NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety

Washington, D.C. 20594

Attachment 36

Flight Test Results for UPS B747 Flight 6 Accident, Oxygen System Data Collection

OPERATIONAL FACTORS/HUMAN PERFORMANCE AND CVR GROUP SUPPORT TO THE U.S. ACCREDITED REPRESENTATIVE

DCA10RA092

SDF Flight Test Results

Aircraft: Boeing 747-400 (BCF[1]), N579UP, Flight 9902

Airport: Louisville, KY (KSDF)

Participants:

Flight Test #1 - Tasks 1 and 2:

NTSB: Katherine Wilson (Operations/Human Performance Group)

David Lawrence (Operations/Human Performance Group)

Doug Brazy (CVR[2] Group)

UPS: Captain Doug Menish

Captain John Fanning[3]

Date/departure Time:[4] November 17, 2010, 1252 EDT

Objectives:

1. To document, in flight, the audio/sound differences when positioning the oxygen mask system to various settings (normal, 100%, emergency) with and without the smoke goggles vent on.
2. To document, on ground, the donning and accessibility of emergency equipment within the cockpit to flight crew members.

Overview:

[1] Boeing converted freighter
[2] Cockpit Voice Recorder
[3] Capt. Fanning was a captain on the B-747-400 and former APD. He was type rated on the B-747-400, B-727, B-757, and B-767, and was a flight engineer on the L-382. He had about 10,000 hours total time and 9,000 hours as pilot in command.
[4] Note: Initial Task 1 and Task 2 data was collected during the 11/17/2010 flight tests in SDF. Additional data for Task 2 was collected on March 3, 2011 in SDF, and is attached as an Addendum.

The group chairmen of the Operational Factors/Human Performance Group and CVR Group participated in an observational study. The airplane used for the observations was a UPS Boeing 747-400, a BCF, N579UP, operating as flight 9902 heavy.

The purpose of the test flight was to document the audio/sound differences on the flight deck when crewmembers have donned oxygen masks and smoke goggles to be used as a comparison to the audio/sounds from the UPS 6 flight. In addition, the accessibility of emergency equipment available in the cockpit was documented.

The pilots and observers were fully briefed on each task and scenario before it was attempted.

During the test flight, the observers captured data via hand written notes, and audio and video recording. At the completion of the flight, the pilots flying provided comments on ease of completing the procedure and other observations made.

Task 1

Takeoff – KSDF

Initial Setup

- Weight - Normal Takeoff, Normal Thrust Setting
- CG - OPTIONAL
- Config - Standard

		Flaps/Gear	
Risk	**Cond.**	**Flaps**	**Operation**
		10	Perform normal flaps 10 takeoff

Climb to FL320

Initial Setup

- Weight - Normal Climb to FL320[5]
- Thrust - Normal Climb
- Config - Standard
- Pressurization - Auto

[5] FL: Flight Level.

Procedure

1) Set Power for normal climb to FL320
2) Maintain normal climb airspeed
3) Perform standard fuel burn
4) Set Standard cabin pressurization
5) Identify Pilot Flying (PF) and Pilot Monitoring (PM) prior to initiation of O2 tests.

		Flaps/Gear	
Risk	**Cond.**	**Flaps**	**Operation**
		Standard	Perform normal climb to FL320

General Setup For Cruise

Initial Setup

- Weight - Normal
- Thrust - Standard Cruise
- Config - Standard
- Pressurization - Auto

Procedure

6) Set Power for normal cruise at FL320
7) Maintain normal climb airspeed
8) Perform standard fuel burn
9) Set Standard cabin pressurization
10) Identify Pilot Flying (PF) and Pilot Monitoring (PM) prior to initiation of O2 tests.

		Flaps/Gear	
Risk	**Cond.**	**Flaps**	**Operation**
		Clean	Establish normal cruise at FL320

General Notes

Task 1: *Position the oxygen mask system to various settings (normal, 100%, emergency) with and without the goggles vent open during flight*

- The aircraft door was closed at 1148 and the flight departed at 1253.

