Operations in Mountainous Areas

Terrain Clearance and Oxygen Requirements

Performance Engineer - Operations
Flight Operations Engineering

November 2002
Agenda:

- Descent Modes
- Terrain Clearance
  - Regulations
  - Analysis Methods
  - Operational Issues
- Oxygen Requirements (Passengers and Crew)
  - Oxygen Systems Overview
  - Regulations
  - Analysis Methods
  - Operational Issues
Issues

Terrain Clearance

- What are the legal requirements that I need to consider to plan a flight over mountainous areas?
- Where do I get terrain elevation information along a route? How much detail do I need?
- How do I conduct a terrain clearance analysis? Where do I find performance data?
- Are there any operational issues that might change how I do an analysis? What are they?
Oxygen Requirements (Passenger and Crew)

- What do the oxygen systems look like on Boeing airplanes for the flight crew? For passengers?
- What are the legal requirements that I need to consider to plan for flight over mountainous areas?
- How do I calculate oxygen requirements?
- Are there any operational or practical issues that I should consider in addition to the legal requirements?
### Enroute Descent Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Constraint</th>
<th>Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal Enroute Descent Modes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Min Fuel</td>
<td>Minimize descent fuel</td>
<td>CI = 0</td>
</tr>
<tr>
<td>• Min Time</td>
<td>Minimize trip time</td>
<td>CI = max</td>
</tr>
<tr>
<td>• Min Cost</td>
<td>Minimize descent cost</td>
<td>CI = K</td>
</tr>
<tr>
<td><strong>Non-normal Descent Modes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Engine Inoperative</td>
<td>Minimize R/D</td>
<td>Best L/D</td>
</tr>
<tr>
<td>Driftdown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Emergency</td>
<td>Maximize R/D</td>
<td>( V_{MO}/M_{MO} )</td>
</tr>
</tbody>
</table>
Operations in Mountainous Areas

Driftdown Profile

1) Set MCT thrust

2) Maintain level flight, decel to driftdown speed...

Engine Fails...

3) Maintain driftdown speed...

4) Choose from the following:

A. Maintain speed and climb as fuel burns off

B. Maintain level flight and accel to EOLRC speed gradually

C. Descend and accel to EOLRC speed immediately

A  B  C
Generic Emergency Descent Profile

1) Don oxygen masks
   Announce descent

2) Select lower altitude on MCP.
   Select LVL CHG, close thrust lever and extend speedbrakes...

3) Adjust speed and level off altitude...

4) Notify ATC
   Request altimeter settings
   Call out altitudes

5) Level off at lowest safe altitude or 10,000 ft whichever is higher
   Long range cruise speed
   Speedbrakes in down detent

6) Determine new course of action

NOTE: If structural damage is suspected, limit airspeed and avoid high maneuvering loads.
Operations in Mountainous Areas

Descent Profile for Various Descent Modes

767-300ER/PW4060
Initial GW = 155,000 kg

Driftdown (Max L/D)
Normal Descent (Cost Index = 50)
Emergency Descent (Mmo/Vmo)
Altitude Capability after Engine Failure for Various Descent Speeds

- **Max L/D (24,750 ft/50 min)**
- **LRC (22,630 ft/42.5 min)**
- **350 KIAS (16,580 ft/39 min)**

767-300ER/PW4060
Initial GW = 155,000 kg
ETOPs Area Capability after Engine Failure for Various Descent Speeds

767-300ER/PW4060
Initial GW = 155,000 kg

Max L/D:
60 Min Area ~ 357 nm

LRC:
60 Min Area ~ 417 nm

350 KIAS:
60 Minute Area ~ 448 nm
Operations in Mountainous Areas

Requirement to calculate terrain clearance

Obtain terrain information

Determine terrain clearance

Consider oxygen requirements

Data Sources

FAR (CFR), JAR OPS, CAA, CAAC, CASA, ???

