therefore, it is only necessary to determine the magnetic tracks, the distances, the minimum off-route altitude and the base of the airways to be used.

The charts to be used are:

- Heathrow airport 10–9
- Heathrow SID 10–3F
- Low-altitude En-route chart 6
- Munich STAR 10–2B
- Munich ILS 08L 11–1
- Munich NDB/DME 08L 16–1

## *Pre-flight charts*

The engine start-up and push back procedures are detailed on Heathrow Airport chart 10–9F. The INS coordinates for setting up or checking the aircraft navigational equipment are quoted for all stands at Heathrow on Airport chart 10–9D. The relationship of the stands to the runways is shown on Airport chart 10–9B, which also enables the taxi route to be followed to the take-off position.

The complete aerodrome layout is depicted on Airport chart 10–9 (see Figure 4.2.). The chart identifier, the country, city and aerodrome names together with its ICAO identifier are stated on the top right of the chart. Beneath the aerodrome name the precise latitude and longitude of the airport datum point, the magnetic variation at the airport and the elevation of the datum are given.

At the top left of the chart the commonly used communication frequencies for taxi and take-off are quoted. Descriptions of the runway crossing procedure and the runway holding areas are given at the bottom of the chart. The runways are shown in black on the chart and, on the runway extension line, the exact magnetic direction of the runway is stated below the runway identifier. The precise elevation of the runway threshold is stated against this position. The runway length (both in feet and metres) is printed approximately midway along the runway. The white numbers on the runway are traffic blocks.

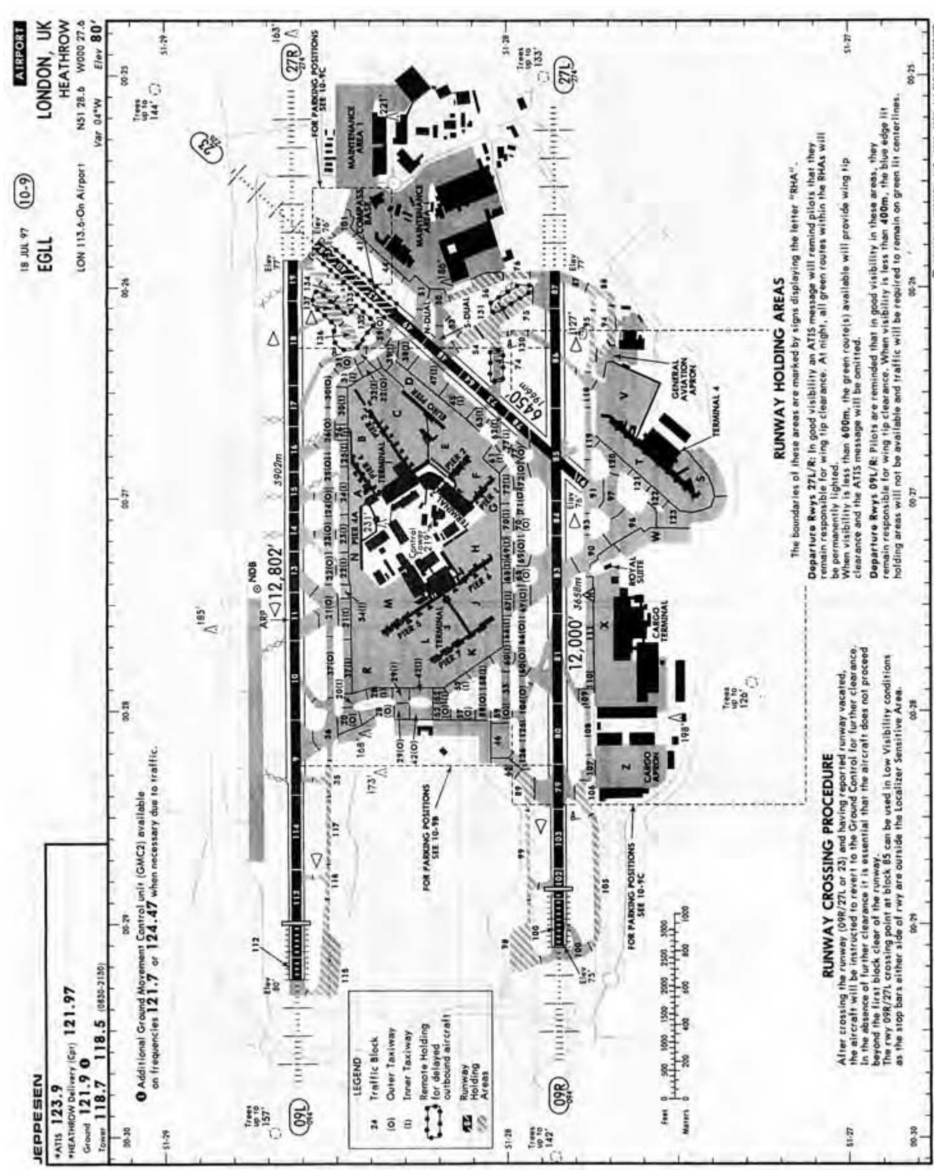


**Figure 4.2** London Heathrow Airport chart 10–9. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

## *The Standard Instrument Departure chart*

There are three decode pages for the SID charts in the Student Pilot Route Manual. They are pages 81, 82 and 83. If any difficulty is experienced understanding the charts, the meaning of any symbol encountered can be clarified by reference to these pages.

Take-off is planned to be on runway 09 right to join airways at Dover. Therefore, the SID chart to be used is 10–3F; check the effective date is still current (it is not so in this training manual example). See Figure 4.3. At the top left of the chart the communications frequency is quoted as being 120.52 MHz, beneath which the transition altitude is given as 6000 ft and that the transition level will be given by ATC. From the route identifiers stated below this the flight plan requires the Dover 6 Juliett to be followed.

The plan view of the procedure contains a considerable amount of information. Above the diagram, it states that a speed limitation of 250 kts IAS is imposed below FL100 unless otherwise cleared by ATC. A small circular diagram to the right of this shows the minimum sector altitude within 25 nm of the aerodrome to the south-east is 2300 ft. Beneath the diagram it states that the cruising level will be issued after take-off by London Control, followed by a reminder not to climb above the altitudes given on the diagram unless cleared by ATC. The table to left of this states that all routes are noise preferential and require a minimum climb gradient of 243 ft per nm (4%).

The table to the bottom left of the diagram describes the take-off, routing and altitude procedures (these descriptions are shown diagrammatically). After take-off, climb straight ahead until reaching 2 nm from the LON DME then turn right on to track 125°(M). At a distance of 4 nm from the LON DME turn left onto track 107°(M). After turning, the DME and VOR should be retuned to Detling on 117.3 MHz. On reaching a range of 29 nm the aircraft should be at or above 3000 ft with the QNH in the altimeter sub-scale.

The aircraft should continue to climb until reaching 6000 ft and maintain this altitude until overhead the Detling VOR. Further clearance to climb will be given by ATC. From the overhead turn right onto a track of 110°(M) and retune the VOR/DME to Dover on 114.95 MHz.

### Lines 1, 2 and 3 of Figure 4.10

For the purposes of the flight plan, see Figure 4.10, the track to the top of climb, line 1, and on to Detling, line 2, should be entered as 107°(M) and the total distance for both legs as 40 nm. The MSA to the top of climb and on to Detling can be entered as 2300 ft. The details for the leg from Detling to Dover are entered on line 3 as MORA 2300 ft (from the London area chart), magnetic track 110 and distance 30 nm.

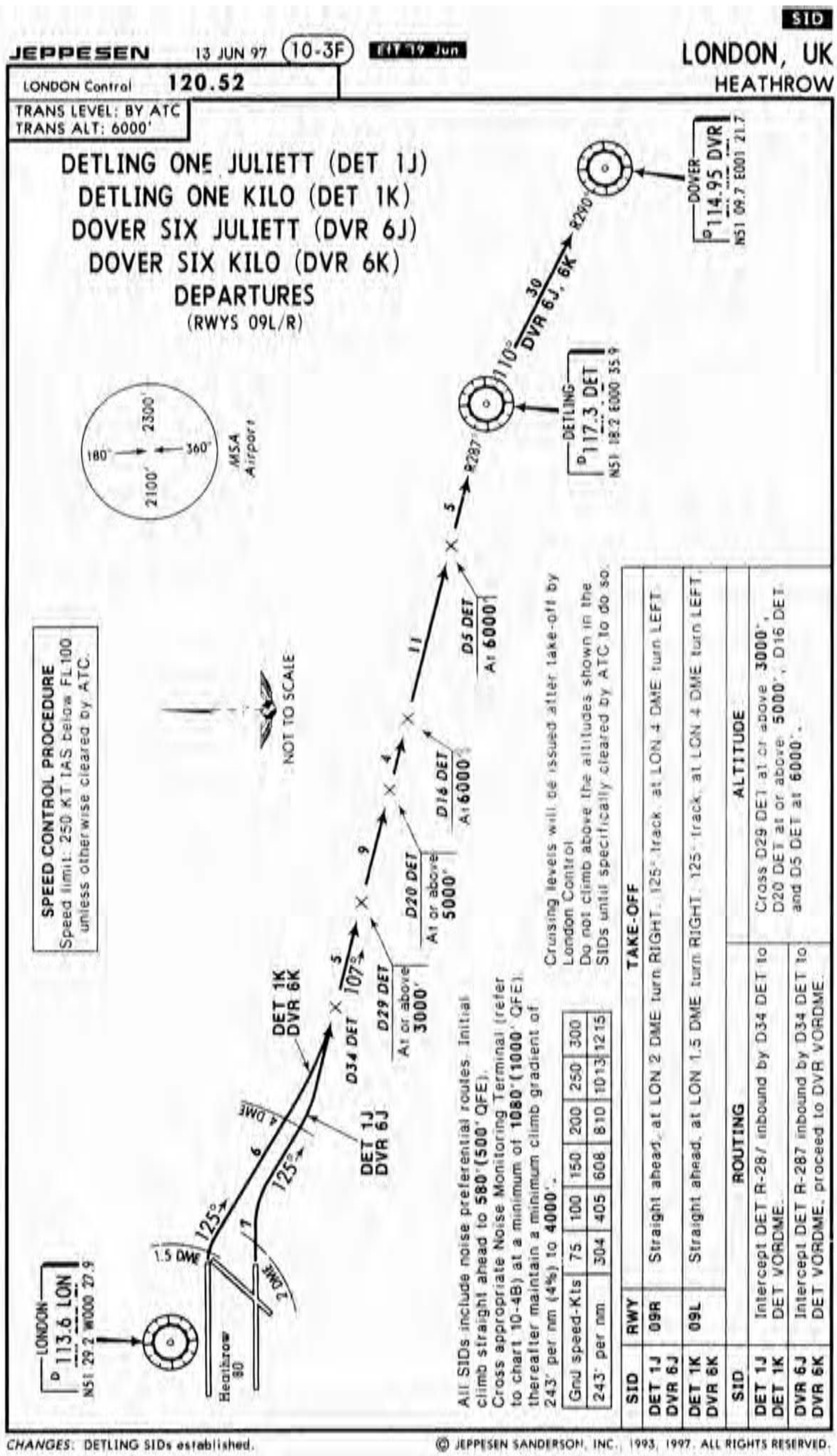


**Figure 4.3** London Heathrow SID chart 10–3F. *(Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.)*

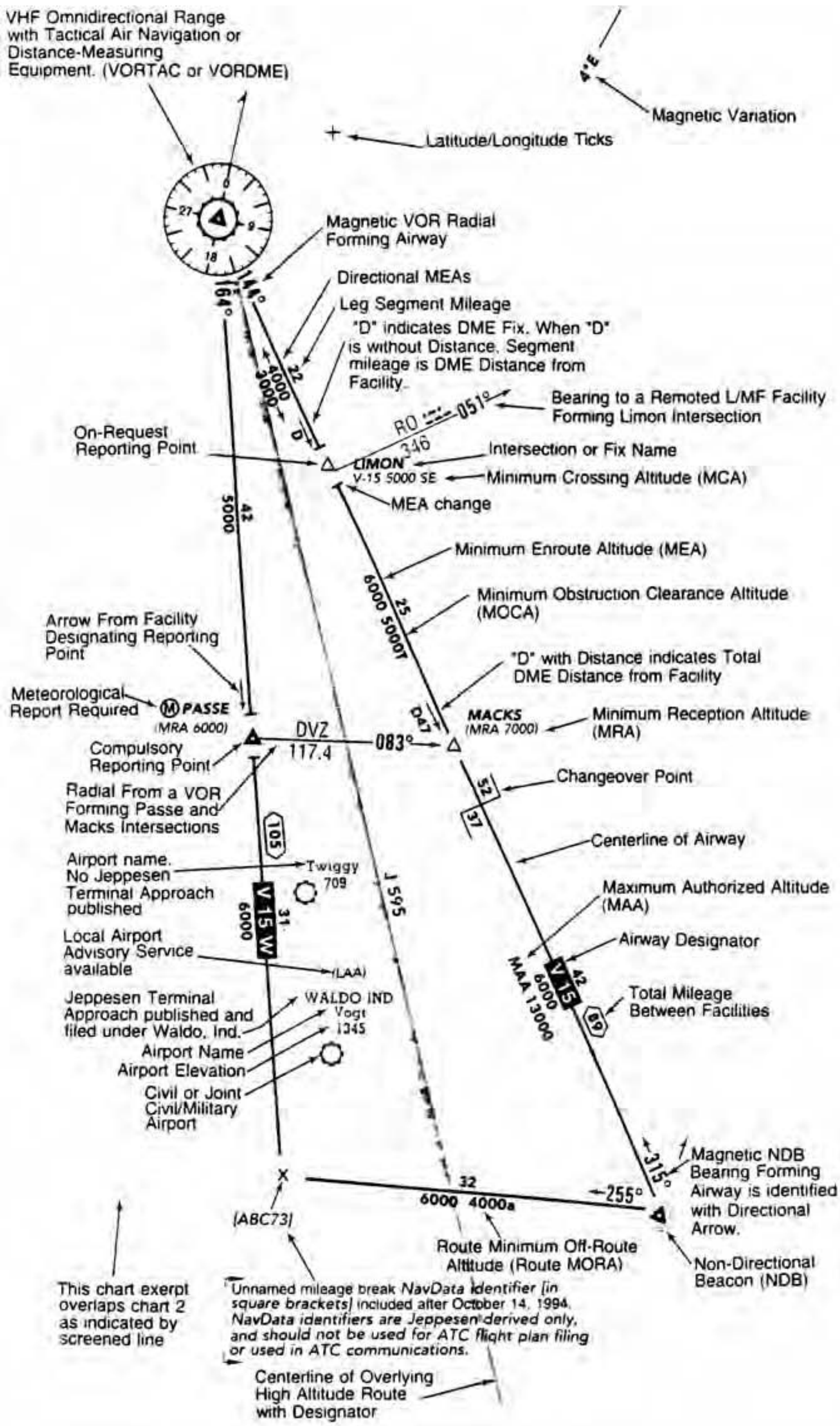


**Figure 4.4** En-route chart legend. (*Reproduced with permission of Jeppesen GmbH.*)

## *The Low-altitude En-route chart*

The chart to be used for the selected route is E (LO) 6. The front cover specifies that the chart is a scale of 1 inch to 15 nm and states that all airways, routes and controlled airspace are generally effective up to the upper limits of the lower airspace for each country. Below this statement are tabulated the limits of the airspace covered by the chart. For this route the countries to be transited are Belgium (upper limit FL195) and Germany (upper limit FL245). Below this table is a sketch map of the area of coverage on which the dates of summer time are overprinted. Notice the chart is effective upon receipt. A decode chart is shown in Figure 4.4.

The lower half of the front panel and two other panels are devoted to the listing of communications frequencies for the chart by place name in alphabetical order. A note at the bottom of the front panel specifies that other panels be devoted to airspace restricted areas (shown in green on the chart), transponder settings and cruising levels.

See Figure 4.5. The G1 airway starting at Dover has a track of 098°(M) and the distance to Koksy is 49 nm (shown in a small six-sided box just before Koksy). The details of navigational aids situated along any airway on the chart are contained in a shadow box. It will contain the name, the call sign, the frequency, the call sign in Morse code and the precise latitude and longitude. The airway identifier is in a large arrow box, which indicates that it is normally a one-way airway eastbound. This is also stated on the airway centre line in small print. Ball flag 6 specifies the exceptions to this in a small panel above the airway.

Konan is a non-compulsory reporting point situated on the Flight Information Region (FIR) boundary, shown by a hollow triangle with the precise latitude and longitude printed below. The boundary is shown by a blue line etched at intervals on both sides. By following this line the ICAO identifiers of the FIRs on both sides of the line can be discovered. They are London EGTT and Amsterdam EHAA.

Along the centre line is detailed the lowest available flight level on the airway as FL80 between Dover and Konan and FL70 between Konan and Koksy. The Minimum Off-Route Altitude is specified as 2300 ft for both legs. To the west of this is the figure D24.7 with a thin arrow; this is the DME distance to Konan from Koksy.

### Lines 4 and 5 of Figure 4.10

Usually, on a flight plan, only the leg details between compulsory reporting points, which are either solid blue or solid green triangles on the route chart, are entered. However, because the track crosses an FIR boundary it is necessary to split the leg for the purposes of entering the flight time details on the ATS Flight Plan. Therefore, line 4 of this flight plan is from Dover to Konan, which is the FIR boundary, for which the details are MORA 2300 ft, track

098°(M) and distance 24 nm. The details for line 5 from Konan to Koksy are MORA 2300 ft, track 097°(M) and distance 25 nm.

### Line 6 of Figure 4.10

The next leg is therefore from Koksy to Dender. See Figure 4.5. Mackel is not a compulsory reporting point. The airway identifier is now in an oblong box indicating that it can be used in either direction, ball flag 6 still applies. The track is 106°(M) and should be entered on line 6. The distance between Koksy and Dender has to be calculated by adding the individual distances along the route centre line together. They are 33 + 21 = 54 nm. The minimum en-route altitude and off-route altitude for this leg are the highest of the individual specified values, which are FL60 and 2200 ft.

Although it is normal practice to tune the number 1 VOR receiver to the beacon ahead of the aeroplane and the number 2 VOR receiver to the beacon behind the aeroplane, with a leg length of 121 nm and at low altitude it is quite likely that the VOR at Olno will not provide a reliable reading for some time after reaching Koksy. It would be prudent to tune the Number 1 VOR to Koksy and to tune the ADF equipment to receive the NDB at Mackel and then to switch the number 2 needle on the instrument to indicate the NDB. The receiver can subsequently be retuned to the Dender beacon and so permit accurate tracking.

### Line 7 of Figure 4.10

Whilst Gatta is a compulsory reporting point (see Figure 4.6) it is only on request

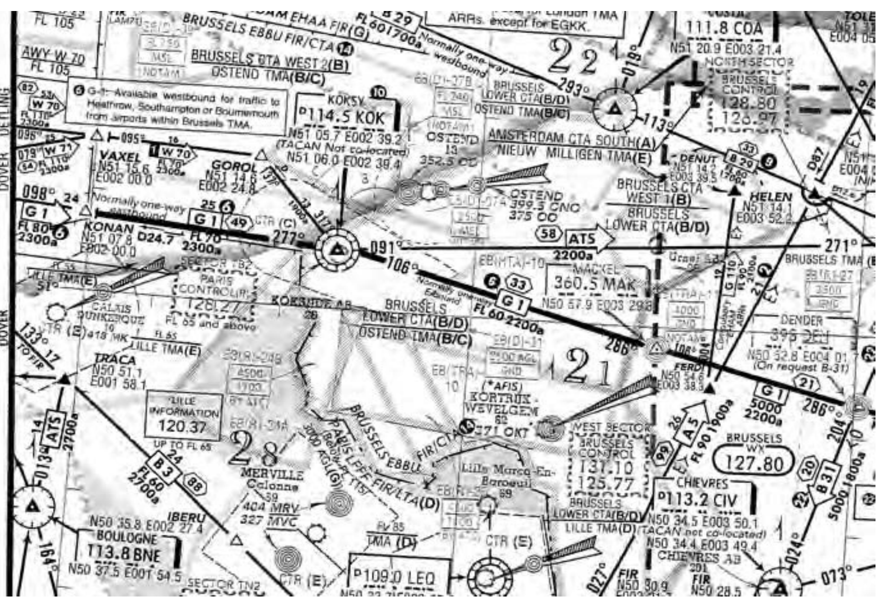

**Figure 4.5** Konan to Dender. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

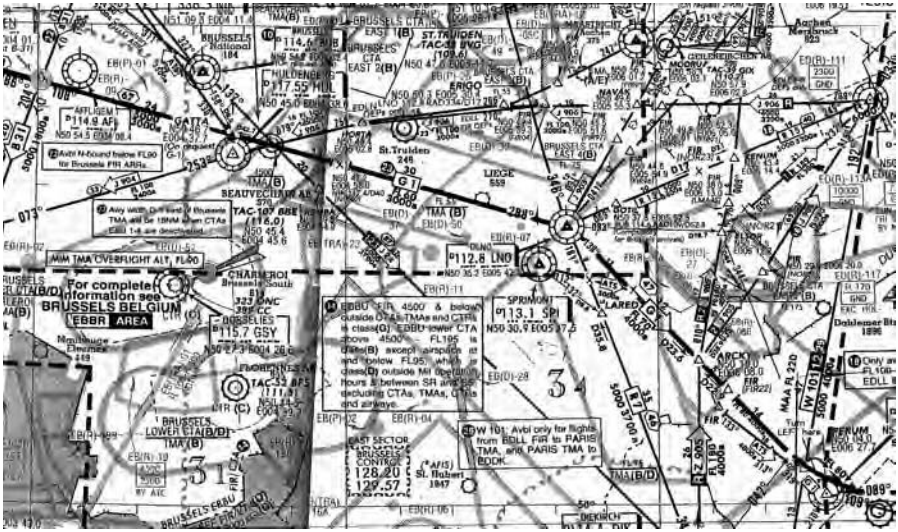


**Figure 4.6** Dender to Nattenheim. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

for airway G1 as noted below the printed latitude and longitude. The details for the leg from Dender to Olno are track 108°(M), distance 67 nm, minimum cruise level FL60 and minimum off-route altitude 3000 ft, which should be entered on line 7 of the flight plan. Ball flag 23 means that airway G1 width east of Brussels TMA will be 16 nm when CTAs East 1–4 are deactivated. The blue cross at N50° 43.2' E004° 58.0' is a mileage break point and has no significance to the flight plan.

### Line 8 of Figure 4.10

Beyond Olno airway G1 reverts to a one-way airway. See Figure 4.6. The next reporting point of significance is where there is a major change of airway direction at Nattenheim; although it is not a compulsory reporting point it must be entered on the flight plan because of this. The details to be entered on line 8 are MORA 4000 ft, track 139°(M) and distance 47 nm. Note the minimum cruising level on this leg is FL80.

### Line 9 of Figure 4.10

The next significant point is Frankfurt (see Figure 4.7), where it is necessary to change to airway to B1 to reach the destination (see Figure 4.8). The details for the flight plan are track 089°(M), distance 81 nm, minimum cruising altitude FL80 and the minimum off-route altitude is 3800 ft. Two NDBs may be of navigational assistance along the route, they are Rudesheim and Wiesbaden. Notice there are two holding patterns, a left-hand pattern at Rudesheim and a right-hand pattern at Frankfurt. These will usually be used only by aircraft landing at Frankfurt.

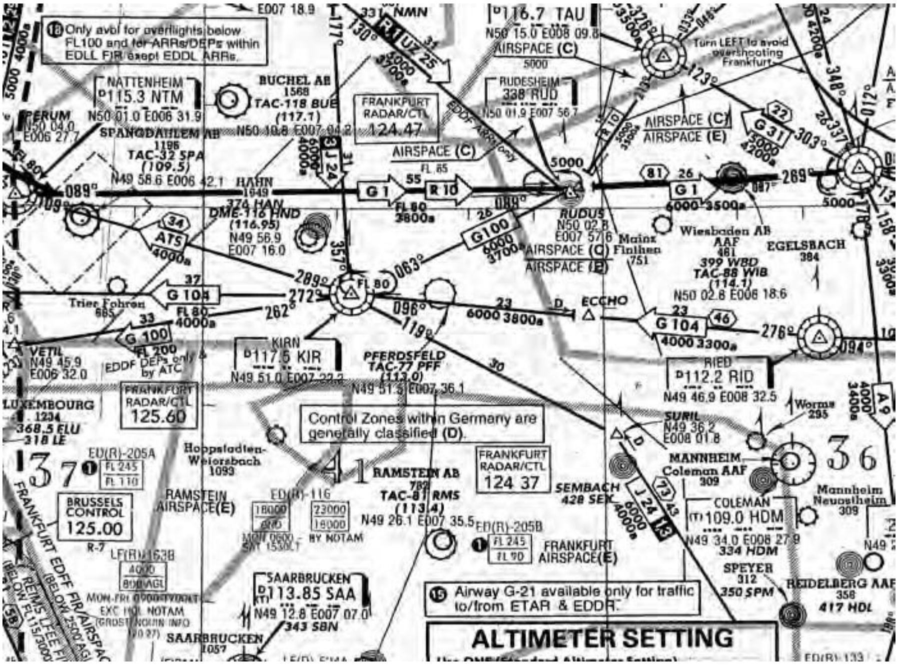


**Figure 4.7** Nattenheim to Frankfurt. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

### Lines 10 and 11 of Figure 4.10

The new airway is B1 and is a one-way airway. See Figure 4.8. The details for the next two legs are Frankfurt to Dinkelsbuhl, line 10, track 132°(M), distance 83 nm, minimum cruising altitude 5000 ft and minimum off-route altitude

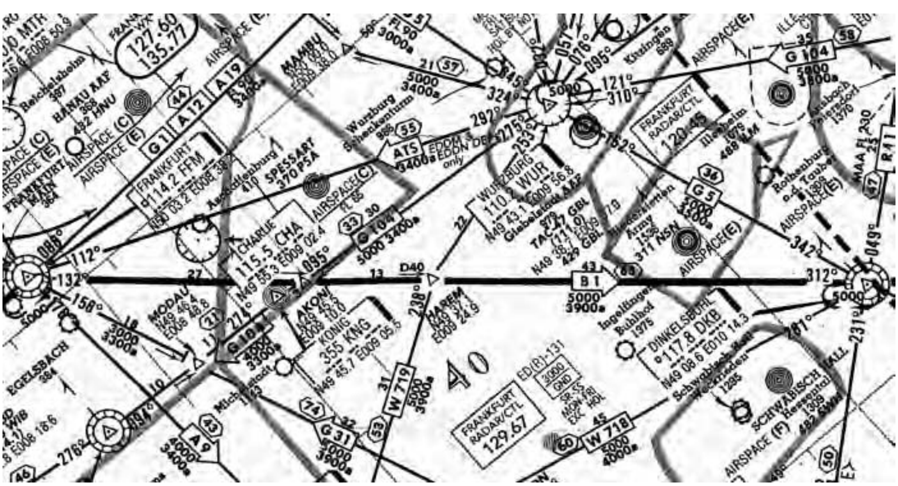


**Figure 4.8** Frankfurt to Dinkelsbuhl. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

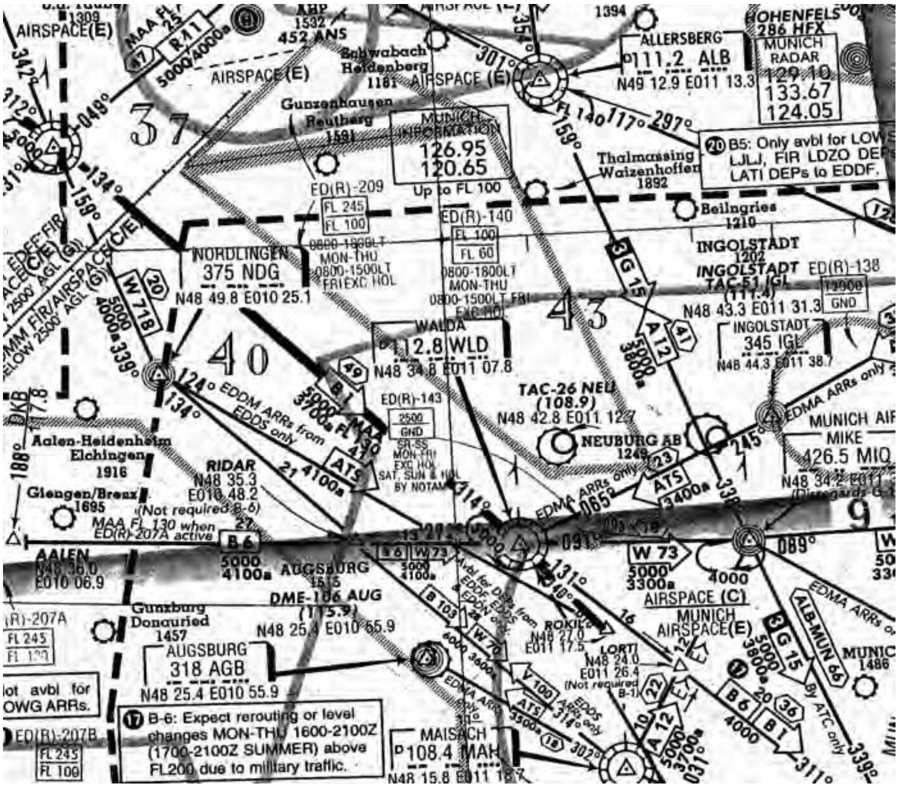


Figure 4.9 Dinkelsbuhl to Walda. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

3900 ft. For line 11, see Figure 4.9, the details are Dinkelsbuhl to Walda, track 134°(M), distance 49 nm, minimum cruising altitude 5000 ft and minimum off-route altitude 3700 ft.

## *The Standard Terminal Arrival (STAR) chart*

The STAR is similar in layout and content to the SID. At the top of the chart is the chart identification label together with the country, town and airport names. The communications frequency box contains that for the Automated Terminal Information Service. Below this box is the transition level and transition altitude information. The names of the arrival procedures included in the chart are listed at the top of the chart diagram.

The chart required for this route is Munich 10–2B (Figure 4.11). From the diagram it can be seen that the route is from Walda to Rokil, which is the Initial Approach Fix (IAF). The track is 140°(M) and distance 10 nm with a Minimum En-Route Altitude of 5000 ft. These details should be entered on the skeleton flight plan (Figure 4.10). If it is necessary to hold, then it is a right-hand racetrack between the 5 nm and 10 nm ranges on the Walda DME.

MEP FUEL PLAN

| STAGE FROM | STAGE TO | TEMP °C | FL | MORA | WIND DIR'N | WIND SPEED | TR (M) | IAS kts | TAS kts | G/S kts | GND DIST nm | TIME mins | FUEL FLOW lbs/hr | START OF LEG AUW lbs | FUEL USED lbs | END OF LEG AUW lbs | FUEL REMAINING lbs | ETA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EGLL | TOC | — | ↗ | 23 | | | 107 | | | | 40 | | | 4750 | | | | |
| TOC | DET | | | 23 | | | 107 | | | | | | | | | | | |
| DET | DVR | | | 23 | | | 110 | | | | 30 | | | | | | | |
| DVR | KONAN | | | 23 | | | 098 | | | | 24 | | | | | | | |
| KONAN | KOK | | | 23 | | | 097 | | | | 25 | | | | | | | |
| KOK | DEN | | | 22 | | | 106 | | | | 54 | | | | | | | |
| DEN | LNO | | | 30 | | | 108 | | | | 67 | | | | | | | |
| LNO | NTM | | | 40 | | | 139 | | | | 47 | | | | | | | |
| NTM | FFM | | | 38 | | | 089 | | | | 81 | | | | | | | |
| FFM | DKB | | | 39 | | | 132 | | | | 83 | | | | | | | |
| DKB | WLD | | | 37 | | | 134 | | | | 49 | | | | | | | |
| WLD | DKB1T | | | 40 | | | 140 | | | | 21 | | | | | | | |
| DKB1T | EDFM | | | 40 | | | RAD | | | | 12 | | | | | | | |

| DEPARTURE A/F | | DESTINATION A/F | | ALTERNATE A/F | | ROUTE CLEARANCE | ROUTE FUEL | |
|---|---|---|---|---|---|---|---|---|
| RUNWAY (M) | 094R | RUNWAY (M) | 083L | RUNWAY (M) | 08 | 09R SID DVR 6J | CONTINGENCY FUEL | |
| W/V | | W/V | | W/V | | G1 FFM B1 WLD DKB 1T | ALTERNATE FUEL | |
| ELEVATION | 80' | ELEVATION | 1486' | ELEVATION | 1267' | | FINAL RESERVE | |
| QNH | | QNH | | QNH | | POWER 65% 2500 rpm | PLANNED TAKE-OFF FUEL | |
| PRESSURE ALT | | PRESSURE ALT | | PRESSURE ALT | | | EXTRA FUEL | |
| TAKE-OFF MASS | | ALT T/O MASS | | | | | TAKE-OFF FUEL | |
| ROUTE FUEL | | ALTERNATE FUEL | | | | | TAXI FUEL | |
| LANDING MASS | | LANDING MASS | | | | | BLOCK FUEL | 738 |

**Figure 4.10** Skeleton Flight Plan – London Heathrow to Munich.

## *The Approach chart*

The Approach Chart, for this example Munich 11–1 (Figure 4.12), is a procedure chart for a particular runway using a specified navigational aid. The chart contains a plan view of the approach and missed approach procedure and a profile view of the approach. At the top right of the chart are the usual identification labels for the country, city and aerodrome. Below this is the type of approach and runway, together with the navigation aid frequency and call sign. The last item in this block is the aerodrome elevation.

The box at the top left of the chart contains all the communications frequencies necessary for the approach. Below this box is the altimeter information. Above the plan view in the centre is a diagram illustrating the minimum safe altitude for a radius of 25 nm from the aerodrome reference point.

The main plan view diagram of the procedure shows all the magnetic tracks, distances and DME ranges needed to complete the procedure. Around the outside of the diagram are etches at 10 minute intervals of latitude and longitude. Along the left vertical edge of the plan view is a distance scale. Also shown on this diagram are all the obstacles (and their elevations), aerodromes and navigational aids in the area surrounding the destination.

A table, positioned below the plan view diagram, details the altitude and

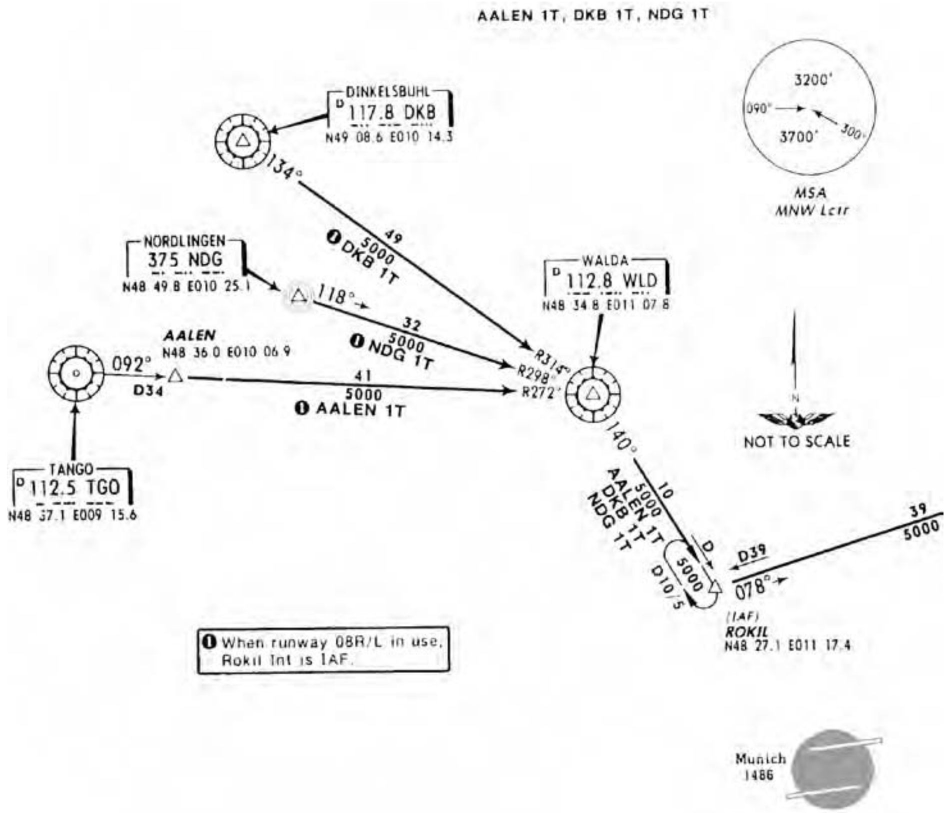


**Figure 4.11** Munich STAR Chart 10–2B. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

height at which an approaching aeroplane should be if the glide slope is unserviceable at specified ranges. It should be noted that the heavy typed figure are altitudes (i.e., with QNH set in the altimeter sub-scale). The figures in brackets are heights (i.e., with QFE set in the altimeter sub-scale).

The profile view of the procedure shows the altitude and height that the aeroplane should be at various points during the approach. TCH is the threshold crossing height. To the right of this diagram is a table listing the Obstacle Clearance Altitude (OCA) and Obstacle Clearance Height (OCH) for each category of aeroplane and for the glide slope unserviceable. Below this table is given the threshold elevation.

Below the profile diagram is a description of the missed approach procedure. Tabulated below this are the Decision Altitude (DA) and Decision Height (DH) for a full ILS procedure and the Minimum Descent Altitude (MDA) and Minimum Descent Height (MDH) for a localiser only or an NDB approach, and the RVR and visibility for each category of aeroplane. To facilitate maintenance of the glide slope a table is provided showing, for specified ground speeds, the rate of descent to be maintained.

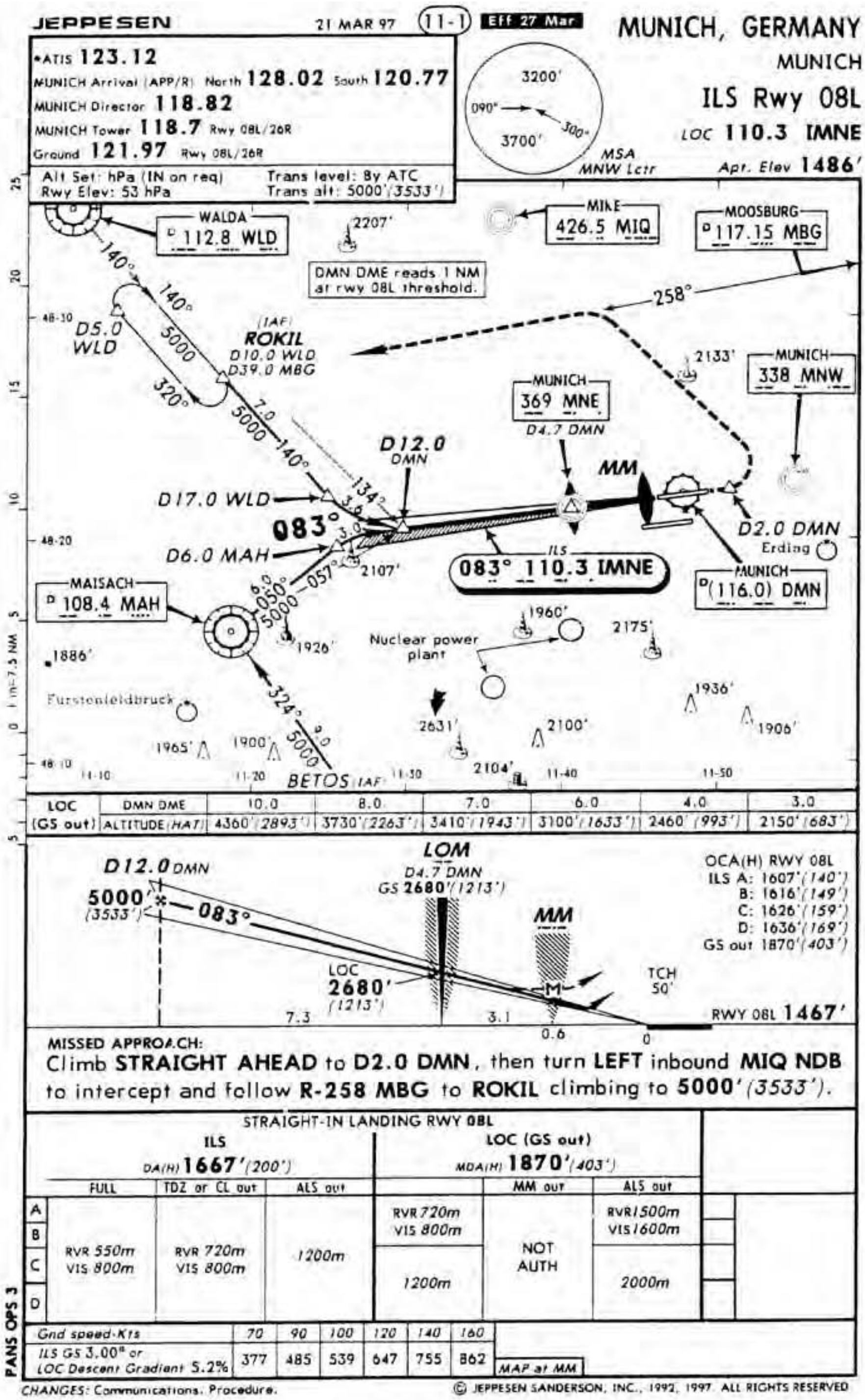


**Figure 4.12** Munich ILS Runway 08L chart. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

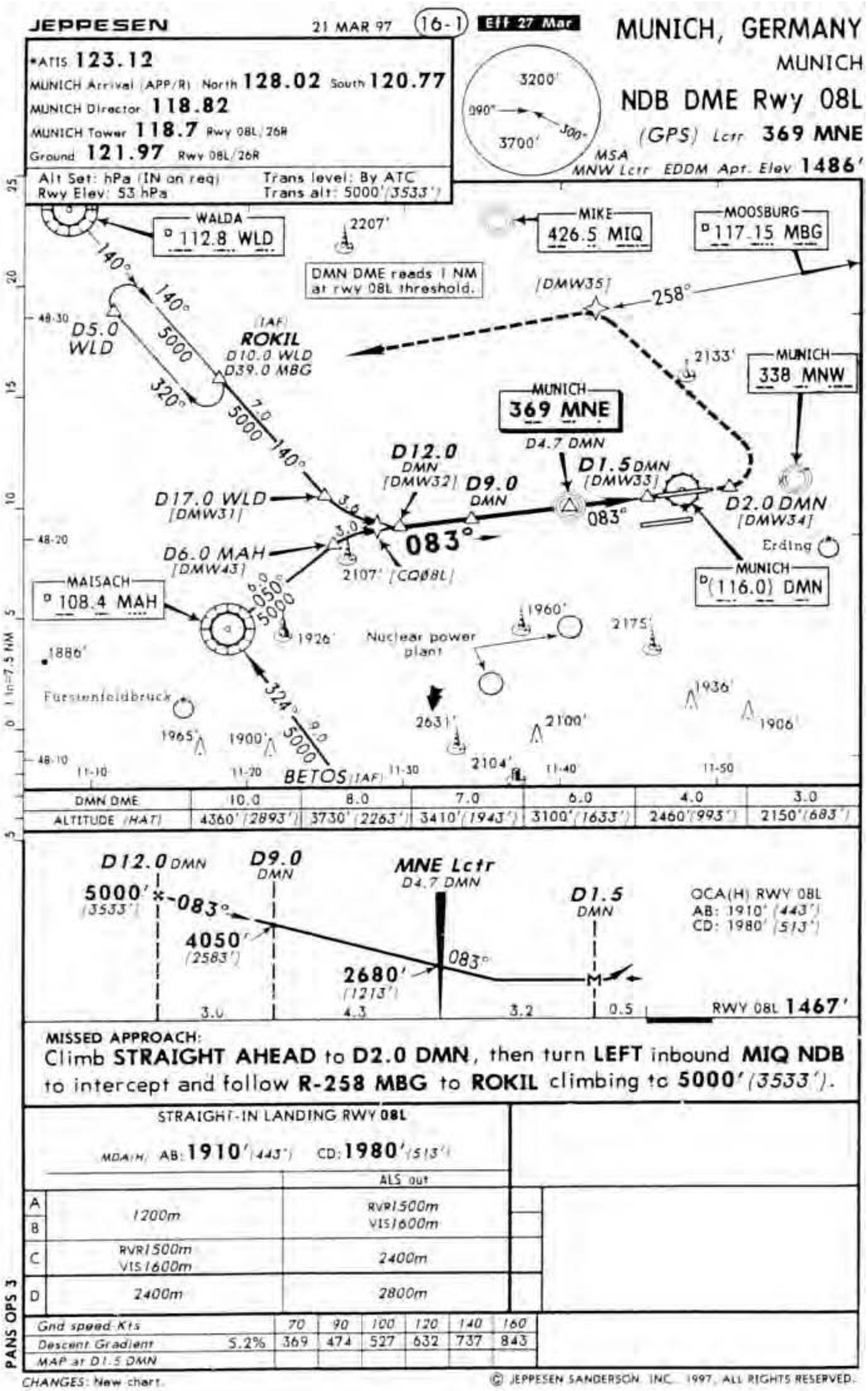


**Figure 4.13** Munich NDB DME Runway 08L chart. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

**Munich ILS Runway 08L chart**

See Figure 4.12. From Rokil the aircraft must continue on magnetic track 140 for 7 nm not below 5000 ft altitude (3533 ft height) until a Walda DME distance of 17 nm is reached. At this point a turn onto 083°(M) is commenced and should have been completed at a distance of 12 nm from the Munich DME. The aeroplane should be at an altitude of 5000 ft at this position, which is the Final Approach Fix (FAF). A descent is now commenced at 3° or 5.2% to pass the Outer Marker, which is also the Munich NDB, MNE on 369 KHz, at an altitude of 2680 ft (1213 ft). If the required visual reference is not established at or before the MAP or cannot be maintained to touchdown from the MAP the prescribed missed approach procedure must be initiated at the MAP. This ensures the statutory minimum obstacle clearance is achieved. If the runway is visible and visual contact can be maintained the descent can be continued and will cross the threshold (TCH) at 50 ft.