- All crew mics were operational. The left jumpseat O2 mask hot mic was inoperative but the intercom worked.
- All scenarios were run at a cruise flight altitude of FL320 and a normal cabin altitude of 4400 feet.
- Prior to each scenario, the observer briefed the participating pilot(s) prior to execution (e.g., "Captain performing scenario 1b, mask normal, vent open, goggles on.").
- For scenarios 1-4, only one pilot participated in the scenario while the other pilot performed the duties of the pilot flying (PF). Only the participating pilot, who was also performing the duties of pilot monitoring (PM), donned the oxygen mask and smoke goggles during scenarios 1-4. For scenarios 1-4, the PM was asked to breathe 5 times (to inhale, hold his breath for 2 seconds and then exhale), followed by 20 seconds of normal breathing. After the completion of scenarios 1-4 by the PM, the pilots switched roles and the PF, now acting as the PM, completed scenarios 1-4. The pilot in the right seat participated in scenarios 1-4 first, followed by the pilot in the left seat.
- For scenario 5, both pilots donned oxygen masks and were asked to breathe normally for 1 minute.
- For scenarios 6-8, the PM was asked to hold the oxygen mask slightly away from his face and to breathe normally for 1 minute. Scenarios 6-8 were performed by the pilot in the left seat.
- Scenarios 9-11 were performed by the pilot in the left seat with the oxygen mask in his lap. For scenario 9, an observer spoke from the rear of the cockpit for 1 minute. For scenario 10, the mask was set to emergency for 5 seconds. For scenario 11, the smoke evacuation vent was open for 10 seconds.
- When the smoke handle was pulled in flight, the cabin altitude was 4400 feet, and the cabin climbed +100 fpm for a brief time before settling at zero climb (no noticeable differential change).
- The flight landed at 1414.
- On shutdown, the crew received a "Crew O2 Low" EICAS[6] message.

Equipment Used

The CVR, FDR and oxygen masks used for Task 1 were identical to those of the accident airplane.

[6] Engine Indicating and Crew Alerting System

Task 1: Oxygen Mask/Smoke Goggles Test

Task/ Seat	O2 Mask Position: PM	Smoke Vent: PM	Goggles: PM	O2 Mask Position: PF	Smoke Vent: PF	Goggles: PF	PM Actions	Start Time	Stop Time	Comments
1a-R	Normal	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	na	na	
1b-R	Normal	Open	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	na	na	Pilot had difficulty finding smoke vent with mask and goggles on.
2a-R	Normal/ Emerg[7]	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1318	1319	
2b-R	Normal/ Emerg	Open	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1319	1320	
3a-R	100%	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1321	1322	
3b-R	100%	Open	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1322	1323	
4a-R	100%/ Emerg[8]	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1323	1324	
4b-R	100%/ Emerg	Open	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1324	1325	
	Pilots switched PM/PF roles									
1a-L	Normal	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1328	1329	
1b-L	Normal	Open	On	N/A	N/A	OFF	5 breaths, 2 secs	1329	1330	Pilot had difficulty finding smoke vent with mask

[7] Mask position set to normal, emergency on
[8] Mask position set to 100%, emergency on