Escape Route
Special Procedure
Reroute
Reduce payload

Escape Route
Special Procedure
Change O2 System
Reroute
Terrain Clearance Analysis
FAR / JAR Requirements for Terrain Clearance

• FAR 121.191 / JAR OPS 1.500

• FAR 121.193 / JAR OPS 1.505
  – Turbine Engine Powered: En Route Limitations: Two Engines Inoperative.

But first, consider FAR 25.123 . . .
**Net Flight Path [Enroute] – FAR 25.123**

**FAR Part 25.123** requires that the actual enroute airplane climb performance be calculated in the most conservative airplane configuration and then further decreased by the following gradient conservatisms:

**One-engine inoperative net flight path requirement**
- 1.1% for two engine airplanes
- 1.4% for three-engine airplanes
- 1.6% for four-engine airplanes

**Two-engine inoperative net flight path requirement**
- 0.3% for three-engine airplanes
- 0.5% for four-engine airplanes

*The enroute net flight path is used to ensure enroute terrain clearance*
AFM Engine-Out Data Uses Low Speed Drag Polar

Operations in Mountainous Areas

Flight Test Data

Low Speed Drag Polar

Req’d Gradient Decrement

AFM Certified Enroute Data (Net)

High Speed Drag Polar

No Gradient Decrement

Ops Manual Performance Data (Gross)
Gross and Net Performance Comparison During Driftdown

767-300ER/PW4060
Initial GW = 155,000 kg
Temperature = ISA

Max L/D

350 KIAS

Gross Performance
Net Performance

Range (nm)
Operations in Mountainous Areas

737-700 Driftdown from 35000 ft

Driftdown Speed = \( L/D_{\text{max}} \)
Initial Altitude = 35000 ft
Mid CG

Initial GW
- 70000 kg
- 66000 kg
- 62000 kg
- 58000 kg

Low Speed Drag Polar
High Speed Drag Polar
Operations in Mountainous Areas

737-700 Driftdown from 35000 ft

Driftdown Speed = 320 KIAS
Initial Altitude = 35000 ft
Mid CG

Initial GW

- 70000 kg
- 66000 kg
- 62000 kg
- 58000 kg

Low Speed Drag Polar
High Speed Drag Polar
FAR 121.191 / JAR OPS 1.500
Turbine Engine Powered: En Route Limitations:
One Engine Inoperative.
FAR 121.191 (paraphrased)

No person shall takeoff in an airplane at a weight that is greater than that which allows for compliance with the requirements of paragraph (a) (1) OR (a) (2), assuming the following conditions:

- En route net flight path data from the AFM is used
- Expected ambient en route temperatures are used
- Normal fuel and oil consumption is assumed
FAR 121.191(a) (1) (paraphrased)

- There is a positive slope (climb gradient) at an altitude of at least 1,000 feet above all terrain and obstructions within five statute miles on each side of the intended track

and

- There is a positive slope (climb gradient) at 1,500 feet above the airport where the airplane is assumed to land after an engine fails.
FAR 121.191(a) (1) (pictorial)

- Driftdown
- Gross Flight Path
- Net Flight Path
- Positive Climb Gradient
- 1000 feet
FAR 121.191(a) (1) (pictorial)

- Driftdown
- Gross Flight Path
- Net Flight Path
- Positive Climb Gradient
- 1500 feet
- Alternate Airport

Operations in Mountainous Areas
FAR 121.191(a) (2) (paraphrased)

The net flight path allows the airplane to continue flight from the **cruising altitude** to an airport where a landing can be made, clearing all terrain and obstructions within five statute miles of the intended track by at **least 2,000 feet vertically**.
FAR 121.191(a) (2) (pictorial)

- Driftdown
- Gross Flight Path
- Net Flight Path
- Positive Climb
- Gradient

2000 feet
FAR 121.191 Performance Assumptions

For the purposes of paragraph (a) (2), it is assumed that:

– The engine fails at the most critical point en route
– Navigational accuracy is considered
– Adverse winds are considered
– Fuel jettison is allowed
– Alternate airport is in dispatch release and meets weather minima (adequate and suitable)
– Take into account normal fuel and oil consumption
JAR OPS 1.500

- Essentially the same as FAR 121.191 with the following exception
  - Must consider terrain and obstructions within 5 nautical miles not 5 statute miles (4.34 nautical miles)
FAR 121.193 / JAR OPS 1.505
Turbine Engine Powered: En Route Limitations: Two Engines Inoperative.
FAR 121.193(c)* (paraphrased)

Enroute Limitations - Two Engines Inoperative

No person may operate a turbine engine powered airplane along an intended route unless he complies with either of the following:

(1) There is no place along the intended track that is more than 90 minutes (with all engines operating at cruising power) from a suitable alternate airport.

OR

(2) The airplane can fly from the point where two engines are assumed to fail simultaneously to a suitable alternate airport, with the net flight path clearing vertically by at least 2,000 feet all terrain and obstructions within five statute miles (4.34 nautical miles) on each side of the intended track.

AND

The net flight path has a positive slope at 1,500 feet above the airport where the landing is assumed to be made after the engines fail;

* For aircraft certificated after August 29, 1959.
Example 747-400 Route and Alternates

FAR 121.193 (c) (1) is satisfied because route stays within 90 minutes of an airport

- 2 engine inoperative driftdown analysis is not required

Circles represent 90 minutes from airport at normal all engine cruise conditions
FAR 121.193 (c) (1) is not satisfied because route is outside the 90 minute circles.

- 2 engine inoperative driftdown analysis is required.
FAR 121.193 (c) (2) (pictorial) (three- and four-engine aircraft only)

Driftdown

Gross Flight Path

Net Flight Path

2000 feet

2000 feet
For the purposes of this subparagraph, it is assumed that:

- The two engines fail at the most critical point en route
- Ambient temperatures anticipated along the route are considered
- Fuel jettison is allowed
- The airplane's weight at the point where the two engines are assumed to fail provides enough fuel to continue to the airport and to fly for 15 minutes at cruise power or thrust, or both
- Analysis takes into account normal fuel and oil consumption
Terrain Information

- 10,000 ft and above
- 7,000 ft to 10,000 ft
- 3,000 ft to 7,000 ft
- Up to 3,000 ft

Operations in Mountainous Areas
Terrain Clearance Information Sources

• Flight Planning Service route profile
• Jeppesen High Altitude Charts
• Jeppesen Low Altitude Charts
• Governmental Terrain Charts
• Operational Navigational Charts (ONC)
• Tactical Pilotage charts (TPC)
• Other Sources ? ? ?
Terrain Profile Provided in Jeppesen FliteStar

- Minimum Enroute Altitude

Normal flight profile
The Minimum Enroute Altitude is the minimum altitude to clear all obstacles within +/- 5 statute miles of the route by at least 2000 feet and also assures acceptable navigational signal coverage.

MEA = 16,000 ft

Grid MORA = 22,300 ft

The Grid Minimum Off Route Altitude is the minimum altitude to clear all obstacles within the grid area by at least 2000 feet.
The Minimum Obstruction Clearance Altitude (MOCA) is the lowest published altitude between radio fixes on VOR airways, off-airway routes, or route segments which satisfy obstacle clearance requirements between the fixes specified. It is followed by a ‘T’ when specified (13500T).

The Minimum Off Route Altitude (MORA) represents altitudes which provide the required clearance over terrain located within 10 nm of the route segment. It is followed by an ‘a’ when specified (17900a).

MOCA = 13,500 ft

MORA = 17,900 ft
Terrain Clearance Information Sources

Jeppesen High Altitude Chart

Only MEAs which are higher than the floor (usually FL180 – FL220) of the upper airspace are depicted.
The Minimum Elevation Figure (MEF) is based on information available concerning the highest known feature in each quadrangle, including terrain and obstructions (trees, towers, antennas, etc.).