If the runway is not visible at the MAP or visual contact cannot be maintained from the MAP, the aeroplane must climb straight ahead to a distance 2 nm on the DMN DME, then turn left inbound for the MIQ NDB to intercept and then follow the 258° radial from MBG NDB to Rokil climbing to 5000 ft.

**Munich NDB DME Runway 08L chart**

See Figure 4.13. The description of the procedure on this chart is similar to that of the ILS chart except the minimum descent altitude and height are much higher because of the imprecise nature of the navigation aid being used. The difference between DA(H), decision altitude (height), and MDA(H), minimum descent altitude (height), is that if the required visual reference is not established by the MAP for a precision approach the pilot must initiate the go-round procedure during which the aircraft may descend below DA(H) but it will avoid all obstacles within the accountability area by the statutory minimum, whereas if the visual reference has not been established for a non-precision approach before MDA(H) the aeroplane must not descend any lower.

**Line 12 of Figure 4.10**

For the purposes of the skeleton flight plan the track from Rokil to the FAF is 140°(M) and distance 11 nm with a minimum safe altitude of 3200 ft. From the FAF to touchdown the track is 083°(M) and the distance is 12 nm. The minimum safe altitude is 3700 ft. The route skeleton flight plan is now complete.

## Summary

The maximum distance from the departure point for a take-off alternate aerodrome is the distance covered in one hour at the one-engine-inoperative cruise speed for non-ETOPS twin-engined aeroplanes and two hours ETOPS twin-engined, three and four-engined aeroplanes.

One destination alternate aerodrome is required to be specified, if the flight time is six hours or less and the destination has two separate usable runways and has the minimum acceptable weather, which is 2000 ft cloud base and visibility 5 km, forecast for the period ETA ± 1 hour. If such is not the case then two destination alternate aerodromes must be specified.

If 3% of the trip fuel is used as the contingency fuel then the en-route alternate aerodrome must be within a circle radius equal to 20% of the total flight plan distance, centred at a distance equal to 25% of the total route distance from the destination or 20% + 50 nm, whichever is the greater.

Twin-engined aeroplane area of operations is restricted to a maximum distance from an adequate aerodrome of a distance equal to:

- 60 minutes at the one-engine-inoperative cruise speed for non-ETOPS Class A aeroplanes having an MTOM greater than 8618 kg or a passenger seating capacity of more than 19
- 90 minutes at the all-engines operating maximum-range cruise speed or 300 nm whichever is less for Class B aeroplanes
- 120 minutes at the one-engine-inoperative cruise speed for aeroplanes not included in the two preceding points
- the authorised diversion time for ETOPS approved aeroplanes.

The semi-width of the corridor for ATLAS calculations is 10 nm for sector lengths up to 100 nm and 10% of the leg length over 100 nm, subject to a maximum semi-width of 60 nm.

IFR semi-circular cruising levels are above FL290 for magnetic tracks 000 to 179 Odd FLs commencing at FL290 at 4000 ft intervals and for magnetic tracks 180 to 359 Even FLs from FL310 at 4000 ft intervals.

## Sample questions

1. The maximum distance that the take-off alternate aerodrome may be from the departure aerodrome, for a non-ETOPS twin-engined aeroplane is:

   a. 1 hour at the all-engines-operating cruise speed
   b. 2 hours at the all-engines-operating cruise speed
   c. 1 hour at the one-engine-inoperative cruise speed
   d. 2 hours at the one-engine-inoperative cruise speed

2. For a 3-hour flight to a destination with two separate runways the minimum acceptable cloud ceiling is … for the period of …. The missing details are:

   a. 2000 ft; ETA ± 2 hr
   b. 2000 ft; ETA ± 1 hr
   c. 1000 ft; ETA ± 2 hr
   d. 1000 ft; ETA ± 1 hr

3. An en-route alternate aerodrome must be located within a radius equal to … of the total route distance if … of the trip fuel is used as contingency fuel. The missing details are:

   a. 20%; 5%
   b. 25%; 3%
   c. 20%; 3%
   d. 25%; 5%

4. The ATLAS formula requires the minimum en-route altitude to be calculated by adding … to the highest point elevation (below 5000 ft) within the corridor. The missing details are:

   a. 1000 ft
   b. 1500 ft
   c. 2000 ft
   d. 2500 ft

5. Which of the following is a suitable cruising FL for a track of 240° (M)?

   a. FL300
   b. FL310
   c. FL320
   d. FL330

6. Using Figure 4.3, what is the maximum speed permitted below FL100 during the Standard Instrument Departure procedure?

   a. 250 kts TAS
   b. 200 kts TAS
   c. 250 kts IAS
   d. 200 kts IAS

7. On an en-route chart, in some navigation aid identification boxes the frequency is preceded by the letter D. The meaning of the letter D is:

   a. Distance
   b. Doppler
   c. DME
   d. D class airspace

8. Use Figure 4.5. The frequency of the navigation aid at Costa 51°21'N 003°21'E is:

   a. 118.1 MHz
   b. 111.8 kHz
   c. 118.1 kHz
   d. 111.8 MHz

9. Use Figure 4.5. When flying eastbound along airway B29, what is the maximum FL permitted without the prior permission of Brussels ACC?

   a. FL80
   b. FL90
   c. FL100
   d. FL110

10. Use Figure 4.5. The minimum off-route altitude on airway B3 is:

   a. 2700 ft amsl
   b. 2700 ft agl
   c. FL60
   d. 6000 ft amsl

11. Use Figure 4.5. When flying along airway A5, a suitable cruising FL would be:

   a. FL70
   b. FL80
   c. FL90
   d. FL100

12. Use Figure 4.6. The symbols at Nicky 51°10'N 004°11'E indicate the following:

    a. VOR/DME 117.4 MHz; NDB 336.5 kHz; non-compulsory reporting point
    b. VOR/DME 117.4 kHz; NDB 336.5 MHz; compulsory reporting point
    c. VOR/DME 117.4 MHz; NDB 336.5 kHz; compulsory reporting point
    d. VOR/DME 117.4 MHz; NDB 336.5 MHz; non-compulsory reporting point

13. Use Figure 4.6. On G1 between Gatta and Olno is a ball flag 23, what does it mean?

    a. Only available for flights to and from the London TMA
    b. The airway width east of the Brussels TMA is 16 nm when CTA East 1–4 deactivated
    c. Available northbound below FL90 for Brussels FIR arrivals
    d. Minimum FL increased to FL80 at weekends

14. Use Figure 4.6. The communications frequencies for the Brussels East Sector are:

    a. 125.0 MHz and 126.52 MHz
    b. 128.2 MHz and 129.57 MHz
    c. 125.0 MHz and 128.2 MHz
    d. 126.52 MHz and 129.57 MHz

15. Use Figure 4.6. The airway identifier, Z905, between Diekirch 49°52'N 006°08'E and Arcky, has the suffix of a white R on a black background. What does the R mean?

    a. Red
    b. Romeo
    c. RNAV route
    d. Weekend airway

16. Use Figure 4.7. The ICAO identifier for the Frankfurt FIR is:

    a. EBBR
    b. EDLL
    c. EDFF
    d. EDMM

17. Use Figure 4.7. What is the MGAA for the area 49°N to 50°N and between 008°E and 009°E?

    a. 4100 ft
    b. 3600 ft
    c. 4000 ft
    d. 3800 ft

18. Use Figure 4.11. The symbol to the east of Munich aerodrome means:

    a. Fan marker and NDB
    b. Bone Marker
    c. Elliptical marker
    d. NDB

19. Use Figure 4.12. At the threshold of runway 08L, what range will be indicated from the DMN DME?

    a. 0.5 nm
    b. 1.0 nm
    c. 1.5 nm
    d. 2.0 nm

20. Use Figure 4.13. On the plan view of the final approach path there is a star symbol at a range of 12.5 nm from the DMN DME. What does it mean?

    a. Final approach fix
    b. Flyover airspace fix
    c. Compulsory airspace fix
    d. Non-compulsory airspace fix

# Chapter 5
# General Fuel Requirements

## General fuel requirements

Every operator must have a fuel policy for both flight planning and in-flight replanning to ensure sufficient fuel is carried for the flight as planned, with sufficient reserve fuel to cover any deviation from that plan. *JAR-OPS 1.255(a).*

The flight plan is to be based on the procedures and data contained in or derived from the Operations Manual or current aeroplane specific data derived from a fuel consumption monitoring system. It is to be calculated using the fuel consumption appropriate to the weight of the aeroplane and the meteorological conditions forecast for the time of the flight and must account any Air Traffic Control restrictions and procedures applicable to the route. *JAR-OPS 1.255(b).*

### *Normal pre-flight requirements*

The fuel required for the flight is to be calculated and loaded before flight. It is to include appropriate amounts of the following:

- taxi fuel
- trip fuel
- contingency fuel
- alternate fuel
- final reserve fuel
- any additional fuel required for the type of operation (e.g., ETOPS)
- any extra fuel required by the Commander.

*JAR-OPS 1.255(c).*

#### Taxi fuel

Taxi fuel is defined as the amount of fuel expected to be used before take-off and should account local conditions at the departure aerodrome and fuel that may be required for the operation of the auxiliary power unit.
*AMC OPS 1.255 paragraph 1.1.*

**Trip fuel**

Sometimes referred to as route fuel, trip fuel includes:

- Fuel for the take-off and climb to the initial cruise altitude, taking into account the expected departure procedure and routing.
- Fuel used in the cruise from the top of the climb to the top of the descent, including any fuel that may be used for intermediate climbs during the cruise.
- Fuel from the top of the descent to the initial approach fix, accounting the expected arrival procedure to that fix.
- Fuel for the approach and landing, including any fuel required for the terminal approach procedure.

*AMC OPS 1.255 paragraph 1.2.*

**Contingency fuel**

This is the fuel carried to cover any deviation from the flight plan, which may be altitude, route, speed, meteorological conditions or individual aeroplane fuel consumption deviation. *IEM OPS 1.255(c)(3)(i).* Contingency fuel must be the **higher** of (a) or (b) below:

(a)

- 5% of the trip fuel, or in the event of replanning in-flight, 5% of the trip fuel for the remainder of the flight, or
- if an en-route alternate is available, not less than 3% of the flight plan trip fuel, or in the event of replanning in-flight, not less than 3% of the trip fuel for the remainder of the flight, or
- sufficient for 20 minutes flying time on the flight plan cruise fuel flow, provided the operator has used a fuel flow monitoring programme for individual aeroplanes to derive that which was used, or
- when an operator has an approved monitoring programme for each individual route/aeroplane combination and uses this statistical analysis to derive the fuel flow, then sufficient to fly for 15 minutes at the holding speed at 1500 ft, or

(b) enough fuel to fly for five minutes at the holding speed at 1500 ft (450 m) above the destination in ISA conditions.

*AMC OPS 1.255 paragraph 1.3.*

**Alternate fuel**

The amount of fuel carried as alternate fuel should be sufficient for:

- a complete missed approach procedure at the destination aerodrome from the MDA/DH to the missed approach altitude

- a climb from the missed approach altitude to cruising level/altitude
- the cruise from the top of climb to the top of descent
- descent from the top of descent to the initial approach fix, accounting the expected arrival procedure
- making an approach and landing at the destination alternate aerodrome, selected in accordance with *JAR-OPS 1.295*
- if it is required by *JAR-OPS 1.295(d)* that two destination alternate aerodromes be selected then the alternate fuel must be sufficient to fly to that which requires the greater amount of fuel.

*AMC OPS 1.255 paragraph 1.4.*

**Final reserve fuel**

The final reserve fuel should be sufficient for:

- 45 minutes' flight for aeroplanes with reciprocating engines, or
- 30 minutes' flight for turbine powered aeroplanes, at the holding speed at 1500 ft (450 m) in ISA conditions at the estimated weight on arrival at the alternate aerodrome (or destination, when no alternate aerodrome is required).

*AMC OPS 1.255 paragraph 1.5.*

**Additional fuel**

This quantity of fuel is included, if required, by the type of operation (e.g., ETOPS) *JAR-OPS 1.255(c)(3)(iv)*. It is only required if the minimum amount of fuel calculated from the sum of trip, contingency, alternate and final reserve fuel is insufficient to permit the following:

- when the flight is operated in IFR conditions, without a destination alternate aerodrome, holding at 1500 ft (450 m) above the destination aerodrome elevation for 15 minutes, and
- at the most critical point along the route in the event of the failure of an engine or the aircraft pressurisation system to:
  - descend, if necessary, and proceed to an adequate aerodrome, and
  - hold there in ISA conditions at 1500 ft (450 m) above the aerodrome elevation for 15 minutes, and
  - make an approach and landing.

*AMC OPS 1.255 paragraph 1.6*

**Extra fuel**

This fuel may be carried at the discretion of the Commander.

### *Example 5.1*

Given:
Missed Approach and Missed Approach Procedure fuel = 600 kg.
Climb fuel from Missed Approach altitude to cruising level = 950 kg.
Noise abatement fuel allowance = 400 kg.
Contingency allowance = 5%.
TOC to TOD = 700 kg.
TOD to approach initial fix and STAR fuel = 800 kg.
Approach and landing fuel = 250 kg.
Baulked landing fuel = 100 kg.
Taxi fuel = 100 kg.
Determine the alternate fuel required.

### *Solution 5.1*

The fuel amounts that have to be included in the calculation of the alternate fuel are listed in the section on Normal Pre-flight Requirements – Alternate fuel, above.

Alternate fuel = 600 + 950 + 700 + 800 + 250 = 3300 kg.

### *Pre-flight requirements with a decision point*

If the operator's fuel policy includes planning to a destination via a decision point then the fuel carried should be the greater of (a) or (b) below:

(a) The sum of:

- taxi fuel
- trip fuel to the destination via the decision point
- contingency fuel, which is equal to not less than 5% of that which is required from the decision point to the destination aerodrome
- alternate fuel, if a destination alternate aerodrome is required
- final reserve fuel
- any additional fuel required for the operation
- any additional fuel required by the Commander.

(b) The sum of:

- taxi fuel
- the estimated fuel required from the departure aerodrome to a suitable en-route alternate aerodrome via the decision point
- contingency fuel which is equal not less than 3% of the estimated fuel required from the departure aerodrome to the en-route alternate aerodrome

- final reserve fuel
- any additional fuel required for the operation
- any additional fuel required by the Commander.

*AMC OPS 1.255 paragraph 2.*

## *Pre-flight requirements for an isolated aerodrome*

If the operator's fuel policy includes planning to an isolated aerodrome, for which a destination alternate aerodrome does not exist, the amount of fuel that should be carried should include:

- taxi fuel
- trip fuel
- contingency fuel of not less than that specified in the normal procedure
- additional fuel, including the final reserve fuel, not less than:
  - for aeroplanes having reciprocating engines, fuel for 45 minutes plus 15% of the flight cruise time **or** two hours, whichever is the less, or
  - for aeroplanes having turbine engines, sufficient fuel to fly for two hours, at the normal cruise fuel consumption, from overhead the destination aerodrome
- any additional fuel required by the Commander.

*AMC OPS 1.255 paragraph 3.*

## *Pre-flight requirements for a destination alternate aerodrome via a predetermined point*

If the operator's fuel policy includes planning to a destination alternate aerodrome, when the distance between the destination aerodrome and the destination alternate is such that a flight can be routed only via a predetermined point to one of the aerodromes, the amount of fuel that should be carried should be the greater of (a) or (b) below:

(a) The sum of:

- taxi fuel
- the trip fuel to the destination aerodrome via the predetermined point
- contingency fuel of not less than that specified in the normal procedure
- additional fuel, including final reserve fuel, not less than:
  - for aeroplanes having reciprocating engines, fuel for 45 minutes plus 15% of the flight cruise time or two hours, whichever is the less, or
  - for aeroplanes having turbine engines, sufficient fuel to fly for two hours, at the normal cruise fuel consumption, from overhead the destination aerodrome

- any additional fuel required by the Commander.

(b) The sum of:

- taxi fuel
- the trip fuel to the alternate aerodrome via the predetermined point
- contingency fuel of not less than that specified in the normal procedure
- additional fuel, including final reserve fuel, not less than:
  - for aeroplanes having reciprocating engines, fuel for 45 minutes
  - for aeroplanes having turbine engines, sufficient fuel to fly for 30 minutes at the holding speed at 1500 ft (450 m) above aerodrome elevation in ISA conditions
- any additional fuel required by the Commander.

*AMC OPS 1.255 paragraph 4.*

## Summary

The total fuel load must include Taxi fuel, Trip fuel, Contingency fuel and Alternate fuel. It may also include additional fuel for the type of operation and any additional fuel required by the Commander.

Contingency fuel is dependent on the conditions but is never less than sufficient to fly for five minutes, at the holding speed, at 1500 ft above the destination in ISA conditions.

Alternate fuel should be sufficient to touch and go at the destination and then continue and land at the specified alternate that requires the greater amount of fuel.

The final reserve should be sufficient for 30 minutes flight for a jet aeroplane, at the holding speed at 1500 ft above the destination in ISA conditions at the estimated landing weight or 45 minutes flight for an aeroplane with reciprocating engines.

Extra fuel may be carried at the discretion of the aircraft Commander and is dependent on the conditions of the flight.

Special rules apply for routes having a decision point, for an isolated destination or for a destination alternate via a predetermined point.

## Sample questions

1. The minimum amount of contingency fuel that may be carried is enough to fly for … at the holding speed at a height of … above aerodrome level in ISA conditions. The correct details to complete the above sentence are:

   a. 5 min; 2000 ft
   b. 5 min; 1500 ft
   c. 10 min; 2000 ft
   d. 10 min; 1500 ft

2. The final reserve fuel for an aeroplane having reciprocating engines should be sufficient to fly for:

   a. 5 min
   b. 15 min
   c. 30 min
   d. 45 min

3. In IFR conditions, when no destination alternate aerodrome has been specified, the total fuel carried should be sufficient to enable the aeroplane to hold at 1500 ft above the destination aerodrome elevation for … and in the event of an engine failure at the most critical point, proceed to an adequate aerodrome and hold for …:

   a. 5 min; 10 min
   b. 10 min; 10 min
   c. 15 min; 15 min
   d. 20 min; 15 min

4. If a suitable en-route alternate aerodrome is specified on the flight plan, for a route containing a decision point, the contingency fuel may be reduced from … of the fuel from the decision point to the destination to … of the fuel from the departure to the en-route alternate aerodrome.

   a. 10%; 5%
   b. 15%; 10%
   c. 5%; 3%
   d. 8%; 5%

5. The fuel requirements for an isolated destination aerodrome include additional fuel which, for a jet aeroplane, must not be less than that required to

fly for … from overhead the destination or … at the holding speed at 1500 ft above the destination aerodrome elevation in ISA conditions.

a. 1 hr; 30 min
b. 2 hr; 30 min
c. 3 hr; 15 min
d. 4 hr; 15 min

6. Which of the following is not included in Trip fuel: i. Taxi fuel; ii. Take-off fuel; iii. Climb fuel; iv. Cruise fuel to TOD; v. Descent fuel; vi. Approach fuel; vii. Landing fuel?

a. ii
b. iv
c. vi
d. i

7. The additional fuel required for a flight to a destination aerodrome via a predetermined point for an aeroplane having reciprocating engines shall not be less than … plus… of the cruise fuel, or … cruise fuel, whichever is the less.

a. 45 min; 15%; 2 hr
b. 30 min; 15%; 2 hr
c. 45 min; 10%; 2 hr
d. 45 min; 15%; 1 hr

8. A jet aeroplane flight is being planned to an isolated aerodrome and for which there is no destination alternate aerodrome. The flight details are: Taxi fuel 325 kg; Trip fuel 11 450 kg; Contingency fuel 5%; Final reserve fuel 1400 kg; Flight time 4 hr 10 min; Cruising level fuel flow 2590 kg/hr. The planned fuel load is:

a. 15 689 kg
b. 17 308 kg
c. 17 527 kg
d. 18 928 kg

# Chapter 6
# SEP Aeroplane Fuel Planning

## Introduction

CAP 697 – The Civil Aviation JAR FCL Examinations Flight Planning Manual – should be in your possession. It contains the flight planning data for three generic types of aeroplane. The green pages are for the single-engine piston (SEP) aeroplane, the blue pages are for the multi-engine piston (MEP) aeroplane, and the white pages are for the medium range jet transport aeroplane.

The details of the single-engine piston (SEP) aeroplane are listed on page 6 of the CAP 697. The maximum take-off and landing weight are equal at 3650 lb. The maximum fuel load is 74 US gallons which is equal to 444 lb, using the recommended conversion of 6 lb per US gallon.

The graphs and tables in the CAP 697 assume that pressure altitude is used for all calculations. Therefore, all aerodrome elevations should be converted to pressure altitudes before commencing any calculation. The value of 1 hPa varies in different documents and the conversion to be used will be stated in the examination. The formula to be used for the conversions in this book is:

Aerodrome Pressure Altitude = Airfield elevation + [(1013.2 hPa – QNH) × 28]

## Climb calculations

Figure 2.1 of the CAP 697 facilitates the calculation of the time taken in minutes, fuel used in US gallons and the air distance travelled from take-off or the start of climb pressure altitude to the top of the climb. The input at the left carpet of the graph is that of ambient temperature in degrees centigrade. The left grid is that of pressure altitude and the right grid is the take-off or start of climb weight in pounds. The conditions assumed in the construction of the graph were:

- Power – full throttle
- RPM – 2500
- Mixture – fully rich
- Cowl flaps – as required
- Climbing speed – 110 kts

The instructions for the use of the graph are given in paragraph 2 of page 6 of the CAP 697. The details of the worked example illustrated on the graph are given below this paragraph. It will be seen that the initial input is the ambient temperature at the aerodrome surface level, and the details of time, fuel and air distance are extracted for the Aerodrome Pressure Altitude. These have to be subtracted from the results obtained using the ambient temperature at cruising level to obtain true values for the climb. This is because all climbs are assumed to commence at a pressure altitude of 0 ft.

Unfortunately, there is no wind component grid on the distance output of the graph. Therefore, due allowance for the effect of the wind component must be made manually. To convert the air distance to a ground distance it has to be multiplied by the mean ground speed and divided by the mean TAS. The mean TAS is calculated by setting the mean climb temperature against the mean climb pressure altitude in the airspeed window on the back of the navigation computer; then against 110 kts on the inner scale. The TAS is read on the outer scale.

## *Example 6.1*

Given: Aerodrome Pressure Altitude 3000 ft; Ambient Temperature +10°C; Take-off Weight 3400 lb; Cruising Pressure Altitude 14 000 ft; Ambient Temperature –20°C; Mean Wind Component 20 kts headwind. Calculate the time taken in minutes, fuel used in pounds and the ground distance travelled during the climb.

## *Solution 6.1*

See Figure 6.1.

**Table 6.1**

| Pressure altitude (ft) | Time taken (min) | Fuel used (US gallon) | Air distance (nm) |
|---|---|---|---|
| To 3000 | 3 | 1 | 5 |
| To 14 000 | 20 | 6.5 | 40 |
| Climb values | 17 | 5.5 | 35 |

Mean Altitude = 8500 ft. Mean temperature = –5°C. TAS = 123.5 kts.
G/S = 103.5 kts.

Ground Distance = (35 × 103.5) ÷ 123.5 = 29.3 nm

Fuel Used = 5.5 × 6 = 33 lb

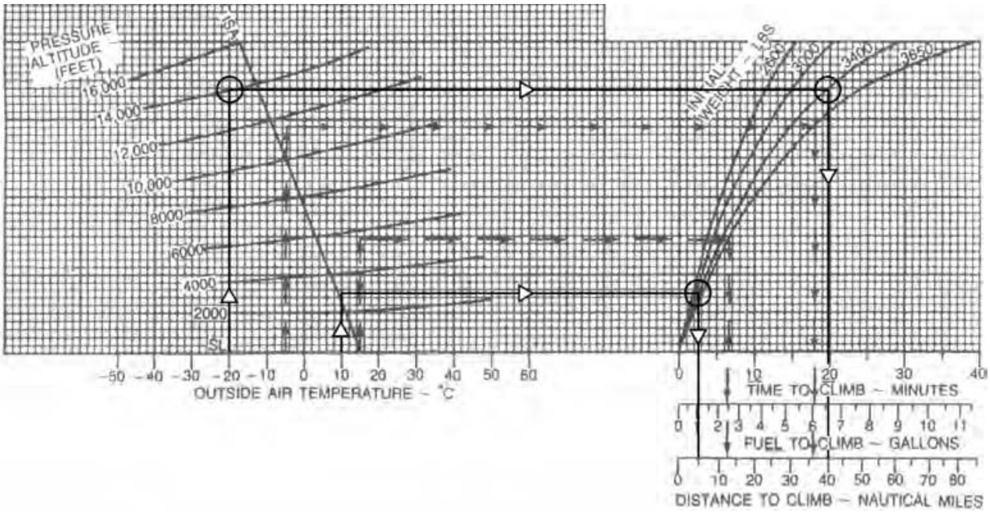


**Figure 6.1** Solution to Example 6.1.

## *Example 6.2*

Given: Start of Climb Pressure Altitude 5000 ft; Ambient Temperature –16°C; Take-off Weight 3000 lb; Cruising Pressure Altitude 15 000 ft; Ambient Temperature –20°C; Mean Wind Component 30 kts tailwind. Calculate the time taken in minutes, fuel used in pounds and the ground distance travelled during the climb.

## *Solution 6.2*

See Figure 6.2.

**Table 6.2**

| Pressure altitude (ft) | Time taken (min) | Fuel used (US gallons) | Air distance (nm) |
|---|---|---|---|
| To 5000 | 3.5 | 1.3 | 6 |
| To 15 000 | 17.0 | 5.8 | 34 |
| Climb values | 13.5 | 4.5 | 28 |

Mean Altitude = 10 000 ft. Mean temperature = –18°C. TAS = 124 kts. G/S = 154 kts.

Ground Distance = (28 × 154) ÷ 124 = 34.8 nm

Fuel used = 4.5 × 6 = 27 lb

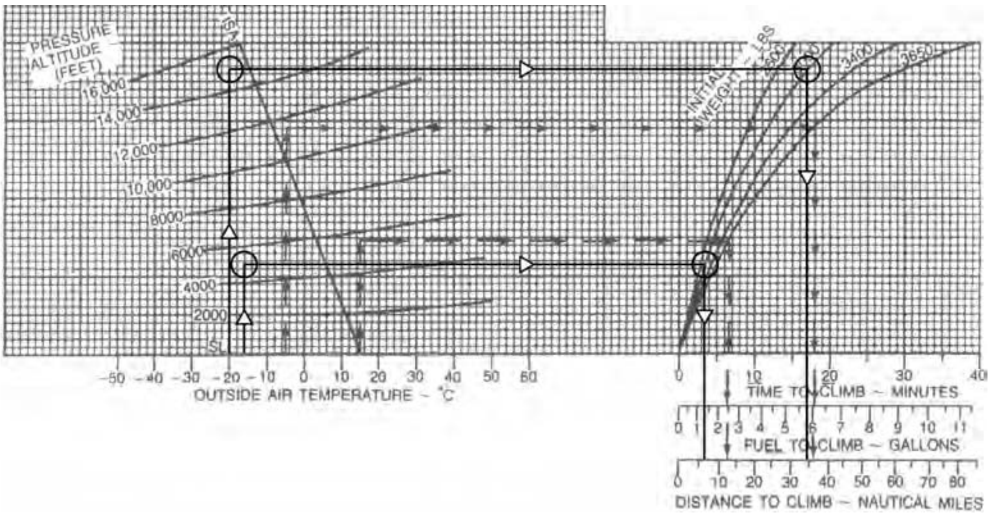


**Figure 6.2** Solution to Example 6.2.

## Cruise calculations

There are four cruise tables from which the manifold pressure, fuel flow and airspeed can be derived. Each table has a different power and/or RPM setting; the first three are for the recommended cruise power settings and the fourth is the economy power setting. They are:

- 25.0 inHg (or full throttle); 2500 RPM
- 25.0 inHg (or full throttle); 2100 RPM
- 23.0 inHg (or full throttle); 2300 RPM
- 21.0 inHg (or full throttle); 2100 RPM.

Each table is divided into blocks of temperature deviation. The top block in each table is for ISA –20°C, the middle block is for ISA 0°C and the bottom block is for ISA +20°C. For absolute accuracy, the values for the actual temperature deviation should be found by interpolating between the values of the appropriate ISA deviation blocks either side. The CAA advise that for the JAA examination, this will be necessary and the table must be exactly interpolated for the Cruising Pressure Altitude.

The shaded area of each table shows the altitudes at which the throttle will be fully open. The lowest altitude at which this occurs is referred to as *full throttle height*. All tables are for 20°C lean mixture. The EGT is used to maintain a lean mixture. The weight used for all tables is 3400 lb.

## *Example 6.3*

Given: Cruising Pressure Altitude 13 500 ft; Ambient Temperature +5°C; Power Setting 23.0 inHg and 2300 RPM. Calculate the manifold pressure, fuel flow in PPH and TAS.

## *Solution 6.3*

ISA deviation = ambient – standard = +5 –(– 12) = +17°C

Page 10 (CAP 697).

**Table 6.3**

| Pressure altitude (ft) | ISA +20° C | | | ISA +0° C | | | ISA +17° C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Man. press (in Hg) | FF (PPH) | TAS (kts) | Man. press (in Hg) | FF (PPH) | TAS (kts) | Man. press (in Hg) | FF (PPH) | TAS (kts) |
| 12 000 | 19.2 | 60.0 | 151 | 19.2 | 61.8 | 152 | 19.2 | 60.27 | 151.15 |
| 14 000 | 17.8 | 57.1 | 142 | 17.8 | 58.5 | 146 | 17.8 | 57.31 | 142.6 |
| 13 500 | 18.15 | 57.83 | 144.3 | 18.15 | 59.33 | 147.5 | 18.15 | 58.05 | 144.7 |

## *Example 6.4*

Given: Cruising Pressure Altitude 9000 ft; Ambient Temperature –10°C; Power Setting 25.0 inHg and 2100 RPM. Calculate the manifold pressure, fuel flow in PPH and TAS.

## *Solution 6.4*

ISA deviation = –10 –(–3) = –10 + 3 = –7°C

Page 9 (CAP 697).

**Table 6.4**

| Pressure altitude (ft) | ISA 0° C | | | ISA –20° C | | | ISA –7° C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Man. press (in Hg) | FF (PPH) | TAS (kts) | Man. press (in Hg) | FF (PPH) | TAS (kts) | Man. press (in Hg) | FF (PPH) | TAS (kts) |
| 8000 | 22.5 | 61.9 | 148 | 22.5 | 63.9 | 148 | 22.5 | 62.6 | 148 |
| 10 000 | 20.8 | 58.5 | 143 | 20.8 | 60.1 | 144 | 20.8 | 59.06 | 143.35 |
| 9000 | 21.65 | 60.2 | 145.5 | 21.65 | 62.0 | 146 | 21.65 | 60.83 | 145.7 |

## Range calculations

The graph on page 12 of the CAP 697 is provided to enable the rapid calculation of the still-air range for an aeroplane with full tanks of fuel at a weight of 3663 lb, before engine start, in ISA temperature conditions (ISA deviation 0°C). The fuel used in the calculations is 444 lb minus the fuel used for taxi, run up and a 45 minutes reserve at economy cruise power. The route profile assumes a take-off from an aerodrome at a pressure altitude of 0 ft followed by a cruise at the selected pressure altitude and power setting. No allowance is possible for a different temperature deviation, take-off weight, Aerodrome Pressure Altitude or fuel load to those used as the standard.

The vertical axis of the graph is pressure altitude and the horizontal axis is the still-air range in nautical miles. The TAS is printed beside each of the power curves within the graph at pressure altitudes of 4000 ft, 8000 ft and 12 000 ft. The TAS for intermediate pressure altitudes must be interpolated.

To use the graph, enter the left vertical axis at the Cruising Pressure Altitude and travel horizontally to the curve for the cruise power setting. At this point, drop vertically to the carpet of the graph to read the still-air range. To allow for the effects of the wind component the still-air range must be multiplied by the ground speed and divided by the TAS.

### *Example 6.5*

Given: Cruising Pressure Altitude 10 000 ft; Power setting full throttle at 2300 RPM; Wind Component 50 kts headwind. Calculate the ground distance of the maximum range.

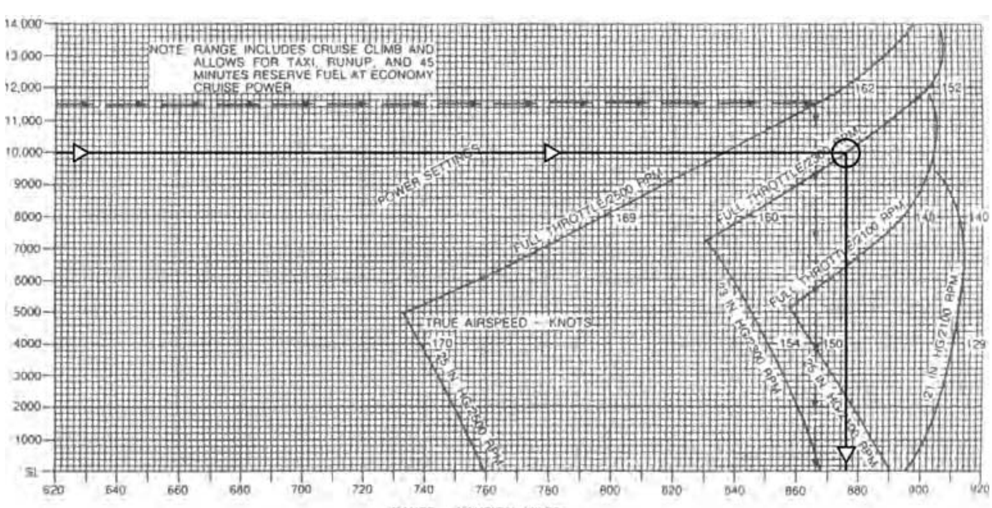


**Figure 6.3** Solution to Example 6.5.

### *Solution 6.5*

See Figure 6.3. Enter the left vertical axis at 10 000 ft and travel to the second power curve. Interpolate the TAS as being 156 kts. Drop vertically to the carpet of the graph and read the still-air distance as 876 nm. Apply the wind component to the TAS to obtain the groundspeed = 156 – 50 = 106 kts. The ground distance of the maximum range = (876 × 106) ÷ 156 = 595.2 nm.

### *Example 6.6*

Given: Cruising Pressure Altitude 4000 ft; Power setting 25 inHg at 2100 RPM; Wind Component 30 kts tailwind. Calculate the ground distance of the maximum range.

### *Solution 6.6*

See Figure 6.4. Enter the left vertical axis at 4000 ft and travel to the third power curve. Read the TAS as being 150 kts. Drop vertically to the carpet of the graph and read the still-air distance as 865 nm. Apply the wind component to the TAS to obtain the groundspeed = 150 + 30 = 180 kts.

The ground distance of the maximum range = (865 × 180) ÷ 150 = 1038 nm

The graph can also be used to determine the best pressure altitude at which to fly, at a specified power setting, over a given ground distance. To use it in this manner the ground distance must be converted to an air distance first, by multiplying by the TAS and dividing by the ground speed.

If such is the case, enter the graph at the carpet, with the air distance. Travel vertically to intercept the appropriate power curve. This vertical may intercept the power curve at two places, in which case the Minimum Safe Altitude must be considered before deciding which is the best altitude at which to fly.

### *Example 6.7*

Given: Route distance 750 nm; Power setting 2300 RPM; Wind Component 20 kts headwind; MSA 4500 ft pressure altitude.

### *Solution 6.7*

Page 10 (CAP 697). 5000 ft; ISA deviation 0°C; TAS = 156 kts.

Ground speed = 156 – 20 = 136 kts

Air distance = (750 × 156) ÷ 136 = 860.3 nm

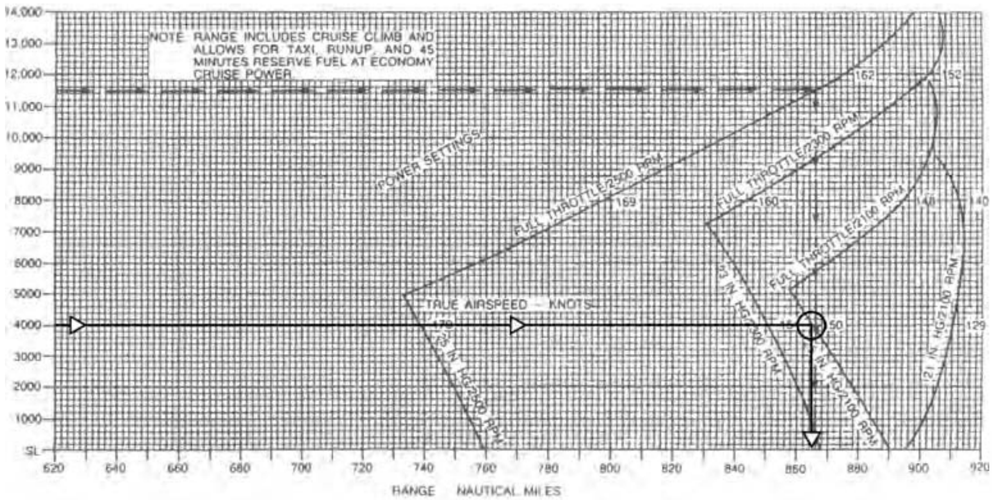


**Figure 6.4** Solution to Example 6.6.

Page 12 (CAP 697). Enter the carpet of the graph at 860nm. Move vertically to read Cruise Pressure Altitudes = 2000 ft and 9000 ft. Select 9000 ft because of the MSA. TAS = 158 kts.

### *Example 6.8*

Given: Cruise Altitude 10 000 ft. Calculate the increase of range achieved by reducing the RPM from 2500 to 2300 with a 30 kts headwind.

### *Solution 6.8*

Figure 2.4 Page 12 (CAP 697).
Still-air range at 2500 RPM = 837 nm. TAS = 166 kts. Ground speed = 136 kts.

Ground distance = (837 × 136) ÷ 166 = 685.7 nm

Still-air range at 2300 RPM = 874 nm. TAS = 157 kts. Ground speed = 127 kts.

Ground distance = (874 × 127) ÷ 157 = 707 nm

Increased ground distance = 707 – 685.7 = 21.3 nm

## Endurance calculations

The graph on page 13 of the CAP 697 is provided to enable the rapid calculation of the endurance for an aeroplane with full tanks of fuel at a weight of 3663 lb before engine start in ISA temperature conditions (ISA deviation 0°C). The fuel used in

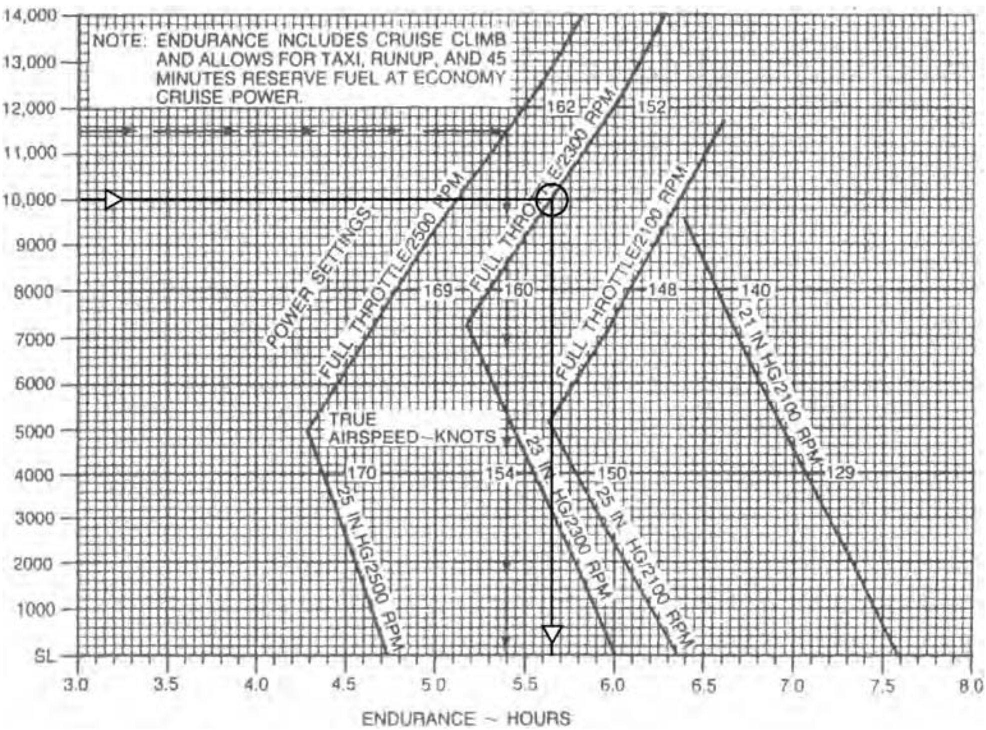


**Figure 6.5** Solution to Example 6.9.

the calculations is 444 lb minus the fuel used for taxi, run up and a 45 minutes reserve at economy cruise power. The route profile assumes a take-off from an aerodrome at a pressure altitude of 0 ft followed by a cruise at the selected pressure altitude and power setting. No allowance is possible for a different temperature deviation, take-off weight or fuel load to those used as the standard.

The left vertical axis of the graph is pressure altitude and the horizontal axis is the endurance in hours and decimals of an hour. The TAS is printed beside each of the power curves within the graph at pressure altitudes of 4000 ft, 8000 ft and 12 000 ft. The TAS for intermediate pressure altitudes must be interpolated.

To use the graph enter the left vertical axis at the Cruising Pressure Altitude and travel horizontally to the curve for the cruise power setting. At this point, drop vertically to the carpet of the graph to read the safe endurance in hours and decimals of an hour. Multiply by 60 to convert the decimals to minutes.

## *Example 6.9*

Given: Cruising Pressure Altitude 10 000 ft; Power setting full throttle at 2300 RPM. Calculate the TAS in knots and the maximum endurance in hours and minutes.

### *Solution 6.9*

See Figure 6.5. Enter the left vertical axis at 10 000 ft and travel to the second power curve. Interpolate the TAS from the graph as being 156 kts. Drop vertically to the carpet of the graph and read the endurance as 5.65 hours = 5 hr 39 min. Add 45 min to obtain the maximum endurance = 6 hr 24 min.

### *Example 6.10*

Given: Cruising Pressure Altitude 4000 ft; Power setting 25 in Hg at 2100 RPM. Calculate the TAS in knots and the safe endurance in hours and minutes.

### *Solution 6.10*

See Figure 6.6. Enter the left vertical axis at 4000 ft and travel to the third power curve. Read the TAS as being 150 kts. Drop vertically to the carpet of the graph and read the endurance as 5.78 hours = 5 hr 46.8 min.

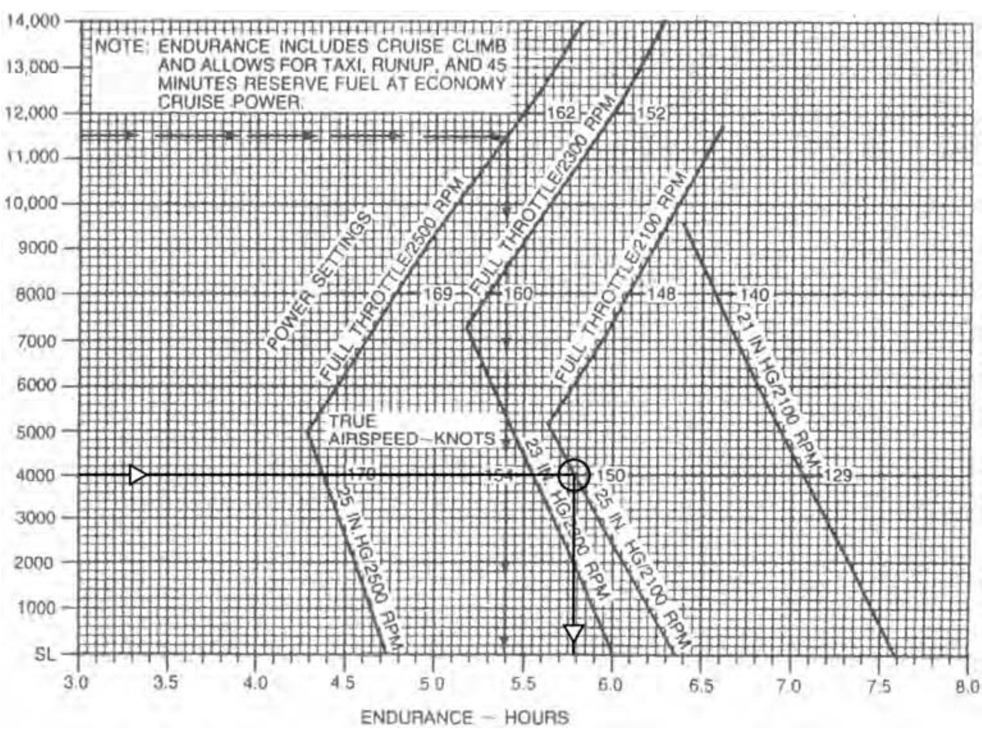


**Figure 6.6** Solution to Example 6.10.

The completed VFR flight plan is shown in Figure 6.7.

| STAGE FROM | STAGE TO | TEMP °C | FL | SAF ALT | WIND DIR'N | WIND SPEED | TR (M) | IAS kts | TAS kts | G/S kts | GND DIST nm | TIME mins | FUEL FLOW lbs/hr | START OF LEG AUW lbs | FUEL USED lbs | END OF LEG AUW lbs | FUEL REMAINING lbs | ETA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GLASENBACH | TOC | — | ↗ | 8500 | 260 | 10 | 339 | 110 | 120 | 118 | 6 / 14 | 3 | | 3650 | 7 | 3643 | | |
| TOC | SBG | +10 | 45 | 6500 | 270 | 20 | 339 | 143 | 150 | 142 | 8 | 3.4 | 66.5 | 3643 | 3.8 | 3639.2 | | |
| SBG | REGENSBERG | +10 | 45 | 3100 | 270 | 20 | 332 | 143 | 150 | 140 | 69 | 29.6 | ✓ | 3639.2 | 32.8 | 3606.4 | | |
| REGENSBERG | SCHWAEBISCH | +10 | 45 | 3900 | 270 | 20 | 261 | 143 | 150 | 130 | 92 | 42.5 | ✓ | 3606.4 | 47.1 | 3559.3 | | |
| SCHWAEBISCH | STUTTGART | +10 | 45 | 3900 | 260 | 20 | 253 | 143 | 150 | 140 | 24 | 10.3 | ✓ | 3559.3 | 11.4 | 3547.9 | | |
| | TOTALS | | | | | | | | | | 199 | 88.8 | | | 102.1 | | | |
| SY. | FREIDRICHSCH | +8 AFEN | 55 | 4300 | 250 | 20 | 164 | 142 | 151 | 148 | 62 | 25.1 | 66.2 | 3547.9 | 27.7 | 3520.2 | | |
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| DEPARTURE A/F | | DESTINATION A/F | | ALTERNATE A/F | | ROUTE CLEARANCE | | |
|---|---|---|---|---|---|---|---|---|
| RUNWAY (M) | 346 | RUNWAY (M) | 263 | RUNWAY (M) | 242 | POWER 25.0 Hg 2100 rpm | ROUTE FUEL | 102 |
| W/V | 290/10 | W/V | 270/10 | W/V | 240/10 | | CONTINGENCY FUEL | 5 |
| ELEVATION | 1411' | ELEVATION | 1267' | ELEVATION | 1367' | | ALTERNATE FUEL | 28 |
| QNH | 993 | QNH | 995 | QNH | 996 | | FINAL RESERVE | — |
| PRESSURE ALT | 1691' | PRESSURE ALT | 1771' | PRESSURE ALT | 1843 | | PLANNED TAKE-OFF FUEL | 135 |
| TAKE-OFF MASS | 3650 | ALT T/O MASS | 3548 | | | | EXTRA FUEL | 305 |
| ROUTE FUEL | 102 | ALTERNATE FUEL | 28 | | | | TAKE-OFF FUEL | 440 |
| LANDING MASS | 3548 | LANDING MASS | 3520 | | | | TAXI FUEL | 4 |
| | | | | | | | BLOCK FUEL | 444 |

**Figure 6.7** The completed VFR flight plan – Solution to Figure 3.6.

## Summary

For all climb calculations subtract the details of the initial climb pressure altitude from those of the top of climb.