Task/ Seat	O2 Mask Position: PM	Smoke Vent: PM	Goggles: PM	O2 Mask Position: PF	Smoke Vent: PF	Goggles: PF	PM Actions	Start Time	Stop Time	Comments
							apart; then 20 secs, normal breathing			and goggles on.
2a-L	Normal/ Emerg	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1330	1331	
2b-L	Normal/ Emerg	Open	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1331	1333	Pilot had difficulty finding smoke vent with mask and goggles on.
3a-L	100%	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1333	1334	Pilot had difficulty finding switch to change mask from Normal to 100%.
3b-L	100%	Open	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1334	1335	Pilot had difficulty finding smoke vent with mask and goggles on.
4a-L	100%/ Emerg	Closed	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1336	1337	Pilot had difficulty finding knob to turn on emergency oxygen.
4b-L	100%/ Emerg	Open	On	N/A	N/A	OFF	5 breaths, 2 secs apart; then 20 secs, normal breathing	1337	1338	Pilot had difficulty finding smoke vent with mask and goggles on.
Both pilots donned mask and goggles; established crew comms via toggle switch between seats.										
5-L/R	Normal	Closed	Off	100%	Closed	OFF	1 minute, normal breathing	1340	1341	Crew received an ATC call; F/O answered call using yoke toggle switch.
Remaining scenarios performed by pilot in left seat										
6-L	Normal, canted to side	Closed	Off	N/A	N/A	OFF	1 minute, normal breathing	1341	1343	Pilot held mask slightly away from face.
7-L	100%, canted to side	Closed	Off	N/A	N/A	OFF	1 minute, normal breathing	1343	1344	Pilot held mask slightly away from face.
8-L	Normal, canted to side	Open	Off	N/A	N/A	Off	1 minute, normal breathing	1344	1345	Pilot held mask slightly away from face. Pilot had difficulty finding smoke vent with mask and goggles on.

Task/ Seat	O2 Mask Position: PM	Smoke Vent: PM	Goggles: PM	O2 Mask Position: PF	Smoke Vent: PF	Goggles: PF	PM Actions	Start Time	Stop Time	Comments
9-L	Normal, in lap	Closed	Off	N/A	N/A	Off	1 minute, normal breathing[9]	1345	1346	Pilot held mask slightly away from face.
10-L	Normal/ Emerg, in lap	Closed	Off	N/A	N/A	Off	5 secs, normal breathing	1346	1346	
11-L	Normal, in lap, smoke evacuative vent open	Closed	Off	N/A	N/A	Off	10 secs, normal breathing	1347	1347	
Pilots returned mask setting to 100%										

Following the test flight, the participating pilots made the following comments:

- There were no difficulties donning the oxygen mask or smoke goggles.
- There were no difficulties hearing or communicating with the other pilot or ATC[10] as long as the mic was checked on.
- Using forced air (emergency setting) was a little uncomfortable compared to not having the emergency setting on.
- It was difficult to find the switch on the mask to switch between normal and 100%; also to turn on emergency.
- The doors where the oxygen mask is stowed must be closed and the reset switch hit to activate the boom mic.
- It was easier to communicate when not in emergency setting.
- If the flight had been at night, one pilot would have been wearing his glasses and it would have been more challenging to don the smoke goggles because the fit would need to be adjusted.

[9] Observer will speak normally from rear of cockpit for at least one minute.
[10] Air Traffic Control

Descent for Landing

Initial Setup

- Weight - Normal
- Thrust - Standard Descent Profile
- Config - Standard
- Pressurization - Auto

Procedure

11) Set Power for normal descent to landing
12) Maintain normal airspeed
13) Perform standard fuel burn
14) Set Standard cabin pressurization

		Flaps/Gear	
Risk	**Cond.**	**Flaps**	**Operation**
		Standard	Establish normal descent to landing

The test flight landed at about 1413 EDT.

Ground Time – 90 minutes

Procedure

15) Normal Ground Operations for Flight Operations
16) NTSB CVR/FDR Specialist conducted CVR download with UPS Tech Ops assistance.
17) NTSB Ops/HP Specialists performed Task 2 items in cockpit

		Flaps/Gear	
Risk	**Cond.**	**Flaps**	**Operation**
		Standard	Normal Ground Operations/NTSB Task 2 and Task 3 Preparations

Task 2

General Notes

Task 2: *Don oxygen mask and smoke goggles and access emergency equipment.*

- Task 2 was conducted on the ground. The NTSB documented task 2 via handwritten notes and photographs.
- For scenarios 10a/b and 11a/b, the participating pilot sat in the captain's seat and donned the oxygen mask and smoke goggles. He attempted to access the emergency equipment (fire extinguisher and portable oxygen bottle) from a seated position. In scenario 10a/b, the seat position was forward and configured for flying. In scenario 11a/b, the seat position was fully back.
- For scenario 12a/b, the participating pilot sat in the left seat and donned the oxygen mask and smoke goggles. He attempted to leave the seat to access the emergency equipment (fire extinguisher and portable oxygen bottle) from a standing position.
- For scenario 13a/b, the participating pilot donned the left seat oxygen mask and smoke goggles. He attempted to access the emergency equipment (fire extinguisher and portable oxygen bottle) from a standing position.
- Subject pilot was 5 feet, 10 inches tall.