MEF = 16,200 ft
Tactical Pilotage Chart (TPC) Area Map
(For Use in Determining Off-track Escape Routes)

MEF = 13,800 ft
Other Sources of Terrain Information???
Example Route for Flight Planning
Terrain Clearance Analysis

Panama City
Buenos Aires
Engine-out Terrain Clearance Analysis Procedure

1) check engine-out net level-off height at takeoff gross weight.

2) check engine-out net level-off height at actual enroute weight upon entering mountainous area.

3) check engine-out driftdown profile at actual enroute weight for critical terrain. If not sufficient, look at re-routing options, escape paths or reduce payload.
Driftdown Data in Documents

**Airplane Flight Manual**
Enroute climb speeds - 1 and 2 engines inoperative
Enroute climb gradient - 1 and 2 engines inoperative
Enroute climb weights - 1 and 2 engines inoperative

**Operations Manual/FPPM**
QRH - Speeds and gross level-off altitude
Dispatch data in OM/FPPM:
- Net driftdown profiles
- Net level off height/weight (optimum)
- Net level off height/weight (ETOPS)
- Driftdown/LRC cruise range capability

**INFLT Software**
Driftdown profiles can be calculated at any speed...
Calculate Takeoff Gross Weight

Airport-Specific Performance Limited TOW

Max Structural TOW

TOW limited by Max Landing Weight for route

Choose most limiting of weights

Add arbitrary MEL/CDL allowance

Use given weight as TOW in terrain analysis
Calculate Takeoff Gross Weight for example analysis

A/P-Specific Performance
Limited TOW
> 70,080 kg

Max Structural TOW
70,080 kg

TOW limited by Max Landing Weight for route
Not Limited

Choose most limiting of weights
70,080 kg

Add arbitrary MEL/CDL allowance
~ 2000 kg

Use given weight as TOW in terrain analysis
72,080 kg
Terrain Profile Provided in Jeppesen FliteStar

- **Minimum Enroute Altitude**
- **Normal flight profile**

Diagram showing a terrain profile with altitude and distance markers.
Check whether TOGW clears terrain by at least 1000 feet
Check whether TOGW clears terrain by at least 1000 feet

**Conclusion:** TOGW does not satisfy terrain clearance requirements.
Engine-out Terrain Clearance Analysis Procedure

1) check engine-out net level-off height at takeoff gross weight.

2) check engine-out net level-off height at actual enroute weight upon entering mountainous area.
Calculate Actual Enroute Weight

- Weight @ 1st Mtns = TOGW - Fuel Burned
  (1st Mtns are 800 nm along the route)

- Fuel Burned = Climb fuel + Cruise fuel
### Operations in Mountainous Areas

#### 280/.78 Enroute Climb

**ISA & Below**

<table>
<thead>
<tr>
<th>PRESSURE ALTITUDE (FT)</th>
<th>UNITS</th>
<th>BRAKE RELEASE WEIGHT (100 KG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MIN/KG NM/KTAS</td>
<td>86</td>
</tr>
<tr>
<td>41000</td>
<td>TIME/FUEL DIST/SPD</td>
<td>23/175</td>
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<tr>
<td>40000</td>
<td>TIME/FUEL DIST/SPD</td>
<td>143/408</td>
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<tr>
<td>39000</td>
<td>TIME/FUEL DIST/SPD</td>
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<td>29000</td>
<td>TIME/FUEL DIST/SPD</td>
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<td>28000</td>
<td>TIME/FUEL DIST/SPD</td>
<td>106/375</td>
</tr>
<tr>
<td>26000</td>
<td>TIME/FUEL DIST/SPD</td>
<td>89/366</td>
</tr>
</tbody>
</table>

**Climb Fuel = 1800 kg**
Cruise Fuel = Fuel Flow/hr X Hours

= $\text{FF/hr X Distance} / \text{Speed}$  \( \text{Distance} = 800 - 120 \text{ nm} = 680 \text{ nm} \)