Climb ground distance = climb air distance × ground speed ÷ TAS.

For cruise calculations ensure the correct table for the power setting is selected. Interpolate exactly for ISA deviation and cruise pressure altitude.

The range ground distance = the range air distance × ground speed ÷ TAS.

Endurance is not affected by the wind component.

Safe endurance is extracted from the graph.

Maximum endurance = safe endurance + 45 minutes.

## Sample questions

1. Given: Aerodrome Elevation 3000 ft; QNH 993 hPa; Ambient Temperature +15°C; Take-off Weight 3200 lb; Cruise Pressure Altitude 11 000 ft; Ambient Temperature –10°C; Mean Wind Component 15 kts tailwind. Calculate the time taken in minutes, fuel used in pounds and the ground distance travelled during the climb.
2. Given: Initial Cruise Pressure Altitude 6000 ft; Ambient Temperature –10°C; Start of Climb Weight 2800 lb; Final Cruise Pressure Altitude 14 000 ft; Ambient Temperature –30°C; Mean Wind Component 25 kts headwind. Calculate the time taken in minutes, fuel used in pounds and the ground distance travelled during the climb from 6000 ft to 14 000 ft.
3. Given: Cruising Pressure Altitude 4500 ft; Ambient Temperature 0°C; Power Setting 25.0 inHg at 2500 RPM. Calculate the manifold pressure, fuel flow in PPH and the TAS.
4. Given: Cruising Pressure Altitude 9000 ft; Ambient Temperature –20°C; Power Setting Economy. Calculate the manifold pressure, fuel flow in PPH and the TAS.
5. For the conditions given in Question 4 calculate the ground distance of the maximum range if the wind component is 30 kts tailwind.
6. For the conditions given in Question 3 calculate the ground distance of the maximum range if the wind component is 20 kts headwind.
7. Given: Cruise Pressure Altitude 7000 ft at the Economy Power setting. Calculate the TAS and the maximum endurance in hours and minutes if the fuel tanks are full.
8. Given: Cruise Pressure Altitude 12 000 ft; Power Setting full throttle and 2300 RPM. Calculate the TAS and the safe endurance in hours and minutes.

## Chapter 7
# MEP Aeroplane Fuel Planning

## Introduction

The details of the multi-engine piston (MEP) aeroplane are listed on page 16 of the CAP 697. The maximum take-off weight is 4750 lb, the maximum zero fuel weight is 4470 lb and the maximum landing weight is 4513 lb. The maximum fuel load is 123 US gallons which is equal to 738 lb, using the recommended conversion of 6 lb per US gallon.

As for the SEP, all graphs and tables assume that pressure altitude will be used for all calculations. Therefore, aerodrome elevations must be converted to pressure altitude, before commencing any calculation, using the formula:

Aerodrome Pressure Altitude = Airfield elevation + [(1013.2 hPa – QNH) × 28]

## Climb calculations

Figure 3.1 on page 17 of the CAP 697 enables all climb calculations to be made. From this graph it is possible to derive the fuel used in US gallons, the time taken in minutes and the still-air distance travelled in nautical miles. The input at the left carpet of the graph is the ambient temperature in degrees centigrade. The left grid is that of pressure altitude but the right grid has different layout to that of the SEP. There are three lines in the right grid, one for each of the details required: fuel used, time taken and air distance travelled. The conditions assumed for this graph are:

- Power – 33 inHg or full throttle
- RPM – 2600
- Mixture – fully rich
- Cowl flaps – closed
- Climbing speed – 120 kts IAS
- Take-off weight – 4750 lb
- Undercarriage – retracted.

The instructions for the use of the graph are given in paragraph 2 on page 16 of the CAP 697. Below this paragraph are the details of the worked example shown on the graph. The initial input is at the left carpet at the ambient temperature at the Aerodrome Pressure Altitude. From this point travel vertically to intercept the grid line for the Aerodrome Pressure Altitude. At this intersection move horizontally right to intercept each of the right grid lines in turn. At each intersection, drop vertically to the carpet to read the appropriate value. Exactly the same procedure is followed for the ambient temperature at Cruising Pressure Altitude and the three values extracted. The values at the aerodrome level are subtracted from those at the cruising level to determine the true values for the climb.

As with the SEP, there is no wind component grid, therefore, the air distance must be converted to a ground distance by using the navigation computer to determine the TAS equivalent for an IAS of 120 kts. The wind component is then applied to the TAS to determine the ground speed. The ground distance travelled is equal to the air distance multiplied by the ground speed and divided by the TAS.

### *Example 7.1*

Given: Aerodrome Elevation 2000 ft; QNH 993 hPa; Ambient Temperature +20°C; Cruise at 16 000 ft Pressure Altitude; Ambient Temperature –10°C; Mean Wind Component 20 kts tailwind. Calculate the time taken, fuel used and the ground distance travelled during the climb.

### *Solution 7.1*

See Figure 7.1.

Aerodrome Pressure Altitude = 2000 + [(1013.2 – 993) × 28] = 2566 ft

**Table 7.1**

| Altitude (ft) | Temperature (° C) | Fuel used (US gallons) | Time (min) | Air distance (nm) |
|---|---|---|---|---|
| 2566 | +20 | 2 | 4 | 6.8 |
| 16 000 | –10 | 14.5 | 26 | 48.5 |
| Mean climb values 9283 ft | +5 | 12.5 | 22 | 41.7 |

TAS = 141 kts. Ground speed = 161 kts.

Ground distance = (41.2 × 161) ÷ 141 = 47.6 nm

Fuel used = 12.5 × 6 = 75 lb

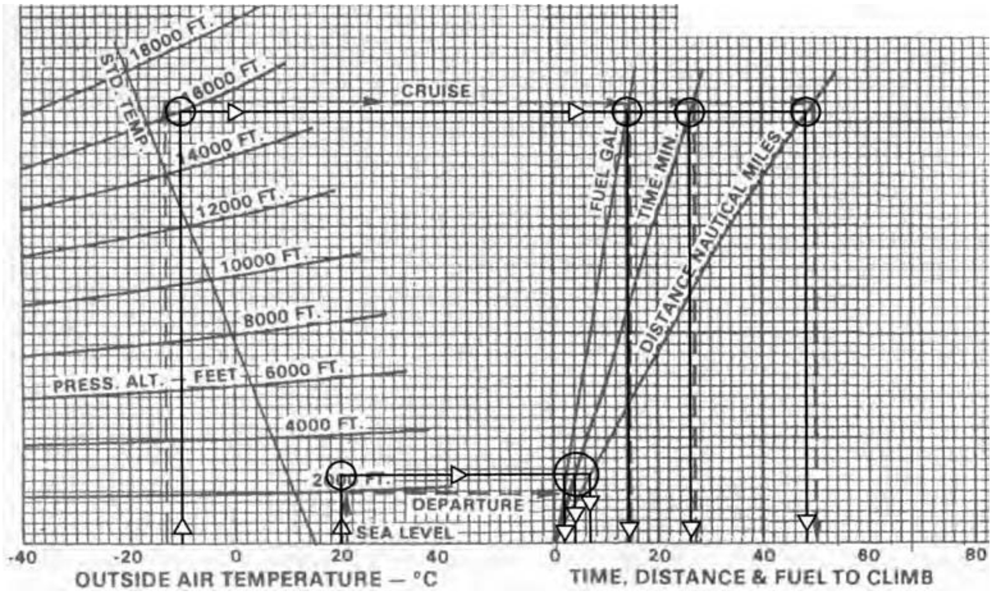


**Figure 7.1** Solution to Example 7.1.

## *Example 7.2*

Given: Start of Climb Pressure Altitude 3000 ft; Ambient Temperature +20°C; Cruise at 15 000 ft Pressure Altitude; Ambient Temperature –20°C; Mean Wind Component 20 kts headwind. Calculate the time taken, fuel used and the ground distance travelled during the climb.

## *Solution 7.2*

See Figure 7.2.

**Table 7.2**

| Altitude (ft) | Temperature (° C) | Fuel used (US gallons) | Time (min) | Air distance (nm) |
|---|---|---|---|---|
| 3000 | +20 | 3 | 4.5 | 8 |
| 15 000 | –20 | 13 | 24 | 42 |
| Mean climb values 9000 ft | 0 | 10 | 19.5 | 34 |

TAS = 138 kts. Ground speed = 118 kts.

Ground distance = (34 × 118) ÷ 138 = 29 nm

Fuel used = 10 × 6 = 60 lb

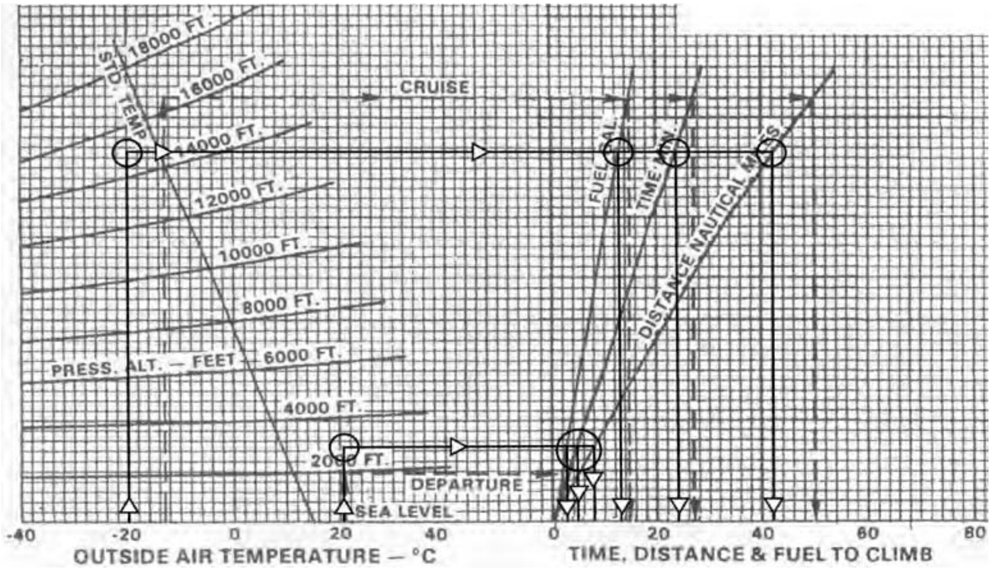


**Figure 7.2** Solution to Example 7.2.

## Range calculations

Range calculations for the MEP can be made using Figure 3.2 on page 18 of the CAP 697. The standard conditions used to construct this graph and Figure 3.5 on page 21 of the CAP 697 were:

- ISA deviation – 0°C
- Take-off weight – 4750 lb
- Usable fuel – 123 US gallons (738 lb)
- Flaps – up
- Cowl flaps – closed
- Undercarriage – retracted
- Climb power – maximum continuous
- Rate of descent – 1000 fpm
- Speed of descent – 145 kts IAS
- Wind component – still air
- Fuel for start, taxi and take-off – 4.2 US gallons (25 lb).

The graph caters for four power settings and two range conditions. The power settings are 75% = High Speed; 65% = Economy; 55% and 45% = Long Range. The two range conditions are the first using the fuel available but retaining a 45 minute reserve at 45% power, in other words the safe range, and the second retaining no reserve fuel which is the absolute range. The range distances, which are still-air distances, include the climb and descent distances.

The graph is used by entering the left vertical axis at the Cruise Pressure Altitude and travelling horizontally right to intersect the appropriate curve, with or without reserve fuel. From the intersection, drop vertically to the carpet of the graph to read the still-air range. This can be corrected for any temperature deviation by adding 1 nm for each degree above the standard or by subtracting 1 nm for each degree below the standard.

### *Example 7.3*

Given: Cruise Pressure Altitude 15 000 ft; Power Setting 65%; Ambient Temperature –5°C; Wind Component 30 kts tailwind. Calculate the range with and without reserve fuel.

### *Solution 7.3*

See Figures 7.3 and 7.4.

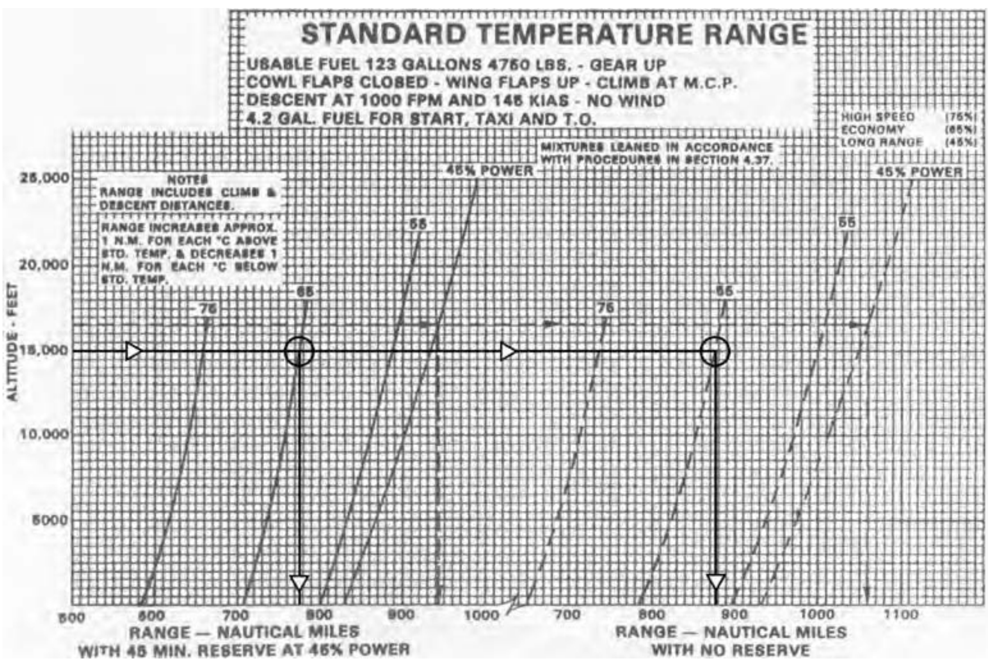


**Figure 7.3** Solution to Example 7.3.

Deviation = Ambient – Standard = –5 – (–15) = –5 + 15 = +10°C

Page 18 (CAP 697).

Still-air Range with reserve fuel = 776 nm + 10 nm (temperature deviation correction) = 786 nm

Page 18 (CAP 697).

Still-air Range without reserve fuel = 878 nm + 10 nm (temperature deviation correction) = 888 nm

Page 20 (CAP 697). See Figure 7.4. Enter the left carpet with the ambient temperature, –5°C, travel vertically to the Cruise Pressure Altitude, 15 000 ft, move horizontally right to the power setting, 65%, then drop vertically to the carpet of the graph to read the TAS, 186 kts.

Ground speed = 186 + 30 = 216 kts

Ground distance with reserve fuel = (786 × 216) ÷ 186 = 912.8 nm

Ground distance without reserve fuel = (888 × 216) ÷ 186 = 1031.2 nm

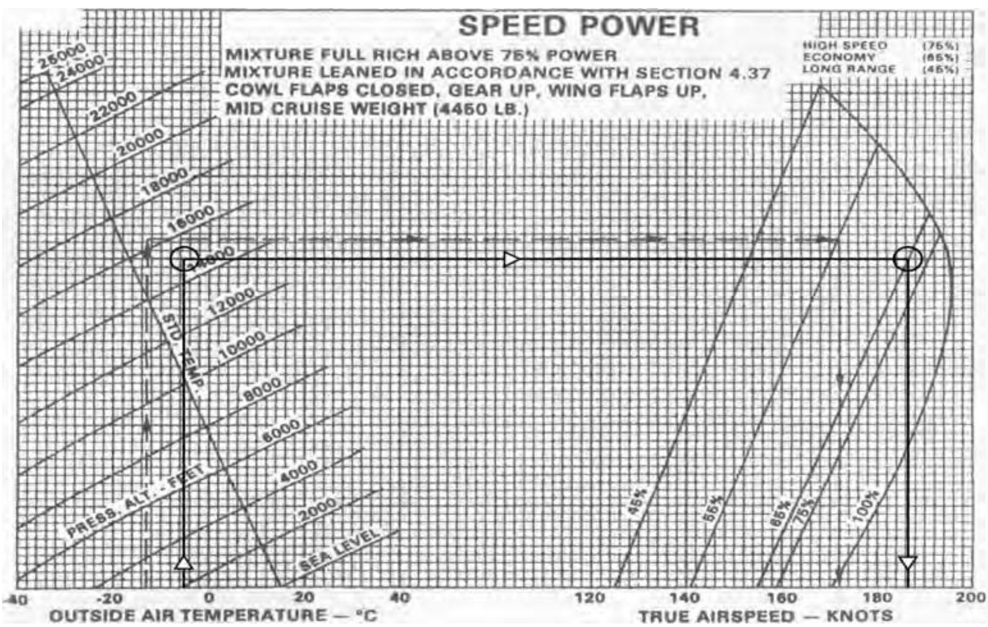


**Figure 7.4** Solution to Example 7.3.

## *Example 7.4*

Given: Cruise Pressure Altitude 10 000 ft; Power Setting 55%; Ambient Temperature 0°C; Wind Component 20 kts headwind. Calculate the range with and without reserve fuel.

### *Solution 7.4*

See Figures 7.5 and 7.6.

Deviation = Ambient – Standard = 0 – (–5) = 0 + 5 = +5°C

Page 18 (CAP 697).

Still-air Range with reserve fuel = 860 nm + 5 nm (temperature deviation correction) = 865 nm

Page 18 (CAP 697).

Still-air Range without reserve fuel = 970 nm + 5 nm (temperature deviation correction) = 975 nm

Page 20 (CAP 697). See Figure 7.6. Enter the left carpet with the ambient temperature, 0°C, travel vertically to the Cruise Pressure Altitude, 10 000 ft, move horizontally right to the power setting, 55%, then drop vertically to the carpet of the graph to read the TAS, 160 kts.

Ground speed = 160 – 20 = 140 kts

Ground distance with reserve fuel = (865 × 140) ÷ 160 = 757 nm

Ground distance without reserve fuel = (975 × 140) ÷ 160 = 853 nm

## Cruise calculations

The tables presented on page 19 of the CAP 697 enable the calculation of the cruise fuel flow and manifold pressure for a specific pressure altitude and power setting. The tables are divided into blocks by power setting. Each block is subdivided in columns by RPM and shows the manifold pressure in inches of mercury against pressure altitude.

The pressure altitude must be interpolated exactly to obtain the precise manifold pressure. The manifold pressure can be corrected for any temperature deviation by adding 1% for each 6°C above standard or subtracting 1% for each 6°C below standard. This correction is subject to an overriding limitation of 34 inches MAP in the cruise. The maximum EGT is listed between the pressure altitudes of 22 000 ft and 24 000 ft. Figure 3.4 (CAP 697) facilitates the determination of TAS.

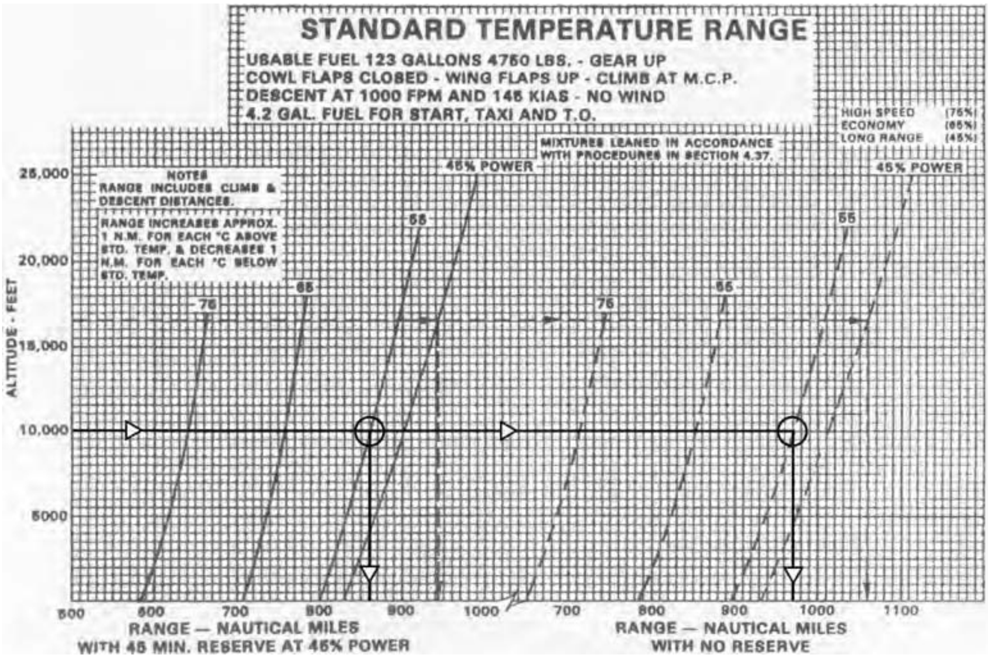


**Figure 7.5** Solution to Example 7.4.

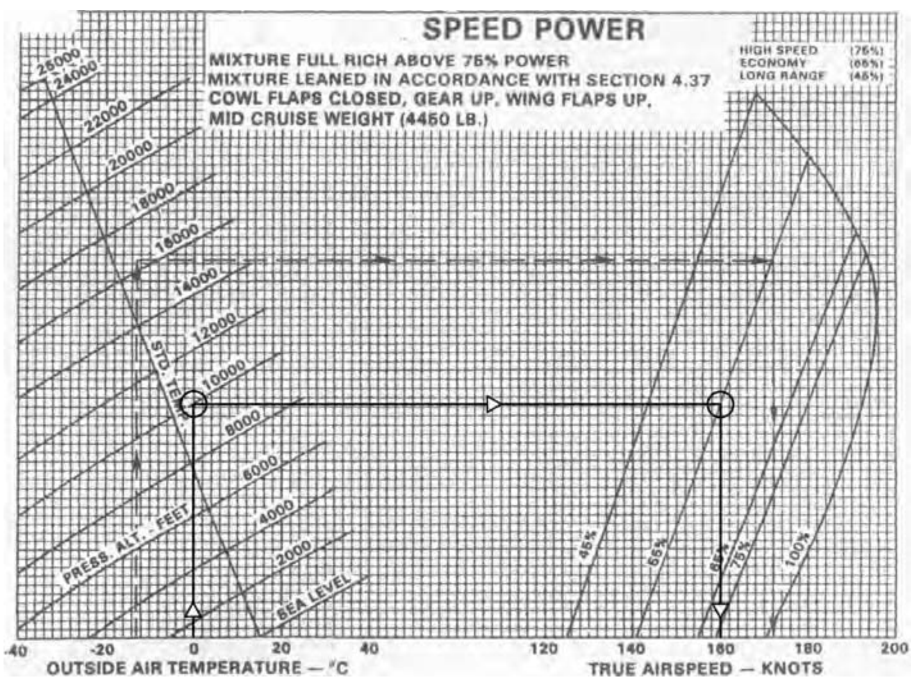


**Figure 7.6** Solution to Example 7.4.

### *Example 7.5*

Given: Cruise Pressure Altitude 15 000 ft; Power Setting 65%; 2600 RPM; Ambient Temperature –5°C; Wind Component 30 kts tailwind. Calculate the time taken, manifold pressure and the fuel used over a distance of 700 nm.

### *Solution 7.5*

Figure 3.4 (CAP 697). TAS = 187 kts. Ground speed = 217 kts.

Time = 700 ÷ 217 = 3.23 hr = 3 hr 13.8 min

Figure 3.3 (CAP 697). Fuel Flow = 23.3 GPH = 139.8 PPH. Manifold Pressure = 29.6 inHg.

Temperature deviation = Ambient – Standard = –5 – (–15) = +10°C

To maintain constant power add (10 ÷ 6)% = 1.67% to the MAP.

Corrected MAP = (29.6 ÷ 100) × 101.67 = 30.1 in Hg MAP

Fuel used = 139.8 × 3.23 = 451.6 lb

### *Example 7.6*

Given: Cruise Pressure Altitude 10 000 ft; Power Setting 55%; 2500 RPM; Ambient Temperature 0°C; Wind Component 20 kts headwind. Calculate the time taken, manifold pressure and the fuel used over a distance of 850 nm.

### *Solution 7.6*

Figure 3.4 (CAP 697). TAS = 160 kts. Ground speed = 140 kts.

Time = 850 ÷ 140 = 6.07 hr. = 6 hr 4.2 min

Figure 3.3 (CAP 697). Fuel Flow = 18.7 GPH = 112.2 PPH. Manifold Pressure = 25.5 in Hg.

Temperature deviation = Ambient – Standard = 0 – (–5) = +5°C

To maintain constant power add (5 ÷ 6)% = 0.83% to the MAP.

Corrected MAP = (25.5 ÷ 100) × 100.83 = 25.7 inHg MAP

Fuel required = 112.2 × 6.07 = 681 lb

## Endurance calculations

The endurance of the aeroplane can be determined from Figure 3.5 on page 21 of the CAP 697. The standard conditions used to construct the graph are the same as those listed for the Range calculations. The graph caters for four power settings and two endurance conditions. The power settings are 75% = High Speed; 65% = Economy; 55% and 45% = Long Range. The two endurance conditions are the first using the fuel available but retaining a 45 minute reserve at 45% power, in other words the safe endurance, and the second retaining no reserve fuel which is the absolute endurance. The endurance times are in hours and decimals of an hour and include the climb and descent times. It is used in precisely the same manner as the range graph at Figure 3.2 (CAP 697) except the result is the endurance in hours and decimals of an hour.

### *Example 7.7*

Given: Cruise Pressure Altitude 15 000 ft; Power Setting 65%; Ambient Temperature –5°C; Wind Component 30 kts tailwind. Calculate the endurance and ground distance travelled both with and without reserve fuel.

### *Solution 7.7*

See Figure 7.7. Figure 3.4 (CAP 697). TAS = 187 kts. Ground speed = 217 kts. Figure 3.5 (CAP 697).

Endurance with reserve fuel = 4.4 hr = 4 hr 24 min

Figure 3.5 (CAP 697).

Endurance without reserve fuel = 4.93 hr = 4 hr 55.8 min

Ground distance travelled with reserve fuel = 217 × 4.4 = 954.8 nm

Ground distance travelled without reserve fuel = 217 × 4.93 = 1069.8 nm

The reason that the difference in times is 31.8 minutes instead of the advertised 45 minutes is because the power setting is 65% and not 45%.

### *Example 7.8*

Given: Cruise Pressure Altitude 10 000 ft; Power Setting 55%; Ambient Temperature 0°C; Wind Component 20 kts headwind. Calculate the endurance and ground distance travelled both with and without reserve fuel.

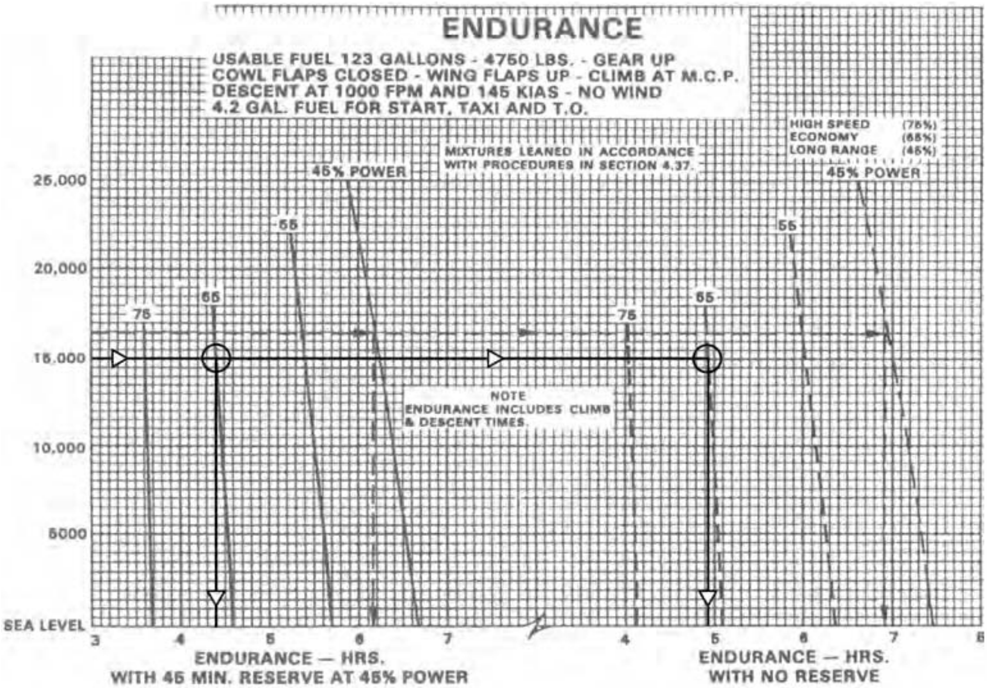


**Figure 7.7** Solution to Example 7.7.

## *Solution 7.8*

See Figure 7.8. Figure 3.4 (CAP 697). TAS = 160 kts. Ground speed = 140 kts. Figure 3.5 (CAP 697).

Endurance with reserve fuel = 5.5 hr = 5 hr 30 min

Figure 3.5 (CAP 697).

Endurance without reserve fuel = 6.16 hr = 6 hr 9.6 min

Ground distance travelled with reserve fuel = 140 × 5.5 = 770 nm

Ground distance travelled without reserve fuel = 140 × 6.13 = 862.4 nm

## Descent calculations

The graph for determining the descent fuel used, time taken and air distance travelled is Figure 3.6 on page 22 of the CAP 697. The assumptions made in the production of the graph were that the descent would be made at a constant rate of 1000 fpm, at a constant speed of 145 kts IAS, in still-air, with both the flaps and the undercarriage retracted.

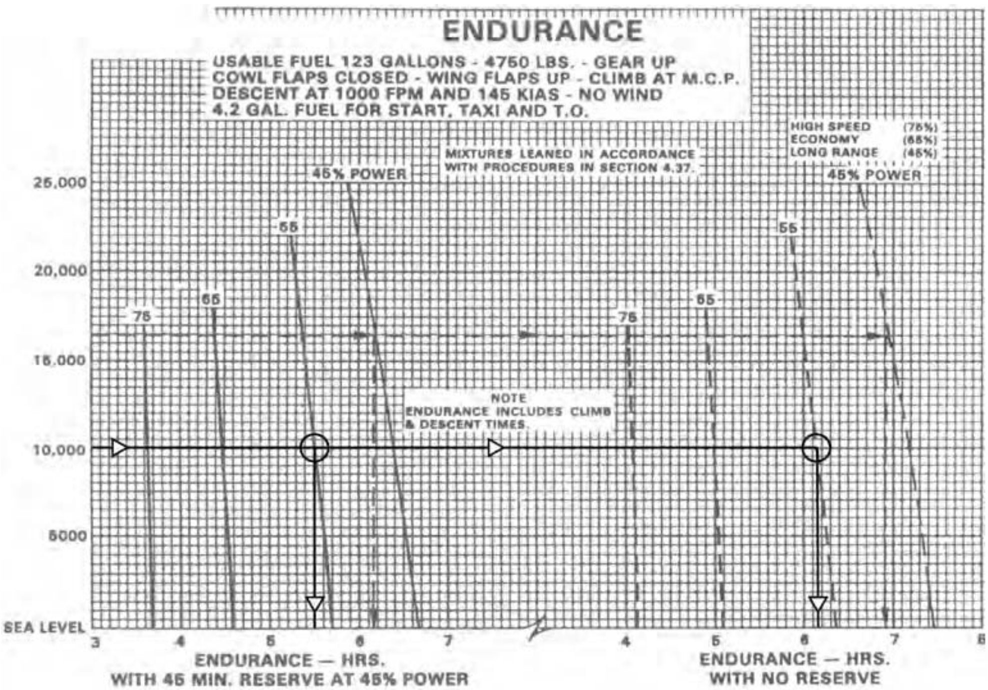


**Figure 7.8** Solution to Example 7.8.

To use the graph enter at the left carpet at the ambient temperature and move vertically to intersect the pressure altitude. From this intersection travel horizontally right to intersect the graph lines for fuel, time and air distance in turn. At each intersection drop vertically to the right carpet to read the exact value. The fuel is in US gallons, the time is in minutes and the air distance in nautical miles.

As with the climb, two entries are required, the first at the Aerodrome Pressure Altitude and the second at the Cruising Pressure Altitude. The results of the first must be subtracted from the second to obtain the values for the descent. The details of the example drawn on the graph are given below the graph.

## *Example 7.9*

Given: Aerodrome Elevation 4000 ft; QNH 1023 hPa; Ambient Temperature +20°C; Cruise Pressure Altitude 14 000 ft; Ambient Temperature –20°C; Mean Wind Component 25 kts tailwind. Calculate the fuel used in pounds, the time taken in minutes and the ground distance travelled for the descent.

## *Solution 7.9*

See Figure 7.9.

Aerodrome Pressure Altitude = 4000 + [(1013.2 – 1023) × 28] = 3726 ft

**Table 7.3**

| Altitude (ft) | Temperature (° C) | Fuel used (US gallons) | Time (min) | Air distance (nm) |
|---|---|---|---|---|
| 3726 | +20 | 1.5 | 4.0 | 10.0 |
| 14 000 | –20 | 4.2 | 13.8 | 37.0 |
| Mean climb values 8863 ft | 0 | 2.7 | 9.8 | 27.0 |

TAS = 166 kts. Ground speed = 191 kts.

Ground distance = (27 × 191) ÷ 166 = 31.1 nm

Fuel used = 2.7 × 6 = 16.2 lb

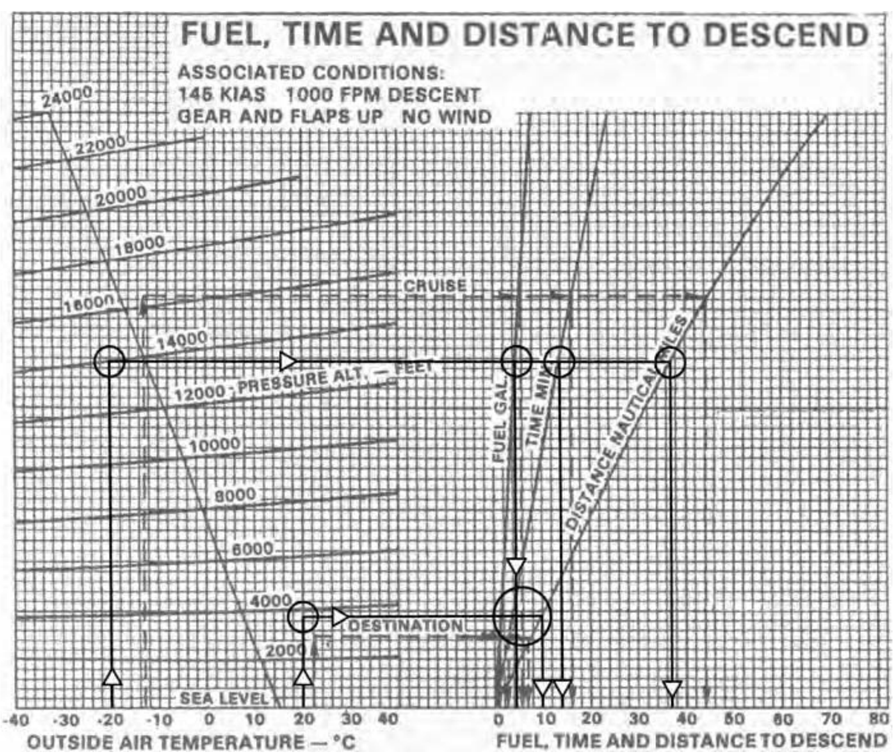


**Figure 7.9** Solution to Example 7.9.

### *Example 7.10*

Given: Aerodrome Elevation 2500 ft; QNH 1003 hPa; Ambient Temperature +30°C; Cruise Pressure Altitude 18 000 ft; Ambient Temperature –20°C; Mean Wind Component 25 kts headwind. Calculate the fuel used in pounds, the time taken in minutes and the ground distance travelled for the descent.

### *Solution 7.10*

See Figure 7.10.

Aerodrome Pressure Altitude = 2500 + [(1013.2 – 1003) × 28] = 2786 ft

**Table 7.4**

| Altitude (ft) | Temperature (°C) | Fuel used (US gallons) | Time (min) | Air distance (nm) |
|---|---|---|---|---|
| 2786 | +30 | 1.0 | 3.0 | 8.0 |
| 18 000 | –20 | 6.0 | 18.0 | 49.0 |
| Mean climb values 10 393 ft | +5 | 5.0 | 15.0 | 41.0 |

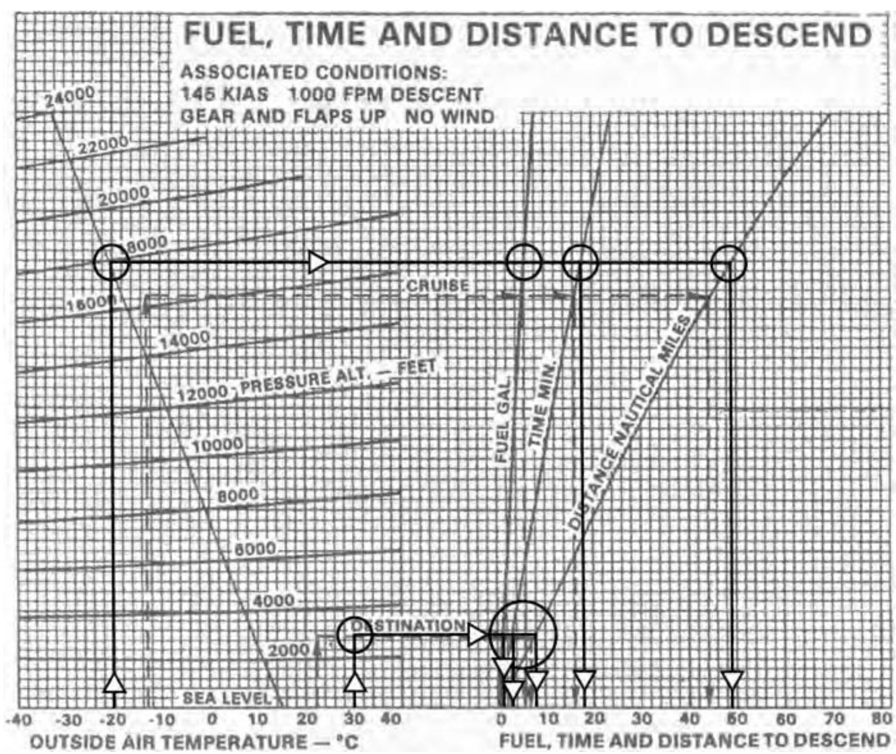


**Figure 7.10** Solution to Example 7.10.

TAS = 173 kts. Ground speed = 148 kts.

Ground distance = (41 × 148) ÷ 173 = 35.1 nm

Fuel used = 5.0 × 6 = 30 lb

The completed fuel plan is shown in Figure 7.11.

MEP FUEL PLAN

| STAGE FROM | STAGE TO | TEMP °C | FL | MORA | WIND DIR'N | WIND SPEED | TR (M) | IAS kts | TAS kts | G/S kts | GND DIST nm | TIME mins | FUEL FLOW lbs/hr | START OF LEG AUW lbs | FUEL USED lbs | END OF LEG AUW lbs | FUEL REMAINING lbs | ETA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EGLL | TOC | — | ↗ | 23 | 090 | 30 | 107 | 120 | 132 | 103 | 33 (40) | 19.2 | | 4750 | 60 | 4690 | | |
| TOC | DET | +10 | 110 | 23 | 070 | 40 | 107 | — | 180 | 147 | 7 | 2.8 | 140 | 4690 | | | | |
| DET | DVR | +10 | 110 | 23 | 070 | 40 | 110 | — | 180 | 148 | 30 | 12.2 | | | | | | |
| DVR | KONAN | +10 | 110 | 23 | 070 | 40 | 098 | — | 180 | 144 | 24 | 10 | | | | | | |
| KONAN | KOK | +10 | 110 | 23 | 070 | 40 | 097 | — | 180 | 144 | 25 | 10.4 | | | | | | |
| KOK | DEN | +10 | 110 | 22 | 060 | 50 | 106 | — | 180 | 142 | 54 | 22.8 | | | | | | |
| DEN | LNO | +10 | 110 | 30 | 060 | 50 | 108 | — | 180 | 142 | 67 | 28.3 | | | | | | |
| LNO | NTM | +7 | 110 | 40 | 060 | 50 | 139 | — | 179 | 162 | 47 | 17.4 | | | | | | |
| NTM | FFM | +7 | 110 | 38 | 060 | 50 | 089 | — | 179 | 133 | 81 | 36.5 | | | | | | |
| FFM | DKB | +7 | 110 | 39 | 050 | 40 | 132 | — | 179 | 169 | 83 | 29.5 | | | | | | |
| DKB | WLD | +7 | 110 | 37 | 050 | 40 | 134 | — | 179 | 170 | 49 | 17.3 | | | 437 | 4253 | | |
| WLD | DKB1T | MEAN +9½ | ↘ | 40 | 070 | 20 | 140 | 145 | 163 | 155 | 21 | 8.1 | | 4253 | 42 | | | |
| DKB1T | EDFM | | ↘ | 40 | 070 | 20 | RAD | 145 | 163 | 135 | 12 | 5.3 | | | | 4211 | | |

| DEPARTURE A/F | | DESTINATION A/F | | ALTERNATE A/F | |
|---|---|---|---|---|---|
| RUNWAY (M) | 094R | RUNWAY (M) | 083L | RUNWAY (M) | 08 |
| W/V | 090/15 | W/V | 080/20 | W/V | 090/15 |
| ELEVATION | 80' | ELEVATION | 1486' | ELEVATION | 1267' |
| QNH | 1013 | QNH | 1023 | QNH | 1022 |
| PRESSURE ALT | 80' | PRESSURE ALT | 1206' | PRESSURE ALT | 1015' |
| TAKE-OFF MASS | 4750 | ALT T/O MASS | 4211 | | |
| ROUTE FUEL | 539 | ALTERNATE FUEL | 1000 | | |
| LANDING MASS | 4211 | LANDING MASS | 3211 | | |

| ROUTE CLEARANCE |
|---|
| 09R SID DVR 6J |
| G1 FFM B1 WLD DKB 1T |
| POWER 65% 2500 rpm |

| | |
|---|---|
| ROUTE FUEL | 539 |
| CONTINGENCY FUEL | 27 |
| ALTERNATE FUEL | 100 |
| FINAL RESERVE | — |
| PLANNED TAKE-OFF FUEL | 666 |
| EXTRA FUEL | 64 |
| TAKE-OFF FUEL | 730 |
| TAXI FUEL | 8 |
| BLOCK FUEL | 738 |

**Figure 7.11** Solution to Figure 4.10.

## Summary

For all climb and descent calculations, subtract the details for the Aerodrome Pressure Altitude from those for the cruise altitude.

The climb/descent/range ground distance = (air distance × ground speed) ÷ TAS.

Interpolate the appropriate cruise table for pressure altitude to obtain the cruise details. Correct the MAP for the temperature deviation, up to a maximum of 34 inches.

## Sample questions

1. Given: aerodrome elevation 4500 ft; QNH 1023 mbs; Ambient temperature +15°C; Cruise Pressure Altitude 18 000 ft; Ambient temperature –35°C; Mean Wind Component 30 kts tailwind. Calculate the fuel used in pounds, the time taken in minutes and the ground distance travelled in the climb.
2. Calculate the fuel used in pounds, the time taken in minutes and the ground distance travelled in a climb from 4000 ft pressure altitude, ambient temperature +20°C to 16 000 ft, ambient temperature –20°C, Wind Component 19 kts tailwind.
3. For an aeroplane cruising at 55% power at a pressure altitude of 19 000 ft, ambient temperature –20°C, calculate the range with and without reserve fuel with a 40 kts headwind.
4. Given: Leg distance 250 nm; Power 55%; RPM 2500; Cruise Pressure Level 14 000 ft; Ambient temperature +7°C; Wind Component 40 kts tailwind. Calculate the leg time in minutes and the fuel used in pounds.
5. Given: Pressure altitude 20 000 ft; Ambient temperature –10°C; Power setting 45%; Wind Component 32 kts tailwind. Calculate the endurance without reserve fuel and the ground distance travelled.
6. Given: Aerodrome Pressure Altitude 5000 ft; Ambient temperature +20°C; Cruise Pressure Altitude 15 000 ft; Ambient temperature –20°C; Wind Component 27 kts headwind. Calculate the time taken in minutes, the fuel used in pounds and the ground distance travelled in the descent from the cruise altitude.

