Improved decompression training with modified oxygen mask with positive pressure

presented by

Dipl.-Ing. Björn Appel (Technische Universität Berlin)
E-Mail: bjoern.appel@tu-berlin.de

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Motivation

- **Flight Safety**
  - Rapid Decompression is very improbable, but can occur

- **High Altitude Operations**
  - Boeing B-787, Airbus A350 XWB will operate more often at higher altitudes
  - Manual flying skills vs. Future Automatic Emergency Descent System

- **Oxygen Mask “Nice to Know vs. Need to Know”**
  - Quick donning times in emergency operations
  - Commercial pilot knowledge and practice about positive pressure breathing

- **Regulations**
  - Different regulations between FAA and EASA for use of oxygen mask during single pilot operations

- **Training Gap**
  - Improved Decompression Training necessary?
Physiological Oxygen Background

- Partial pressure of oxygen decreases with increasing altitude
- Body cannot be supplied with sufficient oxygen
- From 6,000-8,000 m (~20,000-26,000 ft) cabin altitude a **loss of consciousness** can be expected in a short time

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>TUC</th>
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<tbody>
<tr>
<td>15000</td>
<td>30 or more minutes</td>
</tr>
<tr>
<td>18000</td>
<td>20-30 minutes</td>
</tr>
<tr>
<td>22000</td>
<td>5-10 minutes</td>
</tr>
<tr>
<td>25000</td>
<td>3-5 minutes</td>
</tr>
<tr>
<td>28000</td>
<td>2.5-3 minutes</td>
</tr>
<tr>
<td>30000</td>
<td>1-3 minutes</td>
</tr>
<tr>
<td>35000</td>
<td>30-60 seconds</td>
</tr>
<tr>
<td>40000</td>
<td>15-20 seconds</td>
</tr>
<tr>
<td>43000</td>
<td>8-12 seconds</td>
</tr>
<tr>
<td>50000</td>
<td>6-9 seconds</td>
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</table>
Oxygen Mask - Functions

Smoke Protection
- Crew must be protected against fire gases or other toxic gases.
- Mask produces a slight positive pressure to protect the flight crew.
- Smoke protection function must be activated by the flight crew.
- max. pressure is 2hPa

Positive Pressure
- With increasing altitude it is not sufficient to supply pure oxygen.
- In addition, the pressure must be increased to maintain the efficiency of the cockpit crew upright.
- Pressure automatically increased between 39,000-43,000 ft
- Max. pressure is 25hPa
- Exhalation is more difficult
- Interference with communication
- Positive Pressure function cannot be tested with normal oxygen mask

2 EMERGENCY pressure selector

Use of this selector creates an overpressure which eliminates condensation and prevents smoke, smell or ashes from entering the mask.
- Pressing this knob generates an overpressure for a few seconds.
- Turning the knob, in the direction of the arrow, generates a permanent overpressure.

Note: Overpressure supply is automatically started, when cabin altitude exceeds 30,000 feet.
Improved Oxygen Mask Training

Supposition
- Effects of positive pressure function are unknown by commercial pilots

Content of Oxygen Mask Training
- Demonstration and description of all mask functions
- Application of new mask with realistic positive pressure during decompression training
- Special breathing and communication techniques under positive pressure
- Reset of oxygen mask after usage
- Reinstallation of oxygen mask
Scenario Description of Simulator Trial

- Cockpit preparation and Take-off at Vancouver (YVR) for a flight to Frankfurt (FRA)
- Reposition to Greenland at FL430
- One crewmember left cockpit
- Uncontained engine failure caused a rapid decompression (20 sec) and autopilot / flight director failure
- Observation of mask handling with positive pressure function
- Emergency descent considering high terrain
- Realistic ATC and cabin communication
- Diversion to Kangerlussuaq (BGSF) with moderate weather conditions
Comparative analysis with two groups (Trained and Untrained):

- **Trained Group**
  - Pilots with lower flight experience
  - All FO or SFO
  - Pilots receive a briefing in positive pressure breathing before simulator trial

- **Untrained Group**
  - Pilots with higher flight experience
  - All CPT or/and INST
  - Pilots receive a briefing in positive pressure breathing after simulator trial

<table>
<thead>
<tr>
<th>familiar with ...</th>
<th>Group</th>
<th>Trained Group</th>
<th>Untrained Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>before simulator trial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Altitude Operation</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Manual Flight</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>before simulator session</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Decompression</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Positive Pressure Breathing</td>
<td>yes</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Single Engine Operation</td>
<td>no</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>Single Pilot Operation</td>
<td>no</td>
<td>no</td>
<td></td>
</tr>
</tbody>
</table>