Task 2: Access emergency equipment

Scenario #	Mask/ Goggles	Pilot location	Seat position	Action	Fire ext. reached? Y/N	Distance[11] b/t pilot and fire ext	Oxy bottle reached? Y/N	Distance b/t pilot and oxy bottle	Pilot/Observer comments
10a/b	On	Seated, left seat	Forward	Access fire extinguisher/ portable O2 bottle	No	Left arm: 28" Right arm: 51"	No	Left arm: 23"	Pilot turned to both the left and right to attempt to access the equipment. When turning to the right, the pilot did not have a direct line of access to the equipment because of the jumpseat located behind the left seat.
11a/b	On	Seated, left seat	Full back	Access fire extinguisher/ portable O2 bottle	No	Left arm: 23" Right arm: 42"	No	Left arm: 19"	Pilot turned to both the left and right to attempt to access the equipment. When turning to the right, the pilot did not have a direct line of access to the equipment because of the jumpseat located behind the left seat.
12a/b	On	Seated/ Standing	Forward	Access fire extinguisher/ portable O2 bottle	No	Right arm: 29"	No		It took 12.7 seconds for the pilot to undo his seatbelt, move chair back and attempt to exit chair. Pilot was not able to fully get out of seat.
13a/b	On	Standing	N/A	Access fire extinguisher/ portable O2 bottle	No	Right arm: 29"	No		Pilot was not able to fully get out of seat.

Additional observations:

- The cabinet housing the emergency equipment was located on the left side of the cockpit, behind the left jumpseat, and was placarded with "Halon/Portable 02/Crash Axe only". However, also located in the cabinet was a harness for use when evacuating an incapacitated crewmember and a life vest which were placed on top of the O2 bottle.
- The fire extinguisher was mounted upright on the cabinet's left sidewall. The portable oxygen bottle was mounted to the floor of the cabinet. To remove the portable oxygen bottle, the pilot first had to remove the fire extinguisher from the cabinet.
- The oxygen mask hose length measured 56 inches from the captain's panel to the oxygen mask.
- The pilot was not able to access the jumpseat oxygen mask when seated and the seat was forward. The distance between the pilot's fingertips and the mask was 5".

[11] Distance measured from finger tips to edge of cabinet

- The pilot was able to access the left jumpseat oxygen mask when the seat was full back and he reached over the back of the seat. He was not able to fully grab the mask from the housing but his finger tips were able to grab the hose and pull it out.
- The pilot would not be able to fly from the left seat when wearing the left jumpseat oxygen mask.
- It took the pilot 16.5 seconds to stand from the left seat, reach for left jumpseat oxygen mask, remove the left seat oxygen mask, don the jumpseat oxygen mask, and reach the cabinet with the emergency equipment.
- The pilot could not remove the portable O2 bottle without first removing the Halon bottle due to the proximity of the left rear jumpseat backing.