## Chapter 8
# MRJT Aeroplane Fuel Planning

## Introduction

The Medium Range Jet Transport (MRJT) aeroplane section of the CAP 697, the white pages, is by far the largest in the manual and is the most likely source of questions in the examination.

The aeroplane is a twin turbo-jet monoplane with a retractable undercarriage, similar to the Boeing 737–400. The data and constants are detailed on page 24 of the CAP. All weights (masses) in this section are in kilograms.

The maximum structural limitations are listed as:

- Taxi (ramp) mass – 63 060 kg
- Take-off mass (MTOM) – 62 800 kg
- Landing mass (MLM) – 54 900 kg
- Zero fuel mass – 51 300 kg
- Fuel mass – 16 145 kg (5311 US gallons)
- Operating Pressure Altitude – 37 000 ft.

There are four cruise modes available, any one of which may be used, and they are all level cruises, which may be modified to become a stepped cruise to follow the changing optimum altitude as closely as possible as the flight progresses. They are:

- Long range
- Mach 0.74 (M0.74)
- Mach 0.78 (M0.78)
- Low level 300 kts IAS.

## Optimum Cruise Altitude

The Optimum Cruise Altitude is defined as that altitude at which the Specific Air Range (SAR) is maximum. In other words, that altitude at which the air distance per unit fuel is maximised. The penalty for not operating at the optimum altitude is tabulated in paragraph 2.1 on page 24 of CAP 697 and shown here in Table 8.1.

**Table 8.1** Off-optimum altitude fuel penalty

| Off-optimum condition | Fuel mileage penalty (%) | |
|---|---|---|
| | LRC | Mach 0.74 |
| 2000 ft above | 1 | 1 |
| OPTIMUM | 0 | 0 |
| 2000 ft below | 1 | 2 |
| 4000 ft below | 4 | 4 |
| 8000 ft below | 10 | 11 |
| 12 000 ft below | 15 | 20 |

The occasions on which it would be beneficial not to fly at the optimum altitude are:

- on routes of a distance less than 230 nm
- if the wind component changes with altitude, to give a greater tailwind or a lesser headwind, at a rate of 5 kts/1000 ft.

## *Example 8.1*

Given: An aeroplane is operating 8000 ft below optimum altitude in the cruise mode M0.74. Determine the reduction in still-air range.

## *Solution 8.1*

Answer 11% (from Figure 8.1).

Figure 4.2.1 on page 25 of the CAP 697 facilitates the calculation of the Optimum Cruise Altitude for a specified brake release weight or cruise weight and cruise mode. The graph has two horizontal carpet input scales, one for each of the types of weight. There are two grid lines, the lower for the M0.78 cruise mode and the upper for either the long-range cruise or the M0.74 cruise mode. To use the graph enter the appropriate carpet scale and travel vertically up to intersect the cruise mode grid line. From this intersection, move horizontally left to the vertical axis to read the Optimum Pressure Altitude (beware of the scale).

## *Example 8.2*

Given: Cruise weight 62 000 kg; Cruise mode M0.74. Determine the Optimum Pressure Altitude.

## *Solution 8.2*

See Figure 8.1. Enter the upper horizontal axis at 62 000 kg and travel vertically to intersect the upper grid line, and then travel horizontally left to read 31 500 ft. It should be noted that a take-off weight of 63 571 kg would have produced the same answer.

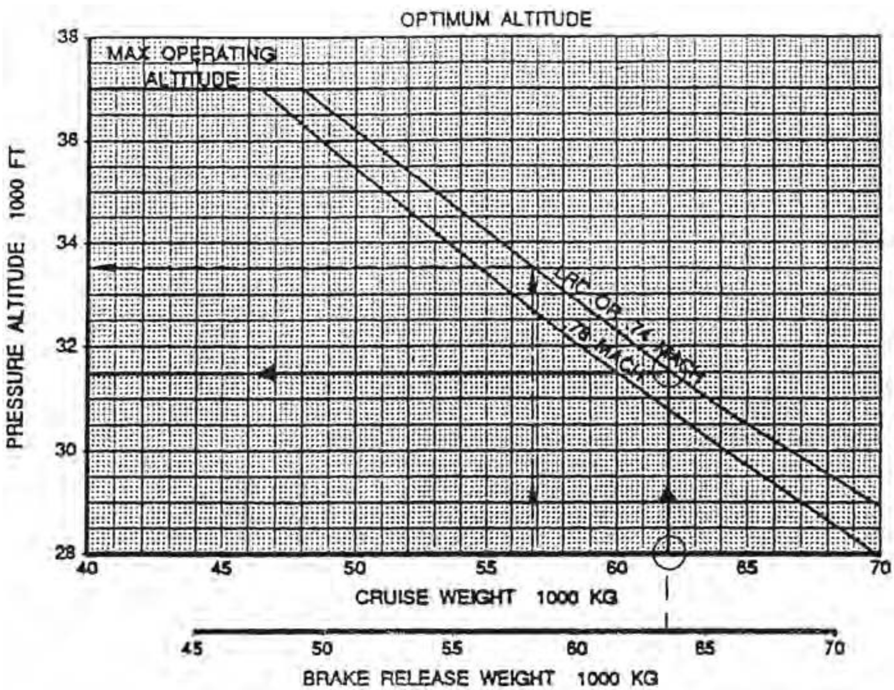


**Figure 8.1** Solution to Example 8.2.

## *Example 8.3*

Given: Brake release weight 57 000 kg; Cruise mode M0.78. Determine the Optimum Cruise Pressure Altitude.

## *Solution 8.3*

See Figure 8.2. 33 150 ft pressure altitude. The same result would have been achieved for a start of cruise weight of 55 700 kg.

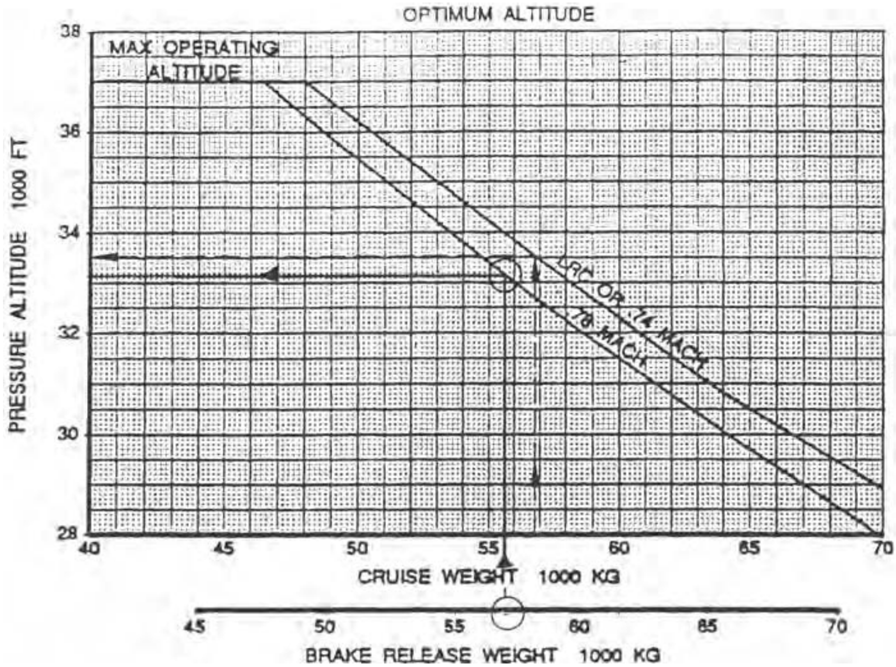


**Figure 8.2** Solution to Example 8.3.

## Short-range Cruise Altitude

Figure 4.2.2 on page 25 of the CAP 697 shows a graph that enables the cruise altitude for routes of distances less than 230 nm to be determined. It comprises two grids, the left for temperature deviation and the right for the brake release weight. The right vertical axis is the pressure altitude although it is not labelled as such.

### *Example 8.4*

Given: Route distance 150 nm; ISA deviation 0°C; Brake release weight 55 000 kg. Determine the cruise altitude.

### *Solution 8.4*

See Figure 8.3. Enter the left carpet at 150 nm, travel vertically to the upper grid line. From this intersection move horizontally right to the reference line of the weight grid, then parallel the curves accounting the convergence of the grid lines. Continue until a vertical from the input of 55 000 kg at the right carpet is reached. From this intersection travel horizontally right to the vertical axis to read the cruise pressure altitude, 25 500 ft.

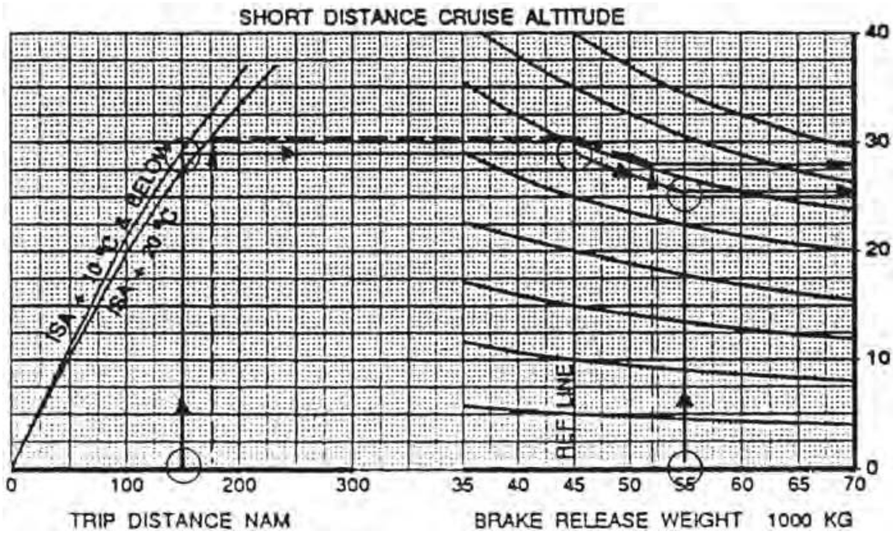


**Figure 8.3** Solution to Example 8.4.

*Note in all graphs in the CAP 697 that contain reference lines, when travelling in the direction of the example arrows always go to the reference line before following the grid lines to the condition. When travelling in the opposite direction to the example arrows go to the condition first and then follow the grid lines to the reference line.*

### *Example 8.5*

Given: Route Distance 117 nm; ISA deviation +20°C; Brake release weight 40 000 kg. Determine the Cruise Pressure Altitude.

### *Solution 8.5*

See Figure 8.4. 25 000 ft pressure altitude.

## Simplified fuel planning

The Simplified Fuel Planning graphs in the CAP 697, pages 28–39, facilitate the rapid calculation of route fuel required and trip time. The graphs have been constructed assuming a climb regime of 280KIAS/M0.74 and a descent regime of M0.74/250KIAS. The graphs include all cruise modes, the stepped climb and alternate planning, and are shown in Table 8.2.

### *Cost index*

The cost index is a fundamental input to the Flight Management System

**Table 8.2** Simplified fuel planning graphs

| Page no. | Cruise mode | Distance coverage (nm) |
|---|---|---|
| 28 | Long-range | 100–600 |
| 29 | Long-range | 200–1200 |
| 30 | Long-range | 1000–3000 |
| 31 | M0.74 | 100–600 |
| 32 | M0.74 | 200–1200 |
| 33 | M0.74 | 1000–3000 |
| 34 | M0.78 | 100–600 |
| 35 | M0.78 | 200–1200 |
| 36 | M0.78 | 1000–3000 |
| 37 | Low-level 300KIAS | 0–1000 |
| 38 | Stepped climb | 1000–4000 |
| 39 | Alternate LRC | 0–500 |

(FMS) in order to compute the optimum speed to fly during the climb, cruise and descent. It is the ratio of the flight time cost (CT) to the fuel cost (CF). The flight time cost will include such things as handling charges at the departure and destination aerodromes, fees for the use of en-route navigational aids, landing fees, crew costs and other operating costs.

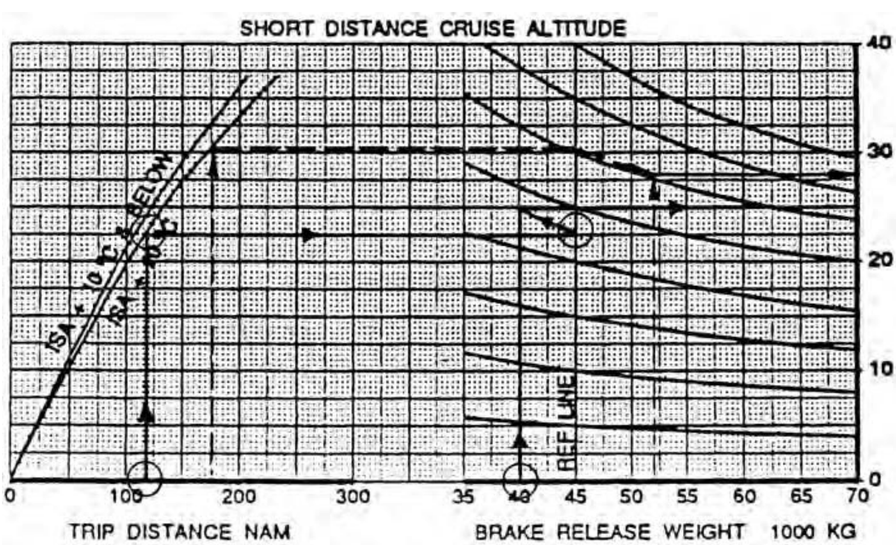


**Figure 8.4** Solution to Example 8.5.

Each airline assigns a cost index to all of its routes, which are stored in the FMS company route file. The crew can modify the allocated cost index in flight. If it is necessary to conserve fuel, the crew can select CI = 0 and the FMS will then compute the speed to fly to ensure the minimum fuel flow is attained. Should the aircraft be behind schedule the crew should select CI = 200 on the FMS which will then compute the speed to fly to reduce the flight time to a minimum.

If it is planned to operate the FMS in the economy mode, then in the case of the Long-range cruise, trip fuel and time adjustments must be made to account for the different speed profile. The adjustments are tabulated in paragraph 3.1(1) on page 26 of the CAP 697, which is reproduced here in Table 8.3.

**Table 8.3** Cost index adjustment

| Cost index | Fuel adjustment: % | Time adjustment: % |
|---|---|---|
| 0 | –1 | +4 |
| 20 | +1 | +1 |
| 40 | +2 | –1 |
| 60 | +4 | –2 |
| 80 | +5 | –3 |
| 100 | +7 | –4 |
| 150 | +10 | –5 |
| 200 | +14 | –7 |

### Additional allowances

If the operational conditions differ from those normally used, additional fuel allowances can be made:

- Pre-flight
  - APU Operation = 115 kg/hr
  - Taxi fuel = 11 kg/min
- Altitude
  - Off-optimum altitude (see Table 8.1)
- Cruise
  - ACS packs on high = 1% increased route fuel
  - Engine anti-icing only = 70 kg/hr
  - Engine and wing anti-icing = 180 kg/hr
- Descent
  - Extra flaps = 75 kg/min
  - Engine anti-icing = 50 kg

**The use of the Simplified Fuel Planning graphs**

The graphs on pages 28–38 of the CAP 697 are used in the same manner; however, the graph on page 39 requires separate explanation. The inputs for the main graphs are:

- Trip (Route) Distance
- Wind Component
- Cruising Pressure Altitude
- Landing Weight
- Cruising Temperature Deviation

*Procedure*

a. Select the graph appropriate to the cruise mode and route ground distance.
b. Enter the centre carpet at the route ground distance.
c. Travel vertically to the wind grid reference line.
d. Draw a curve parallel to the grid lines allowing for any convergence or divergence.
e. Enter the lower left vertical axis at the mean wind component for the route.
f. Travel horizontally right to intersect the curved line drawn in d above.
g. From the intersection, draw a vertical line upward through the whole graph.
h. Move up this vertical line until the planned cruise pressure altitude is intersected for the first time.
i. From this point move horizontally right to intersect the landing weight reference line.
j. Draw a curve through this point to represent the actual Cruise Pressure Altitude, interpolating if necessary between the curves representing FL10 and FL33.
k. Enter the right carpet with the estimated landing weight and travel vertically to intersect the curve drawn in j above.
l. From this intersection proceed horizontally right to the vertical axis to read the route fuel required (trip fuel).
m. Return to the vertical line drawn in g above. Continue vertically to intersect the actual Cruise Pressure Altitude for the second time, interpolating between the grid lines, if necessary.
n. From this intersection, travel horizontally left to the temperature deviation reference line and draw a line parallel to the grid lines through this point.
o. Enter the left carpet of the graph at the cruise temperature deviation and move vertically up to intercept the curve drawn in n above.
p. Proceed horizontally left from this intersection to the vertical axis to read the trip time in hours and decimals of an hour.

## *Example 8.6*

Given: Cruise Mode – Long-range; Route Distance 1000 nm; Optimum Cruise Altitude; Take-off Weight 60 000 kg; Estimated Landing Weight 54 000 kg; Wind Component 50 kts tailwind; ISA deviation +10°C. Calculate the route fuel required and the trip time in hours and minutes.

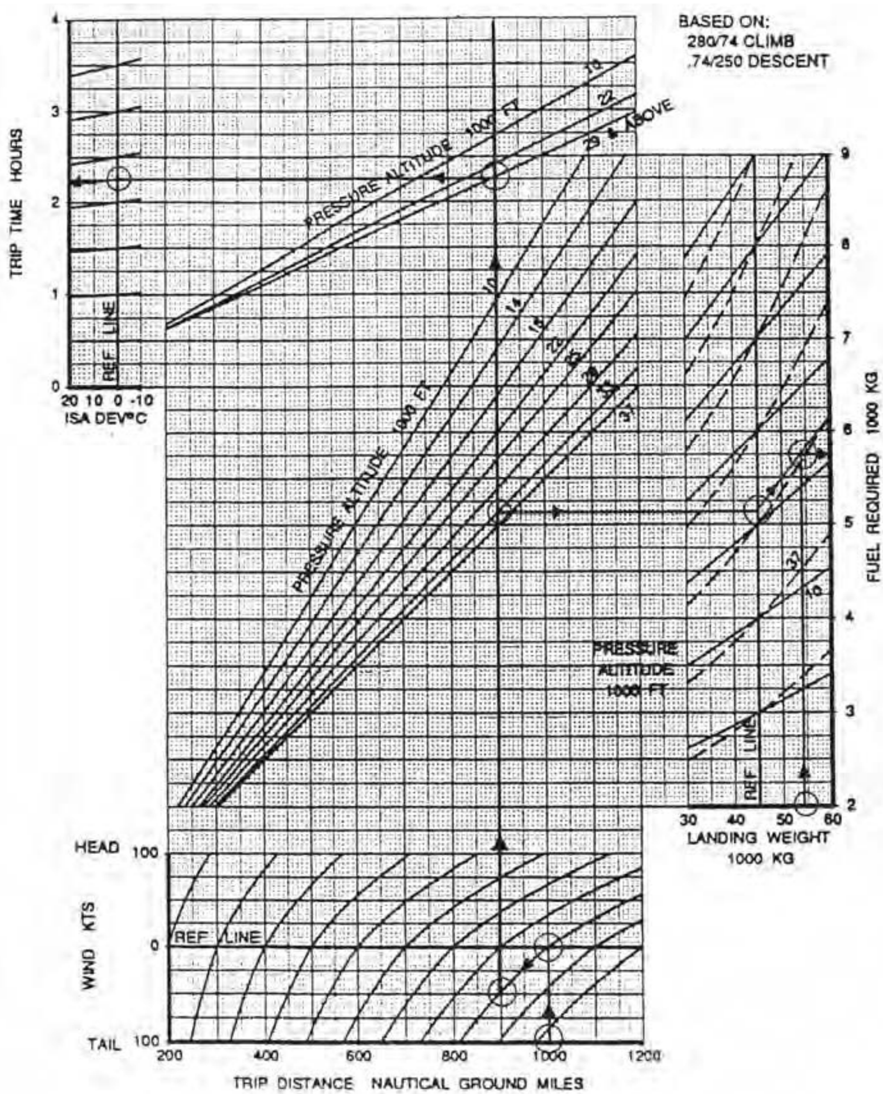


**Figure 8.5** Solution to Example 8.6.

## *Solution 8.6*

Figure 4.2.1 (CAP 697). Optimum Cruise Altitude 32 900 ft (i.e., FL330). See Figure 8.5. Route fuel required = 5750 kg. Trip time = 2.225 hr = 2 hr 13.5 min.

## *Example 8.7*

Given: Cruise Mode M0.74; Route Distance 2250 nm; Cruise Altitude FL310; Take-off Weight 65 000 kg; Estimated Landing Weight 50 000 kg; Wind Component 30 kts headwind; ISA deviation –10°C. Calculate the route fuel required and the trip time in hours and minutes.

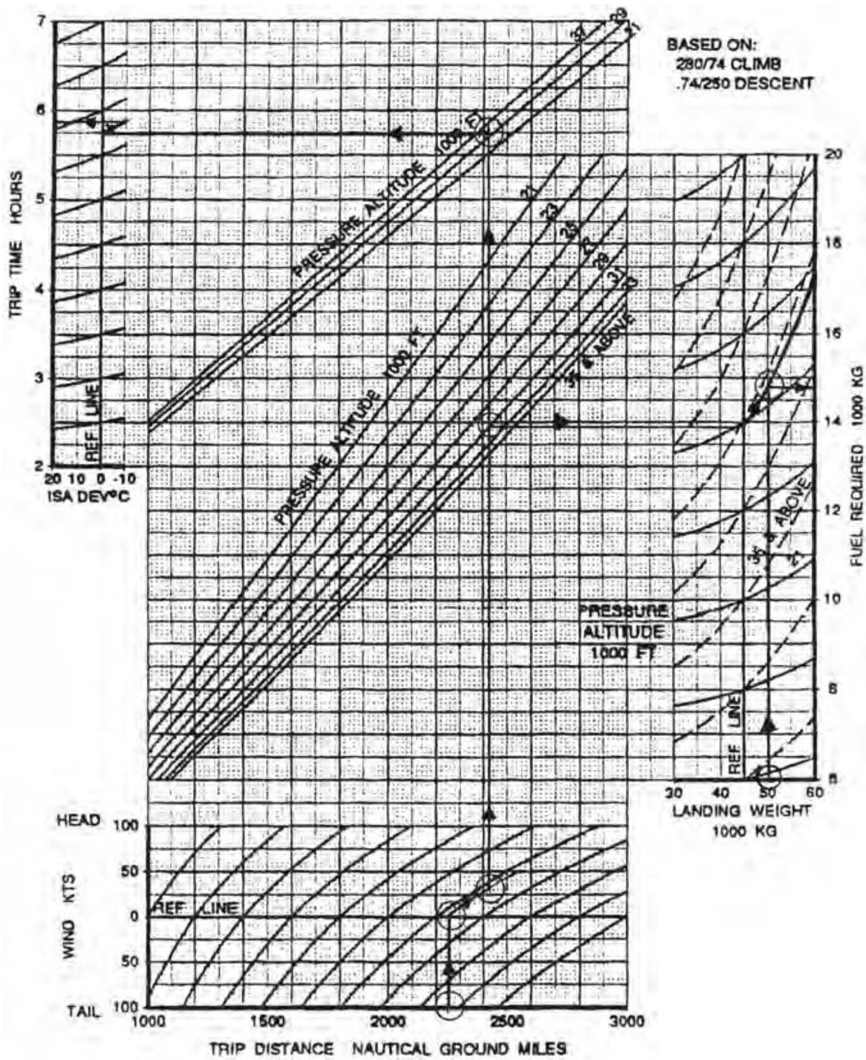


**Figure 8.6** Solution to Example 8.7.

### *Solution 8.7*

See Figure 8.6. (CAP 697 Figure 4.3.2C.) Route fuel required = 14 800 kg. Trip time = 5.87 hr = 5 hr 52.2 min.

### *Example 8.8*

Given: Cruise Mode M0.78; Route Distance 1800 nm; Cruise Altitude FL350; Estimated Landing Weight 38 000 kg; Wind Component 50 kts headwind; ISA deviation +20°C. Calculate the route fuel required and the trip time in hours and minutes.

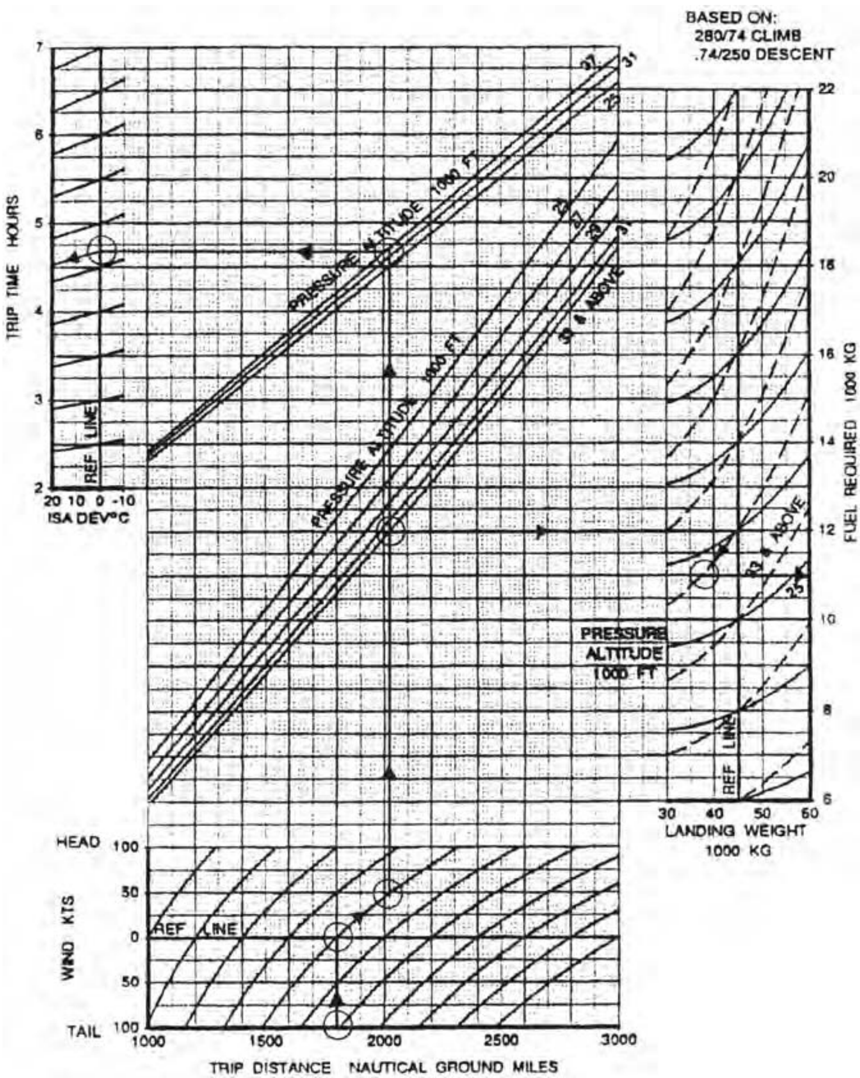


**Figure 8.7** Solution to Example 8.8.

## *Solution 8.8*

See Figure 8.7. (CAP 697 Figure 4.3.3C.) Route fuel required = 11 000 kg. Trip time = 4.55 hr = 4 hr 33 min.

### The stepped cruise climb

The Optimum Pressure Altitude increases as the aeroplane weight decreases with fuel burn. This gradual continuous process would require the aeroplane to cruise climb to maintain its cruise altitude at the optimum. However, Air Traffic Control regulations do not usually permit this mode of operation. The stepped climb enables the aeroplane to closely follow the Optimum Pressure Altitude in level steps.

This mode of operation commences with the aeroplane, at the top of its initial climb, being flown level at the optimum altitude. It continues level until the weight has reduced sufficiently for the optimum altitude to be 2000 ft above its cruise level. The aeroplane is then climbed 4000 ft, so that it is 2000 ft above the optimum level.

A level cruise is recommenced and continued until the aeroplane is once again 2000 ft below the optimum. This whole process is repeated for the entire flight to the top of the descent. With this mode of operation, the aeroplane will achieve 95% of the maximum range.

The graph on page 38 of the CAP 697 permits the rapid calculation of the fuel required and the trip time using this mode of operation. It is a simplified version of the previous simplified fuel planning graphs.

*Procedure*

a. Enter the carpet with the route ground distance and apply the wind component.
b. From this point, draw a vertical line through both weight grids.
c. At the intersection of this line with the brake release weight grid line, in the lower grid, move horizontally right to the vertical axis to read the route fuel required (trip fuel).
d. Continue up the vertical line to the second weight grid line.
e. At this intersection, travel horizontally left to the temperature deviation reference line.
f. Parallel the grid lines to intersect the cruise mean temperature deviation input and then continue left to read the trip time in hours and decimals of an hour.

## *Example 8.9*

Given: Cruise mode – Stepped Climb; Route Distance 2700 nm; Wind

Component 25 kts tailwind; Brake Release Weight 65 000 kg; ISA Deviation – 10°C. Calculate the route fuel required and the trip time.

## *Solution 8.9*

See Figure 8.8. (CAP 697 Figure 4.3.5.) Route fuel required 15 250 kg; Trip time 6.3 hr = 6 hr 18 min.

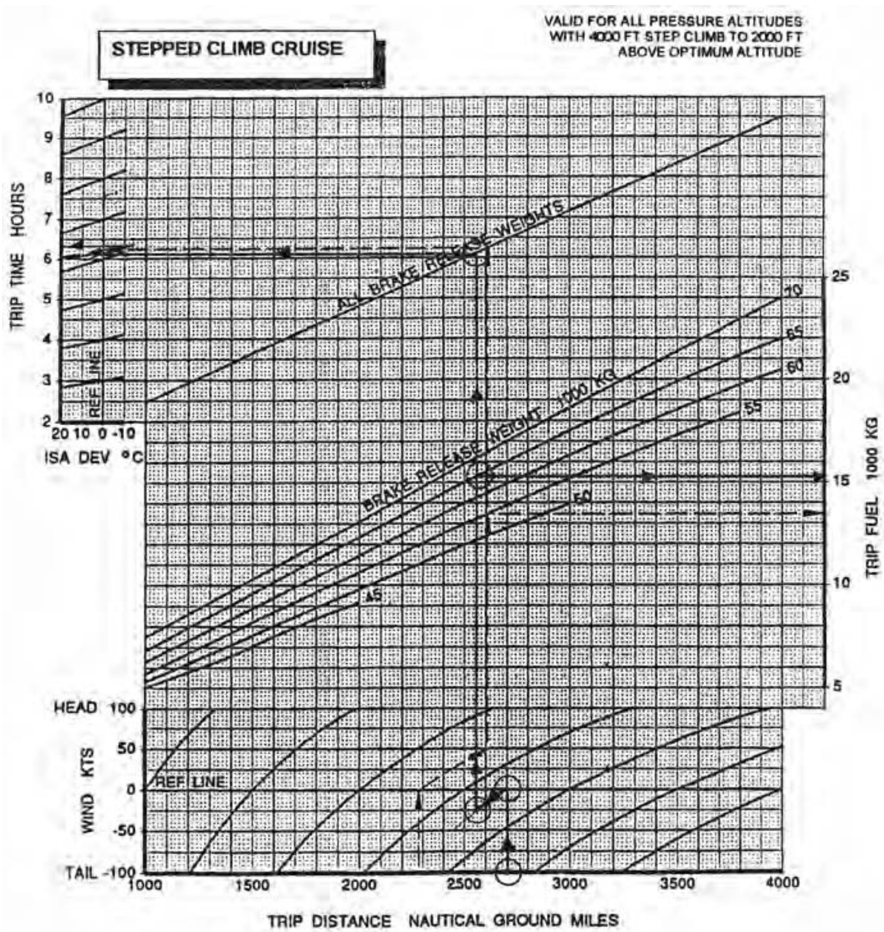


**Figure 8.8** Solution to Example 8.9.

### The Alternate Simplified Fuel Planning Graph

This graph is provided to enable the rapid calculation of the fuel required and time taken to divert to the destination alternate aerodrome. The graph is used in the same manner as previous simplified fuel planning graphs except the weight grids employ landing weights instead of brake release weights.

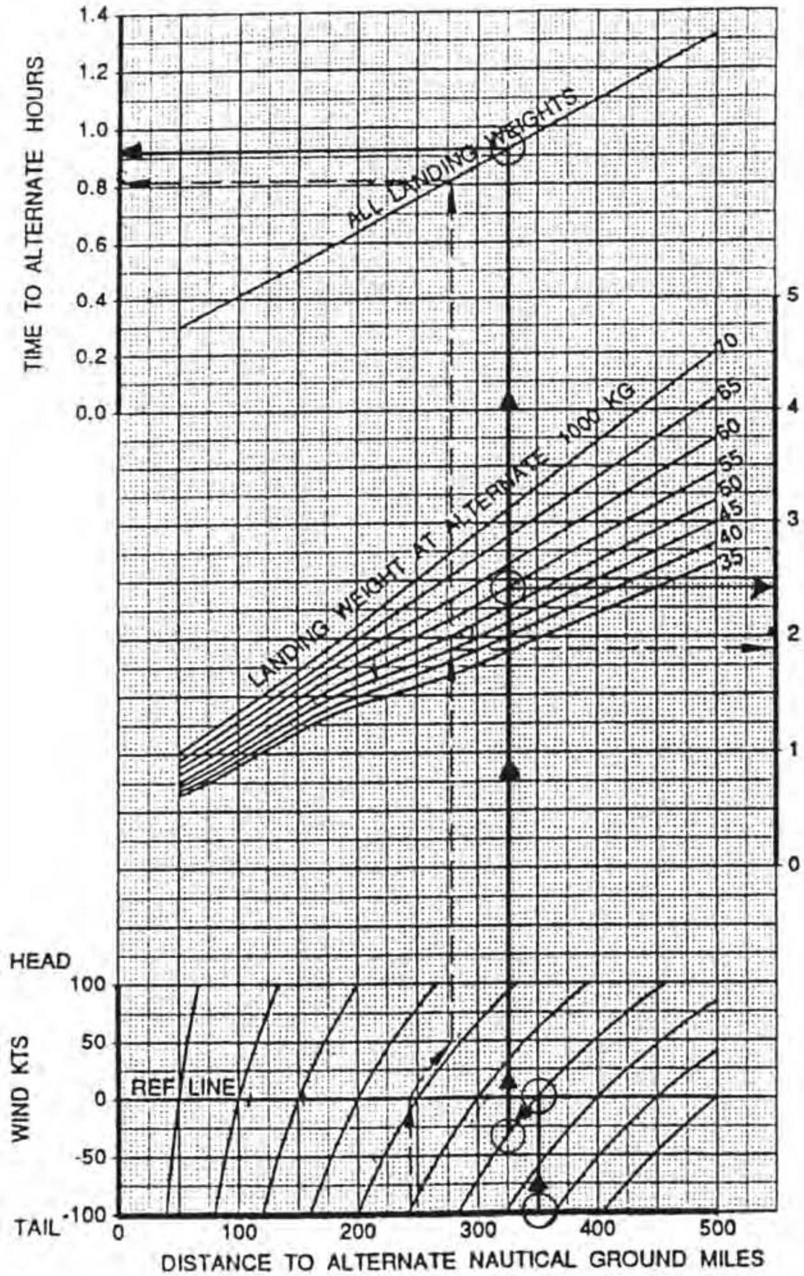


**Figure 8.9** Solution to Example 8.10.

### *Example 8.10*

Given: Alternate ground distance 350 nm; Wind Component 35 kts tailwind; Landing Weight 55 000 kg. Determine the alternate fuel required and the time taken from the destination to reach the alternate aerodrome.

### *Solution 8.10*

See Figure 8.9. (CAP 697 Figure 4.3.6.) Fuel required 2425 kg. Time to the alternate = 0.92 hr = 55.2 min.

### *Holding fuel flow*

Holding is usually made in a racetrack pattern. The fuel flow for a holding reserve is shown in Figure 4.4 of the CAP 697. The table is based on the assumption that the aeroplane will be flown at VIMD but not less than 210 kts with the undercarriage and the flaps retracted. The pressure altitude for the hold is listed in the left column and the main body of the table is divided in columns of aeroplane weight in 1000 kg at 2000 kg intervals.

The table must be interpolated for pressure altitude and for the holding weight. Although the mid-weight of the hold should be used for these purposes, the examiners require the hold entry weight to be used. If the holding is to be made in straight and level flight, instead of a racetrack pattern, then the calculated fuel flow has to be reduced by 5%.

### *Example 8.11*

Given: Holding Pressure Altitude 22 000 ft; Hold Entry Weight 51 500 kg. Fuel available for the hold 4300 kg. Calculate the maximum time that the aeroplane can hold in a racetrack pattern.

### *Solution 8.11*

**Table 8.4**

| **Pressure altitude (ft)** | **Weight (kg) × 1000** | | |
|---|---|---|---|
| | 52 | 50 | 51.5 |
| | **Total fuel flow (kg/hr)** | | |
| 25 000 | 2240 | 2160 | 2220 |
| 20 000 | 2260 | 2180 | 2240 |
| 22 000 | 2252 | 2172 | 2232 |

Maximum holding time = (4300 kg ÷ 2232) × 60 = 115.6 min = **1hr 36 min**

### *Example 8.12*

Given: An aeroplane is to be held in straight and level flight at FL280 at a start weight of 47 500 kg. Calculate the fuel flow.

### *Solution 8.12*

Fuel flow at FL300 = 1960 + [(100 ÷ 2000) × 1500] = 2035 kg/hr

Fuel flow at FL250 = 2000 + [(80 ÷ 2000) × 1500] = 2060 kg/hr

Fuel flow at FL280 = 2060 – [(25 ÷ 5) × 3] = 2045 kg/hr

Reduction for straight and level flight = (2045 ÷ 100) × 95 = 1943 kg/hr

## Detailed fuel planning

### *Climb calculations*

The tables for the detailed climb calculations are presented on four pages of the CAP 697, each embracing 10°C of temperature deviation (see Table 8.5).

**Table 8.5**

| CAP 697 page number | Temperature deviation |
|---|---|
| 41 | ISA –6°C to –15°C |
| 42 | ISA –5°C to +5°C |
| 43 | ISA +6°C to +15°C |
| 44 | ISA +16°C to +25°C |

The assumptions made in the construction of the tables are that the aerodrome take-off surface level is 0 ft pressure altitude and the climb regime is 280KIAS/M0.74. A correction table is presented below the main body of the table to correct for the actual pressure altitude of the departure aerodrome. Each cell of the main table contains the time in minutes, the fuel used in kilograms, the air distance travelled in nautical miles, and the TAS in knots. The fuel used and time taken are from the brake release point, whereas the air distance is from a pressure altitude of 1500 ft, and the TAS is the average value between 1500 ft and the top of the climb.

The left column of each table is the pressure altitude of the top of climb. The main body of the table is divided in columns of brake release weight at 2000 kg intervals. Again the table must be interpolated for the top of climb pressure altitude and brake release weight, if necessary. If the aerodrome pressure altitude is above 0 ft, the fuel extracted from the table must be corrected.

Because the distance derived from the tables is an air distance it has to be converted to a ground distance to be of any use in the flight plan. This is done by multiplying the air distance by the ground speed and dividing by the TAS.

### *Example 8.13*

Given: Aerodrome Pressure Altitude 5000 ft; Top of Climb 31 000 ft Pressure Altitude; Brake Release Weight 60 750 kg; ISA deviation +15°C; Wind Component 35 kts headwind. Calculate the time taken, the fuel used, the ground distance travelled and the average TAS for the climb.

### *Solution 8.13*

Page 43, Figure 4.5.1 (CAP 697).

**Table 8.6**

| **Pressure altitude (ft)** | **Brake release weight (kg)** | | |
|---|---|---|---|
| | 62 000 | 60 000 | 60 750 |
| 31 000 | 18/1550<br>101/383 | 17/1500<br>95/382 | **17.4**/1519<br>97.3/**382** |

Aerodrome Pressure Altitude correction = –150 kg

Fuel used in the climb = 1519 – 150 = **1369 kg**

Ground distance travelled in the climb = (97.3 × 347) ÷ 382 = **88.4 nm**

### *Example 8.14*

Given: Aerodrome Pressure Altitude 4500 ft; Top of Climb 35 000 ft Pressure Altitude; Brake Release Weight 62 350 kg; ISA deviation –10°C; Wind Component 25 kts tailwind. Calculate the time taken, the fuel used, the ground distance travelled and the average TAS for the climb.

### *Solution 8.14*

Page 41 Figure 4.5.1 (CAP 697).

**Table 8.7**

| **Pressure altitude (ft)** | **Brakes release weight (kg)** | | |
|---|---|---|---|
| | 64 000 | 62 000 | 62 350 |
| 35 000 | 24/1850<br>139/383 | 22/1700<br>125/381 | **22.4**/1726<br>127.4/**381** |

Aerodrome Pressure Altitude correction = –112.5 kg

Fuel used in the climb = 1726 – 112.5 = **1614 kg**

Ground distance travelled in the climb = (127.4 × 406) ÷ 381 = **135.8 nm**

### *The Wind Range Correction graph*

The Wind Range Correction graph is provided to enable the conversion of air distance to ground distance accounting the wind component and vice versa. Regrettably, it is not a very accurate method because the scale of the graph does not lend itself to precise readings. It is far easier to use a calculator for these conversions.

To use the graph enter the left carpet at the average cruise TAS. Proceed vertically up from this position to intersect the wind component grid line. Draw a horizontal line through the right grid. Enter the right grid at the air distance and travel vertically up to intersect the line just drawn. At this intersection read the ground distance in nautical miles.

### *Example 8.15*

Given: Average TAS 450 kts; Wind Component 75 kts headwind; Air distance 500 nm. Calculate the ground distance.

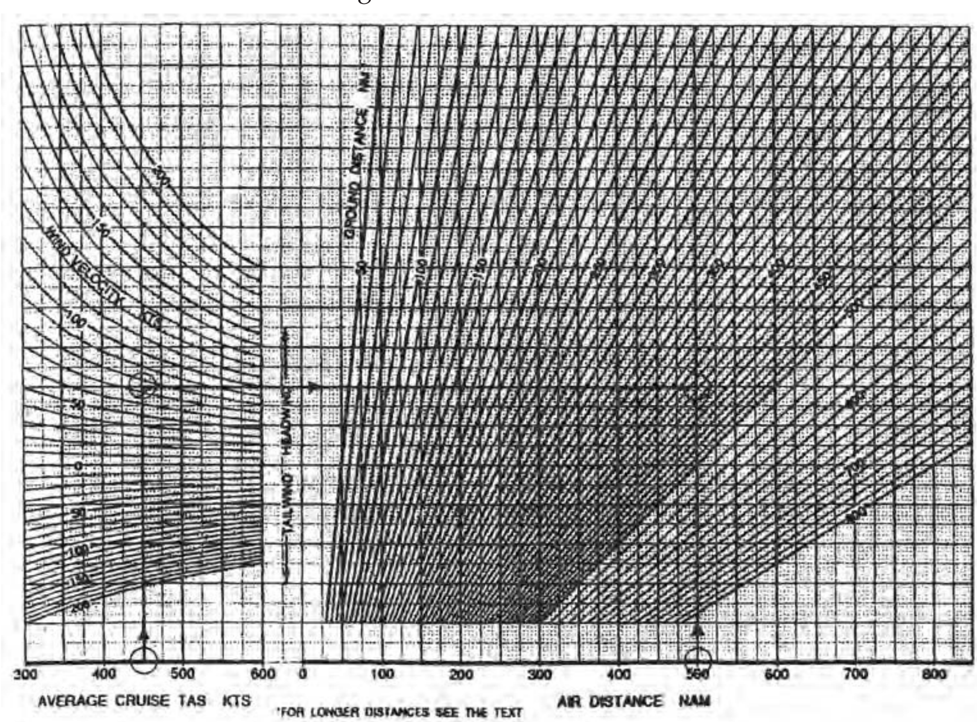


**Figure 8.10** Solution to Example 8.15.

## *Solution 8.15*

See Figure 8.10 (CAP 697 Figure 4.5.2.)

Ground distance 418 nm. By calculation, (500 × 375) ÷ 450 = 416.7 nm.

## *Cruise calculations*

The integrated range tables enable detailed cruise calculations to be made. The tables cover the four cruise modes for various pressure altitudes at the standard temperature (i.e., ISA deviation 0°C). They are listed in Table 8.8.

**Table 8.8**

| Figure | Cruise mode and FL | CAP 697 pages |
|---|---|---|
| 4.5.3.1. | Long-range Cruise FL270–FL370 | 25–35 |
| 4.5.3.2. | M0.74 Cruise FL210–FL370 | 36–52 |
| 4.5.3.3. | M0.78 Cruise FL290–FL370 | 53–58 |
| 4.5.3.4. | Low-level Cruise FL140–FL210 | 59–66 |

The left column of the table details the gross weight of the aeroplane in thousands of kilograms. The next column tabulates the TAS for the Long-range cruise tables, but for the remaining cruise modes, the TAS is clearly stated above the main body of the table. The remaining columns of all tables divide the table into 100 kg increments to enable accurate interpolation.

The principle used in the construction of the tables is that the aeroplane is assumed to be in a level cruise in the conditions stated for the table at a start weight of 67 900 kg. Of course, this is not possible because the maximum take-off weight is 62 800 kg. The figure quoted in each cell of the table is the equivalent still-air distance for that weight. Thus, the difference between two still-air distances represents a difference between two weights, which is the amount of fuel that was burnt to travel that air distance.