= 1291 kg/eng/hr X 2 engines X 680 nm / 453 nm per hour

= 3875 kg
Enroute Weight @ 1st Mountains

- Weight@Mtns = TOGW - Fuel Burned

- Fuel Burned = Climb + Cruise
  = 1800 kg + 3875 kg
  = 5675 kg

- Weight@Mtns = 72,080 kg - 5675 kg
  = 66405 kg
Check whether enroute weight clears terrain by at least 1000 feet.
Check whether enroute weight clears terrain by at least 1000 feet

Conclusion: Enroute weight satisfies terrain clearance at first mountains. Check enroute weight at second mountains.
Calculate Actual Enroute Weight

• Weight @ 2nd Mtns = TOGW - Fuel Burned
  (2\text{nd} Mtns are 1400 nm along route)

• Fuel Burned = Climb + Cruise
Cruise Fuel = Fuel Flow/hr X Hours

= FF/hr X Distance / Speed

Distance = 1400 nm – 120 nm = 1280 nm

= 1190 kg/eng/hr X 2 engines X 1280 nm / 448 nm per hour

= 6800 kg
Enroute Weight @ 2nd Mtns

- Weight@Mtns = TOGW - Fuel Burned

- Fuel Burned = Climb + Cruise
  
  $= 1800 \text{ kg} + 6800 \text{ kg}$
  
  $= 8,600 \text{ kg}$

- Weight@Mtns = 72,080 kg – 8,600 kg
  
  $= 63,480 \text{ kg}$
Check whether enroute weight clears terrain by at least 1000 feet
Operations in Mountainous Areas

Check whether enroute weight clears terrain by at least 1000 feet

Conclusion: Enroute weight does not meet terrain clearance requirements. Consider driftdown profile.
Engine-out Terrain Clearance Analysis Procedure

1) check engine-out net level-off height at takeoff gross weight.

2) check engine-out net level-off height at actual enroute weight upon entering mountainous area.

3) check engine-out driftdown profile at actual enroute weight for critical terrain. If not sufficient, look at re-routing options, escape paths or reduce payload.
Determine the driftdown distance to 20,200 ft (terrain + 2000 ft) at the actual enroute weight (63,500 kg).

**Remember, winds must be considered in this analysis**

Wind ~ 40 kt headwind from Jujuy to LaPaz (85% Annual)
Turnback required before this point
Either continuation or turnback is possible
Example text of dispatch pilot procedures

- Between BLOTA (S08 08.9 W071 16.2) and RAXUN (S14 26.9 W069 28.8), divert on-track to Puerto Maldonado.
- Between RAXUN (S14 26.9 W069 28.8) and OROKO (S21 52.0, W066 08.0), divert on-track to La Paz.
- After OROKO (S21 52.0, W066 08.0), divert on-track to Jujuy.
Operational Considerations for Terrain Clearance Analysis???
Possible Turnback Scenario at High Speeds/Small Bank Angles

- Initiate Turnback
- Engine Failure/Decompression Occurs
- Radius of Turn $F(TAS, \text{Bank Angle})$
- Track Width (4.3 nm)
## Radius of Turn Requirements at Cruise Speeds

**Initial Cruise Speed (.78 Mach, FL370) ~ 240 IAS (430 KTAS)**

<table>
<thead>
<tr>
<th>Bank Angle</th>
<th>Radius of Turn</th>
<th>Req’d Track Width (2*R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°</td>
<td>67,500 ft</td>
<td>22.2 nm</td>
</tr>
<tr>
<td>25°</td>
<td>38,000 ft</td>
<td>12.6 nm</td>
</tr>
<tr>
<td>35°</td>
<td>26,000 ft</td>
<td>8.6 nm</td>
</tr>
</tbody>
</table>