Photo 1 Cockpit Emergency Equipment Closet (B747-400BCF)

Photo 2 O2 mask and goggles donned (goggle vent open)

Photo 3 Left hand reaching from seated flight position

Photo 4 Right hand reaching from a seated flight position

Photo 5 Right hand reaching from a full back position

Photo 6 Left hand reaching from a full back position

Photo 7 Furthest cockpit travel with O2 mask on

Photo 8 Seated position using left observers O2

Photo 9 Emergency equipment access with observers O2 donned

Photo 10 B747-400BCF emergency equipment cabinet

Photo 11 BCF portable cockpit O2 bottle (Halon bottle removed)

Photo 12 B747-400BCF portable O2 bottle (removed)

Addendum:

Task 2a (March 3, 2011)

General Notes

Task 2a: *Don oxygen mask and access emergency equipment on B-747-400 Freighter.*

- Task 2a was conducted onboard aircraft N570UP, a Boeing 747-400F identical to the accident aircraft N571UP, at the UPS ramp in SDF. The documentation for Task 2a was designed to supplement data from the original Task 2 conducted in SDF on November 17, 2010.
- Task 2a was conducted on the ground. The NTSB documented Task 2a via handwritten notes and photographs.
- For scenarios 10a/b and 11a/b, the participating pilot sat in the captain's seat and donned the oxygen mask. He attempted to access the emergency equipment (fire extinguisher and portable oxygen bottle) from a seated position. In scenario 10a/b, the seat position was forward and configured for flying. In scenario 11a/b, the seat position was fully back. For scenario a, the pilot reached with his left arm and for scenario b, the pilot reached with his right arm.
- For scenario 12a/b, the participating pilot sat in the left seat and donned the oxygen mask. He attempted to stand and access the emergency equipment (fire extinguisher and portable oxygen bottle) from a standing position. The pilot left the seat area as necessary to access the equipment as determined by the length of the oxygen mask hose length. For scenario a, the pilot reached with his left arm and for scenario b, the pilot reached with his right arm.
- For scenario 13, the participating pilot sat in the left seat and donned the oxygen mask. He attempted to reach the jumpseat oxygen mask located behind his position (could be done with either arm), donned the jumpseat oxygen mask and accessed the emergency equipment (fire extinguisher and portable oxygen bottle).

Additional Tasks:

- Documented emergency equipment locations in cockpit and supernumerary.
- Documented and recorded the following aural alerts:
  - Autopilot disconnect – manual
  - O2 "Crew Oxy Low" (if available)
  - Fire bell (use fire test to record).

Task 2: Access emergency equipment

Scenario #	Mask/ Goggles	Pilot location	Seat position	Action	Fire ext. reached? Y/N	Distance b/t pilot[12] and fire ext	Oxy bottle reached? Y/N	Distance b/t pilot and oxy bottle	Pilot/Observer comments
10a/b	On/Off	Seated, left seat	Forward	Access fire extinguisher/ portable O2 bottle	No	Left arm:38" Right arm: 36"	No	Left arm: 33" Right arm: 33"	Subject pilot was: 5 ft 10 inches
11a/b	On/Off	Seated, left seat	Full back	Access fire extinguisher/ portable O2 bottle	No	Left arm: 30" Right arm: 34"	No	Left arm: 21" Right arm: 32"	
12a/b	On/Off	Seated/ Standing	Full back	Access fire extinguisher/ portable O2 bottle		Left arm: 28" Right arm: 32"		Left arm:21" Right arm:26"	Subject could not get to Halon bottle with right arm stretched out but could reach the observers mask.
13	On/Off	Seated/ Standing	Full back	Access fire extinguisher/ portable O2 bottle	Yes	Left arm: Right arm:		Left arm: Right arm:	Standing – could just reach halon with right and left arms, "better with the left". Could reach both bottles standing up, better with the left. Subject had difficulty unlatching both the halon and O2bottles and could not pull them out of the closet for use. F/O was unable to reach observers mask or any emergency equipment regardless of seat position. Access to bottles only possible when hose ran along left side of captain's seat (next to wall).