If the temperature is other than standard, for that pressure altitude, corrections must be made to the fuel used and to the TAS. These are often ignored or forgotten and can lead to large errors in the calculation results. The example calculation given on page 46 of the CAP 697 does not demonstrate the complicated calculation that must be made if such is the case.

### Calculation procedure

The details that must be known before a cruise calculation can be made are the cruise mode, the cruise pressure altitude, the temperature deviation, the leg distance and the start of leg weight. Interpolation in the table is essential. The sequence of calculation is:

a. Select the table appropriate to the cruise mode and pressure altitude.
b. Extract the TAS against the listed start of leg weight or from the top of the table.
c. Correct the TAS for temperature deviation.
d. Apply the wind component to obtain the ground speed.
e. Divide the leg distance by the ground speed to obtain the leg time in hours and decimals of an hour (and multiply the result by 60 if the leg time is required in minutes).
f. Calculate the air distance travelled by the formula NAM = (Leg distance × TAS) ÷ ground speed.
g. Enter the table with the start of leg weight, interpolating if necessary, and extract the still-air distance equivalent to that weight.
h. Subtract the leg air distance calculated in f from the start of leg air distance to obtain the end of leg air distance.
i. Re-enter the table with end of leg air distance and extract the equivalent weight, interpolating if necessary.
j. Calculate the fuel used by subtracting the end of leg weight in i from the start of leg weight.
k. Correct the fuel used for the temperature deviation, if necessary, according to the instructions at the bottom of the table.
l. Subtract the corrected fuel used from the start of leg weight to obtain the start of leg weight for the next leg.
m. Repeat the procedure for each subsequent leg.

### *Example 8.16*

Given: Cruise mode – Long Range; Cruise Pressure Altitude 31 000 ft; Temperature Deviation +13°C; Wind Component 23 kts tailwind; Leg Distance 327 nm; Start of leg Weight 56 330 kg. Calculate the fuel used, the leg time in hours and minutes and the start weight for the next leg.

### *Solution 8.16*

a. CAP 697 page 51
b. TAS 437 kts
c. Temperature deviation correction = + 13. Revised TAS = 437 + 13 = 450 kts
d. Ground speed = 450 + 23 = 473 kts
e. Leg time = 327 ÷ 473 = 0.69 hr = **41.5 min**
f. Leg air distance = (327 × 450) ÷ 473 = 311 nm
g. Start weight equivalent air distance = 4186 + [(30 ÷ 100) × 17] = 4191 nm

**Table 8.9**

| Gross weight (kg) | TAS (kts) | 300 | 400 | 330 |
|---|---|---|---|---|
| 56 000 | 437 | 4186 | 4203 | **4191** |

h. End of leg air distance = 4191 – 311 = **3880** nm
i. End of leg air distance equivalent weight = 54 500 + {[(3880 – 3871) ÷ (3889 – 3871)] × 100} = 54 550 kg

**Table 8.10**

| Gross weight (kg) | TAS (kts) | 500 | 600 | **550** |
|---|---|---|---|---|
| **54 000** | 437 | 3871 | 3889 | 3880 |

j. Fuel used = 56 330 – 54 550 = 1780 kg
k. Fuel correction = (+13 ÷ 10) × 0.6 = 0.78%.
Corrected fuel used = (1780 ÷ 100) × 100.78 = **1794 kg**
l. Next leg start weight = 56 330 – 1794 = **54 536 kg**

## *Example 8.17*

Given: Cruise Mode – M0.74; Cruise Pressure Altitude 35 000 ft; Temperature Deviation –17°C; Wind Component 42 kts headwind; Leg Distance 463 nm; Start of leg Weight 59 670 kg. Calculate the fuel used, the leg time in hours and minutes and the start weight for the next leg.

## *Solution 8.17*

a. CAP 697 page 72
b. TAS 426 kts
c. Temperature deviation correction = –17. Revised TAS = 426 – 17 = 409 kts
d. Ground speed = 409 – 42 = 367 kts
e. Leg time = 463 ÷ 367 = 1.26 hr = **1 hr 15.7 min**
f. Leg air distance = (463 × 409) ÷ 367 = 516 nm
g. Start weight equivalent air distance = 5010 + [(70 ÷ 100) × 17] = 5022 nm

**Table 8.11**

| Gross weight (kg) | TAS (kts) | 600 | 700 | 670 |
|---|---|---|---|---|
| 59 000 | 426 | 5010 | 5027 | **5022** |

h. End of leg air distance = 5022 – 516 = **4506 nm**
i. End of leg air distance equivalent weight = 56 600 + {[(4506 – 4494) ÷ (4511 – 4494)] × 100} = 56 671 kg

**Table 8.12**

| Gross weight (kg) | TAS (kts) | 600 | 700 | 671 |
|---|---|---|---|---|
| **56 000** | 426 | 4494 | 4511 | 4506 |

j. Fuel used = 59 670 – 56 671 = 2999 kg
k. Fuel correction = (–17 ÷ 10) × 0.6 = 1.02%. Corrected fuel used = (2999 ÷ 100) × 98.98 = **2968 kg**
l. Next leg start weight = 59 670 – 2968 = **56 702 kg**.

## *Example 8.18*

Given: Cruise Mode – M0.78; Cruise Pressure Altitude 29 000 ft; Temperature Deviation +23°C; Wind Component 37 kts tailwind; Leg Distance 294 nm; Start of leg Weight 55 770 kg. Calculate the fuel used, the leg time in hours and minutes and the start weight for the next leg.

## *Solution 8.18*

a. CAP 697 page 75
b. TAS 462 kts
c. Temperature deviation correction = +23. Revised TAS = 462 + 23 = 485 kts
d. Ground speed = 485 + 37 = 522 kts
e. Leg time = 294 ÷ 522 = 0.56 hr = **33.8 min**
f. Leg air distance = (294 × 485) ÷ 522 = 273 nm
g. Start weight equivalent air distance = 3628 + [(70 ÷ 100) × 16] = 3639 nm

**Table 8.13**

| Gross weight (kg) | TAS (kts) | 700 | 800 | 770 |
|---|---|---|---|---|
| 55 000 | 462 | 3628 | 3644 | **3639** |

h. End of leg air distance = 3639 – 273 = **3366 nm**
i. End of leg air distance equivalent weight = 54 000 + {[(3366 – 3354) ÷ (3371 – 3354)] × 100} = 54 071 kg

**Table 8.14**

| Gross weight (kg) | TAS (kts) | 000 | 100 | **071** |
|---|---|---|---|---|
| **54 000** | 462 | 3354 | 3371 | 3366 |

j. Fuel used = 55 770 – 54 071 = 1699 kg
k. Fuel correction = (+23 ÷ 10) × 0.6 = 1.38%. Corrected fuel used = (1699 ÷ 100) × 101.38 = **1722 kg**
l. Next leg start weight = 55 770 – 1722 = **54 048 kg**.

### *Example 8.19*

Given: Cruise Mode – Low-level Cruise; Cruise Pressure Altitude 14 000 ft; Temperature Deviation –23°C; Wind Component 13 kts headwind; Leg Distance 363 nm; Start of leg Weight 52 830 kg. Calculate the fuel used, the leg time in hours and minutes and the start weight for the next leg.

### *Solution 8.19*

a. CAP 697 page 81
b. TAS 366 kts
c. Temperature deviation correction = –23. Revised TAS = 366 – 23 = 343 kts
d. Ground speed = 343 – 13 = 330 kts
e. Leg time = 363 ÷ 330 = 1.1 hr = **1 hr 06 min**
f. Leg air distance = (363 × 343) ÷ 330 = 377 nm
g. Start weight equivalent air distance = 2471 + [(30 ÷ 100) × 13] = 2475 nm

**Table 8.15**

| Gross weight (kg) | TAS (kts) | 800 | 900 | 830 |
|---|---|---|---|---|
| 52 000 | 366 | 2471 | 2484 | **2475** |

h. End of leg air distance = 2475 – 377 = **2098 nm**
i. End of leg air distance equivalent weight = 50 000 + {[(2098 – 2097) ÷ (2110 – 2097)] × 100} = 50 008 kg

**Table 8.16**

| Gross weight (kg) | TAS (kts) | 000 | 100 | **008** |
|---|---|---|---|---|
| **50 000** | 366 | 2097 | 2110 | 2098 |

j. Fuel used = 52 830 – 50 008 = 2822 kg
k. Fuel correction = (–23 ÷ 10) × 0.5 = –1.15%. Corrected fuel used = (2822 ÷ 100) × 98.85 = **2790 kg**
l. Next leg start weight = 52 830 – 2790 = **50 040 kg**.

### *Descent calculations*

There are two descent tables presented on page 89 of the CAP 697. Both tables were calculated assuming the 'flight idle' thrust is selected for the descent and that a straight-in approach with the undercarriage extended will be made at the destination. The destination is assumed to be at 0 ft pressure altitude. The upper table is for an economy descent at M0.74/250 kts IAS and the lower table is for turbulence penetration at M0.70/280 kts IAS.

The construction of both tables is the same. The first column on the left is the pressure altitude for the top of descent and the bottom of descent or aerodrome pressure altitude. The second column tabulates the time taken and the third column the fuel used to reach 0 ft pressure altitude against the top of descent pressure altitude. Although it is not specified in the tables, two minutes and 100 kg of fuel is included in the tabulated values of the tables for the approach and landing. This allowance enables calculations to be made for descents to high elevation aerodromes. There is no adjustment required to the descent distance to such an aerodrome. The remaining columns list the still-air distance, for landing weights at 10 000 kg intervals from 35 000 kg, from the top of descent to 0 ft pressure altitude.

The tables must be interpolated for pressure altitude and landing weight. Due allowance must be made for the effects of wind component, to determine the ground distance travelled. To calculate the TAS use the mean ambient temperature against the mean pressure altitude in the airspeed window on the back of the navigation computer. Against the appropriate IAS on the inner scale read the TAS on the outer scale. The ground distance travelled in the descent = (air distance × ground speed) ÷ TAS.

For intermediate descents or for descents to high elevation aerodromes, two entries of the appropriate table are necessary. The unit values are first extracted for the top of descent pressure altitude and the second entry is to extract details for the pressure altitude of the destination aerodrome or the bottom of the descent. The weight to be used for an intermediate descent is that at the bottom of the descent. The second set of values is subtracted from the first set of values to determine the true values for the descent. However, for descents to high elevation aerodromes an allowance of two minutes and 100 kg of fuel must be added to the results of the calculation. (Although these values are not specified they can be calculated and must be added to allow for the approach and landing.)

### *Example 8.20*

Given: An aeroplane is to make an economy descent from FL340, ambient temperature –50°C, to an aerodrome at pressure altitude 7000 ft, ambient temperature 0°C. The landing weight is 47 000 kg. Wind Component 23 kts headwind. Calculate the time taken, fuel used and the ground distance travelled in the descent.

## *Solution 8.20*

**Table 8.17**

| **Pressure altitude (ft)** | **Time (min)** | **Fuel (kg)** | **Air distance (nm)** | | |
|---|---|---|---|---|---|
| | | | **Landing weight (kg)** | | |
| | | | 45 000 | 55 000 | 47 000 |
| 35 000 | 22 | 290 | 105 | 110 | |
| 33 000 | 21 | 285 | 99 | 103 | |
| 34 000 | 21.5 | 287.5 | 102 | 106.5 | 102.9 |
| | | | | | |
| 10 000 | 9 | 185 | 32 | 33 | |
| 5000 | 6 | 140 | 18 | 18 | |
| 7000 | 7.2 | 158 | 23.6 | 24 | 23.7 |
| | | | | | |
| Descent | 14.3 | 129.5 | | | 79.2 |
| App and Ldg | +2 | +100 | | | |
| Totals | 16.3 | 229.5 | | | 79.2 |

Mean Pressure Altitude = 20 500 ft. Mean Ambient Temperature = –25°C. Navigation computer – TAS = 343 kts. Ground speed = 343 – 23 = 320 kts. Ground distance travelled = (79.2 × 320) ÷ 343 = **73.9 nm**.

## *Example 8.21*

Given: An aeroplane is to make an economy descent from FL320, ambient temperature –45°C, to a pressure altitude of 12 000 ft, ambient temperature –5°C. The weight at the bottom of the descent is estimated to be 43 000 kg. Wind Component 17 kts tailwind. Calculate the time taken, fuel used and the ground distance travelled in the descent.

## *Solution 8.21*

**Table 8.18**

| Pressure altitude (ft) | Time (min) | Fuel (kg) | Air distance (nm) | | |
|---|---|---|---|---|---|
| | | | Landing weight (kg) | | |
| | | | 35 000 | 45 000 | 43 000 |
| 33 000 | 21 | 285 | 89 | 99 | |
| 31 000 | 20 | 280 | 83 | 93 | |
| 32 000 | 20.5 | 282.5 | 86 | 96 | 94 |
| | | | | | |
| 15 000 | 12 | 215 | 43 | 46 | 45.4 |
| 10 000 | 9 | 185 | 30 | 32 | 31.6 |
| 12 000 | 10.2 | 197 | 35.2 | 37.6 | 37.12 |
| | | | | | |
| Descent | 10.3 | 85.5 | 50.8 | 58.4 | 56.88 |

Mean Pressure Altitude = 22 000 ft. Mean Ambient Temperature = –25.0°C. Navigation computer – TAS = 354 kts. Ground speed = 354 + 17 = 371 kts. Ground distance travelled = (57 × 371) ÷ 354 = **59.7 nm**.

## *Abnormal operation*

Should an aeroplane develop a fault with the undercarriage retraction system away from base and there is no repair facility available, it would be necessary to fly it back to base with the undercarriage extended. This would impose restrictions on the maximum speed and pressure altitude at which to operate the aeroplane. Consequently, the fuel consumption would increase and the time taken for any specific distance would increase.

To cater for such an eventuality the manufacturers usually include a simplified fuel-planning graph to account the different performance of the aeroplane in these circumstances. Figure 4.6.1 on page 90 of the CAP 697 is such a graph. It is based on a maximum IAS of 220 kts for the climb, cruise and descent. The graph is used in the same manner as the previous simplified fuel planning graphs.

## *Example 8.22*

Given: An aeroplane has to make a ferry flight back to base with the undercarriage extended. The ground distance to base is 650 nm and the wind component is 25 kts tailwind. The cruising pressure altitude will be 20 000 ft at which the mean temperature deviation for the flight will be ISA −10°C. The landing weight will be 40 000 kg. Calculate the route fuel required and the trip time in hours and minutes.

### *Solution 8.22*

See Figure 8.11. 6500 kg of route fuel is required and the trip time is 2.2 hr = 2 hr 12 min.

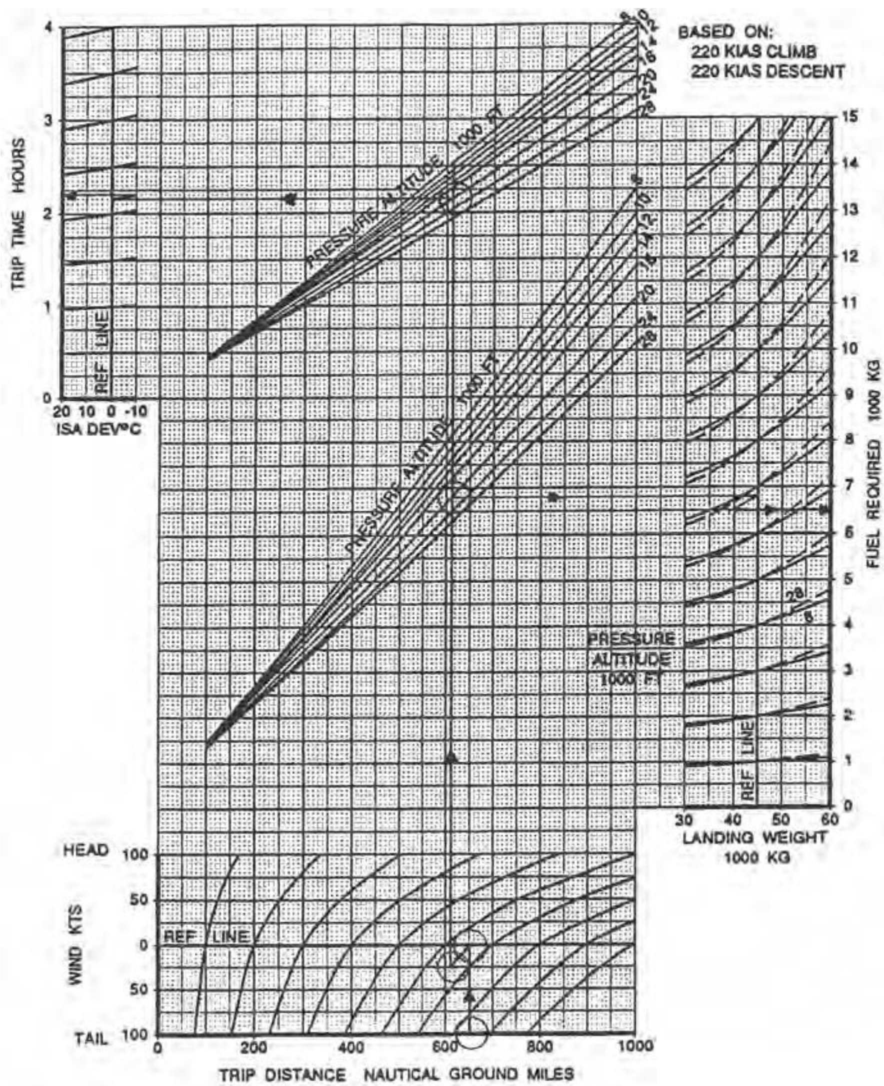


**Figure 8.11** Solution to Example 8.22.

## *Extended range operations*

A full explanation of the rules and regulations governing Extended Range Operations (EROPS) is given in Chapter 11 of this book. The operator of a twin-engined aeroplane is restricted to an area of operations that is no further than the distance that would be covered in 60 minutes at the one-engine-inoperative cruising speed, still-air conditions, from an adequate aerodrome, unless permission is granted to operate using the EROPS regulations. Dependent on the experience and efficiency of the airline the maximum distance granted by a national Civil Aviation Authority may be up to that which would be covered in 180 minutes at the one-engine-inoperative cruise speed in still-air.

To enable the appropriate distance to be calculated a table is provided on page 94 of the CAP 697. The table is divided in blocks by the mode of operation. There are five modes of operation, all at the one-engine-inoperative speed. Each block has entering arguments of diversion weight on the left and rule time along the top. The tables are based on the assumption that the aeroplane is cruising at or near the optimum altitude, in ISA conditions, and will commence a drift-down on suffering an engine failure.

## *Example 8.23*

Given: The mode of operation is M0.74/290 kts IAS. The aeroplane weight at the time of diversion is 53 000 kg. The maximum approved time is 138 minutes. Calculate the maximum distance from an adequate aerodrome.

## *Solution 8.23*

Enter the second block of Figure 4.7.2 of the CAP 697.

**Table 8.19**

| Diversion distance (nm) | | | |
|---|---|---|---|
| **Diversion weight (kg)** | **Rule time (min)** | | |
| | 130 | 140 | 138 |
| 50 000 | 844 | 907 | 894.4 |
| 55 000 | 828 | 890 | 877.6 |
| 53 000 | 834.4 | 896.8 | **884.3** |

### Critical fuel reserve

An aeroplane operating to EROPS standards must have sufficient fuel available at the critical point to reach the planned en-route alternate aerodrome and arrive at the aerodrome with at least the minimum reserve requirement. The CAP 697

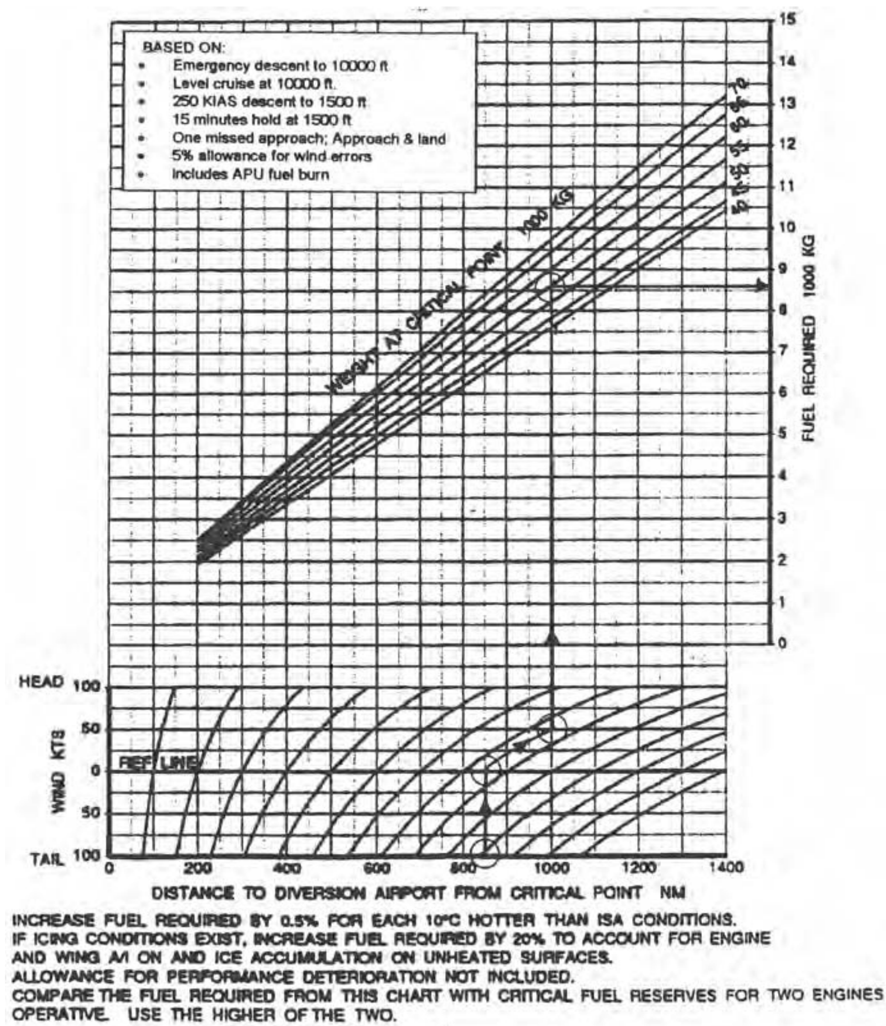


**Figure 8.12** Solution to Example 8.24.

provides two graphs for this purpose. CAP 697 Figure 4.7.1a is for the one-engine-inoperative configuration, and CAP 697 Figure 4.7.1b is for the all-engines-operating configuration. Both graphs are based on the following criteria:

- An emergency descent is made immediately to 10 000 ft pressure altitude followed by a level cruise at 10 000 ft pressure altitude to the top of descent
- A descent to 1500 ft pressure altitude at 250 kts IAS
- An allowance for a hold of 15 minutes at 1500 ft pressure altitude
- An allowance for one missed approach followed by a landing
- An allowance of 5% of the diversion fuel for wind errors
- In the one-engine-inoperative case a fuel allowance for the use of the APU.

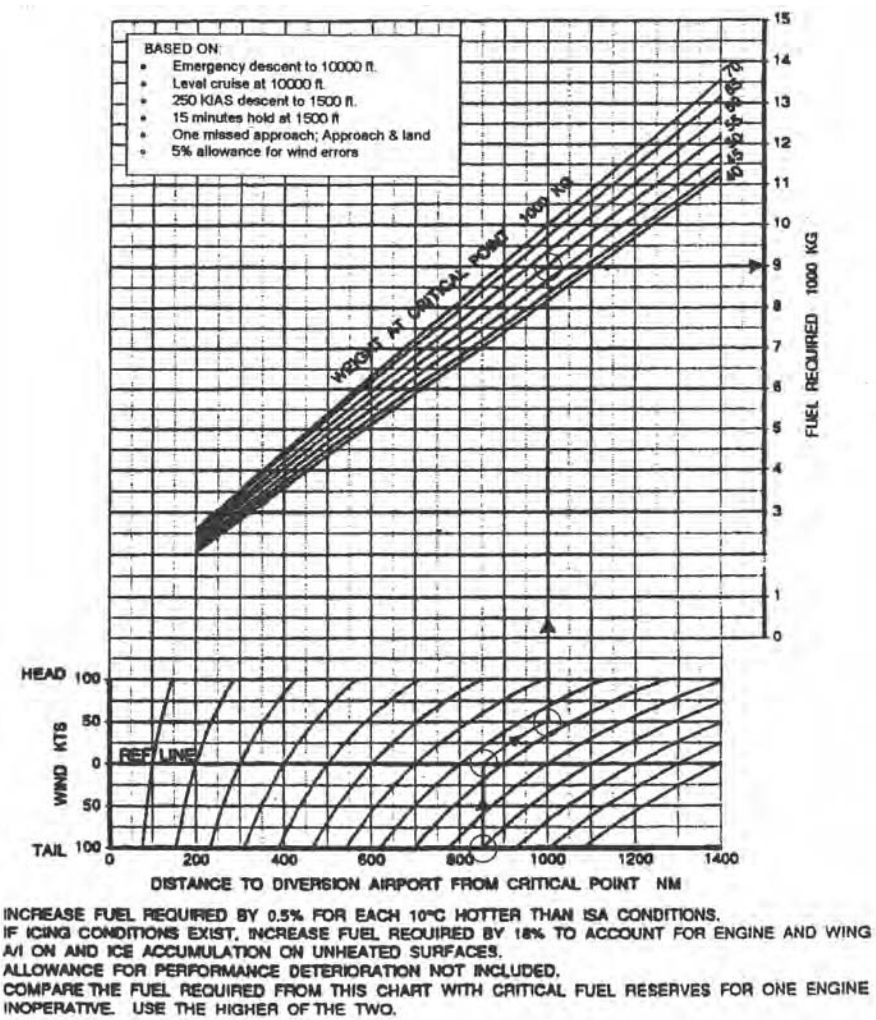


**Figure 8.13** Solution to Example 8.24.

Both graphs require the resulting fuel required to be corrected by 0.5% for each +10°C ISA deviation. There is no correction if the temperature deviation is below ISA. To account for the use of engine and wing anti-ice equipment and the accumulation of ice on unheated surfaces the required fuel must be increased by 20% in the case of the one-engine-inoperative configuration and 18% for the all-engines-operating case. No allowance has been made in the graphs for any performance deterioration.

The minimum critical fuel reserve is the **higher** of the fuel required from each of the graphs. The graphs are relatively simple to use. Enter the carpet with the distance from the critical point to the en-route alternate aerodrome. Travel vertically to the reference line. Apply the appropriate wind component and continue vertically to the weight grid lines. On intersecting the line representing the aeroplane weight at the critical point move horizontally right to the vertical axis to read the fuel required. Compare the results of both graphs and accept the higher as being the critical fuel reserve.

### *Example 8.24*

Given: Aeroplane Weight at the critical point 55 000 kg; Temperature Deviation 0°C; Diversion distance 850 nm; Wind Component 50 kts headwind; Icing is forecast. Calculate the critical fuel reserve.

### *Solution 8.24*

Enter the carpet of both graphs at 850 nm. Travel vertically to the reference line; apply the wind component, 50 kts headwind. Continue vertically to the 55 000 kg weight grid line and move horizontally right to the vertical axis. From Figure 4.7.1a (CAP 697) read 8650 kg and add 20% for icing. The critical reserve one-engine-inoperative is 10 380 kg. See Figure 8.12. From Figure 4.7.1b (CAP 697) read 9000 kg and add 18% for icing. See Figure 8.13. The critical reserve all-engines-operating is 10 620 kg. The reserve fuel that must be available at the critical point is, therefore, 10 620 kg.

### *In-flight diversion*

Sometimes during flight, often for some unforeseen circumstance, the aeroplane has to divert to an en-route alternate aerodrome. A medical emergency that requires immediate treatment, or a pressurisation system failure that requires an immediate descent and prevents continuing the planned flight, are typical examples. The graph in Figure 4.7.3 on page 95 of the CAP 697 enables the rapid calculation of the fuel required and the time taken to reach the diversion aerodrome. This graph is used in precisely the same manner as the simplified planning graphs previously described.

### *Example 8.25*

Given: Diversion distance 750 nm; Wind Component 30 kts headwind; Cruise Pressure Altitude 22 000 ft; Aeroplane weight at the Point of Diversion 60 000 kg; ISA Deviation +10°C. Calculate the fuel required and the time taken to reach the diversion aerodrome.

### *Solution 8.25*

Enter the carpet at 750 nm and travel vertically up to the wind grid reference

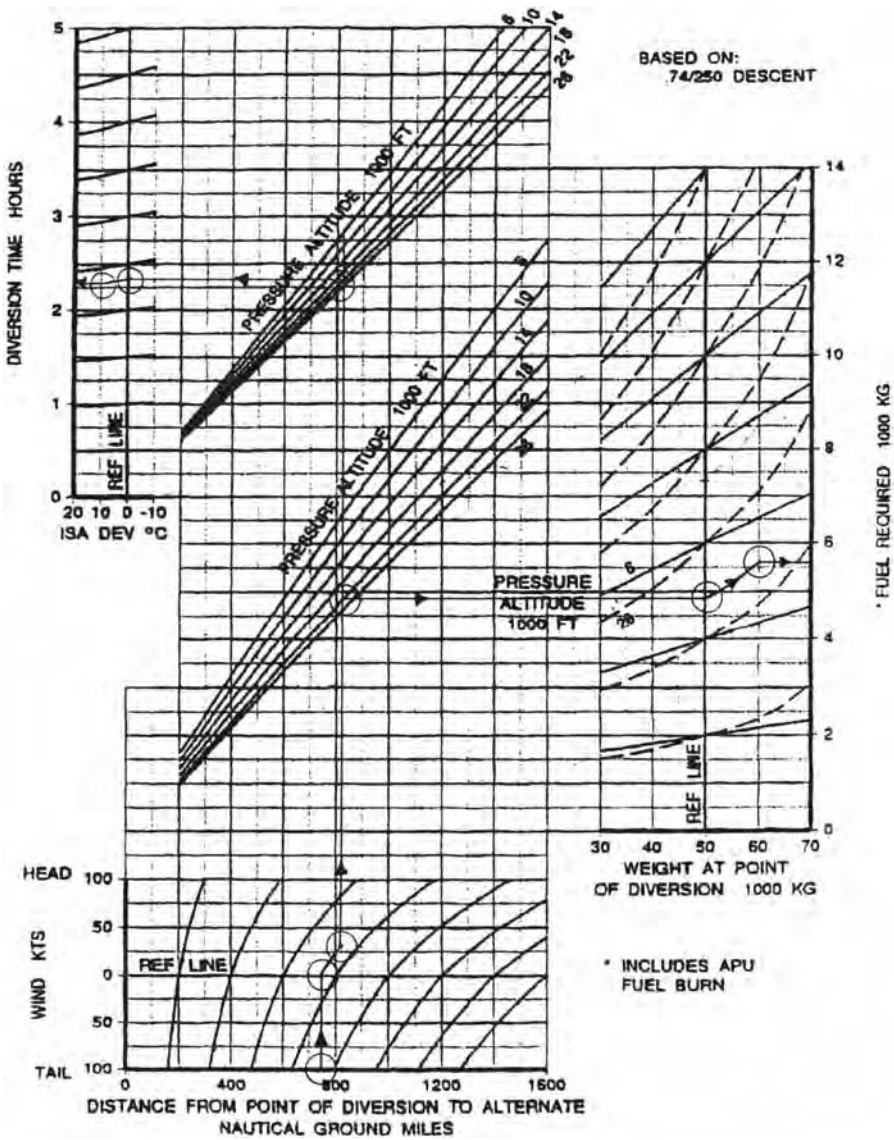


**Figure 8.14** Solution to Example 8.25.

line. Parallel the grid lines, allowing for the divergence of the lines, to 30 kts headwind. Draw a vertical line through the graph. Continue vertically from the wind component grid to reach the first pressure altitude of 22 000 ft. At this intersection travel horizontally right to the weight grid reference line. From this point, draw a line, interpolating as necessary, to represent 22 000 ft Pressure Altitude. Move along this line to intersect a vertical from the right carpet at 60 000 kg. Now travel horizontal right to the vertical axis to read the fuel required to reach the diversion, 5650 kg.

Return to the vertical line drawn from the wind grid and travel vertically to the second Pressure Altitude intersection of 22 000 ft. Move horizontally left from this intersection to reach the ISA deviation reference line and then parallel the grid lines to reach a vertical input of ISA +10°C. From this intersection travel horizontally left to reach the left vertical axis to read the time taken to reach the diversion aerodrome, 2.3 hr or 2 hr 18 min. (See Figure 8.14.)

## *Fuel tankering*

For the economical operation of an airline it is essential to keep the operating costs as low as possible. A major contributing factor to these costs is that of fuel. Consideration must be given to the price differential between the departure aerodrome and the destination aerodrome. Often economic benefit can be gained by carrying sufficient fuel for the leg onward from the destination. This practice is referred to as *tankering*. The capacity of the fuel tanks or the performance maximum take-off weight limitation may restrict the amount of excess fuel that can be carried, and the cruise performance may be depleted by the carriage of excess fuel. However, it may still be economically advantageous to carry as much excess fuel as possible, thus reducing the amount of fuel required at the destination charging a higher price.

There are two graphs that have to be used to determine whether tankering is a feasible proposition. The carriage of excess fuel increases the weight of the aeroplane, consequently the performance is depleted and the fuel flow is increased. The first graph determines the fuel penalty for tankering as a percentage of the normal fuel burn for the journey to the destination. Figure 4.8.1 on page 97 of the CAP 697 shows two versions of this graph, one for the long-range cruise mode and the other for the M0.74 cruise mode. The second graph (Figure 4.8.2 on page 98 of the CAP 697) converts the excess fuel burn percentage and the price of fuel at the departure aerodrome to determine the break-even price at the destination aerodrome. If the actual price of fuel at the destination exceeds the calculated break-even price then it is definitely economically advantageous to tanker fuel from the departure aerodrome. If the resulting break-even value is greater than the actual cost of the fuel at the destination then tankering is not a viable proposition.

## *Example 8.26*

Given: Route distance 2000 nm; Cruise mode M0.74; Cruise Pressure Altitude 35 000 ft; Landing weight without tankered fuel 45 000 kg; Fuel price at departure aerodrome $1.20; Fuel price at the destination aerodrome $1.35. Determine whether tankering is viable.

### *Solution 8.26*

See Figures 8.15 and 8.16. CAP 697 Figure 4.8.1 lower graph. Enter the left vertical axis at 2000 nm and travel horizontally right to the Cruise Pressure Altitude 35 000 ft. From this intersection drop vertically to the Landing Weight reference line. Parallel the grid lines to reach an input from the right vertical axis of 45 000 kg. Drop to the carpet of the graph from this intersection to read 18.6% surplus burn. With this result enter Figure 4.8.2 (CAP 697) at the carpet of the graph and move vertically up to intersect the fuel price at the departure aerodrome, 120 cents. Travel horizontally left to the vertical axis to read 146 cents as the break-even fuel price. The actual fuel price at the destination is 135 cents, therefore tankering fuel is not economically viable.

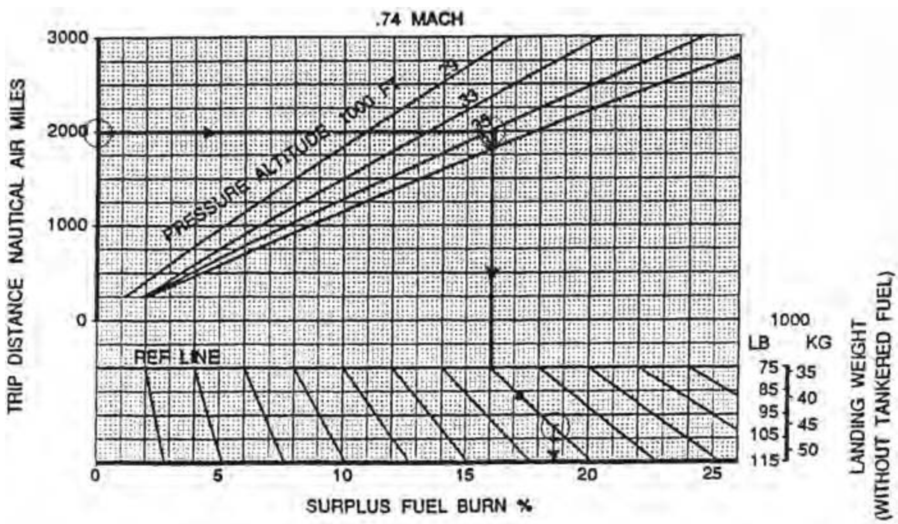


**Figure 8.15** Solution to Example 8.26.

## The complete fuel plan

Although, to date, the examiners have not asked candidates to complete a full flight plan for the MRJT, it is necessary to demonstrate the procedure of using the graphs and tables in practice.

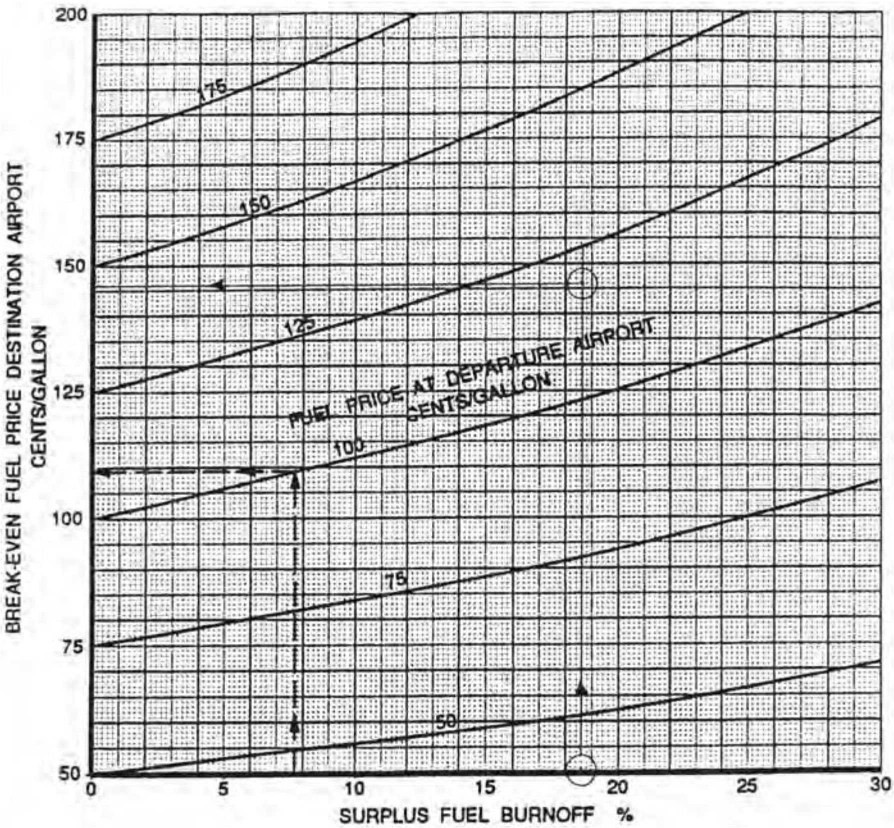


**Figure 8.16** Solution to Example 8.26.

## *Example 8.27*

Given the skeleton flight plan in Figure 8.17 complete the full calculations for a M0.74 cruise for the MRJT. Use 5% of the Trip Fuel as contingency fuel.

## *Solution 8.27*

### Initial calculations

- Determine the temperature deviations for all the cruise legs. Temperature deviation = Ambient – Standard. The standard temperature for Pressure Altitude 31 000 ft = +15 – (2 × 31) = –47°C. Therefore, the temperature deviations are TOC to *B* +12°C, *B* to *C* +14°C, *C* to *D* +15°C and *D* to TOD +15°C. Insert these values in the 'Temp Dev' column for each of the legs.
- The Pressure Altitude of the departure aerodrome = 3434 ft + [(1013.2 – 993) × 28] = 4000 ft. The Pressure Altitude of the destination aerodrome = 4714 ft + [(1013.2 – 1003) × 28] = 5000 ft. The Pressure Altitude of the alternate aerodrome = 742 ft + [(1013.2 – 1004) × 28] = 1000 ft.

MRJT1 FUEL PLAN

| STAGE FROM | STAGE TO | TEMP °C | FL | TEMP DEV °C | MGAA | WIND VELOCITY (M) | TR (M) | TAS kts | CORR TAS kts | G/S kts | GND DIST nm | TIME mins | AIR DIST | START OF LEG AUW kgs | START EQUIV DIST | END EQUIV DIST | END OF LEG AUW kgs | FUEL USED kgs | CORR FUEL USED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | TOC | — | ↗ | +10 | 23 | 300/30 | 100 | | | | 350 | | | 62000 | — | — | | | |
| TOC | B | -35 | 310 | +12 | 35 | 300/40 | 100 | | | | | | | | | | | | |
| B | C | -33 | 310 | +14 | 43 | 300/60 | 130 | | | | 460 | | | | | | | | |
| C | D | -32 | 310 | +15 | 47 | 280/80 | 150 | | | | 310 | | | | | | | | |
| D | TOD | -32 | 310 | +15 | 37 | 270/50 | 070 | | | | 260 | | | | | | | | |
| TOD | E | | ↘ | +12 | 29 | 260/30 | 070 | | | | | | | | | | | | |
| | TOTALS | | | | | | | | | | 1380 | | | | | | | | |
| E | F | | ↗↘ | +12 | 31 | 280/50 | 180 | | | | 220 | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
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| DEPARTURE A/F | | DESTINATION A/F | | ALTERNATE A/F | | ROUTE CLEARANCE | ROUTE FUEL | |
|---|---|---|---|---|---|---|---|---|
| RUNWAY (M) | 30 | RUNWAY (M) | 24 | RUNWAY (M) | 31 | | CONTINGENCY FUEL | |
| W/V | 290/20 | W/V | 250/20 | W/V | 300/15 | CRUISE M0.74 | ALTERNATE FUEL | |
| ELEVATION | 3434' | ELEVATION | 4714' | ELEVATION | 742' | | FINAL RESERVE | 1000 |
| QNH | 993 | QNH | 1003 | QNH | 1004 | | PLANNED TAKE-OFF FUEL | |
| PRESSURE ALT | | PRESSURE ALT | | PRESSURE ALT | | | EXTRA FUEL | |
| TAKE-OFF MASS | 62000 | ALT T/O MASS | | | | | TAKE-OFF FUEL | 15000 |
| ROUTE FUEL | | ALTERNATE FUEL | | | | | TAXI FUEL | 200 |
| LANDING MASS | | LANDING MASS | | | | | BLOCK FUEL | 15200 |

**Figure 8.17** A Skeleton Flight Plan for the MRJT.

### Climb –line *A* to TOC

- Select the climb table for ISA +10°C (i.e., page 43 of CAP 697).
- Enter at the Cruise Pressure Altitude, 31 000 ft, and in the Brake Release Weight column, 62 000 kg, extract 18 min, 1550 kg fuel required, 101 nm air distance travelled and TAS 383 kts. Insert 18 min in the 'Time' column and 101 in the 'Air Dist' column of the first line.
- Correct the fuel required for the Aerodrome Pressure Altitude 4000 ft using the table at the bottom of the CAP 697 page. Correction = –100 kg.
- Corrected fuel required = 1550 – 100 = **1450 kg**. Enter this amount in both the 'Fuel Used' and the 'Corr Fuel Used' columns of the flight plan. Subtract this figure from the start of leg weight to determine the end of leg weight = 62 000 – 1450 = 60 550 kg. Insert in the 'End of Leg AUW' column of the first line.
- Use the navigation computer with the W/V, TAS and the TR (T) to determine the ground speed = 412 kts. Enter 383 in the 'TAS' and the 'Corr TAS' columns, 412 in the 'G/S' column.
- Use a calculator to determine the ground distance travelled in the climb = (air distance × ground speed) ÷ TAS = (101 × 412) ÷ 383 = 109 nm. Insert this in the top right corner of the 'Gnd Dist' column. Note this distance

cannot be calculated by multiplying the ground speed by the leg time because of the approximate nature of the tables.
- Subtract the ground distance from the total distance, *A* to *B*, to determine the distance remaining on that leg in the cruise = 350 – 109 = 241. Insert this figure in the bottom right corner of the second line.

**Level cruise at M0.74**

- Select the cruise page 68 in the CAP 697. Read the TAS for the whole cruise as 434 kts. Correct the TAS according to the notes at the bottom of the page. Therefore, the TASs for each leg are: TOC to *B*, 446 kts; *B* to *C*, 448 kts; *C* to *D*, 449 kts; and *D* to TOD, 449 kts. Insert each of the values on the appropriate line in the 'TAS' column.
- With the navigation computer and using the TAS, Wind Velocity and TR (T) for each leg, determine the ground speed for each leg. These values should be: TOC to *B*, 471 kts; *B* to *C*, 505 kts; *C* to *D*, 496 kts; and *D* to TOD, 494 kts. Insert in the appropriate column and lines.
- Calculate the leg times in minutes for each of the legs, except *D* to TOD, which cannot be resolved until later in the calculations. Divide the leg distance by the ground speed and multiply by 60. The leg times are: TOC to *B*, 30.7 min; *B* to *C*, 54.7 min; and *C* to *D*, 37.5 min.
- For leg TOC to *B*, enter 60 550 kg (this was the end of leg weight for the climb) in the table column 'Start of Leg AUW'. Extract the equivalent air distance, 4849 nm. Enter this figure in the 'Start Equiv Dist' column for the leg TOC to *B*.
- Calculate the air distance travelled on the leg as (TAS ÷ 60) × leg time in minutes = (446 ÷ 60) × 30.7 = 228 nm.
- The equivalent air distance at the end of the leg = 4849 – 228 = 4621 nm. Re-enter the table to determine the aeroplane weight for this equivalent distance = 59 176 kg. Enter this weight in the 'End of Leg AUW' column.
- Fuel used = (Start of leg weight – End of leg weight) = 60 550 – 59 176 = 1374 kg. Enter this amount in the 'Fuel Used' column. This has now to be corrected for the temperature deviation. The correction = (+12 ÷ 10) × 0.6% = +0.72%. The corrected fuel used = (1374 ÷ 100) × 100.72 = 1384 kg. Enter in the 'Corr Fuel Used' column.
- Subtract this amount from the start weight of the leg TOC to *B* to find the start weight for the next leg = 60 550 – 1384 = 59 166 kg. Enter in the 'Start of Leg AUW' column for leg *B* to *C*.
- Enter the table at the weight of 59 166 kg and extract the equivalent air distance = 4619 nm. Enter this distance in the 'Start Equiv Dist' column for leg *B* to *C*.
- Calculate the air distance travelled on the leg as (TAS ÷ 60) × leg time in minutes = (448 ÷ 60) × 54.7 = 408 nm.
- The equivalent air distance at the end of the leg = 4619 – 408 = 4211 nm. Re-

enter the table to determine the aeroplane weight for this equivalent distance = 56 772 kg.