**Approximate Final Driftdown Speed ~ 220 IAS (320 KTAS)**

<table>
<thead>
<tr>
<th>Bank Angle</th>
<th>Radius of Turn</th>
<th>Req’d Track Width (2*R)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15°</td>
<td>35,000 ft</td>
<td>11.6 nm</td>
</tr>
<tr>
<td>25°</td>
<td>20,000 ft</td>
<td>6.6 nm</td>
</tr>
<tr>
<td>35°</td>
<td>13,000 ft</td>
<td>4.2 nm</td>
</tr>
</tbody>
</table>
Considerations for Turn Radius

• Terrain outside of 5 statute mile track width?
• Difficult terrain on one side of track, but not on the other
• Flight path after turnback: go back to track or continue parallel to track (offset by XX nm)
• Can you meet engine out requirements for a 23 nm track width on both sides of the flight path? On one side of the flight path?
Operations in Mountainous Areas

Left hand turn into terrain w/ grid MORA = 22,900; 24,800 ft

Right hand turn into terrain w/ grid MORA = 20,300; 12,500 ft
Gradient Decrement Profile in a Turn with One Engine Inoperative

- Begin to Decelerate to Max L/D Speed
- Engine Failure Occurs
- Turnback (at increased gradient decrement)
- Begin Driftdown
- FL370
- FL330
- FL290
Procedure Assumed for Altitude Decrement Calculation Due to Turnback

-All Aircraft-

• Initiate turnback 1 minute after engine failure.

• Speed: LRC before loss of engine
  Max L/D after loss of engine

• Weight: Generally middle to light weight
  \( \sim \text{MLW} + 5000 \text{ kg} \)

• Assume gross driftdown performance;

• Assume A/C maintains constant gradient decrement in turn (initial gradient);

• Turn radius calculated based on TAS entering turn.
Effect of Turning on Altitude

Maximum Altitude Decrease Due to Turnback
Effect of Turning on Altitude
Gross vs. Net Performance

Terrain Envelope
Oxygen Systems, Requirements & Analysis
**Oxygen Systems**

- **Flight Crew**
  - Gaseous System (fixed bottles)

- **Passenger Cabin**
  - Chemical System (fixed canisters)
  - Gaseous System (fixed bottles)
Flight Crew Oxygen System
Passenger Chemical Oxygen System
Passenger Gaseous Oxygen System
1) Don oxygen masks
Announce descent

2) Select lower altitude on MCP.
Select LVL CHG, close thrust lever and extend speedbrakes...

3) Adjust speed and level off altitude...

4) Notify ATC
Request altimeter settings
Call out altitudes

5.) Level off at lowest safe altitude or 10,000 ft whichever is higher
Long range cruise speed
Speedbrakes in down detent

6.) Determine new course of action

NOTE: If structural damage is suspected, limit airspeed and avoid high maneuvering loads.
Operations in Mountainous Areas

737-700 CFM56-7 Emergency Descent Profiles for Chemical Oxygen System

- Standard day, no wind
- Initial FL 350
- Spoilers extended during descent
- Includes initial 20 second delay
- Descent: Vmo/Mmo(340 kt/.82 M)
- Cruise @ 10,000 ft: LRC

**Standard 12 Minute System**

**Optional 22 Minute System**

- Altitude (ft)
- Range (nm)
### FARs Governing Crew and Passenger Oxygen Systems

<table>
<thead>
<tr>
<th>Crew</th>
<th>Passenger</th>
<th>Federal Air Regulation (FAR)</th>
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<tbody>
<tr>
<td>X</td>
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<td><strong>25.1439</strong> Protective Breathing Equipment</td>
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<tr>
<td>X</td>
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<td><strong>25.1443</strong> Minimum Mass Flow of Supplemental Oxygen</td>
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<td>X</td>
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<td><strong>25.1447</strong> Equipment Standards for Oxygen Dispensing Units</td>
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<tr>
<td>X</td>
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<td><strong>121.329</strong> Supplemental Oxygen for Sustenance: Turbine Engine Powered Airplanes</td>
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<tr>
<td>X</td>
<td>X</td>
<td><strong>121.333</strong> Supplemental Oxygen for Emergency Descent and for First Aid: Turbine Engine Powered Airplanes with Pressurized Cabins</td>
</tr>
<tr>
<td>X</td>
<td></td>
<td><strong>121.337</strong> Operators Protective Breathing Requirements</td>
</tr>
</tbody>
</table>
**Oxygen Requirements**