Single Pilot Operation with One Engine Out new for both groups
Simulator Trials

- With qualified A330 Full Flight Simulator
- Technical preparation in Berlin and Helsinki to ensure equal trial conditions and examination:
  - Installation of experimental oxygen mask
  - Repositioning scripts
  - Malfunctions scripts / programming
    - Engine Failure & Engine Rapid Burst,
    - Decompression, Autopilot off, FD ok
  - Record of 300 simulator parameters
  - ATC and trial schedule
  - Audio/Video and ECG recording
- February 2010 in Helsinki at Finnair flight training center
Results – Groups and Demographics

- All Pilots participated voluntarily from one airline
- All pilots with A330/A340 rating
- 9 Sessions were filled with complete crews, all participants were male.
- Last decompression training took place in average 12-23 month before trial

Untrained Group
- Mean Experience: 17,000 flight hours
- 9x Captain (2x Instructor)
- 1x Senior First Officer

Trained Group
- Mean Experience: 6,000 flight hours
- 4x Senior First Officer / 4x First Officer
Results – Mask Donning Time

- **Untrained Group**
  - Mean time: 10-12 seconds
  - Max. time: 14 seconds
  - 3x pilots had mask on before decompression

- **Trained Group**
  - Mean time: 6-7 seconds
  - Max. time: 14 seconds
  - 2x pilots had mask on before decompression

- **Conclusion**
  - Trained group is faster
Results – Positive Pressure Breathing

- Positive Pressure can be confused with the emergency pressure
- or positive pressure can be misunderstood as a faulty mask!
  - **Untrained Group**
    - 5x pilots
  - **Trained Group**
    - no pilots

**Conclusion**
- **Untrained group** had no knowledge and experience of positive pressure

During the experiment, I thought that the mask was faulty.
Results – Task Load

Background ECG

- Heart Rate
  - → No significant Task Load Indication
- Heart Rate Variability
  - → Significant Task Load Indication

Before Decompression

- Both groups have high heart rate variability
- Low workload indication
Results – Task Load (2)

During Positive Pressure Breathing
- **Untrained Group** has significant lower heart rate variability than **Trained Group**
- **Untrained Group** has higher task load

After Positive Pressure Breathing
- **Untrained Group** has lower heart rate variability than **Trained Group**
- **Untrained Group** has higher task load and needs more time to normalize heart rate
Results – Flight Parameters (1)

Lateral Profile
- Pilots left actual track to left and right side
- No differences between both groups

Vertical Profile
- **Trained Group** reached lower altitudes earlier than **Untrained Group**
Results – Flight Parameters (2)

**Speed Profile**
- Tendency of lower airspeeds than autopilot for both groups

**Vertical Speed**
- Both groups show greater variability of vertical speed than the vertical speed of autopilot.

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*Untrained Group*  
*Trained Group*  
*Autopilot*
Results - Performance Index

During Positive Pressure Breathing
- **Untrained Group** has significant larger deviation from autopilot than **Trained Group**

After Positive Pressure Breathing
- **Untrained Group** and **Trained Group** have same deviation from autopilot profile
Recommendations

Training
- Mask with positive pressure are useful for decompression training
- Training with realistic and challenging scenarios are useful to increase safety and identify problems
- Emergency descent under manual flight is useful to train flying skills

Operations
- Check the oxygen mask before every aircraft take over.
- Discuss an addition of the oxygen mask reset to decompression checklist.
- Harmonize operational regulation for mask usage during single pilot operation above certain altitudes.

Handbooks
- Explain the positive pressure function of the masks in more detail
- Clearly highlight the differences between smoke pressure and high altitude positive pressure
- Highlight the mask reset function after mask usage

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Thank you very much for your attention

Prof. Dr.-Ing. Gerhard Hüttig
Dipl.-Ing. Björn Appel
Dipl.-Ing. Ekkehart Schubert
Technische Universität Berlin (TUB)
Department of Aeronautics and Astronautics
Chair of Flight Guidance and Air Transportation
Marchstr. 12-14
D-10587 Berlin
GERMANY
Internet: http://www.ff.tu-berlin.de

Prof. Dr. Jürgen Wenzel
German Aerospace Center (DLR)
Institute of Aerospace Medicine
Flight Physiology
Linder Höhe
D-51147 Cologne
GERMANY
Internet: http://www.dlr.de/me/