- Fuel used = (Start of leg weight – End of leg weight) = 59 166 – 56 772 = 2394 kg. Enter this amount in the 'Fuel Used' column. This has now to be corrected for the temperature deviation = (+14 ÷ 10) × 0.6% = +0.84%. The corrected fuel used = (2394 ÷ 100) × 100.84 = 2414 kg. Insert in the 'Corr Fuel Used' column.
- Subtract this amount from the start weight of the leg *B* to *C* to find the start weight for the next leg = 59 166 – 2414 = 56 752 kg. Enter in the 'Start of Leg AUW' column on leg *C* to *D*.
- Enter the table at the weight of 56 752 kg and extract the equivalent air distance = 4207 nm. Enter this distance in the 'Start Equiv Dist' column for leg *C* to *D*.
- Calculate the air distance travelled on the leg as (TAS ÷ 60) × leg time in minutes = (449 ÷ 60) × 37.5 = 281 nm.
- The equivalent air distance at the end of the leg = 4207 – 281 = 3926 nm. Re-enter the table to determine the aeroplane weight for this equivalent distance = 55 139 kg.
- Fuel used = (Start of leg weight – End of leg weight) = 56 752 – 55 139 = 1613 kg. Enter this amount in the 'Fuel Used' column. This has now to be corrected for the temperature deviation = (+15 ÷ 10) × 0.6% = +0.9%. The corrected fuel used = (1613 ÷ 100) × 100.9 = 1628 kg. Insert in the 'Corr Fuel Used' column.
- Subtract this amount from the start weight of the leg *C* to *D* to find the start weight for the next leg = 56 752 – 1628 = 55 124 kg. Enter in the 'Start of Leg AUW' column on leg *D* to TOD.
- Before the details of the leg *D* to TOD can be calculated it is necessary to determine the leg distance. This can only be found by calculating the descent details first.

**Descent calculations**

- Select the upper table on page 89 of the CAP 697. Estimate the landing weight at the destination, 53 500 kg. If this estimate proves to be in error by a large amount the calculations from this point will have to be reworked.
- Enter the table at 31 000 ft pressure altitude. Extract the time, 20 minutes, the fuel, 280 kg, and the air distance, 96 nm. These values will have to be adjusted because of the pressure altitude of the destination.
- Re-enter the upper table at 5000 ft pressure altitude. Extract time, 6 minutes, fuel used, 140 kg, and the air distance travelled, 18 nm.
- Subtract these figures to obtain the true descent details. Descent time = 20 – 6 = 14 min. Descent fuel used = 280 – 140 = 140 kg. Descent air distance = 96 – 18 = 78 nm. Add in the approach and landing allowance of two

minutes and 100 kg. The corrected time is 16 minutes and the corrected fuel is 240 kg. Enter these values in the appropriate columns of the flight plan.
- Determine the mean TAS for the descent by dividing the air distance by the descent time in minutes and multiplying by 60 = (78 ÷ 14) × 60 = 334 kts. Note, only the descent time, not including the approach and landing allowance, is used for this process. Enter in the 'TAS' and 'Corr TAS' columns.
- Calculate the ground speed using the navigation computer = 365 kts.
- Calculate the ground distance travelled = (365 ÷ 60) × 14 = 85 nm or (78 ÷ 334) × 365 = 85 nm. Enter in the 'Gnd Dist' column for the leg TOD to *E*.
- The distance of the cruise for the leg *D* to TOD = 260 – 85 = 175 nm.

**Last cruise leg – *D* to TOD**

- Leg time = (175 ÷ 494) × 60 = 21.3 min. Insert in the 'Time' column.
- Determine the equivalent air distance for the start of leg weight 55 124 kg = 3923 nm.
- The air distance travelled on the leg *D* to TOD = (449 ÷ 60) × 21.3 = 159 nm. Subtract from the start of leg air distance to determine the end of leg air distance = 3923 – 159 = 3764 nm.
- Convert this distance to an end of leg weight = 54 224 kg. The fuel used on this leg = 55 124 – 54 224 = 900 kg. Temperature deviation correction = 0.9%. Corrected fuel used = (900 ÷ 100) × 100.9 = 908 kg.
- Start of leg weight for the descent = 55 124 – 908 = 54 216 kg. Subtract the descent fuel, including the approach and landing allowance, 240 kg, from this weight to determine the start of diversion weight = 54 216 – 240 = 53 976 kg.

**Alternate planning calculations**

- Estimate the landing weight at the alternate aerodrome as 52 500 kg. Determine the wind component for the leg using the squared portion of the slider of the navigation computer as 8 kts tailwind. Insert in the 'Wind Velocity' column.
- Select the Alternate Planning graph (Figure 4.3.6 on page 39 of the CAP 697). Determine the fuel required as 1750 kg and the time taken as 39.6 min.
- Determine the pressure altitude at which to cruise for the diversion, 31 000 ft (Figure 4.2.2 page 25 of the CAP 697). Enter all of these details on the line *E* to *F*.

**The fuel block**

- Total the route fuel as 8024 kg and enter in the fuel block section of the fuel plan. Calculate 5% of this amount as the contingency fuel, 401 kg. Enter the alternate fuel, 1750 kg in the fuel block. The final reserve was given as 1000 kg. Add these four quantities to determine the planned take-off fuel of 11 175 kg.

- The difference between the planned take-off fuel (11 175 kg) and the actual take-off fuel (15 000 kg) is the extra fuel carried (3825 kg). The block fuel is the actual take-off fuel plus the taxi fuel, 200 kg = 15 200 kg. The details of the take-off and landing weights can now be completed in the aerodrome blocks and the fuel plan is complete.

The complete solution to Example 8.27 is shown in Figure 8.18. A further completed example is shown in Figure 8.19 for a flight from London (Heathrow) to Munich.

MRJT1 FUEL PLAN

| STAGE FROM | STAGE TO | TEMP °C | FL | TEMP DEV °C | MGAA | WIND VELOCITY (M) | TR (M) | TAS kts | CORR TAS kts | G/S kts | GND DIST nm | TIME mins | AIR DIST | START OF LEG AUW kgs | START EQUIV DIST | END EQUIV DIST | END OF LEG AUW kgs | FUEL USED Kgs | CORR FUEL USED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | TOC | — | ↗ | +10 | 23 | 300/30 | 100 | 383 | 383 | 412 | 109 (350) | 18 | 101 | 62000 | — | — | 60550 | 1450 | 1450 |
| TOC | B | -35 | 310 | +12 | 35 | 300/40 | 100 | 434 | 446 | 471 | 241 | 30.7 | | 60550 | 4849 | 4621 | 59176 | 1374 | 1384 |
| B | C | -33 | 310 | +14 | 43 | 300/60 | 130 | 434 | 446 | 505 | 460 | 54.7 | | 59166 | 4619 | 4211 | 56772 | 2394 | 2414 |
| C | D | -32 | 310 | +15 | 47 | 280/80 | 150 | 434 | 449 | 496 | 310 | 37.5 | | 56752 | 4207 | 3926 | 55139 | 1613 | 1628 |
| D | TOD | -32 | 310 | +15 | 37 | 270/50 | 070 | 434 | 449 | 494 | 175 (260) | 21.3 | | 55124 | 3923 | 3764 | 54224 | 900 | 908 |
| TOD | E | | ↘ | +12 | 29 | 260/30 | 070 | 334 | 334 | 365 | 85 | 16 | | 54216 | — | — | 53976 | 240 | 240 |
| | TOTALS | | | | | | | | | | 1380 | | | | | | | | |
| E | F | | ↗↘ | +12 | 31 | 280/50 | 180 | — | — | — | 220 | 39.6 | | 53976 | — | — | 52226 | 1750 | 1750 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |

| DEPARTURE A/F | | DESTINATION A/F | | ALTERNATE A/F | | ROUTE CLEARANCE | | |
|---|---|---|---|---|---|---|---|---|
| RUNWAY (M) | 30 | RUNWAY (M) | 24 | RUNWAY (M) | 31 | | ROUTE FUEL | 8024 |
| W/V | 290/20 | W/V | 250/20 | W/V | 300/15 | | CONTINGENCY FUEL | 401 |
| ELEVATION | 3434' | ELEVATION | 4714' | ELEVATION | 742' | CRUISE M0.74 | ALTERNATE FUEL | 1750 |
| QNH | 993 | QNH | 1003 | QNH | 1004 | | FINAL RESERVE | 1000 |
| PRESSURE ALT | 4000' | PRESSURE ALT | 5000' | PRESSURE ALT | 1000' | | PLANNED TAKE-OFF FUEL | 11175 |
| TAKE-OFF MASS | 62000 | ALT T/O MASS | 53976 | | | | EXTRA FUEL | 3825 |
| ROUTE FUEL | 8024 | ALTERNATE FUEL | 1750 | | | | TAKE-OFF FUEL | 15000 |
| LANDING MASS | 53976 | LANDING MASS | 52226 | | | | TAXI FUEL | 200 |
| | | | | | | | BLOCK FUEL | 15200 |

**Figure 8.18** Solution to Example 8.27.

MRJT 2 FUEL PLAN

| STAGE FROM | STAGE TO | TEMP °C | FL | TEMP DEV °C | MGAA | WIND VELOCITY (M) | TR (M) | TAS kts | CORR TAS kts | G/S kts | GND DIST nm | TIME mins | AIR DIST | START OF LEG AUW kgs | START EQUIV DIST | END EQUIV DIST | END OF LEG AUW kgs | FUEL USED kgs | CORR FUEL USED |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EGLL | DET | — | ↗ | -11 | 24 | 080/30 | 107 | 374 | 374 | 349 | 40 | 8.1 | — | 62000 | — | — | — | 1550 | 1550 |
| DET | DVR | -30 | 17.0 ↗ | ✓ | 24 | ✓ | 110 | ✓ | ✓ | 350 | 30 | 6.1 | — | — | — | — | — | — | — |
| DVR | TOC | ✓ | ↗ | ✓ | 23 | ✓ | 097 | ✓ | ✓ | 346 | 24 / 24 | 4.9 | — | — | — | — | 60450 | — | — |
| TOC | KONAN | -60 | 330 | -9 | 23 | 090/45 | 097 | 430 | 421 | 377 | 0 | — | — | — | — | — | — | — | — |
| KONAN | KOK | ✓ | ✓ | ✓ | 23 | ✓ | 097 | ✓ | ✓ | ✓ | 25 | 4.0 | | 60450 | 5014 | | | | |
| KOK | SP1 | ✓ | ✓ | ✓ | 34 | ✓ | 110 | ✓ | ✓ | 380 | 118 | 18.6 | | | | | | | |
| SP1 | NTM | ✓ | ✓ | ✓ | 43 | ✓ | 132 | ✓ | ✓ | 389 | 46 | 7.1 | 356 | | | | | | |
| NTM | KRH | ✓ | ✓ | ✓ | 43 | ✓ | 129 | ✓ | ✓ | 386 | 101 | 15.7 | | | | | | | |
| KRH | TGO | ✓ | ✓ | ✓ | 55 | ✓ | 131 | ✓ | ✓ | 388 | 35 | 5.4 | | — | — | 4656 | 58347 | 2103 | 2092 |
| TGO | WLD | -32 | ↘ | -13 | 46 | 080/30 | 092 | 294 | 294 | 266 | 74 | 16.7 | | 58,358 | — | — | — | 285 | 285 |
| WLD | ROKIL | ✓ | 17.0 ↘ | ✓ | 37 | ✓ | 140 | ✓ | ✓ | 279 | 10 | 2.2 | — | — | — | — | — | — | — |
| ROKIL | EDFM | ✓ | ↘ | | 37 | ✓ | RADAR | ✓ | ✓ | ✓ | 22 | 4.7 | — | — | — | — | 58073 | — | — |
| | TOTALS | | | | | | | | | | 525 | 93.5 | | | | | | | 3927 |

| DEPARTURE A/F | | DESTINATION A/F | | ALTERNATE A/F | EDDS | ROUTE CLEARANCE | ROUTE FUEL | 3927 |
|---|---|---|---|---|---|---|---|---|
| RUNWAY (M) | 093L | RUNWAY (M) | 083L | RUNWAY (M) | 08 | M0.74 CRUISE | 5% CONTINGENCY FUEL | 196 |
| W/V | 090/20 | W/V | 080/20 | W/V | 070/15 | M0.74 / 250KIAS DESCENT | ALTERNATE FUEL | 500 |
| ELEVATION | 80' | ELEVATION | 1496' | ELEVATION | 1267 | | FINAL RESERVE | — |
| QNH | 1013 | QNH | 1023 | QNH | 1022 | | PLANNED TAKE-OFF FUEL | 4623 |
| PRESSURE ALT | 80' | PRESSURE ALT | 1200 | PRESSURE ALT | 1015 | | EXTRA FUEL | 1000 |
| TAKE-OFF MASS | 62000 | ALT T/O MASS | 58073 | | | | TAKE-OFF FUEL | 5623 |
| ROUTE FUEL | 3927 | ALTERNATE FUEL | 500 | | | | TAXI FUEL | 100 |
| LANDING MASS | 58290 | LANDING MASS | 57573 | | | | BLOCK FUEL | 5723 |

**Figure 8.19** Completed Flight Plan London (Heathrow) to Munich.

## Summary

The optimum cruise altitude should be flown for routes of 230 nm or more, otherwise a fuel mileage penalty will be incurred.

For any graph containing reference lines, when travelling in the direction of the example, arrows always go to the reference line and then to the condition.

The cost index stored in the FMS can be modified in flight. Select 0 to minimise the fuel flow or 200 to minimise the flight time.

The simplified fuel planning graphs can be used to rapidly determine the trip fuel and the time to enable a rapid check to be made of the computer flight plan.

The stepped cruise climb enables an aeroplane to approximate the optimum cruise altitude within the constraints of ATC.

The holding fuel flow table assumes the aeroplane to be flown at VIMD, but not less than 210 kts, with the undercarriage and flaps retracted.

The detailed fuel planning tables facilitate the accurate calculation of fuel and time for any given cruise mode.

The critical fuel reserve graphs enable the calculation of the fuel requirements in an emergency at the EROPS critical point. They are based on an immediate descent to 10 000 ft pressure altitude followed by a cruise at that altitude. Other specific considerations accounted in the graphs are tabulated on the graphs.

## Sample questions

1. An aeroplane is cruising at a weight of 52 000 kg at the long-range cruise speed at 30 000 ft pressure altitude. Calculate the reduction this causes to the optimum still-air range. (Use CAP 697 Figure 4.2.1.)
2. The remaining flight time of an aeroplane is 3 hr 20 min. The Captain has been directed by ATC to arrive six minutes earlier than planned. To what value must the FMS be set to achieve this requirement? (Use CAP 697 page 26.)
3. Given: TOW 65 000 kg; Route distance 3000 nm; Wind component 50 kts headwind; Stepped cruise mode. Determine the trip fuel and time in hours and minutes if the temperature deviation is –10°C. (Use CAP 697 Figure 4.3.5.)
4. Given: Trip distance 600 nm; Wind component 37 kts tailwind; Cruise pressure altitude 20 000 ft; Landing weight 50 000 kg; ISA deviation +20°C. Determine the trip fuel and time in hours and minutes for a 300KIAS cruise. (Use CAP 697 Figure 4.3.4.)
5. An aeroplane has to hold in a racetrack pattern at 17 000 ft pressure altitude. The hold entry weight 48 500 kg. Fuel available 5000 kg. Determine how long it can remain in the hold. (Use CAP 697 Figure 4.4.)
6. Given: Aerodrome pressure altitude 7500 ft; Top of climb 31 000 ft; Brake release weight 61 500 kg. ISA deviation +10°C; Wind component 12 kts headwind. Calculate the time taken, fuel used, ground distance travelled and the average TAS for this climb. (Use CAP 697 Figure 4.5.1.)
7. Given: Cruise mode M0.74; Cruise Pressure Altitude 21 000 ft; Ambient temperature –15°C; Wind component 55 kts tailwind; Leg distance 277 nm; Start of leg weight 60 437 kg. Calculate the leg fuel used, time taken and the start weight for the next leg. (Use CAP 697 Figure 4.5.3.2.)
8. Cruise mode – Low-level 300KIAS; Cruise Pressure Altitude 19 000 ft; Ambient temperature –37°C; Wind component 12 kts headwind; Leg distance 383 nm; Start of leg weight 58 228 kg. Calculate the leg fuel used, time taken and the start weight for the next leg. (Use CAP 697 Figure 4.5.3.4.)

9. An aeroplane is to descend at M0.70/280KIAS from a cruise altitude of 35 000 ft; Ambient temperature –35°C to an aerodrome at pressure altitude 6000 ft; Ambient temperature +25°C; Landing weight 57 000 kg; Mean wind component 37 kts headwind. Calculate the time taken, fuel used and ground distance travelled in the descent. (Use CAP 697 Figure 4.5.4.)
10. A ferry flight with the undercarriage down is to be made. The trip distance is 850 nm; Wind component 25 kts headwind; Cruise Pressure Altitude 16 000 ft; Landing weight 40 000 kg; Ambient temperature –7°C. Calculate the trip fuel required and the time taken in hours and minutes. (Use CAP 697 Figure 4.6.1.)
11. Given: Cruise mode – Long-range; Weight at the time of diversion 46 500 kg; Maximum approved diversion time 120 minutes. Calculate the maximum distance that the route may be from an adequate aerodrome. (Use CAP 697 Figure 4.7.2.)
12. Given: The aeroplane weight at the ETOPS critical point 60 000 kg; Temperature deviation +20°C; Wind component 25 kts tailwind; Diversion distance 900 nm; Icing is forecast en route. Calculate the critical fuel reserve required. (Use CAP 697 Figures 4.7.1a and 4.7.1b.)
13. Given: Route distance 2200 nm; Cruise mode – Long-range; Cruise Pressure Altitude 31 000 ft; Landing weight without tankered fuel 47 000 kg; Fuel price at the departure aerodrome $1.00 per US gallon; Fuel price at the destination aerodrome $1.30 per US gallon. Determine whether tankering fuel is a viable option. (Use CAP 697 Figures 4.8.1 and 4.8.2.)
14. Given: Diversion distance 900 nm; Wind component 50 kts tailwind; Cruise Pressure Altitude 20 000 ft; Aeroplane weight at the point of diversion 40 000 kg; Temperature deviation +20°C. Calculate the fuel required and time taken to reach the diversion aerodrome in the long-range cruise mode. (Use CAP 697 Figure 4.7.3.)

# Chapter 9
# The In-flight Fuel Requirements

## In-flight fuel checks and management

It is the operator's responsibility to establish a procedure to ensure that in-flight fuel checks and fuel management are carried out by their crews. *JAR-OPS 1.375(a).* However, it is the responsibility of the aircraft commander to ensure that sufficient fuel is available at all times in flight to enable the aeroplane to safely proceed to an adequate aerodrome and arrive with the final reserve fuel remaining intact. *JAR-OPS 1.375(b).*

To comply with this requirement the Commander must establish a routine in compliance with the company operating procedures whereby fuel checks are made at regular intervals. On short flights, these checks are usually made overhead reporting points or turning points. However, on long haul flights, where the interval between checks would be too great, it is normal to set up a routine such that checks are made at regular intervals of time, usually every half an hour. *Appendix 1 to JAR-OPS 1.375*.

The fuel remaining in tanks at each check must be recorded and evaluated in order to:

- compare the actual fuel consumption with that of the fuel plan
- check that sufficient fuel remains to complete the flight
- predict the amount of fuel that should be in tanks on arrival at the destination.

*Appendix 1 to JAR-OPS 1.375(a)(1)*.

The record may be kept in tabular or graphical format. However, the graphical method, referred to as the Flight Progress chart, is by far the easier to use, because it gives a visual presentation from which the Commander is able to make critical decisions rapidly. The Flight Progress chart is described in detail later in this chapter.

If it becomes apparent from the in-flight fuel checks that the predicted fuel remaining on arrival at the destination will be less than that required to continue to the alternate and arrive with the final reserve, a decision must be made regarding the continuation of the flight. The aircraft commander must decide whether to continue to the destination or to divert to an en-route alternate, where the aeroplane is able to arrive with the final reserve fuel intact. In making this decision, the Commander must account the prevailing traffic, operational and weather conditions at the destination, the destination alternate and along the route to the alternate aerodrome. *Appendix 1 to JAR-OPS 1.375(b)(1).*

## Flights to an isolated aerodrome

If the destination is an isolated aerodrome then the decision whether to continue must be made **before** reaching the last point of diversion to an en-route alternate aerodrome. This point should be planned before flight and amended in flight taking into account the prevailing conditions. The Commander must assess from the fuel checks whether the predicted fuel remaining on arrival at the destination will be sufficient to comply with the minimum fuel requirements for an isolated aerodrome and decide whether to continue or to divert. In making this decision, the Commander must account the prevailing traffic, operational and weather conditions at the destination, at the en-route alternate aerodrome and along the route to both. *Appendix 1 to JAR-OPS 1.375(b)(2).*

If the in-flight fuel calculations reveal that the fuel remaining in tanks on arrival at an isolated destination will be less than the Additional Fuel calculated before flight, then the Commander must divert the aeroplane, at the Last Point of Diversion (LPD), to the en-route alternate aerodrome, provided the weather forecast for time of arrival is at or above the required minima. This requirement may be ignored if the destination has two separate runways available or if, from the information available at the LPD, it appears inadvisable to divert to the en-route alternate aerodrome. *Appendix 1 to JAR-OPS 1.375(b)(2).*

**If the actual usable fuel on board is less than the final reserve fuel, the aircraft commander must declare an emergency.** *JAR-OPS 1.375(c).*

### *Example 9.1*

Given: During a flight to an isolated aerodrome with a single runway, an in-flight fuel check reveals that there will be 6550 kg of fuel remaining in tanks on reaching the LPD. The time to reach the en-route alternate aerodrome from the LPD will be 1hr 50 min and the fuel flow will be 2700 kg/hr. If the final reserve is 1450 kg and the contingency fuel allowance is 5%, what action should the aircraft commander take on reaching the LPD?

### *Solution 9.1*

The route fuel required to reach the en-route alternate aerodrome is 4950 kg. There is no requirement to include contingency fuel in alternate fuel calculations. Thus, the total fuel required to reach the en-route alternate aerodrome is 4950 + 1450 = 6400 kg. However, the fuel required to reach the destination will be more than that to reach the en-route alternate aerodrome because the distance exceeds the distance to the en-route alternate aerodrome by at least 5% of the total route distance, or 50 nm, whichever is the greater (see Chapter 4 – En-route Alternate Aerodromes). However, if this were the case then the destination would not be classified as *isolated*. In practice, the fuel required to reach the destination will be considerably more. In addition, on arrival at the destination, there must be sufficient fuel remaining in tanks for at least two hours further flight at the normal cruise fuel flow – this includes the final reserve fuel (see Chapter 5 – Pre-flight Requirements for an Isolated Aerodrome). Therefore, on reaching the LPD, the Commander must elect to divert to the en-route alternate aerodrome because there will be insufficient fuel remaining in tanks on arrival at the destination to comply with the requirements.

## The Flight Progress chart

The Flight Progress chart is a graphical means of relating the actual progress of a flight to that which was predicted by the flight plan. Both the PSR and the PET can be depicted on the same graph. The horizontal axis of the graph represents the distance travelled along track from the departure point. The left vertical axis shows the fuel remaining in tanks and the right vertical axis is graduated in hours of time.

The planned PSR is at the intersection of the outbound and inbound fuel consumption lines. The position of the PSR can be described as a distance from the departure point or any intermediate reporting or turning point. Its position can also be amended in flight to account the prevailing conditions.

### *Example 9.2*

Given: Fuel in tanks 25 000 kg at *A*. Reserve fuel 5000 kg that is to be unused. Plot the Flight Progress chart for the details shown in Table 9.1 and determine the distance of the PSR to *A*.

**Table 9.1**

| Leg | Ground speed (kts) | Fuel flow (kg/hr) | Leg distance (nm) | Leg time (hr) | Fuel used (kg) |
|---|---|---|---|---|---|
| *A–B* | 250 | 3300 | 180 | 0.72 | 2376 |
| *B–C* | 270 | 3100 | 220 | 0.81 | 2526 |
| *C–D* | 235 | 3000 | 300 | 1.28 | 3830 |
| *D–E* | 255 | 2900 | 250 | 0.98 | 2843 |
| *E–D* | 280 | 3100 | 250 | 0.89 | 2768 |
| *D–C* | 250 | 3200 | 300 | 1.20 | 3840 |
| *C–B* | 300 | 3400 | 220 | 0.73 | 2493 |
| *B–A* | 280 | 3500 | 180 | 0.64 | 2250 |

## *Solution 9.2*

The fuel in tanks at the start of the flight, 25 000 kg, is plotted on the left vertical axis at distance 0, labelled *A*. For each of the turning points a heavy vertical line is drawn at the appropriate accumulative distance from *A*. On each vertical line the calculated fuel remaining in tanks is plotted. Joining the plotted points represents the fuel consumption line outbound from *A* to *E*.

A similar line can be constructed for the return flight back to A. This fuel consumption line is drawn by starting at *A* with the reserve fuel, 5000 kg. The fuel required for the last leg is added to this quantity and plotted on the vertical at *B*. For each leg, the fuel is added to the previous total. The cumulative total is then plotted on the vertical appropriate to the turning point at the beginning of the leg.

The point of intersection of the two fuel consumption lines is the PSR and a vertical line to the carpet of the graph shows the distance at which it occurs from *A*. The aircraft can progress towards *E* until it reaches this point but must turn round at this point if it is to arrive back at *A* with 5000 kg of reserve fuel in tanks. These plotted lines are illustrated in Figure 9.1.

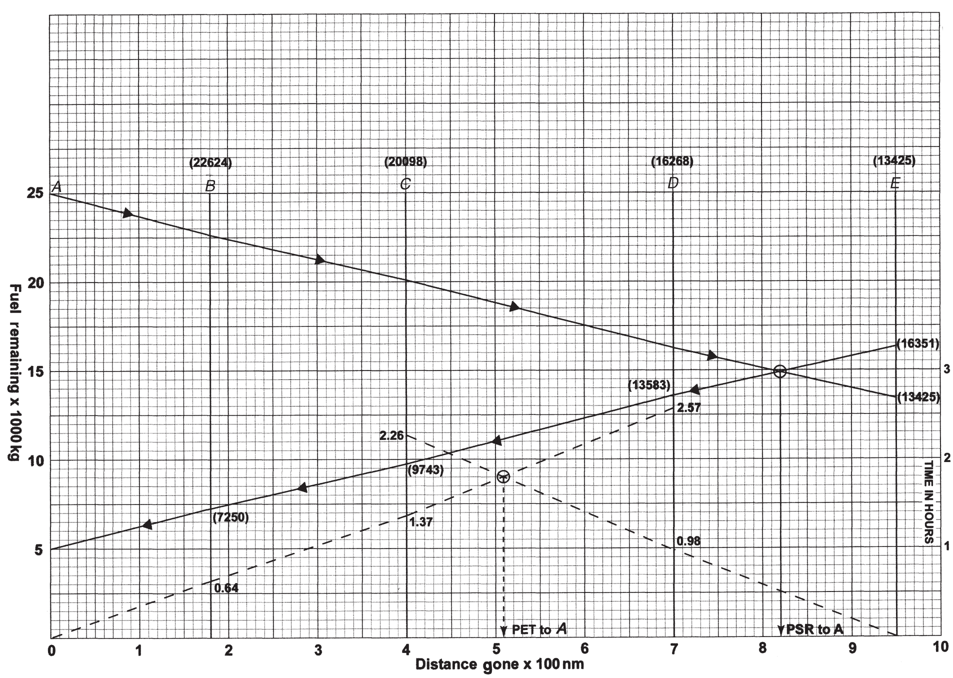



**Figure 9.1** Solution to Example 9.1.

See Table 9.2.

**Table 9.2**

| Leg | Ground speed (kts) | Leg distance (nm) | Accumu-lative distance (nm) | Time (hr) | Accumu-lative time (hr) | Fuel used (kg) | Fuel remaining in tanks (kg) |
|---|---|---|---|---|---|---|---|
| *A–B* | 250 | 180 | 180 | 0.72 | | 2376 | 22 624 at *B* |
| *B–C* | 270 | 220 | 400 | 0.81 | | 2526 | 20 098 at *C* |
| *C–D* | 235 | 300 | 700 | 1.28 | 2.26 at *C* | 3830 | 16 268 at *D* |
| *D–E* | 255 | 250 | 950 | 0.98 | 0.98 at *D* | 2843 | 13 425 at *E* |
| *E–D* | 280 | 250 | 950 | | | 2768 | 16 351 at *E* |
| *D–C* | 250 | 300 | 700 | 1.20 | 2.57 at *D* | 3840 | 13 583 at *D* |
| *C–B* | 300 | 220 | 400 | 0.73 | 1.37 at *C* | 2493 | 9743 at *C* |
| *B–A* | 280 | 180 | 180 | 0.64 | 0.64 at *B* | 2250 | 7250 at *B* |

It can be seen from Figure 9.1 that the outbound and inbound fuel remaining lines intersect at a distance of 820 nm from *A*. This is the flight-planned PSR.

Although it is not part of the JAA syllabus, the critical point can be found by labelling the right vertical axis to a convenient scale in hours. The accumulative time is then calculated to the departure point and to the destination. The accumulative time from *B* from *A* is 0.64 hr, from *C* to *A* is 0.64 + 0.73 = 1.37 hr and from *D* to *A* is 0.64 + 0.73 + 1.2 = 2.57 hr. The accumulative times are now plotted on each of the turning point vertical lines starting at *A* with 0. The accumulative times on to *E* are now calculated and plotted; starting at *E* with 0, then *D* with 0.98 and *C* with 2.26. The point of intersection of the two lines is the PET. In this example, it is 509 nm from *A*. It can be shown to be correct because the time from the PET to *A* is 0.64 + 0.73 + (109 ÷ 250) = 1.80 hr and the time from the PET on to *E* is 0.98 + (191 ÷ 235) = 1.79 hr. (The small difference in times is caused by rounding errors.) This procedure was necessary because of the differing ground speeds on each of the legs. As will be seen in the next section, if the PET is required between two successive turning points the procedure is considerably easier.

## In-flight fuel checks

During flight, fuel readings should be taken at each of the turning points as they are reached, or every half an hour, and plotted on the Flight Progress chart. This enables a direct comparison to be made between the actual and predicted values and gives a visual indication of whether the actual fuel consumption is better or worse than planned. This enables the Commander to make a rational decision regarding the continuation of the flight. If the actual consumption line falls below the forecast line, it may be necessary to divert to an en-route alternate aerodrome or even to return to the departure point.

For example, if the aeroplane in Example 9.1 had departed *A* at 1000 hrs and the readings shown in Table 9.3 have been taken, then by plotting these values and joining the fuel fixes by straight lines the actual fuel consumption line is shown. From these details, not only can the mean fuel flow be calculated, but also the mean ground speed. Additionally, the fuel consumption tendency can be seen and the fuel remaining on arrival at the destination can be forecast. From these indications, a decision can be made by the Commander regarding the rest of the flight.

**Table 9.3**

| Time | Position | Total fuel remaining (kg) |
|---|---|---|
| 1000 | A | 25 000 |
| 1045 | *B* | 22 000 |
| 1135 | *C* | 19 000 |
| 1255 | *D* | 15 000 |

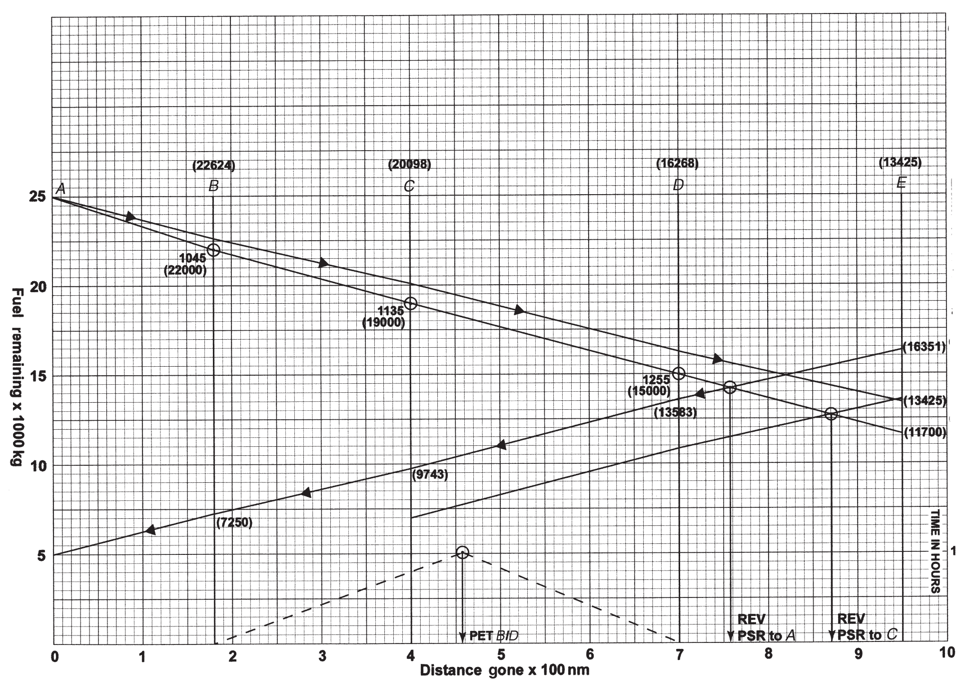



**Figure 9.2** Solution to Example 9.1 with in-flight readings.

### *In-flight observations*

The mean ground speed between *B* and *D* is calculated by dividing the difference in distance by the time difference in minutes multiplied by 60. In this example, the calculation is (520 nm ÷ 130) × 60 = 240 kts. The mean fuel flow is calculated in a similar manner. The difference in the fuel remaining is divided by the time difference in minutes and multiplied by 60. In this example, (7000 kg ÷ 130) × 60 = 3231 kg/hr.

The position and time of reaching the PSR may be revised by extending the actual fuel consumption line until it intersects the return planned fuel consumption line. Dropping a vertical to the carpet of the graph at this point will determine the exact distance from *A* at which the revised PSR occurs. By dividing the distance from *D* to this position by the mean ground speed a revised estimated time of arrival at the PSR can be calculated. In Figure 9.2, it can be seen that the revised position of the PSR is at a distance of 758 nm from *A* (this is a distance of 58 nm from *D*). The revised time to reach the PSR from *D* is, therefore, (58 ÷ 240) × 60 = 14.5 min. This makes the ETA 1255 + 14.5 min. = 1309.5 hrs.

Extending the actual fuel consumption line to *E* will reveal the amount of fuel that will be remaining in the tanks on arrival, if the fuel flow remains the same. In this example, it is 11 700 kg. The reason that the actual consumption line differs from the planned line may be due to a change of altitude, ambient temperature or wind component. If the actual line had differed dramatically from the planned line, then the Commander would have to make a decision regarding the rest of the flight. In this example, no such decision is necessary.

If, for some unforeseen reason, *A* is not available for a return journey but *C* is available and the minimum reserve fuel required on arrival is 7000 kg, then the graph may still be used to determine a PSR to *C*. It is found by plotting 7000 kg at *C* and from this point back plotting a line parallel to the planned inbound fuel line until it intersects the actual outbound fuel consumption line. The point of intersection is the PSR to *C*, a distance of 870 nm from *A*.

If it is required to discover the location of the PET between *B* and *D*, then the mean ground speeds can be used to determine this point. The mean ground speed determined from *B* to *D* was 240 kts. The mean flight plan ground speed between *D* and *B* is 275 kts. Each of these speeds is plotted as a distance on the one-hour input line. In the case of the leg *B* to *D* it is back plotted from *D*, and for the leg *D* to *B* it is plotted on from *B*.

The distance scale datum is *A*, therefore the plotted distances will be *B* to *D* = 700 – 240 = 460 nm, which is joined by a straight line to 0 at *D*. For the leg *D* to *B* it will be 180 + 275 = 455 nm, which is joined to 0 at *B* by a straight line. The intersection of the straight lines is the PET, which is a distance of 458 nm from *A*. The proof is that the distance PET to *D* is 242 nm and time = 242 ÷ 240 = 1.01 hr. The distance from the PET to *B* is 278 ÷ 275 = 1.01 hr.

## Summary

**Flight Progress Chart**. This is a visual means of comparing the flight plan and actual fuel consumption.

**The PSR**. The intersection of the planned outbound and planned inbound graph lines is the planned PSR. This may be revised in flight by using the intersection of the actual fuel consumption line outbound and the planned inbound fuel consumption line.

**In-flight observations**. In-flight observations must be routinely made and recorded. The actual fuel flow and ground speed can be determined from in-flight observations by dividing the difference between the observations by the difference between the time of the observations in minutes and multiplying by 60.

**Fuel at the destination**. The extension of the planned outbound fuel line to the destination vertical line indicates the planned fuel on arrival at the destination. This can be revised in flight by using the same procedure with the in-flight fuel line.

**The PET**. The PET can be determined from the Flight Progress chart by plotting from the turning points either side of the route mid-point the ground speeds against the time in hours.

## Sample questions

1. Construct a Flight Progress chart from the details given in Table 9.4, and determine the flight plan PSR to A. Fuel in tanks 25 000 kg at *A*. Reserve fuel 5000 kg that is to be unused. Fuel in tanks at *A* on return 5000 kg.

**Table 9.4**

| Leg | Ground speed (kts) | Leg distance (nm) | Accumulative distance (nm) | Fuel flow (kg/hr) | Fuel used (kg) | Fuel remaining in tanks (kg) |
|---|---|---|---|---|---|---|
| *A–B* | 280 | 180 | | 3500 | | at *B* |
| *B–C* | 300 | 220 | | 3400 | | at *C* |
| *C–D* | 250 | 300 | | 3300 | | at *D* |
| *D–E* | 280 | 250 | | 3200 | | at *E* |
| *E–D* | 255 | 250 | | 3100 | | at *E* |
| *D–C* | 235 | 300 | | 3000 | | at *D* |
| *C–B* | 270 | 220 | | 2900 | | at *C* |
| *B–A* | 250 | 180 | | 2800 | | at *B* |

2. Given the in-flight observations shown in Table 9.5, calculate the mean fuel flow and mean ground speed from *B* to *D*.

**Table 9.5**

| Time | Position | Accumulative distance (gone) (nm) | Total fuel remaining (kg) |
|---|---|---|---|
| 0947 | *A* | 0 | 25 000 |
| 1032 | *B* | 200 | 22 000 |
| 1127 | *C* | 430 | 19 000 |
| 1300 | *D* | 750 | 15 000 |

3. From the details given in Question 2 determine the distance of the revised PSR from *A*.
4. Using the details given in Question 2 determine the distance from *A* of the revised PSR to return to *B* with 6000 kg of reserve fuel.
5. Construct a flight progress chart from the details given in Table 9.6, and determine the flight plan PSR. Fuel in tanks 28 000 kg at *A*. Reserve fuel required on return to *A* is 7000 kg that is to be unused. Fuel in tanks at *A* 7000 kg.

**Table 9.6**

| Leg | Ground speed (kts) | Leg distance (nm) | Accumulative distance (nm) | Fuel flow (kg/hr) | Fuel used (kg) | Fuel remaining in tanks (kg) |
|---|---|---|---|---|---|---|
| *A–B* | 320 | 250 | | 4800 | | at *B* |
| *B–C* | 350 | 200 | | 4700 | | at *C* |
| *C– D* | 370 | 280 | | 4600 | | at *D* |
| *D–E* | 390 | 310 | | 4500 | | at *E* |
| *E–D* | 420 | 310 | | 4400 | | at *E* |
| *D–C* | 400 | 280 | | 4300 | | at *D* |
| *C–B* | 380 | 200 | | 4200 | | at *C* |
| *B–A* | 350 | 250 | | 4100 | | at *B* |

6. Given the in-flight observations shown in Table 9.7, calculate the mean fuel flow and mean ground speed from *B* to *D*.

**Table 9.7**

| Time | Position | Accumulative distance (gone) (nm) | Total fuel remaining (kg) |
|---|---|---|---|
| 1430 | *A* | 0 | 28 000 |
| 1520 | *B* | 200 | 23 800 |
| 1600 | *C* | 430 | 20 600 |
| 1656 | *D* | 750 | 16 000 |

7. From the details given in Question 6 determine the distance of the revised PSR from *A*.
8. Using the details given in Question 6 determine the distance from *A* of the revised PSR to return to *B* with 6000 kg of reserve fuel.
9. Given: During a flight to an isolated aerodrome with a single runway, an in-flight fuel check reveals that there will be 5195 kg of fuel remaining in tanks on reaching the LPD. The time to reach the en-route alternate aerodrome from the LPD will be 1 hr 40 min and the fuel flow will be 2350 kg/hr. If the final fuel reserve is 1150 kg and the contingency fuel allowance is 5%, what action should the aircraft commander take on reaching the LPD?

   a. Divert to the en-route alternate aerodrome
   b. Return to the departure aerodrome
   c. Proceed to the destination
   d. Proceed to the destination using 3% contingency allowance.

## Chapter 10
# The Computer and ICAO ATS Flight Plans

## The computer flight plan

Nearly all large modern airlines use computer flight planning. Most utilise the services of an international provider, usually American. They have large mainframe computers that are fed with aeroplane performance data, route and alternative route information, and which are continuously updated with meteorological details of wind velocities and temperatures. The resulting flight plan is produced to meet the specifications of the customer. Some smaller operators, unable to afford the cost of such a product, make use of comparatively simple software packages to produce their own version of the computer flight plan. The differences between the resulting products are principally layout and not content.

### *The contents of the database*

The specific information fed into the database of the mainframe computer will vary according to the requirements specified by the customer. However, there will be many common data no matter what the specification. Some, if not all, of the following will be used by the computer to produce a flight plan:

- the operator's standard routes and alternative routes
- the latitude and longitude of all the ground based navigational aids and waypoints that are likely to be used en route
- the latitude and longitude of all aerodromes along the route that could be used for emergency diversion purposes
- the possible ATC routes to the destination, accounting the standard instrument departures (SIDs) and the standard arrival procedure routes (STARs)
- the current NOTAM information of prohibited, danger or restricted areas likely to affect the route
- the current North Atlantic routes to be used, as issued by the controlling authority, if applicable
- the current meteorological information such as the wind velocities, temperatures and significant weather – this is normally automatically fed in by one of the main World Meteorological Offices
- the performance details for the take-off, climb, cruise, descent and landing

for the aeroplane type – these will be held permanently in the database but the individual aircraft basic weight and fuel in tanks at start up will have to be provided on the day
- the details of the available distances, wind velocity and surface ambient temperature for the departure, destination and nominated alternate aerodromes
- the operator's preferred method of cruise control
- the operator's fuel reserve policy
- the operator's method of costing the flight, to produce the cost index
- the operators preferred alternate aerodromes, together with their priority rating.

## *The activation procedure*

To activate the mainframe computer there is usually a terminal, which can be utilised by the operator. It will prompt the user by asking for certain information in a specific sequence such as:

- the aircraft type
- departure point and destination
- the proposed time off-blocks
- the dry operating mass of the aeroplane
- the cruise control method to be used
- any special routing instructions.

The computer will then select the route to be used according to the instructions given by the operator, the ATC information and the meteorological details. It will then produce the track and distance between each waypoint along the route from its pre-programmed route coordinates. Then, using the weather information together with the aeroplane performance data, it will produce a flight plan such as that shown in Figure 10.1.

This example computer flight plan has been compiled from the MRJT flight plan 1, which was calculated in Chapter 8, and would have been automatically provided by the server's computer on request from the operator.

## *Interpretation of the computer flight plan*

### The heading/title block

- **Line 1**. Computer Flight Plan number 1234. From EGLL = Heathrow to EDDM = Munich. The aeroplane is a 737–400 using a 0.74 Mach cruise in IFR. The date is presented in the American style and is 3 January 2002.
- **Line 2**. It is a non-stop flight and the flight plan was computed at 1045UTC for an ETD of 1730UTC using the prognostic charts of 0600UTC of 3 January 2002. All weights are in kilograms.