There are two types of requirements for oxygen:

**Supplemental Oxygen**
- Protects against hypoxia in the case of decompression or loss of cabin altitude
- Oxygen required is altitude dependent (higher oxygen flow rate is required at higher altitudes)

**Protective Oxygen**
- Protects against smoke and harmful gas inhalation in the case of a fire etc. (required for flight crews only; not required for passengers)
Flight Crew Oxygen Requirements

The flight crew oxygen system must supply sufficient oxygen to each flight deck occupant for each of the following conditions:

FAR Sec. 121.329 (b)(1),(b)(2) – Supplemental Oxygen
– The airplane’s actual emergency descent profile from maximum certified cruise altitude to 10,000 feet following the loss of cabin pressurization.

FAR Sec. 121.333(b) – Supplemental Oxygen
– The FAA theoretical constant rate of descent from the airplane’s maximum certified cruise altitude to 10,000 feet in 10 minutes, followed by 110 minutes at 10,000-foot cabin altitude.

FAR Sec. 121.337(b)(7)(i) – Protective Oxygen
– 15 minutes of protective breathing for each crew member at a normal cabin pressure altitude of 8,000 ft (no decompression).
Flight Crew mask Usage

3 settings:

**EMERG** Used for Protective Breathing

**100%** Used for Supplemental/Descent

**NORMAL** Used after Descent (level off)
# Operations in Mountainous Areas

## Flight Crew Oxygen Requirements (Protective Breathing)

### Flight Planning

Simplified Flight Planning

Flight Planning and Performance Manual

### Crew Oxygen Requirements

#### Required Pressure (PSI) for 76 FT3 Cylinder

<table>
<thead>
<tr>
<th>BOTTLE TEMPERATURE</th>
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<th>3</th>
<th>4</th>
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#### Required Pressure (PSI) for 114/115 FT3 Cylinder

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Operations in Mountainous Areas

FAR 121.329(c) / JAR 1.770  Passenger Cabin Oxygen Requirements

Each certificate holder shall provide a supply of oxygen for passengers in accordance with the following:

- **10% Passenger Oxygen Required**
- **100% Passenger Oxygen Required**
- **No Passenger Oxygen Required**

FAR 121.333(e) There must be not less than a 10-minute supply of oxygen for passenger cabin occupants.
Operations in Mountainous Areas

Oxygen Requirements Analysis
FAR 121.657 (c)
All-engine Terrain Clearance

- No person may operate an aircraft under IFR including over-the-top or at night under VFR at an altitude less than 1,000 feet above the highest obstacle within a horizontal distance of five miles from the center of the intended course, or, in designated mountainous areas, less than 2,000 feet above the highest obstacle within a horizontal distance of five miles from the center of the intended course.
All-engine Mountainous Terrain Clearance Requirement
All-engine Mountainous Terrain Clearance Requirement
FAR 121.329(c) / JAR 1.770  Passenger Cabin Oxygen Requirements

Each certificate holder shall provide a supply of oxygen for passengers in accordance with the following:

- 100% Passenger Oxygen Required
- 30% Passenger Oxygen Required
- 10% Passenger Oxygen Required
- No Passenger Oxygen Required
Operations in Mountainous Areas
Range of Decision Points

- **Point of No Return (PNR)** - Last point from which course reversal & diversion to Cali is possible.
- First point from which forward diversion to Iquitos is possible.
Route beyond critical point
Oxygen Profile from Critical Point to Iquitos