Additional Observations:

- Aircraft used: N570UP (B747-400F)

[12] Measured from pilot's finger tips

- Fire bell and associated aural and visual alerts were noted via Fire/OVT test switch. Autopilot disconnect aural alert was heard via ground disconnect of the left autopilot CMD switch.
- Measurement subject: Captain Phil Spiker, UPS 747-400 Assistant Chief Pilot
- "Crew Oxy Low" light illuminated on EICAS at approximately 490psi. There was no aural alert associated with this EICAS alert.
- "Crew Oxy Low" light illuminated approximately 22 seconds after all valves on the crew oxygen system were closed and both pilots were breathing.
- Crew could not breathe with mask in 100% about 1:27 seconds after oxygen valves were closed.
- F/O and Captain's masks (Lawrence and Brazy) switched from mask mic to boom mic at approximately 40psi (as observed by listening to the CVR via headset (Martin Henshaw).
- Both pilots reported "I can't breathe" at about 30psi system pressure (measured by the EICAS) with each mask in 100%.
- Masks in normal could continue to breathe after 100% and O2 shut off, though it was with greater effort.

Photo 13 Supernumerary Emergency Equipment

Photo 14 Cockpit Emergency Equipment

Photo 15 Pressure switch in cockpit oxygen mask box

Photo 16 Oxygen synoptic page (note oxygen pressure)

Photo 17 Portable O2 bottle (lav, rest areas)

Photo 18 Left observers' seat w/ emergency equipment closet

Photo 19 Main Deck emergency equipment

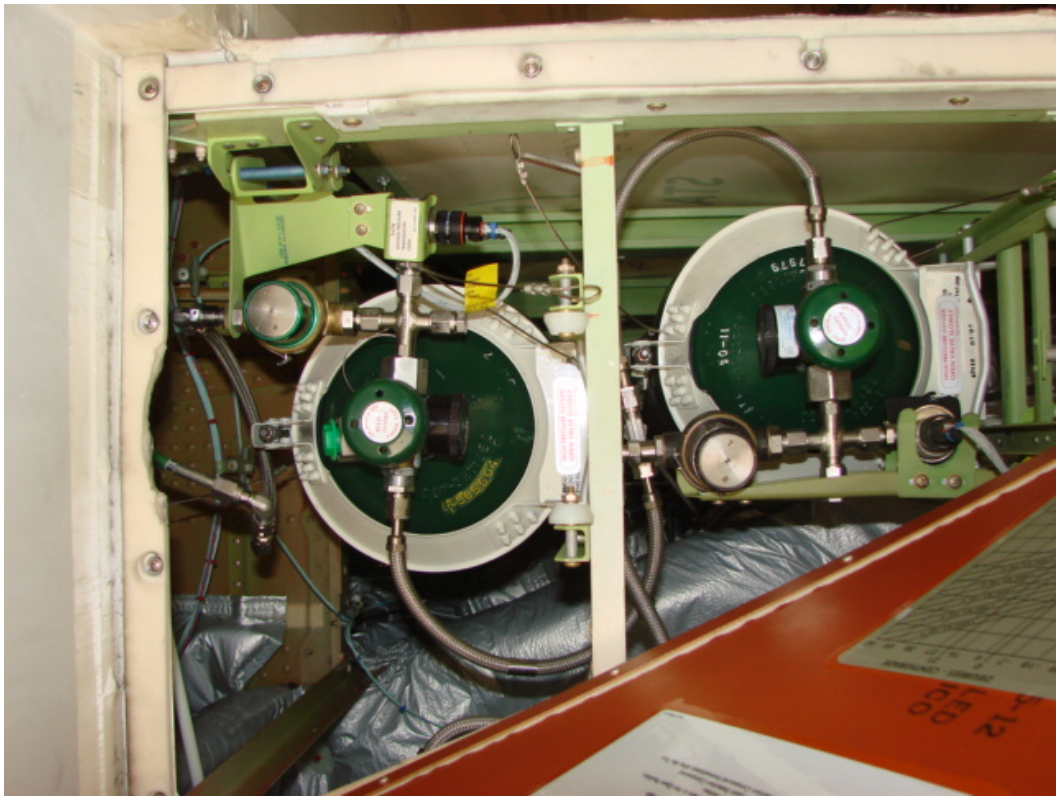

Photo 20 Flight crew O2 bottles 1 and 2

Photo 21 Flight crew O2 bottle (left only)

Photo 22 Right Observers Seat O2 panel