PLAN 1234 EGLL TO EDDM 737–400 M74/F IFR 01/03/02
NONSTOP COMPUTED 1045Z FOR ETD 1730Z PROGS 030600Z kgS.

| | | FUEL | TIME | DIST | ARRIVE | TAKEOFF | LAND | AVPLD | OPNLWT |
|---|---|---|---|---|---|---|---|---|---|
| POA | EDDM | 003927 | 01/31 | 0513 | Z | O62000 | 058290 | 010000 | 042000 |
| ALT | EDDS | 001200 | 00/27 | 0110 | Z | COMP | P030 | | |
| HLD | | 001300 | 00/30 | | | | | | |
| CONT | | 000196 | 00/04 | | | | | | |
| REQ | | 006623 | 02/32 | | | | | | |
| XTR | | 00000 | 00/00 | | | | | | |
| TOT | | 006623 | 02/32 | | | | | | |

EGLL DVR6J DVR KONAN UG1 NTM UB6 TGO B6 WLD D10 AALEN1T EDDM
WIND M042 MXSH 5/KOK TEMP M09 NAM 578
FL330
M74 FL330 003927 01/31
M74 FL370 003850 01/34
M74
EGLL ELEV 00080FT

| AWY | WPT | MTR | DFT | ZD | ZT | ETA | ATA | CT | WIND | COMP | GRS | DSTR | REM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSA | FRQ | | | | | | | | | | | | |
| DVR6 | DVR | 107 | R02 | 070 | 0/15 | | | 0/15 | 08030 | M025 | 350 | 0443 | |
| 023 | 134.9 | | | | | | | | | | | | |
| UG1 | KONA | 097 | R01 | 024 | 0/4 | | | 0/19 | 08030 | M025 | 345 | 0419 | 84.5 |
| 023 | 134.9 | | | | | | | | | | | | |
| UG1 | KOK | 097 | R01 | 025 | 0/4 | | | 0/23 | 09045 | M044 | 377 | 0394 | |
| 023 | 114.5 | | | | | | | | | | | | |
| UG1 | SPI | 110 | R02 | 118 | 0/19 | | | 0/42 | 09045 | M041 | 380 | 0276 | |
| 034 | 132.2 | | | | | | | | | | | | |
| UG1 | NTM | 132 | R04 | 046 | 0/07 | | | 0/49 | 09045 | M032 | 389 | 0230 | |
| 043 | 129.5 | | | | | | | | | | | | |
| UB6 | KRH | 129 | R04 | 101 | 0/16 | | | 1/05 | 09045 | M035 | 386 | 0129 | |
| 055 | 129.5 | | | | | | | | | | | | |
| UB6 | TGO | 131 | R04 | 035 | 0/05 | | | 1/10 | 09045 | M035 | 388 | 0094 | 63.6 |
| 055 | 132.4 | | | | | | | | | | | | |
| B6 | WLD | 092 | R01 | 074 | 0/17 | | | 1/27 | 08030 | M028 | 266 | 0020 | |
| 046 | 133.7 | | | | | | | | | | | | |
| D10 | ROKIL | 140 | R05 | 010 | 0/02 | | | 1/29 | 08030 | M015 | 279 | 0010 | |
| 037 | 126.4 | | | | | | | | | | | | |
| AL1T | EDDM | – | – | 010 | 0/02 | | | 1/31 | 08030 | – | | 0000 | 60.7 |
| 037 | 126.4 | | | | | | | | | | | | |

ELEV 1486FT
EGLL N51286E000027 DVR N51097E001217 KONAN N51078E002000
KOK N51057E002392 SPI N50309E005375 NTM N50010E006320
KRH N48596E008351 TGO N48372E009156 WLD N48348E011079
ROKIL N48271E011174 EDDM N48206E011452
FIRS EBUR/0019 EDDU/0045
FPL -AB234-IN
B737/M S/C
EGLL 1730
N0421F330 DVR6J DVR UG1 NTM UB6 TGO B6 WLD
EDDM 0131 EDDS
EET/EBUR 0019 EDDU 0045
REG/GWXYZ SEL/ABCD
E/0345 P/110 R/V S/M J/L D/6 150 C/YELLOW
A/RED

**Figure 10.1** Example computer flight plan for G-WXYZ from Heathrow to Munich.

**The fuel block**

- **Line 3**. FUEL = Fuel Required for that item. TIME = the time equivalent for each item. DIST = the distance for that item. ARRIVE = ETA UTC and is filled in after take-off. TAKEOFF = the take-off weight. LAND = the landing weight. AVPLD = the available payload. OPNLWT = the basic aeroplane weight (i.e., weight less fuel less payload).
- **Line 4**. POA = the point of arrival (destination Munich). Fuel required = 3927 kg. Flight time = 1 hr 31 min. Distance = the ground distance (track distance) to the destination = 513 nm. The take-off weight at Heathrow = 62 000 kg. The landing weight at Munich is estimated to be 58 290 kg. The payload available on departure = 10 000 kg. The basic aeroplane weight is 42 000 kg.
- **Line 5**. ALT = the alternate aerodrome = Stuttgart. The fuel required from the destination to the alternate = 1200 kg. The time taken from Munich to Stuttgart = 27 min. The ground distance from Munich to Stuttgart = 110 nm. COMP = the mean wind component from Munich to Stuttgart.
- **Line 6**. HLD = the holding fuel carried = 1300 kg, which is equivalent to 30 min flight time (the statutory minimum).
- **Line 7**. CONT = the contingency fuel carried = 196 kg (5% of the statutory minimum), which is equivalent to 4 min flight time.
- **Line 8**. REQ = the total fuel required for the flight (excluding taxi fuel) and the total time.
- **Line 9**. XTR = any extra fuel the Captain considers necessary for the flight and its flight time equivalent.
- **Line 10**. TOT = the total fuel required for the flight (excluding the taxi fuel) and its flight time equivalent.

**The route summary block**

- **Line 11**. This is the route summary including the SID and the STAR.
- **Line 12**. WIND = the mean wind component for the whole route. This is calculated by the formula (NAM – Total ZD) ÷ total time in minutes × 60. P (plus) is a tailwind and M (minus) is a headwind. MXSH = the maximum wind shear along the route, in this case 5 kts/1000 ft at KOK. If the wind shear had exceeded 5 kts/1000 ft, it would have been prudent and economic to change the cruising level. TEMP = the average temperature deviation along the route. NAM = the total air distance in nautical miles.
- **Line 13**. The cruising level or cruising levels for the flight. In this example FL330.
- **Lines 14–16** . These lines summarise the total fuel required and the flight time for the same route but at alternative flight levels.
- **Line 17**. This is the elevation of the departure aerodrome.

### The detailed route block

- **Line 18**. AWY = Airway. WPT = waypoint. MTR = magnetic track. DFT = drift (L = left/port, R = right/starboard). ZD = zone (leg) distance. ZT = zone (leg) time. ETA (estimated time of arrival) and ATA (actual time of arrival) are filled in during flight as each of the turning points is reached. CT = accumulative time from take-off. WIND = the wind velocity used for that leg (e.g., 08030 means 080°(M)/30 kts). COMP = the wind component on that leg. GRS = the ground speed on that leg. DSTR = the total distance remaining at the end of the leg. REM = the fuel remaining at the end of the leg.
- **Line 19**. MSA = minimum safe altitude for the leg. FRQ = the suggested communications frequency to be used for that leg. TOC = top of climb when it is not a waypoint. TOD = top of descent when it is not a waypoint.
- **Lines 20–39** . These lines contain the specific details for each leg of the flight, including the standard instrument departure procedure and the standard arrival procedure.
- **Line 40**. ELEV = the destination elevation.

### The navigation block

- **Lines 41–44** . These lines contain the precise waypoint coordinates in the format for entering in the on-board navigation equipment, if not already loaded.
- **Line 45**. FIRS = the FIR boundary ICAO identifier and the elapsed time from take-off to that boundary. In this example Brussels/19 min and Rhein/45 min.

### The ATS Flight Plan block

**Lines 46–54** . These lines contain the information required by the ATS Flight Plan form in the correct sequence for entry.

## *Verifying the computer flight plan*

Although the computer can rapidly produce an accurate flight plan from the details fed into it, there can be errors, which are caused mainly by input errors. It is, therefore, **always** essential to check the flight plan for mistakes. It is not possible to check every detail for accuracy, because it would take too long and would defeat the purpose of the computer making the calculations in the first place. The checks that should be made are that the results are reasonable, and if possible, correct, and that they should contain the following:

- the general direction of the tracks
- the take-off weight and the fuel on board at take-off
- the total ground distance

- the cruise FL and mode
- the mean wind velocity and temperature compared with the forecast
- the correct alternate aerodrome
- the total time and fuel compared with previous flight plans for the same route
- the route the computer has chosen.

If there appears to be a large discrepancy, then ask the operations staff to check or, failing that, phone the server's helpline.

### *Additional information*

Some computer companies will, on request, provide additional services, such as the latest METARs, TAFs and NOTAMs that are likely to affect the conduct of the flight. If these are part of a service contract, then they will be automatically provided and updated by the server. Some companies will also file the ATS Flight Plan as part of the service.

## The ICAO ATS Flight Plan

### *The submission of flight plans*

ICAO Annex 2 Chapter 3 requires a Flight Plan, in the United Kingdom designated form CA48, to be submitted to an Air Traffic Service Unit (ATSU) on the following occasions, when such a submission is **mandatory**:

- on any IFR flight in Advisory airspace
- on any flight across an international boundary
- on VFR flights within Class B, C or D controlled airspace
- on advisory routes if the pilot requires the use of the advisory service
- when the destination is to be notified of a Special Visual Flight Rules (SVFR) clearance
- when the Maximum Take-off Mass (MTOM) is greater than 5700 kg and the flight is longer than 40 km.

On the following occasions, the submission of a Flight Plan is **advisory**:

- when the route extends beyond 10 nm from a coastline
- when the route is over a sparsely populated area
- when the route is over an area in which search and rescue operations may prove difficult.

The source documents for the completion of the Flight Plan are:

- the navigation plan
- the fuel plan

- the mass and balance sheet
- the operating data manual.

*JAR-OPS1.300* states that an operator shall ensure that a flight is not commenced unless an ATS Flight Plan has been submitted, or adequate information has been deposited in order to permit alerting services to be activated, if required. If an ATS Flight Plan is not submitted an authorised person is to be responsible for alerting search and rescue services if an aeroplane is overdue or missing, using the information contained in the VFR flight plan. *AMC OPS 1.300*.

## *Flight Plan categories*

There are three categories of Flight Plan:

- full flight plans which are described later in this chapter
- repetitive flight plans
- abbreviated flight plans.

### Repetitive Flight Plans

For IFR flights that occur on a regular scheduled basis and which have the same basic details, a Repetitive Flight Plan (RPL) can be filed by the operator. This is submitted to the Central Flow Management Unit (CFMU) at Eurocontrol. If the route extends beyond the boundaries of this controlling authority the RPL is also filed with the individual national authorities over which the route passes. All controlling authorities have to agree to accept the RPL before it can be used. There are two types of submission:

- **New Lists** (NLST). These contain only new information, such as at the start of a new summer or winter season. They must be submitted and received by Eurocontrol a minimum of 14 days before the first scheduled flight.
- **Revised Lists** (RLST). These contain revised information, in particular alterations, cancellations or additional flights. This type must be received at least seven days (to include two Mondays) before the first amended flight is scheduled.

### Specific requirements for RPL operations

The basic principles for RPL operations are described in detail in ICAO documents 4444 and 7030. An example RPL form is given in the Jeppesen student pack on page 442. However, within the Eurocontrol area the following differences apply:

- every ATS authority affected by the flight must agree to accept the RPL
- to cancel or amend an existing RPL the original RPL must be submitted together with the new RPL

- all NLST or RLST must be sequentially numbered starting at 001
- a suspension of an RPL must be for at least three days and notification must be submitted two days before the affected flight
- to cancel, delay or change one flight, notification must be made by the operator to the IFPS units concerned but not earlier than 20 hours before the estimated off-blocks time (EOBT).

**Abbreviated flight plans**

If a flight is to cross through controlled airspace or through an airway, a full Flight Plan is not required. The details of the portion of the flight passing through the controlled airspace can be filed in an abbreviated form by telephone before take-off or by radio when in flight at least 10 minutes before entering controlled airspace.

### *The full ATS Flight Plan*

The complete instructions for the completion of the ATS Flight Plan form (CA48) are given in the Jeppesen student pack pages 435–441. It is, however, necessary to explain certain items in more detail for examination purposes. The completed Flight Plan should be submitted a minimum of one hour before leaving the ramp (EOBT). If the flight is subject to flow control then the minimum time for submission is increased to three hours before the estimated off blocks time.

It is important when completing a Flight Plan to adhere to the prescribed format and to fill in the spaces provided from the left, leaving any blank spaces to the right. **All times are to be four-figure UTC times** and all elapsed time are to be four-figures (hours and minutes). Only items 7–19 have to be completed by the person submitting the Flight Plan.

The following are brief descriptions and points to note about each of the items from 7–19.

- **Item 7 –The aircraft identification** . This should not exceed seven characters. It is often the flight number or the call sign of the aeroplane. If this is the case, the aircraft registration number must be quoted in Item 18.
- **Item 8 –Type of flight**. Most public transport flights will be conducted under IFR, therefore the letter I will be inserted in this box. The type of flight is most likely to be either a scheduled air service (S) or a non-scheduled air transport operation (N), and the appropriate letter should be inserted in the next box.
- **Item 9 –Number of aircraft** . This box is only filled in if there is more than one aeroplane. Normally this only applies to military formations. The type of aircraft is denoted by inserting the allocated ICAO identifier in the next box. The wake turbulence category, in the third box, is determined by the

maximum certificated take-off mass (MTOM). It will be either Heavy (136 000 kg or more) – H, Medium (between 7001 kg and 135 999 kg) – M, or Light (7000 kg or less) – L.

- **Item 10 – Communication and navigation equipment**. This is used to indicate the serviceable type of communication and radio navigation equipment carried by the aeroplane. More often than not the letter S (for standard) will be entered here before the oblique stroke to indicate that VHF RTF, ADF, VOR and ILS are carried and serviceable, unless the appropriate ATS authority has prescribed a different required combination. After the oblique stroke in the box, one or two letters should be entered to indicate the type of serviceable surveillance equipment carried. The appropriate code letters for each type of this equipment are given on page 436 of the Jeppesen manual.
- **Item 13 – ICAO identifier**. The ICAO identifier for the departure aerodrome is entered here. If one has not been allocated, enter ZZZZ and insert the name of the aerodrome in Item 18. When filing the Flight Plan after take-off, AFIL should be entered, and the ICAO identifier of the ATS unit from which more details can be obtained entered in Item 18. For a Flight Plan submitted before departure, the estimated off-blocks time should be entered in the time block. If the Flight Plan is filed in flight, the ETA at the first point on the Flight Plan is entered instead.
- **Item 15 – Cruising speed and level**
    - The *cruising speed box* should contain no more than five characters. This is the TAS for the first cruising leg or the whole route. It may be expressed in kilometres per hour (kmh), in which case the speed is indicated by inserting the letter K followed by four figures; in knots, which is shown by inserting the letter N followed by four figures; or as a Mach number, which is expressed by the letter M followed by three figures.
    - The *cruising level box* should contain no more than five characters. It is the planned cruising level of the first leg or portion of the route to be flown. It may be expressed as:

        a. a Flight Level, which is indicated by inserting the letter F followed by three figures, or
        b. Standard Metric Level in tens of metres, which is shown by a letter S followed by four figures, or
        c. altitude in hundreds of feet, expressed as A followed by three figures, or
        d. altitude in tens of metres shown as M followed by four figures.
        e. If the flight is VFR the letters VFR are inserted.

    - The *route details* are entered on the lines provided. If the departure point is located on or connected to an ATS route, enter the ATS route designator. If not, enter the letters DCT followed by the point at which the ATS route is joined. Then enter each point at which the TAS, level or ATS route changes and/or a change of flight rules is planned. Leave a gap after each entry. These details will normally be obtained from the computer flight plan. Full information on how the route details should be entered is provided on pages 437 and 438 of the Jeppesen manual.

- A *change of speed* of 5% of the TAS or 0.01 Mach or a *change of the planned cruising level* must be entered on the Flight Plan in the route section. The point at which the change will occur is entered first followed by an oblique stroke then the cruising speed and cruising level in sequence, without a gap. All of these details must be given, even if only the speed or the cruising level changes, (e.g., MAY/N0305F180). More examples of the method used for these entries are shown on page 438 of the Jeppesen manual.
- **Item 16 –Destination aerodrome and alternate aerodromes** . The ICAO designator for the destination aerodrome is entered in the first box and the total elapsed time from take-off (in hours and minutes) is entered in the second box. The third box is for the ICAO identifier of the first nominated alternate aerodrome and the fourth box is for the ICAO identifier of the second alternate aerodrome, if any. If any of these aerodromes does not have an ICAO designator allocated, then insert ZZZZ and enter the name of the aerodrome in item 18.
- **Item 18 –Other information** . This area of the Flight Plan is provided for any miscellaneous information considered to be of significance to the conduct of the flight. A list of the information that can be included, together with the abbreviations that should be used, is given on pages 438 and 439 of the Jeppesen manual.
- **Item 19 –Supplementary information** .
  - The *'E' box* is provided to enter (in hours and minutes) the estimated total endurance using the fuel available in tanks at start up.
  - The *'P' box* is provided for entering the total number of persons on board, that is, the total number of passengers plus the total number of crew members at take-off. Often it is not possible to fill in this box at the time of submission of the Flight Plan, because the final passenger total may be unknown. If this is the case then TBN should be entered to signify that the final total will be notified to Air Traffic Control on start up.
  - The *'R' boxes* are to notify the authorities of the emergency communication radios carried on board in the survival equipment. A cross should be placed in the boxes of those radios not carried. Cross out U if 243 MHz is not available, V if 121.5 MHz is not available and E if an emergency locator transmitter is not available.
  - The *'S' boxes* are provided to indicate the type of survival equipment carried in the aeroplane. Once again, cross out the boxes of those not

carried. Cross out P if polar survival equipment is not available, D if desert survival equipment is not available, M if maritime survival equipment is not available and J if jungle survival equipment is not available.

- The *'J' boxes* are provided to indicate the type of equipment on the lifejackets carried on board the aeroplane. Cross out L if they are not equipped with lights, F if not equipped with fluorescein, U if not equipped with UHF radios and V if not equipped with VHF radios.
- The *'D' boxes* are provided to describe the number of dinghies in the first box and the second box is for the total capacity, in persons, of all the dinghies carried.
- The *'C' box* must be crossed out if the dinghies are not covered. If dinghies are carried then insert their colour in the next box.
- The *'A' box* should be filled in if the aeroplane has distinctive colours over large areas of the surfaces. Cheek lines or 'go faster' stripes should not be included.
- The *'N' box* should be crossed out if there are no remarks regarding the survival equipment. If there are, then print them in the next box.
- The *'C' box* must be completed by printing the name of the pilot-in-command.

A completed example of an ATS Flight Plan is shown in Figure 10.2 and on page 441 of the Jeppesen manual. This example has been compiled from the information in the computer flight plan given in Figure 10.1 using lines 41–54.

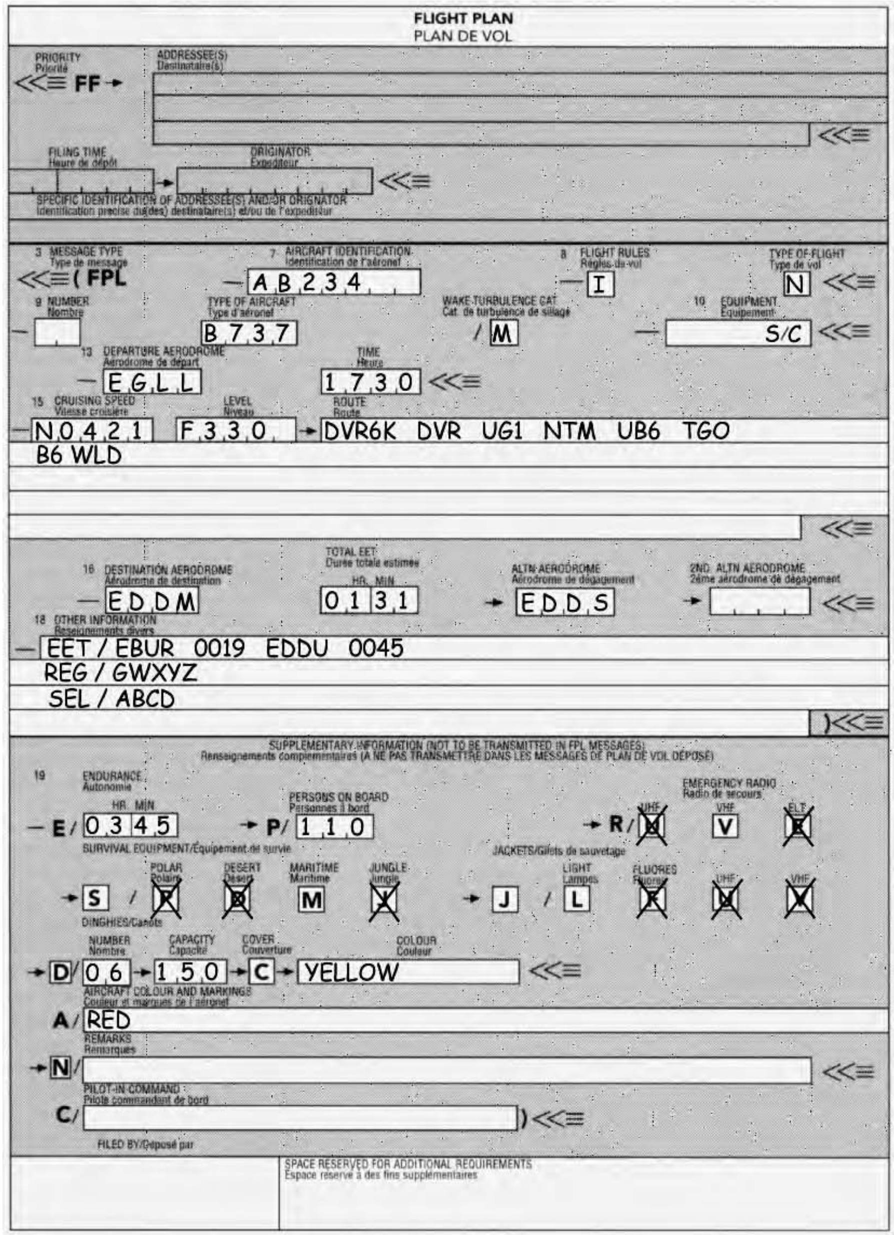
## *Flight Plan procedures*

### Submission of Flight Plans

For a flight to be provided with an Air Traffic Control service or an Air Traffic advisory service a Flight Plan must be submitted to an Air Traffic Service reporting office 60 minutes before departure from the ramp, or, if submitted in flight, at least 10 minutes before the aircraft reaches the point of entry or crossing of a CTA, airway or advisory route. If the flight is subject to Air Traffic Flow Management (ATFM) the Flight Plan must be filed three hours before the departure time from the ramp.

In the event of a delay in departure of 30 minutes for a controlled flight or 60 minutes for an uncontrolled flight the Flight Plan **must** be amended or a revised Flight Plan submitted and the original Flight Plan cancelled.

**Any** changes made to the original Flight Plan submitted for an IFR flight or a VFR controlled flight must be reported to the agency to which the original Flight Plan was submitted. Only **significant** changes such as fuel endurance or the number of persons on board need be reported for VFR flights.


FLIGHT PLAN
PLAN DE VOL

PRIORITY Priorité
<<≡ FF →
ADDRESSEE(S) Destinataire(s)
<<≡
FILING TIME Heure de dépôt
ORIGINATOR Expéditeur
<<≡
SPECIFIC IDENTIFICATION OF ADDRESSEE(S) AND/OR ORIGINATOR
Identification précise du(des) destinataire(s) et/ou de l'expéditeur

3 MESSAGE TYPE Type de message
<<≡ ( FPL
7 AIRCRAFT IDENTIFICATION Identification de l'aéronef
— A B 2 3 4
8 FLIGHT RULES Règles de vol
— I
TYPE OF FLIGHT Type de vol
N <<≡
9 NUMBER Nombre
TYPE OF AIRCRAFT Type d'aéronef
B 7 3 7
WAKE TURBULENCE CAT. Cat. de turbulence de sillage
/ M
10 EQUIPMENT Équipement
— S/C <<≡
13 DEPARTURE AERODROME Aérodrome de départ
— E G L L
TIME Heure
1 7 3 0 <<≡
15 CRUISING SPEED Vitesse croisière
— N 0 4 2 1
LEVEL Niveau
F 3 3 0
ROUTE Route
→ DVR6K DVR UG1 NTM UB6 TGO
B6 WLD
<<≡

16 DESTINATION AERODROME Aérodrome de destination
— E D D M
TOTAL EET Durée totale estimée HR. MIN
0 1 3 1
ALTN AERODROME Aérodrome de dégagement
→ E D D S
2ND. ALTN AERODROME 2ème aérodrome de dégagement
→ <<≡
18 OTHER INFORMATION Renseignements divers
— EET / EBUR 0019 EDDU 0045
REG / GWXYZ
SEL / ABCD
)<<≡

SUPPLEMENTARY INFORMATION (NOT TO BE TRANSMITTED IN FPL MESSAGES)
Renseignements complémentaires (À NE PAS TRANSMETTRE DANS LES MESSAGES DE PLAN DE VOL DÉPOSÉ)
19 ENDURANCE Autonomie HR. MIN
— E / 0 3 4 5
PERSONS ON BOARD Personnes à bord
→ P / 1 1 0
EMERGENCY RADIO Radio de secours
→ R / UHF VHF ELT
V
SURVIVAL EQUIPMENT/Équipement de survie
POLAR Polaire DESERT Désert MARITIME Maritime JUNGLE Jungle
→ S / M
JACKETS/Gilets de sauvetage
LIGHT Lampes FLUORES Fluores UHF VHF
→ J / L
DINGHIES/Canots
NUMBER Nombre CAPACITY Capacité COVER Couverture COLOUR Couleur
→ D / 0 6 → 1 5 0 → C → YELLOW <<≡
AIRCRAFT COLOUR AND MARKINGS Couleur et marques de l'aéronef
A / RED
REMARKS Remarques
→ N / <<≡
PILOT-IN-COMMAND Pilote commandant de bord
C / )<<≡
FILED BY/Déposé par
SPACE RESERVED FOR ADDITIONAL REQUIREMENTS
Espace réservé à des fins supplémentaires

**Figure 10.2** Example of completed ATS Flight Plan.

### Closing the Flight Plan

For any Flight Plan submitted to an ATS, an arrival report must be made by radio or in person to the appropriate ATS unit to close the Flight Plan. This should be done as soon as possible after landing. If no ATS unit exists at the arrival aerodrome, then the arrival report must be made as soon as practicable by the most rapid means available (e.g., telephone) to the nearest ATS unit. If such a facility is not available, then a radio transmission must be made immediately prior to landing to an appropriate ATS unit responsible for the FIR.

### Adherence to the Flight Plan

Except in an emergency, the pilot must adhere to the Flight Plan as submitted and accepted (or amended) by the ATS unit. If a change to the original Flight Plan is required, then the request must be made to the appropriate ATS unit before any change is made. Any inadvertent deviation from the Flight Plan must be reported immediately to the appropriate controlling ATS unit.

A change of average speed of the aircraft of ±5% of the TAS or ± 0. 01 Mach must be reported in flight to the controlling authority. The same applies if the ETA at the next reporting point is greater than three minutes in error.

### Changes to in-flight weather conditions

The PIC may change from an IFR to a VFR flight by cancelling the IFR Flight Plan with the controlling authority. If an ATS unit is aware that a flight, for which a VFR Flight Plan has been submitted, is likely to encounter IMC then it will inform the PIC.

## Summary

A computer flight plan has five blocks. They are the heading/title block, the fuel block, the route summary block, the detailed route block and the ATS Flight Plan block.

An ATS Flight Plan is mandatory for IFR flight in Advisory airspace, across international boundaries, for VFR flights in Class B, C or D airspace, to obtain advisory service on advisory routes, for SVFR flights if the destination is to be notified and when the MTOM is greater than 5700 kg and the flight is further than 40 km.

An ATS Flight Plan is advisory for flights that extend beyond 10 nm from the coast, over sparsely populated areas and over areas where search and rescue may be difficult.

A Flight Plan should be closed by notification of landing to the appropriate ATS unit as soon as possible.

A flight must be adhered to as closely as possible unless directed by ATS to change. Inadvertent changes must be notified to the controlling authority. Maximum allowable deviation is less than ±5% TAS or 0.01 Mach and three minutes of ETA.

## Sample questions

1. Certain abbreviations are used in the heading block of a computer flight plan. The interpretation of XTR is:

   a. Across track
   b. Extra fuel
   c. Extraordinary
   d. Except the track

2. The submission of an ATS Flight Plan is mandatory when the maximum take-off mass is greater than … and the flight is longer than …:

   a. 7500 kg; 40 nm
   b. 5700 kg; 40 nm
   c. 7500 kg; 40 km
   d. 5700 kg; 40 km

3. It is advisable to submit an ATS Flight Plan when the route extends beyond a distance of … from the coastline.

   a. 10 km
   b. 10 nm
   c. 20 km
   d. 20 nm

4. The suspension of a Repetitive Flight Plan (RPL) for a period of three days or more must be notified to the ATS authority … before the affected flight.

   a. 1 day
   b. 2 days
   c. 3 days
   d. 4 days

5. For a flight along airways an ATS Flight Plan must be submitted …before EOBT.

   a. 10 min
   b. 20 min
   c. 30 min
   d. 60 min

6. To delay, cancel or change one flight of an RPL operation, the earliest the IFPS units concerned can be notified is:

   a. 10 hr
   b. 20 hr
   c. 24 hr
   d. 36 hr

7. Which of the following is the correct entry for the ATS Flight Plan to notify a planned change of speed:

   a. BCN /F330N350
   b. BCN/F330 N350
   c. BCN/N350F330
   d. BCN/ N350F330

8. If a flight is subject to flow control then the minimum time for the submission of an ATS Flight Plan is:

   a. 1 hr
   b. 2 hr
   c. 3 hr
   d. 4 hr

9. At Item 10 of the ATS Flight Plan, when 'S' is entered before the oblique stroke to indicate that standard communication and navigation equipment is carried and serviceable it means:

   a. VHF RTF, ADF, VOR and ILS
   b. UHF RTF, ADF, VOR and ILS
   c. VHF RTF, ADF, VOR and MLS
   d. UHF RTF, ADF, VOR and MLS

10. In flight, a Flight Plan must be submitted to the appropriate authority at least …before entering controlled airspace.

    a. 5 min
    b. 10 min
    c. 15 min
    d. 20 min

11. In the event of a delayed departure a Flight Plan must be amended for a VFR flight if the delay is … or more.

a. 10 min
b. 20 min
c. 30 min
d. 60 min

12. In flight, if the average speed of the aeroplane changes by … of TAS or … Mach it must be notified to the controlling authority.

a. ±5%; 0.10
b. ±10%; 0.10
c. ±5%; 0.01
d. ±10%; 0.01

# Chapter 11
# Extended Range Twin Operations

## ETOPS

### *Adequate aerodrome*

All twin-engined public transport aeroplanes with a maximum authorised take-off weight greater than 5700 kg **and** certificated to carry more than 19 passengers are subject to the requirements of the CAP 513. An operator is not permitted to operate a twin-engined aeroplane beyond a specified maximum distance from an **adequate** aerodrome unless the appropriate aviation authority grants Extended Range Twin Operations (ETOPS) permission. The maximum distance is dependent on the performance class and type of aeroplane and is referred to as the *threshold* distance, which is determined by the *threshold* time and TAS used for this purpose. Thus, *extended range operations* are those intended to be, or which actually are, conducted on a route that contains a point further than the *threshold* distance from an adequate aerodrome.

An aerodrome that is available at the anticipated time of use and is equipped with the necessary ancillary services (such as ATC, lighting, communications, weather reporting, navigation aids and safety cover) and having at least one let-down aid available for an instrument runway is referred to as an adequate aerodrome.

### *Suitable aerodrome*

A suitable aerodrome is an adequate aerodrome that is used as an en-route alternate or diversion aerodrome. It would normally be used only in the event of an engine failure or the loss of primary airframe systems. However, at the anticipated time of use, weather reports, forecasts, or any combination thereof, indicates the weather conditions must be at or above the normal operating minima at the time of the intended operation. If, in a weather forecast for the appropriate time there is a PROB (see Chapter 2), which is less than 40% it may be ignored for planning purposes. Other conditional qualifications must be accounted.

The minimum acceptable weather conditions for an ETOPS en-route alternate aerodrome are shown in Table 11.1.

**Table 11.1**

| Planning minima – ETOPS | | |
|---|---|---|
| RVR/visibility required (and ceiling if applicable) | | |
| Type of approach | Aerodrome with at least two separate approach procedures based on two separate aids serving two separate runways | Aerodrome with at least two separate approach procedures based on two separate aids serving one runway<br>or,<br>at least one approach procedure based on one aid serving one runway |
| Precision approach Cat II, III (ILS, MLS) | Precision approach Cat I minima | Non-precision approach minima |
| Precision approach Cat I (ILS, MLS) | Non-precision approach minima | Circling minima or, if not available, non-precision approach minima plus 200 ft/1000 m |
| Non-precision approach | The lower of non-precision approach minima plus 200 ft/ 1000 m or circling minima | The higher of circling minima or non-precision approach minima plus 200 ft/1000 m |
| Circling approach | Circling minima | |

### *Threshold time*

The threshold time is that which is used to calculate the threshold distance (i.e., the maximum distance from an adequate aerodrome for twin-engined aeroplanes without ETOPS approval) and is 60 minutes for Class A aeroplanes, 120 minutes for Class B aeroplanes and 120 minutes for Class C aeroplanes.

### *Threshold distance*

Unless specifically approved by the appropriate authority (ETOPS approval) an operator is not permitted to operate a twin-engined aeroplane on any route that contains a point beyond the maximum threshold distances from an adequate aerodrome (specified later in this chapter).

Class A aeroplanes having a maximum approved passenger seating capacity (MAPSC) of 20 or more or a maximum take-off mass of 45 360 kg (100 000 lb) or more are restricted to a distance that could be covered in 60 minutes at the one-engine-inoperative cruising speed, in still-air ISA conditions, from an adequate aerodrome. *JAR-OPS 1.245(a)(1).*

An operator shall not operate any twin-engined Class A aeroplane having an approved passenger seating capacity of 19 or less **and** a maximum take-off mass less than 45 360 kg, including cargo aeroplanes, on any route that contains a point beyond a distance that could be flown in 120 minutes, or if approved by the appropriate authority up to 180 minutes for turbo-jet aircraft, at the one-engine-inoperative cruise speed, in still-air ISA conditions, from an adequate aerodrome. *JAR-OPS 1.245(a)(2).*

Aeroplanes in performance classes B or C are restricted to a distance that could be flown in 120 minutes at the all-engines maximum-range cruising speed or 300 nm, whichever is less, in still-air ISA conditions, from an adequate aerodrome. *JAR-OPS 1.245(a)(3).*(See Figure 11.1). *IEM OPS 1.245(a).*

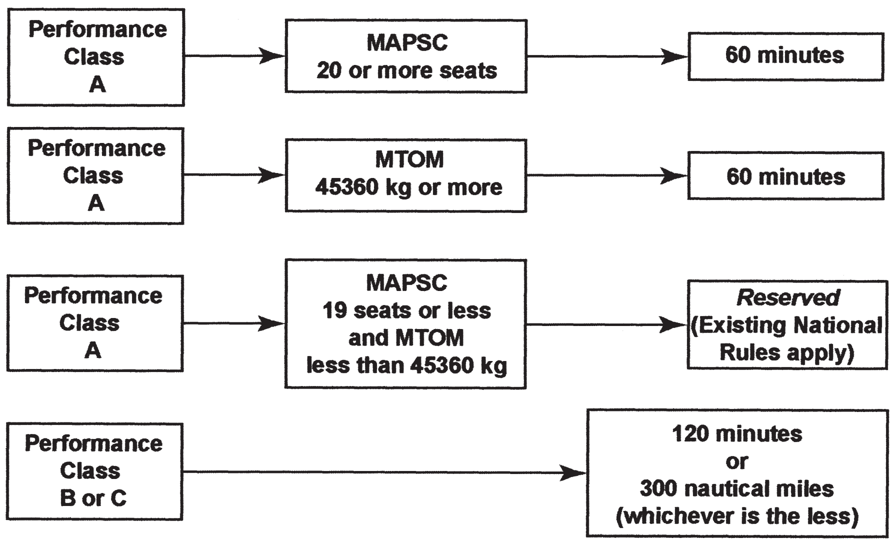



**Figure 11.1** Maximum distance from an adequate aerodrome for twin-engined aeroplanes *without* ETOPS approval.

## *One-engine-inoperative cruise speed*

The speed to be used to determine the threshold distance for any particular aeroplane is the TAS that would exist in level flight with one-engine-inoperative, and the other set at the maximum continuous power setting, in ISA conditions, not exceeding VMO. The weight to be used to determine this speed is that which would be obtained after take-off at the maximum authorised take-off weight then climbing from msl to the long-range cruising altitude and cruising for a period equal to the threshold time at the long-range cruise speed with all-engines-operating. The cruising level to be used to determine the one-engine-inoperative cruising TAS is FL170 for turbo-jet aeroplanes and FL80 for propeller driven aircraft, or the maximum FL to which the aeroplane can climb and maintain with one-engine-inoperative using the gross rate of climb specified in the Aeroplane Flight Manual (AFM).

### *Rule time*

The maximum diversion time that any point on the route of an ETOPS-approved aeroplane may be from a **suitable** aerodrome is referred to as the *rule time*. On initial approval the rule time is 120 minutes. After six months of satisfactory operations the rule time may be increased to 138 minutes, and after a further 12 months of incident free operations to 180 minutes.

### *Rule distance*

The maximum distance an operator may plan any route from a **suitable** aerodrome is that which would be covered at the normal one-engine-inoperative cruising speed, in still air, in the rule time.

### *ETOPS segment*

The portion of a flight that commences at the point at which the aeroplane is first beyond the *threshold distance* from an **adequate** aerodrome and finishes when the aircraft is last more than the threshold distance from an adequate aerodrome.

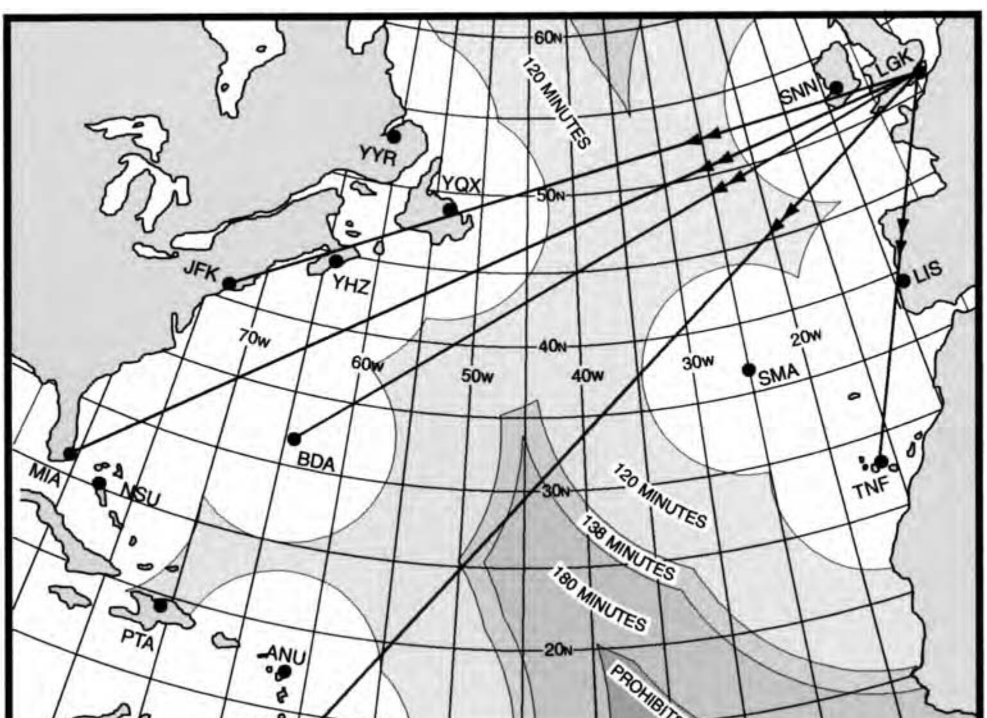



**Figure 11.2** North Atlantic ETOPS areas.

## *Permitted ETOPS area*

The airline operator is required to fulfil certain obligations regarding the aircraft's engines, systems reliability and servicing schedules before the appropriate authority will grant permission for Extended Range Twin Operations. When approval is given, the authority will specify the area in which the airline may operate and the standard maximum diversion time from a **suitable** aerodrome (the *rule time*). These details will be specified in the Air Operator's Certificate issued by the authority. An example of the restriction placed on operations over the North Atlantic by the *rule time* is shown in Figure 11.2 for an aircraft having a one-engine-inoperative cruising TAS of 420 kts. Figure 11.3 is an example of part of the North Atlantic ETOPS chart for an A330 as published for use by aircrew.

## *Minimum Equipment List*

The primary system redundancy levels appropriate to extended range operations are listed in the Minimum Equipment List (MEL). In the event of an engine failure sufficient communications and radio navigation equipment must remain available to safely continue to the destination or planned alternate aerodrome with the required navigation accuracy.

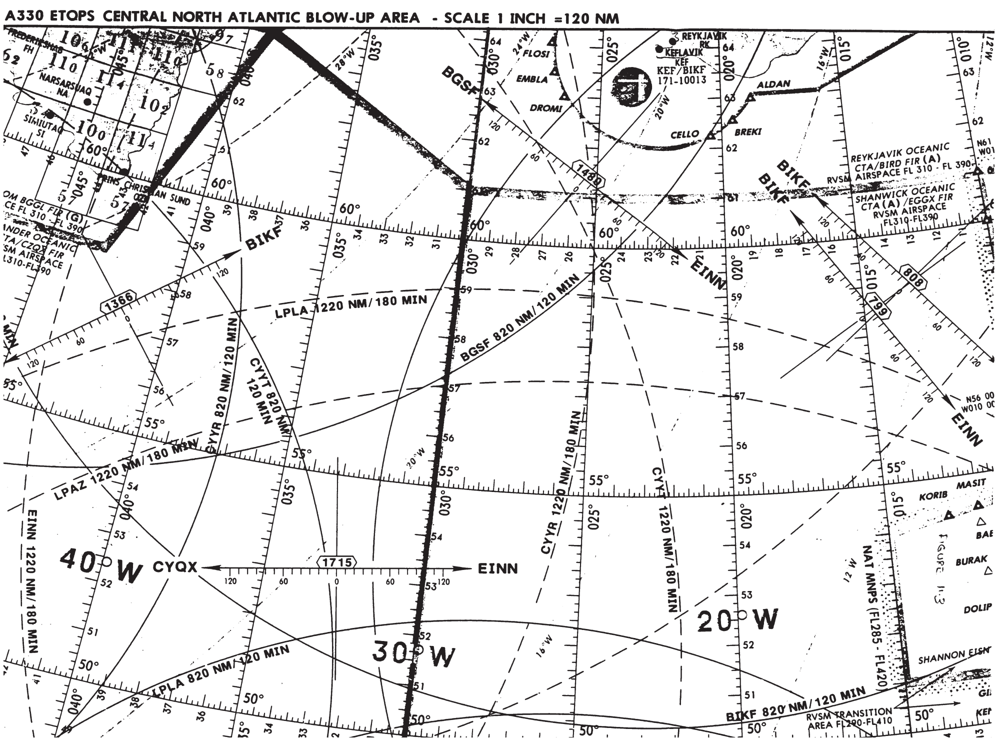



**Figure 11.3** Portion of an ETOPS en-route chart. (*Not for navigational purposes – information only. Reproduced with permission of Jeppesen GmbH.*)

### *ETOPS maintenance requirements*

The specific technical and maintenance requirements are given in Appendix 3 of the CAP 513 which contains details of the oil consumption programme, engine condition monitoring, reliability monitoring, maintenance training and ETOPS parts control.

## Summary

An adequate aerodrome is one that is available at the anticipated time of use and suitably equipped with ancillary services with at least one let-down aid for an instrument runway.

A suitable aerodrome is an adequate aerodrome used as an en-route alternate or diversion aerodrome and has weather at or above the minimum acceptable.

Threshold distance is the maximum distance an ETOPS-authorised twin-engined aeroplane, over 5700 kg and certified to carry more than 19 passengers, may operate from an adequate aerodrome without special permission.

The threshold time for twin-engined Class A aeroplanes having a passenger seating capacity of 20 or more or an MTOM 45 360 kg is 60 minutes. For other Class A aeroplanes it is 120 minutes or, if approved by the authority, up to 180 minutes. For Class B and C aeroplanes, the threshold time is 120 minutes.

The threshold distance for Class A aeroplanes is calculated using the one-engine-inoperative cruising speed in still-air and ISA conditions. For Class B and C aeroplanes the all-engines maximum-range cruising speed is used for this purpose.

Rule time is the maximum diversion time that any point on the route, for a twin-engined ETOPS aeroplane, may be from a *suitable* aerodrome. It is specified by the authority for each operator.

An ETOPS segment begins at the point at which the aeroplane is first beyond the threshold distance from an adequate aerodrome and finishes when it is last more than the threshold distance from an adequate aerodrome.

## Sample questions

1. For an aerodrome to be considered *adequate* it must have at least:

   a. Two usable instrument runways
   b. Two parallel instrument runways
   c. One let-down aid for an instrument runway
   d. Two let-down aids for an instrument runway

2. If an adequate aerodrome is to be considered *suitable* any probability in the weather forecast must be less than … for it to be ignored.

   a. 20%
   b. 30%
   c. 40%
   d. 50%

3. The *threshold times* used to calculate the threshold distance for ETOPS purposes are:

   a. Class A 60 min; Class B 60 min; Class C 120 min

   b. Class A 60 min; Class B 90 min; Class C 120 min

   c. Class A 90 min; Class B 90 min; Class C 120 min

   d. Class A 60 min; Class B 120 min; Class C 120 min

4. The speed to be used to determine the threshold distance for a jet aeroplane is the speed attained with:

   a. One-engine-inoperative at FL170
   b. All-engines-operating at FL170
   c. One-engine-inoperative at FL80
   d. All-engines-operating at FL80

5. *Rule time*, the maximum diversion time from a suitable aerodrome, is … on initial approval, … after six months and … after 12 months incident-free operation.

   a. 90 min or less; 120 min; 138 min

   b. 120 min or less; 138 min; 180 min

   c. 138 min or less; 180 min; 240 min

   d. 120 min or less; 180 min; 240 min

6. The ETOPS planning minima for a non-precision approach at an ETOPS en-route alternate aerodrome, having two separate runways is:

   a. The non-precision approach minima
   b. The non-precision approach minima plus 200 ft/1000 m
   c. The circling minima
   d. The lower of b or c.