Clearance Requirement

Iquitos
Operations in Mountainous Areas

Procedures as part of the dispatch package

- Example text of dispatch pilot procedures
  - Between ASIKO (N04 14.8 W076 53.9) and Waypoint #1 (N01 59.4 W075 43.8), divert on-track to Cali.
  - Between Waypoint #1 and Waypoint #2 (S14 28.64 W069 03.81), divert on-track to Iquitos.
Operations in Mountainous Areas
Terrain for Second Half of Route

La Paz

Iquitos
12-minute oxygen system into La Paz
12-minute oxygen system into La Paz

Conclusion: The 12-minute system is not sufficient
Options if 12 Minute System does not meet Requirements

- Determine the details of limiting terrain to see if descent to 10,000 ft is possible while avoiding terrain.
- Consider off-track diversions to alternates.
- Establish a different flight plan to avoid the limiting terrain.
- Consider a 22 minute oxygen system instead of a 12 minute system.
- Add portable supplemental oxygen bottles to increase the time that the airplane can fly over limiting terrain and still meet the oxygen requirements.
Diversion to La Paz with 22-minute system
Diversion along track beyond critical point
Diversion along track beyond critical point

Conclusion: On-track diversion is not an option beyond La Paz. Identify off-track alternate airport.
Off-route Alternates

Critical point

La Paz
Cochabamba
Sucre
Tarija
Jujuy
Off-route diversion from critical point to Sucre
Off-route Alternates

- La Paz
- Sucre
- Jujuy

Critical point
2nd critical point
Off-route diversion from second critical point to Sucre
Off-track Alternate Availability Areas

Critical Point

La Paz

125 nm

Sucre

Jujuy
Operations in Mountainous Areas

Generic Descent Profile for 22-minute System
Off-route Alternates

- La Paz
- Sucre
- Jujuy

Critical point
2nd critical point
On-track diversion from 2nd critical point to Jujuy
On-track diversion from 2nd critical point to Jujuy

Conclusion: Cannot reach Jujuy from second critical point. Must identify third critical point.
Operations in Mountainous Areas

Off-route Alternates

La Paz
Critical point

Sucre

Tarija

Jujuy

2nd critical point

3rd critical point
Off-route diversion from second critical point to Tarija
Off-route diversion from 3rd critical point to Tarija
On-track diversion from 3rd critical point to Jujuy
Off-track Alternate Availability Areas

Critical Point

La Paz

Sucre

Tarija

Jujuy
Terrain Height between Jujuy and Buenos Aires is not critical for oxygen analysis.
Operations in Mountainous Areas

Procedures as part of the dispatch package
Example text of dispatch pilot procedures

– Between Waypoint #2 (S14 28.64 W069 03.81) and Waypoint #3 (S18.30 W067 30.00), divert on-track to La Paz.
– Between Waypoint #3 (S18 30.00 W067 30.00) and Waypoint #4 (S20 30.00 W066 50.00), divert off-track to Sucre.
– Between Waypoint #4 (S20 30.00 W066 50.00) and Waypoint #5 (S22 30.00 W066 00.00), divert off-track to Tarija.
– After Waypoint #5 (S22 30.00 W066 00.00), divert on-track to Jujuy.
Modifying a Route to Avoid High Terrain
Operations in Mountainous Areas

Re-routed Track

Route distance = 2960 nm

Original Track

Route distance = 2900 nm
Pros and Cons to Rerouting to Avoid Terrain

- Increased track distance (2%)
  - Increased Fuel (Potential loss of P/L?)
  - Crew duty time?
  - Flight time

+ Requirement to verify suitable alternate airports at dispatch over high terrain with escape plans

+ Decreased complexity of crew work load in normal flight plan

+ If event occurs, less complicated diversion workload for flight crew

+/- Weather?
Operational Considerations for Oxygen Analysis???
Operation in Mountainous Areas

- Terrain clearance requirements satisfied ✓
- Oxygen requirements satisfied ✓
- Dispatch package includes special procedures or information ✓