7. An ETOPS segment is that portion of flight that commences when … and finishes when …:

   a. First beyond the threshold distance from an adequate aerodrome; last more than the threshold distance from an adequate aerodrome
   b. First beyond the threshold distance from a suitable aerodrome; last more than the threshold distance from a suitable aerodrome
   c. First beyond the threshold time from an adequate aerodrome; last more than the threshold time from an adequate aerodrome
   d. First beyond the threshold time from a suitable aerodrome; last more than the threshold time from a suitable aerodrome

8. Which of the following are required to be available at the anticipated time of use, for an aerodrome to be considered adequate?

   a. One let-down aid for an instrument runway
   b. Two let-down aids for an instrument runway
   c. Let-down aids are not required
   d. Two let-down aids for two instrument runways.

# Answers to Sample Questions

## *Chapter 1 Exercise 1.1*

**Table 12.1**

| Wind velocity | Track (T): ° | Drift: ° | Heading (T): ° | TAS (kts) | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|---|---|---|---|
| 080/40 | 240 | 4.5 S | 235.5 | 180 | 217 | 213 | 58.9 |
| 250/50 | 330 | 13 S | 317 | 220 | 205.5 | 176 | 51.4 |
| 350/30 | 020 | 3 S | 017 | 300 | 274 | 242 | 53.0 |
| 170/60 | 130 | 5 P | 135 | 420 | 372 | 315 | 50.8 |
| 030/30 | 176 | 9 S | 167 | 110 | 134 | 94 | 42.1 |
| 120/50 | 218 | 11 S | 207 | 256 | 258 | 135 | 31.4 |

## *Chapter 1 Exercise 1.2*

**Table 12.2**

| Q | Leg distance (nm) | All-engine G/S On (kts) | One-engine-inoperative G/S On (kts) | All-engine G/S Home (kts) | One-engine-inoperative G/S Home (kts) | All-engine PET distance and time | One-engine-inoperative PET distance and time |
|---|---|---|---|---|---|---|---|
| 1 | 1420 | 420 | 370 | 350 | 300 | 645.5 nm<br>1 h 32.2 m | 635.8 nm<br>1 h 30.8 m |
| 2 | 879 | 380 | 330 | 350 | 300 | 421.4 nm<br>1 h 06.5 m | 418.6 nm<br>1 h 06.1 m |
| 3 | 1250 | 320 | 270 | 370 | 320 | 670.3 nm<br>2 h 05.7 m | 678.0 nm<br>2 h 07.1 m |
| 4 | 2323 | 295 | 245 | 330 | 280 | 1226.5 nm<br>4 h 09.5 m | 1238.9 nm<br>4 h 12.0 m |
| 5 | 1952 | 250 | 200 | 300 | 250 | 1064.7 nm<br>4 h 15.5 m | 1084.4 nm<br>4 h 20.3 m |

## *Chapter 1 Exercise 1.3*

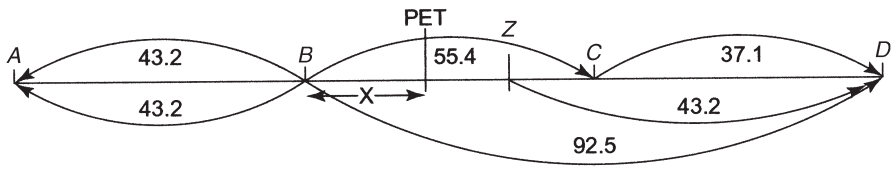



**Figure 12.1** Chapter 1. Solution to Exercise 1.3 Question 1.

**Solution 1**. See Figure 12.1.

$BZ$ = (92.5 – 43.2) × G/S $BC$ = (49.3 × 260) ÷ 60 = 213.6 nm

$X = DH/O + H$ = (213.6 × 230)/(260 + 230) = 100.3 nm

Time $B$ to PET = (100.3 ÷ G/S $BC$) × 60 = 23.1 min

Distance $A$ to PET = $AB$ + 100.3 nm = 180 + 100.3 = 280.3 nm

Time $A$ to PET = $AB$ + 23.1 min = 46.0 + 23.1 min = 69.1 min

**Table 12.3**

| Leg | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *P–R* | 300 | 200 | 40.0 |
| *R–S* | 320 | 300 | 56.3 |
| *S–T* | 350 | 400 | 68.6 |
| *T–S* | 320 | 400 | 75.0 |
| *S–R* | 290 | 300 | 62.1 |
| *R–P* | 270 | 200 | 44.4 |

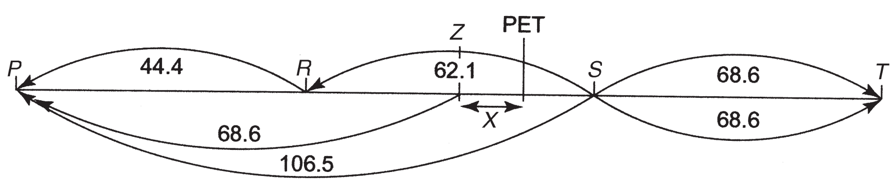



**Figure 12.2** Chapter 1. Solution to Exercise 1.3 Question 2.

**Solution 2** See Figure 12.2.

$ZS$ = (106.5 – 68.6) × G/S $SR$ = (37.9 × 290) ÷ 60 = 183.2 nm

$RZ = RS - ZS$ = 300 – 183.2 nm = 116.8 nm

$X = DH/O + H = (183.2 \times 290)/(320 + 290) = 87.1$ nm

Time $Z$ to PET = $(87.1 \div$ G/S $RS) \times 60 = (87.1 \div 320) \times 60 = 16.3$ min

Time $R$ to $Z$ = $(116.8 \div$ G/S $RS) \times 60 = (116.8 \div 320) \times 60 = 21.9$ min

Distance $P$ to PET = $PR + RZ + X = 200 + 116.8 + 87.1 = 403.9$ nm

Time $P$ to PET = $PR + RZ + t = 40.0 + 21.9 + 16.3 = 78.2$ min

**Solution 3** See Figure 12.3.

**Table 12.4**

| Leg | Ground speed (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *H–J* | 200 | 300 | 90.0 |
| *J–K* | 300 | 320 | 64.0 |
| *K–L* | 400 | 350 | 52.5 |
| *L–K* | 370 | 350 | 56.8 |
| *K–J* | 270 | 320 | 71.1 |
| *J–H* | 170 | 300 | 105.9 |

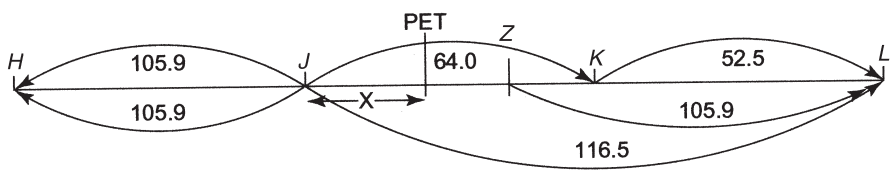



**Figure 12.3** Chapter 1. Solution to Exercise 1.3 Question 3.

$ZK = (116.5 - 105.9) \times$ G/S $JK = (10.6 \times 300) \div 60 = 53.0$ nm

$X = DH/O + H = (53.0 \times 270)/(300 + 270) = 25.1$ nm

Time $J$ to PET = $(25.1 \div$ G/S $JK) \times 60 = 5.0$ min

Distance $H$ to PET = $HJ$ + 25.1 nm = 300 + 25.1 = 325.1 nm

Time $H$ to PET = $HJ$ + 5.0 min = 90.0 + 5.0 min = 95.0 min

## *Chapter 1 Exercise 1.4*

**Table 12.5**

| Q | Leg distance (nm) | All-engine G/S On (kts) | Fuel flow On (kg/hr) | All-engine G/S Home (kts) | Fuel flow Home (kg/hr) | All-engine PEF distance (nm) |
|---|---|---|---|---|---|---|
| 1 | 1420 | 420 | 4200 | 350 | 4800 | 598.8 |
| 2 | 879 | 380 | 3600 | 350 | 3100 | 454.3 |
| 3 | 1250 | 320 | 5200 | 370 | 4600 | 708.2 |
| 4 | 2323 | 295 | 6000 | 330 | 5000 | 1331.3 |
| 5 | 1952 | 250 | 4700 | 300 | 5500 | 988.3 |

## *Chapter 1 Exercise 1.5*

**Table 12.6**

| Leg | G/S (kts) | Distance (nm) | Fuel flow (kg/hr) | Fuel used (kg) |
|---|---|---|---|---|
| *A–B* | 320 | 180 | 6500 | 3656 |
| *B–C* | 335 | 200 | 6300 | 3761 |
| *C–D* | 350 | 350 | 6100 | 6100 |
| *D–E* | 360 | 450 | 5900 | 7375 |
| *E–D* | 370 | 450 | 5700 | 6932 |
| *D–C* | 390 | 350 | 5500 | 4936 |
| *C–B* | 400 | 200 | 5300 | 2650 |
| *B–A* | 410 | 180 | 5100 | 2239 |

The solution to this problem is a little different to previous examples. The fuel from *D* to *E* far exceeds the sum of the fuel from *B* to *A* and from *C* to *B*. Therefore, it is necessary to try to equalise this by including the fuel from *D* to *C* (see Figure 12.4). The fuel from *D* to *E* is 7375 kg but the total fuel from *D* to *A* is 9825 kg. This must be reduced to the smaller value by introducing point *Z*. The difference in fuel is then (9825 – 7375) kg = 2450 kg. The distance $ZD$ = (2450 × 390) ÷ 5500 = 173.7 nm. Therefore, the distance $CZ$ is (350 – 173.7) nm. The PEF will fall between *Z* and *D*. The distance from *Z* to the PEF is *Y* and is located by using the formula.

Thus, $Y = (173.7 \times 390 \times 6100)/[(350 \times 5500) + (390 \times 6100)] = 96$ nm

The distance from *A* to the PEF = $AB + BC + CZ + Y = 180 + 200 + 176.3 + 96 =$ **652.3** nm

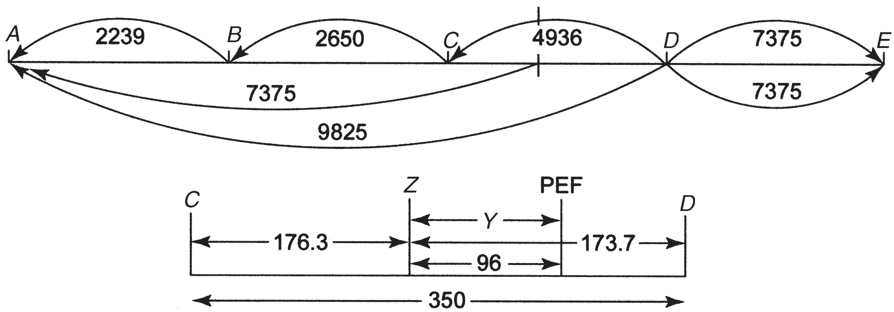



**Figure 12.4** Chapter 1. Solution to Exercise 1.5.

## *Chapter 1 Exercise 1.6*

**Table 12.7**

| Q | W/V | Track (T): ° | TAS (kts) | Endurance (hr) | G/S On (kts) | G/S Home (kts) | PSR distance (nm) | PSR time (hr) |
|---|---|---|---|---|---|---|---|---|
| 1 | 240/50 | 180 | 260 | 7.5 | 233 | 280 | 953.8 | 4.09 |
| 2 | 090/40 | 030 | 210 | 6.0 | 190 | 226 | 619.3 | 3.26 |
| 3 | 320/30 | 120 | 310 | 9.5 | 340 | 281 | 1461.6 | 4.30 |
| 4 | 110/45 | 240 | 290 | 8.2 | 316 | 260 | 1169.6 | 3.70 |
| 5 | 190/55 | 280 | 380 | 7.2 | 376 | 376 | 1353.6 | 3.60 |

## *Chapter 1 Exercise 1.7*

**Table 12.8**

| Leg | G/S (kts) | Fuel flow (kg/hr) | Leg distance (nm) | Leg time (hr) | Fuel used (kg) |
|---|---|---|---|---|---|
| *A–B* | 300 | 6500 | 200 | 0.67 | 4333 |
| *B–C* | 320 | 6400 | 230 | 0.72 | 4600 |
| *C–D* | 350 | 6300 | 180 | 0.51 | 3240 |
| *D–E* | 330 | 6200 | 250 | 0.76 | 4697 |
| *E–D* | 290 | 6100 | 250 | 0.86 | 5259 |
| *D–C* | 310 | 6000 | 180 | 0.58 | 3484 |
| *C–B* | 280 | 5900 | 230 | 0.82 | 4846 |
| *B–A* | 260 | 5800 | 200 | 0.77 | 4462 |

Fuel required from *A* to *B* and back to *A* = 4333 + 4462 = 8795 kg

Fuel required from *A* to *C* and back to *A* = 8795 + 4600 + 4846 = 18 241 kg

Fuel required from *A* to *D* and back to *A* = 18 241 + 3240 + 3484 = 24 965 kg

Fuel required from *A* to *E* and back to *A* = 24 965 + 4697 + 5259 = 34 921 kg

The fuel available is insufficient to reach *E* and return to *A*. However, there is enough fuel to reach beyond *D* and to return to *A*. The distance that the PSR is beyond *D* now has to be determined. The fuel available from *D* to the PSR and to return to *D* is 30 000 – 24 965 = 5035 kg. To determine the distance that this will enable the aeroplane to travel outbound and to return to *D* the fuel available must be divided by the total gross fuel flow (GFF) for both legs.

The GFF outbound from *D* = Fuel flow *D*–*E* divided by the ground speed from *D*–*E* = 6200 kg/hr ÷ 330 kts = 18.79 kg/nm.

For the return leg, the fuel flow *E*–*D* must be divided by the ground speed *E*–*D* = 6100 kg/hr ÷ 290 kts = 21.03 kg/nm.

Therefore, the total GFF = 18.79 + 21.03 = 39.82 kg/nm

The distance from *D* to the PSR is equal, therefore, to 5035 kg ÷ 39.82 = 126.4 nm

The time from *D* to the PSR is equal to 126.4 nm ÷ 330 = 0.38 hr

The total distance from *A* to the PSR = 200 + 230 + 180 + 126.4 = 736.4 nm

The total time from *A* to the PSR = 0.67 + 0.72 + 0.51 + 0.38 = 2.28 hr = 2 hr 16.8 min

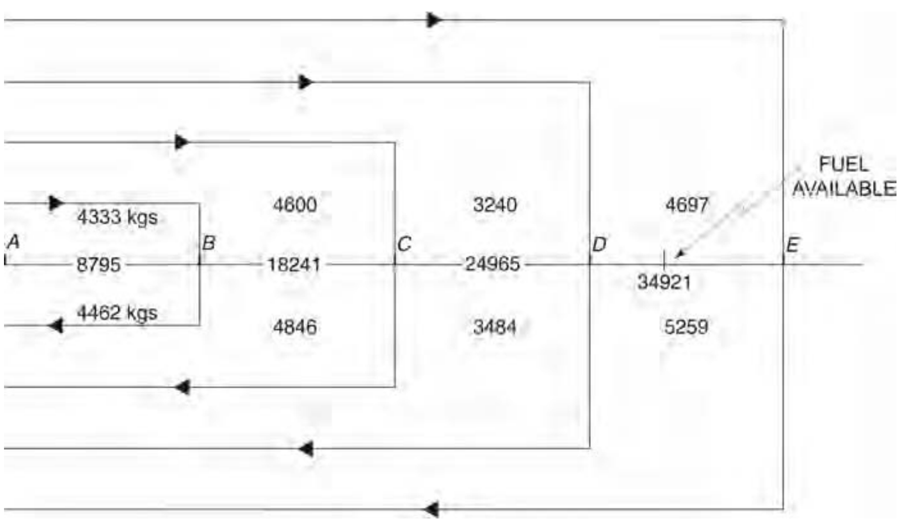



**Figure 12.5** Chapter 1. Solution to Exercise 1.7.

## *Chapter 1 Sample questions*

1.
   a. Heading (T) **228°.**
   b. Ground speed **180 kts**.
   c. 2.21 hr = **132.3 min**.

2.

$X = DH/(O + H) = (397 \times 230)/(180 + 230) = 91\,310/410 =$ **222.7 nm**

$t = (222.7 \div 180) \times 60 =$ **74.2 min**

3.

$Y = DH(FO)/[O(FH) + H(FO)] = (397 \times 230 \times 6000)/[(180 \times 5500) + (230 \times 6000)]$

$= 547\,860\,000/(990\,000 + 1\,380\,000) = 547\,860\,000/2\,370\,000 =$ **231.1 nm**

$t = (231.1 \div 180) \times 60 = 77.0$ min = **1 hr 17.0 min**

Proof:

397 – 231.1 = 165.9 nm

Fuel on = (165.9 ÷ 180) × 6000 = 5530 kg

Fuel home = (231.1 ÷ 230) × 5500 = 5526 kg

4.

Ground speed on = 119 kts. Ground speed home = 169 kts.

$X = DH/(O + H) = (397 \times 169)/(119 + 169) = 67\,093/288 =$ **233 nm**

$t = (233 \div 180) \times 60 =$ **77.7 min**

5. See Figure 12.6.

**Table 12.9**

| Leg | G/S (kts) | Distance (nm) | Time (min) |
|---|---|---|---|
| *A–B* | 480 | 325 | 40.63 |
| *B–C* | 450 | 276 | 36.8 |
| *C–D* | 430 | 405 | 56.5 |
| *D–E* | 410 | 370 | 54.15 |
| *E–D* | 480 | 370 | 46.25 |
| *D–C* | 500 | 405 | 48.6 |
| *C–B* | 520 | 276 | 31.85 |
| *B–A* | 550 | 325 | 35.45 |

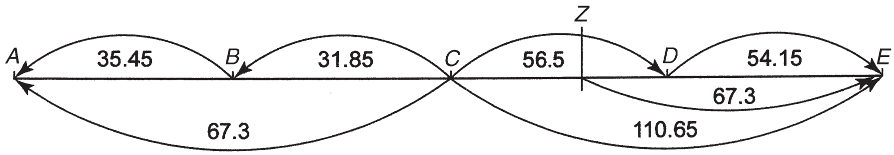



**Figure 12.6** Chapter 1. Solution to Question 5.

$CZ = (110.65 - 67.3) \times$ G/S $CD = (43.35 \times 430) \div 60 = 310.68$ nm

$X = DH/(O + H) = (310.68 \times 500)/(430 + 500) = 155\,373.3/930 = 167$ nm

Distance from $A = AB + BC + X = 325 + 276 + 167 =$ **768 nm**

$t = (167.1 \div 430) \times 60 = 23.3$ min

Time to PET from $A = AB + BC + t = 40.63 + 36.8 + 23.3 =$ **100.7 min**

6.

Ground speed on = 283 kts. Ground speed home = 333 kts.

$X = EOH/(O + H) = (8.2 \times 280 \times 333)/(280 + 333) = 764\,568/613 =$ **1247.3 nm**

$t = (1247.3 \div 280) \times 60 = 267.3$ min = **4 hr 27.3 min**

7. See Figure 12.7.

**Table 12.10**

| Leg | G/S (kts) | Fuel flow (kg/hr) | Leg distance (nm) | Leg time (hr) | Fuel used (kg) |
|---|---|---|---|---|---|
| *A–B* | 260 | 6500 | 200 | 0.77 | 5000 |
| *B–C* | 280 | 6400 | 230 | 0.82 | 5257 |
| *C–D* | 310 | 6300 | 180 | 0.58 | 3658 |
| *D–E* | 290 | 6200 | 250 | 0.86 | 5345 |
| *E–D* | 330 | 6100 | 250 | 0.76 | 4621 |
| *D–C* | 350 | 6000 | 180 | 0.51 | 3086 |
| *C–B* | 320 | 5900 | 230 | 0.72 | 4241 |
| *B–A* | 300 | 5800 | 200 | 0.67 | 3867 |

Fuel available from $D = 30\,000 - 25\,109 = 4891$ kg

GFF outbound = 6200/290 = 21.4 kg/nm

GFF inbound = 6100/330 = 18.5 kg/nm

Total GFF = 21.4 + 18.5 =39.9 kg/nm

Distance *D* to the PSR = 4891/39.9 = 122.6 nm

Total distance from *A* = 200 + 230 + 180 + 122.6 = **732.6 nm**

Total time from *A* = 0.77 + 0.82 + 0.58 + (122.6/290) = 2.59 hr = 2 hr 35.6 min

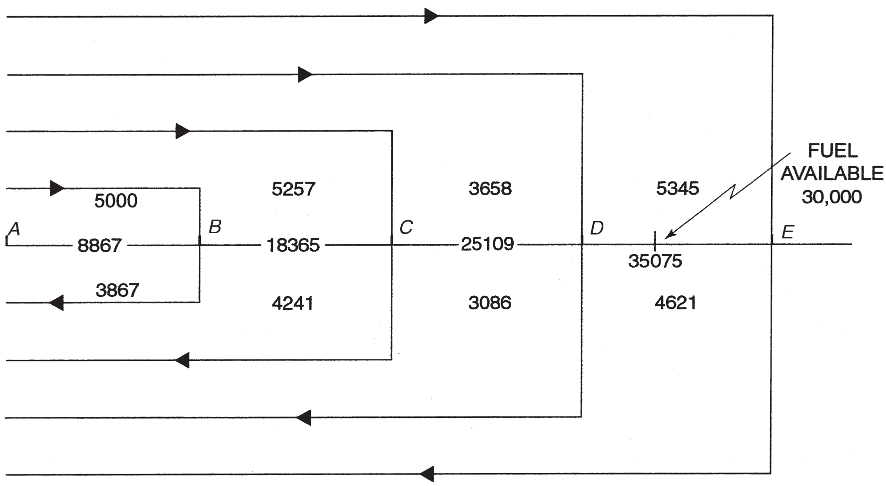



**Figure 12.7** Chapter 1. Solution to Question 7.

8. See Figure 12.8.

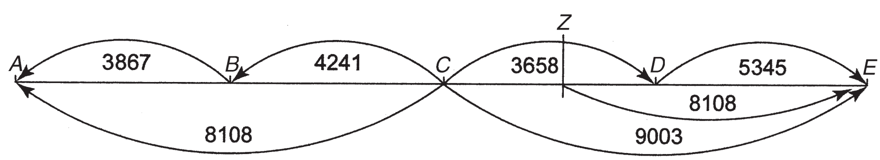



**Figure 12.8** Chapter 1. Solution to Question 8.

Unbalanced fuel = 9003 – 8108 = 895 kg

Unbalanced distance = (895 ÷ FF *CD*) × G/S *CD* = (895 ÷ 6300) × 310 = 44 nm

Y = *DH*(*FO*)/[*O*(*FH*) + *H*(*FO*)] = (44 × 350 × 6300)/[(310 × 6000) + (350 × 6300)]

= 97 020 000/(1 860 000 + 2 205 000) = 97 020 000/4 065 000 = 23.9 nm

Distance from *A* to PEF = *AB* + *BC* + 23.9 = **453.9 nm**

Time from *A* to PEF = 0.77 + 0.82 + (23.9/310) = 0.77 + 0.82 + 0.077 = 1.667 hr = 100 min = **1hr 40 min**

## *Chapter 2 Sample questions*

**Table 12.11**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1.** | d | **6.** | b | **11.** | d | **16.** | a |
| **2.** | d | **7.** | c | **12.** | a | **17.** | d |
| **3.** | d | **8.** | b | **13.** | c | **18.** | c |
| **4.** | c | **9.** | a | **14.** | a | **19.** | b |
| **5.** | c | **10.** | b | **15.** | b | **20.** | b |

## *Chapter 3 Sample questions*

**Table 12.12**

| | | | |
|---|---|---|---|
| **1.** | c | **6.** | a |
| **2.** | d | **7.** | d |
| **3.** | d | **8.** | a |
| **4.** | c | **9.** | d |
| **5.** | a | **10.** | b |

## *Chapter 4 Sample questions*

**Table 12.13**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **1.** | c | **6.** | c | **11.** | d | **16.** | c |
| **2.** | b | **7.** | c | **12.** | c | **17.** | b |
| **3.** | c | **8.** | d | **13.** | b | **18.** | a |
| **4.** | b | **9.** | d | **14.** | b | **19.** | b |
| **5.** | b | **10.** | a | **15.** | c | **20.** | d |

## *Chapter 5 Sample questions*

**Table 12.14**

| | | | |
|---|---|---|---|
| **1.** | b | **5.** | b |
| **2.** | d | **6.** | d |
| **3.** | c | **7.** | a |
| **4.** | c | **8.** | d |

8. Total fuel = 325 + 11 450 + (5% of 11 450) + 1400 + (2 × 2590) = 18 928 kg

## *Chapter 6 Sample questions*

1.

Aerodrome Pressure Altitude = elevation + [(1013 – 993) × 28] = 3560 ft

**Table 12.15**

| Altitude / Temperature | Time (min) | Fuel: US gallon | Air distance (nm). |
|---|---|---|---|
| 3560 ft at +15°C | 5 | 2 | 9 |
| 11 000 ft at –10°C | 12 | 4.2 | 24 |
| Difference | 7 | 2.2 | 15 |

IAS 110 kts at 7280 ft +2.5°C. TAS = 124 kts. Ground speed = 139 kts.

Ground distance = (15 × 139) ÷ 124 = 16.8 nm

Fuel used = 2.2 × 6 = 13.2 lb

2.

**Table 12.16**

| Altitude / Temperature | Time (min) | Fuel: US gallon | Air distance (nm) |
|---|---|---|---|
| 6000 ft at –10°C | 4 | 1.5 | 7 |
| 14 000ft at –30°C | 13 | 4.6 | 26 |
| Difference | 9 | 3.1 | 19 |

IAS 110 kts at 10 000 ft –20°C. TAS = 125 kts. Ground speed = 100 kts.

Ground distance = (19 × 100) ÷ 125 = 15.2 nm

Fuel used = 3.1 × 6 = 18.6 lb

3.

Deviation = Ambient – Standard = 0 – (+6) = –6°C

**Table 12.17**

| Pressure altitude (ft) | ISA –20° C | | | ISA +0° C | | | ISA –6° C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Man. press: inHg | FF: PPH | TAS (kts) | Man. press: inHg | FF: PPH | TAS (kts) | Man. press: inHg | FF: PPH | TAS (kts) |
| 4000 | 25.0 | 92.3 | 169 | 25.0 | 88.5 | 170 | 25.0 | 89.6 | 170 |
| 6000 | 24.1 | 89.8 | 170 | 24.1 | 86.1 | 171 | 24.1 | 87.2 | 171 |
| 4500 | 24.8 | 91.7 | 169 | 24.8 | 87.9 | 170 | 24.8 | 89.0 | 170 |

4.

Deviation = Ambient – Standard = –20 –(–3) = –17°C

**Table 12.18**

| Pressure altitude (ft) | ISA –20° C | | | ISA +0° C | | | ISA –17° C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Man. press: inHg | FF: PPH | TAS (kts) | Man. press: inHg | FF: PPH | TAS (kts) | Man. press: inHg | FF: PPH | TAS (kts) |
| 8000 | 21.0 | 58.9 | 141 | 21.0 | 57.3 | 140 | 21.0 | 58.7 | 141 |
| 10 000 | 20.8 | 60.1 | 144 | 20.8 | 58.5 | 143 | 20.8 | 59.9 | 144 |
| 9000 | 20.9 | 59.5 | 142.5 | 20.9 | 57.9 | 141.5 | 20.9 | 59.3 | 142.5 |

5.

Air distance = 908 nm. TAS = 142.5 kts. G/S = 172.5 kts.

Ground distance = (908 × 172.5) ÷ 142.5 = **1099 nm**

6.

Air distance = 736 nm. TAS = 170 kts. G/S = 150 kts.

Ground distance = (736 × 150) ÷ 170 = **649 nm**

7.

Safe endurance = 6.68 hr = 6 hr 40.8 min

Maximum endurance = 6 hr 40.8 min + 45 min = **7 hr 25.8 min**

TAS = **137 kts**

8.

Safe endurance = 5.98 hr = **5 hr 58.8 min**. TAS = **152 kts**.

## *Chapter 7 Sample questions*

1.

Aerodrome Pressure Altitude = 4500 ft + [(1013 – 1023) × 28] = 4220 ft

**Table 12.19**

| Altitude/ Temperature | Time (min) | Fuel (US gallon) | Air distance (nm) |
|---|---|---|---|
| 4220 ft at +15°C | 7 | 4 | 12 |
| 18 000 ft at –35°C | 26.5 | 14.5 | 49.0 |
| Difference | 19.5 | 10.5 | 37.0 |

IAS 120 kts at 11 110 ft –10°C. TAS = 141 kts. Ground speed = 171 kts.

Ground distance = (37.0 × 171) ÷ 141 = **44.9 nm**

Fuel used = 10.5 × 6 = **63 lb**

2.

**Table 12.20**

| Altitude / Temperature | Time (min) | Fuel (US gallon) | Air distance (nm) |
|---|---|---|---|
| 4000 ft at +20°C | 6.2 | 3.8 | 11.5 |
| 16 000 ft at –20°C | 25.2 | 13.8 | 46.0 |
| Difference | 19.0 | 10.0 | 34.5 |

IAS 120 kts at 10 000 ft –0°C. TAS = 141 kts. Ground speed = 160 kts.

Ground distance = (34.5 × 160) ÷ 141 = **39.1 nm**

Fuel used = 10.0 × 6 = **60 lb**

3.

At 55% power at 19 000 ft pressure altitude with reserve fuel the still-air range is 906 nm, without reserve fuel the still-air range is 1020 nm. The TAS from Figure 3.4 is 176 kts. The ground speed is 136 kts.

Ground distance with reserve fuel = (906 × 136) ÷ 176 = **700 nm**

Ground distance without reserve fuel = (1020 × 136) ÷ 176 = **788.2 nm**

4.

Deviation = Ambient – Standard = +7 –(–13) = +20°C

Figure 3.3 at 14 000 ft pressure altitude and 55% power the fuel flow is 18.7 GPH and the manifold pressure is 25.2 inHg at 2500 RPM. Correction to the MAP = +(20/6)% = 3.33%. Corrected MAP = **26.04 inHg**.

Figure 3.4. TAS = 170 kts. Ground speed = 210 kts.

Leg time = (250 ÷ 210) × 60 = 1.19 hr = **71.4 min**

Fuel used = 18.7 × 1.19 × 6 lb = **133.6 lb**

5.
Figure 3.5. Endurance without reserve fuel = 6.82 hr = **6 hr 49.2 min**.
Figure 3.4. TAS = 163 kts. Ground speed = 195 kts.

Distance travelled = 195 × 6.82 = 1330 nm

6.

**Table 12.21**

| Altitude / Temperature | Time (min) | Fuel (US gallon) | Air distance (nm) |
|---|---|---|---|
| 5000 ft at +20°C | 5.0 | 2.0 | 13.0 |
| 15 000 ft at –20°C | 14.5 | 4.5 | 40.0 |
| Difference | 9.5 | 2.5 | 27.0 |

IAS = 145 kts at 10 000 ft –0°C. TAS = 170 kts. Ground speed = 143 kts.

Ground distance = (27 × 143) ÷ 170 = **22.7 nm**

Fuel used = 2.5 × 6 = **15 lb**

## *Chapter 8 Sample questions*

1.

Figure 4.2.1 (CAP 697). Optimum altitude = 35 350 ft.

Altitude difference = 35 350 – 30 000 = 5350 ft

CAP 697 page 24. 4000 ft below optimum altitude = 4%; 8000 ft below optimum altitude = 10%; 5350 ft below optimum altitude = 6.025%.

2.

The time adjustment is (6 ÷ 200) × 100 = 3%

CAP 697 page 26. The cost index to be set is 80. This will increase the fuel used by 5%.

3.

Figure 4.3.5 (CAP 697). Trip fuel = **19 400 kg**. Trip time = 8.3 hr = **8 hr 18 min**.

4.

Figure 4.3.4 (CAP 697). Fuel required = **4050 kg**. Time = 1.425 hr = **1 hr 25.5 min**.

5.

Figure 4.4 (CAP 697).

**Table 12.22**

| Pressure altitude (ft) | Weight (kg) | | |
|---|---|---|---|
| | 50 000 | 48 000 | 48 500 |
| | Fuel flow (kg/hr) | | |
| 20 000 | 2180 | 2100 | 2120 |
| 15 000 | 2220 | 2140 | 2160 |
| 17 000 | 2204 | 2124 | **2144** |

Fuel available = 5000 kg. Time in hold = 2 hr 20 min.

6.

Figure 4.5.1 (CAP 697 page 43).

**Table 12.23**

| Pressure altitude (ft) | Brake release weight (kg) | | | |
|---|---|---|---|---|
| 31 000 | | 62 000 | 60 000 | 61 500 |
| | Time/Fuel<br>Dist/TAS | 18/1550<br>101/383 | 17/1500<br>95/382 | **17.75**/1537.5<br>**99.5/383** |

Fuel adjustment = –237.5 kg. Adjusted fuel = **1300 kg**.

7.

Deviation = Ambient – Standard = –15 –(–27) = +12°C.

Figure 4.5.3.2 (CAP 697). TAS 453 kts.
Temperature correction = +12 kts. Corrected TAS = 465 kts.

Ground speed = 465 + 55 = 520 kts

Leg time 277 ÷ 520 = 0.53 hr × 60 = **32 min**

Leg air distance = (277 × 465) ÷ 520 = 247.7 nm

Start weight equivalent air distance = 3668 + [(37 ÷ 100) × 13] = 3673 nm

End of leg equivalent air distance = 3673 – 248 = 3425 nm

End of leg weight = 58 600 + [(6 ÷ 14) × 100] = 58 643 kg

Fuel used = 60 437 – 58 643 = 1794 kg

Temperature correction = (12 ÷ 10) × 0.6% = +0.72%

Corrected fuel used = **1807 kg**

Next leg start weight = 60 437 – 1807 = **58 630 kg**

8.

Deviation = Ambient – Standard = –37 –(–23) = –14°C.

Figure 4.5.3.4 (CAP 697). TAS 394 kts.
Temperature correction = –14 kts. Corrected TAS = 380 kts.

Ground speed = 380 – 12 = 368 kts

Leg time = 383 ÷ 368 = 1.04 hr × 60 = **62.4 min**

Leg air distance = (383 × 380) ÷ 368 = 395.5 nm

Start weight equivalent air distance = 3507 + [(28 ÷ 100) × 14] = 3511 nm

End of leg equivalent air distance = 3511 – 396 = 3115 nm

End of leg weight = 55 400 + [(6 ÷ 14) × 100] = 55 443 kg.

Fuel used = 58 228 – 55 443 = 2785 kg

Temperature correction = (–14 ÷ 10) × 0.6% = –0.84%

Corrected fuel used = **2762 kg**

Next leg start weight = 58 228 – 2762 = **55 466 kg**

9.

Figure 4.5.4 (CAP 697).

**Table 12.24**

| Pressure altitude (ft) | Time (min) | Fuel (kg) | Distance NAM | | |
|---|---|---|---|---|---|
| | | | Landing weight (kg) | | |
| | | | 55 000 | 65 000 | 57 000 |
| 35 000 | 20 | 275 | 102 | 105 | 102.6 |
| 10 000 | 9 | 185 | 33 | 34 | |
| 5000 | 6 | 140 | 18 | 18 | |
| 6000 | 6.6 | 149 | 21 | 21.2 | 21.04 |
| Difference | **13.4** | **126** | | | **81.56** |
| App and Ldg | 2 | 100 | | | |
| Totals | 15.4 | 226 | | | |

Mean pressure altitude = 20 500 ft. Mean ambient temperature = –5°C. KIAS 280 kts. TAS = 397 kts. Ground speed = 360 kts.

Ground distance = (81.56 × 360) ÷ 397 = 74 nm

10.

Figure 4.6.1 (CAP 697).

Fuel required = 10 500 kg

ISA deviation = –7 – (–17) = +10°C

Trip time = 3.35 hr = 3 hr 21 min

11.

Figure 4.7.2 (CAP 697).

**Table 12.25**

| Speed | Diversion weight (kg) | Time (min) |
|---|---|---|
| | | 120 |
| LRC | 45 000 | 739 |
| | 50 000 | 742 |
| | 46 500 | **739.9** |

12.

Figure 4.7.1a (CAP 697).

Fuel required = 8750 kg

Temperature correction = +1%

Corrected fuel required = 8837.5 kg

Icing correction = +20%

Corrected fuel required = 10 605 kg

Figure 4.7.1b (CAP 697).

Fuel required = 9100 kg

Temperature correction = +1%

Corrected fuel required = 9191 kg

Icing correction = +18%

Corrected fuel required = **10 845 kg**

13.

Figure 4.8.1 (CAP 697). Surplus fuel burn = 18.8%.
Figure 4.8.2 (CAP 697). Break even price = 123.5 cents per US gallon.
Therefore, fuel tankering is viable.

14.

Figure 4.7.3 (CAP 697).

Fuel required = 4250 kg

Diversion time = 2.2 hr = 2 hr 12 min.

## *Chapter 9 Sample questions*

1.

See Figure 12.9.
Fuel in tanks at *A* 25 000 kg. Reserve fuel required on return to *A* 5000 kg.

**Table 12.26**

| Leg | G/S (kts) | Leg distance (nm) | Accumulative distance (nm) | Fuel flow (kg/hr) | Fuel used (kg) | Fuel remaining (kg) |
|---|---|---|---|---|---|---|
| *A–B* | 280 | 180 | 180 | 3500 | 2250 | 22 750 at *B* |
| *B–C* | 300 | 220 | 400 | 3400 | 2493 | 20 257 at *C* |
| *C–D* | 250 | 300 | 700 | 3300 | 3960 | 16 297 at *D* |
| *D–E* | 280 | 250 | 950 | 3200 | 2857 | 13 340 at *E* |
| *E–D* | 255 | 250 | 950 | 3100 | 3039 | 16 248 at *E* |
| *D–C* | 235 | 300 | 700 | 3000 | 3830 | 13 209 at *D* |
| *C–B* | 270 | 220 | 400 | 2900 | 2363 | 9379 at *C* |
| *B–A* | 250 | 180 | 180 | 2800 | 2016 | 7016 at *B* |

Flight plan PSR = **828 nm from *A***.

2.

See Figure 12.9.

**Table 12.27**

| Time | Position | Accumulative distance Gone (nm) | Fuel remaining (kg) |
|---|---|---|---|
| 0947 | *A* | 0 | 25 000 |
| 1032 | *B* | 200 | 22 000 |
| 1127 | *C* | 430 | 19 000 |
| 1300 | *D* | 750 | 15 000 |

Distance travelled from *B* to *D* = 550 nm

Time from *B* to *D* = 2 hr 28 min

Mean ground speed = (550 ÷ 148) × 60 = **223 kts**

Fuel used between *B* and *D* = 22 000 – 15 000 = 7000 kg

Mean fuel flow = (7000 ÷ 148) × 60 = **2838 kg/hr**

3.

See Figure 12.9.
Revised PSR is **771 nm from *A***.

4.

See Figure 12.9.

Revised PSR to *B* with 6000 kg reserve fuel = **812 nm from *A***

Time to the revised PSR to *B* = [(812 – 700) ÷ 223] × 60 = 30 min

ETA at revised PSR to *B* = 1300 + 30 min = **1330**

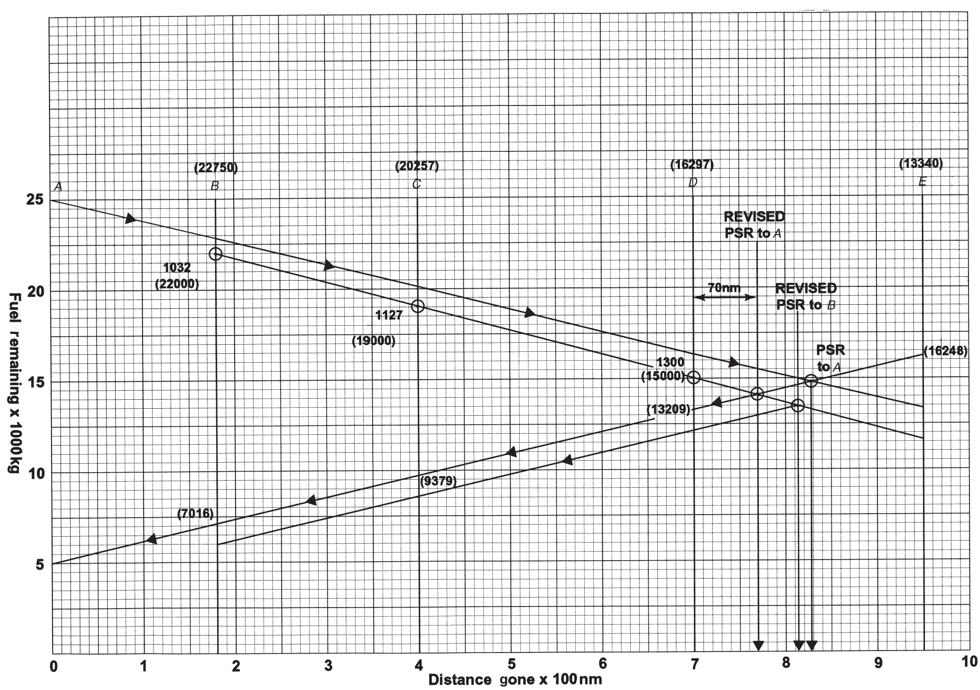



**Figure 12.9** Chapter 9. Solution to Questions 1–4.

5.

See Figure 12.10.
Fuel in tanks at *A* 28 000 kg. Reserve fuel required on return to *A* 7000 kg.

**Table 12.28**

| Leg | G/S (kts) | Leg distance (nm) | Accumulative distance (nm) | Fuel flow (kg/hr) | Fuel used (kg) | Fuel remaining (kg) |
|---|---|---|---|---|---|---|
| *A–B* | 320 | 250 | 250 | 4800 | 3750 | 24 250 |
| *B–C* | 350 | 200 | 450 | 4700 | 2686 | 21 564 |
| *C–D* | 370 | 280 | 730 | 4600 | 3481 | 18 083 |
| *D–E* | 390 | 310 | 1040 | 4500 | 3577 | 14 506 |
| *E–D* | 420 | 310 | 1040 | 4400 | 3248 | 18 398 |
| *D–C* | 400 | 280 | 730 | 4300 | 3010 | 15 150 |
| *C–B* | 380 | 200 | 450 | 4200 | 2211 | 12 140 |
| *B–A* | 350 | 250 | 250 | 4100 | 2929 | 9929 |

Flight plan PSR = **875 nm from *A***.

6.

See Figure 12.10.

**Table 12.29**

| Time | Position | Accumulative distance Gone (nm) | Fuel remaining (kg) |
|---|---|---|---|
| 1430 | *A* | 0 | 28 000 |
| 1520 | *B* | 250 | 23 800 |
| 1600 | *C* | 450 | 20 600 |
| 1656 | *D* | 730 | 16 000 |

Distance travelled from *B* to *D* = 480 nm

Time from *B* to *D* = 1 hr 36 min

Mean ground speed = (480 ÷ 96) × 60 = **300 kts**

Fuel used between *B* and *D* = 23 800 – 16 000 = 7800 kg

Mean fuel flow = (7800 ÷ 96) × 60 = **4875 kg/hr**

7.

See Figure 12.10.
Revised PSR is **763 nm from *A***.

8.

See Figure 12.10.

Revised PSR to *B* with 6000 kg reserve fuel = **910 nm from *A***

Time to the revised PSR to *B* = [(910 – 730) ÷ 300] × 60 = 36.0 min

ETA at revised PSR to *B* = 1656 + 36.0 min = **1732**

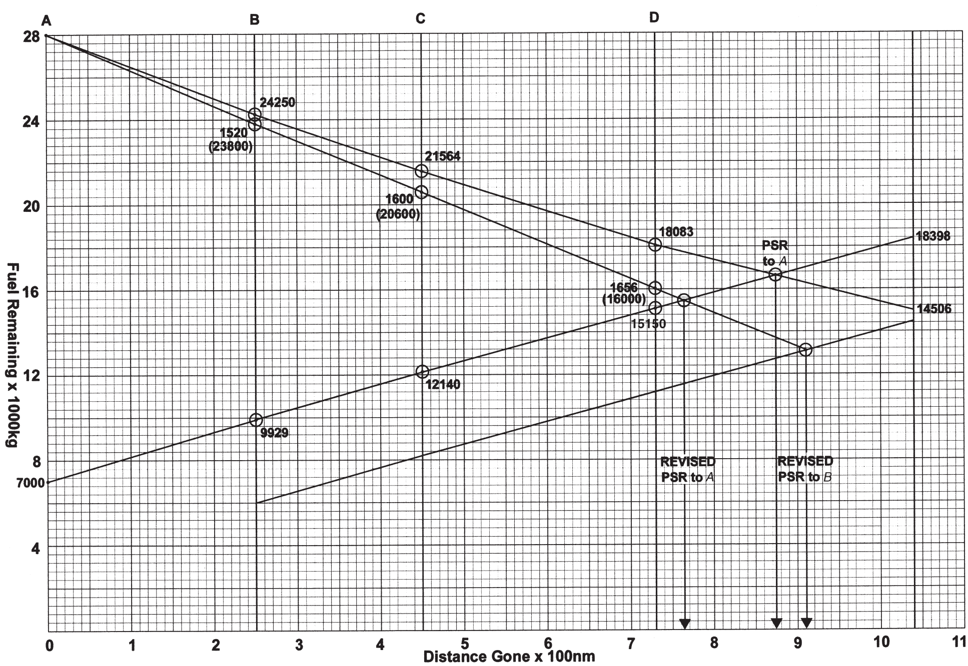



**Figure 12.10** Chapter 9. Solution to Questions 5–8.

## *Chapter 10 Sample questions*

**Table 12.30**

| | | | | | |
|---|---|---|---|---|---|
| **1.** | b | **5.** | d | **9.** | a |
| **2.** | d | **6.** | b | **10.** | b |
| **3.** | b | **7.** | c | **11.** | d |
| **4.** | b | **8.** | c | **12.** | c |

## *Chapter 11 Sample questions*

**Table 12.31**

| | | | |
|---|---|---|---|
| **1.** | c | **5.** | b |
| **2.** | c | **6.** | d |
| **3.** | d | **7.** | a |
| **4.** | a | **8.** | a |

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