الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Serious Incident

- Final Report -

AAIS Case Nº: AIFN/0016/2014

Hydraulic Fluid Mist and Protective Breathing Equipment Fire in the Passenger Cabin

Operator:	Emirates
Make and model:	Airbus A330-243
Nationality and registration:	The United Arab Emirates, A6-EAQ
Place of occurrence:	Karachi International Airport
State of Occurrence:	Pakistan
Date of occurrence:	4 October 2014

Air Accident Investigation Sector
General Civil Aviation Authority
The United Arab Emirates

Incident Brief

GCAA AAI Report No.:	AIFN/0016/2014
Operator:	Emirates
Aircraft Type and Registration:	Airbus A330-243
MSN	0518
Registration	A6-EAQ
No. and Type of Engines:	Two, RR Trent 772B-60, turbofan engines
Date and Time (UTC):	4 October 2014, 1430
Location:	Karachi International Airport
Type of Flight:	Passengers
Persons Onboard:	82
Injuries:	None

Investigation Objective

This Investigation is performed pursuant to the United Arab Emirates Federal Act No. 20 of 1991, promulgating the *Civil Aviation Law, Chapter VII- Aircraft Accidents*, article 48. It is in compliance with the United Arab Emirates *Civil Aviation Regulations, Part VI, Chapter 3*, in conformity with *Annex 13 to the Convention on International Civil Aviation* and in adherence to the *Air Accidents and Incidents Investigation Manual*.

The sole objective of this Investigation is to prevent aircraft accidents and incidents. It is not the purpose of this activity to apportion blame or liability.

Investigation Process

The occurrence involved an Airbus A330 passenger Aircraft, registration A6-EAQ, and was notified to the Air Accident Investigation Sector (AAIS) of the United Arab Emirates, by phone call to the Duty Investigator (DI) Hotline Number +971 50 641 4667.

Since the State of Occurrence was different to the State of Registry, the AAIS contacted the State of Occurrence (Pakistan) to determine whether an investigation would be conducted by the Civil Aviation Authority. The State of Occurrence informed the AAIS that no investigation would be opened; therefore, an Investigation File was opened by the AAIS, after an official delegation letter was received from the State of Occurrence.

After the Initial Investigation phase, the occurrence was classified as a 'serious incident'.

An Investigation Team was formed in line with the *Annex 13 to the Convention on International Civil Aviation* in line with the obligations of the United Arab Emirates being the State of Registry.

The Investigation into this Serious Incident is limited to the events leading up to the occurrence, and to significant safety issues that were non-contributing but could have caused severe consequences.

This Final Report is prepared according to the AAIS 'Report Writing Style' and is made public at the below link:

https://www.gcaa.gov.ae/en/epublication/pages/investigationreport.aspx

Notes:

1 Whenever the following words are mentioned in this Report with the first letter Capitalized, it shall mean:

- (Aircraft)- the aircraft involved in this serious incident
- (Investigation)- the investigation into this serious incident
- (Incident)- this investigated serious incident
- (Report)- this serious incident investigation Final Report.

2 Unless otherwise mentioned, all times in this Report are Coordinated Universal Time (UTC), (Karachi Local Time minus 5 hours).

3 Photos used in the text of this Report are taken from different sources and are adjusted from the original for the sole purpose to improve clarity of the Report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast or insertion of text boxes, arrows or lines.

Abbreviations

AAIS	The Air Accident Investigation Sector
AAP	Additional Attendant Panel
AC	Advisory circular
ACO	The Aircraft Certification Office in the Federal Aviation Administration of the United States
ACP	Area Call Panel
AD	Airworthiness Directive
AIP	All Attendant Indication Panels
ARFF	Aircraft rescue and firefighting
ATC	Air traffic control
ATPL	Airline Transport Pilot License
CCOM	The Operator's *Cabin Crew Operating Manual*
CIDS	Cabin Intercommunication Data System
CRT	Cathode ray tube
CS	*Certification Specification*
CT	Computed Tomography
CVR	Cockpit Voice Recorder
DDP	Declaration of Design and Performance
DI	Duty Investigator
EASA	European Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitoring
ECB	Electronic control box
EEPMS	Electrical Emergency Escape Path Marking System
FAA	Federal Aviation Administration of the United States
FADEC	Full Authority Digital Engine Control
FAP	Forward Attendant Panel
FAR	Federal Aviation Regulations of the United States
FCOM	The Operator's *Flight Crew Operating Manual*
FDR	Flight Data Recorder
FWC	Flight warning computer
GCAA	The General Civil Aviation Authority of the United Arab Emirates
GPU	Ground power unit
HSMU	Hydraulic System Monitoring Unit
IGV	Inlet guide vane
JAR	Joint Aviation Requirements
MOC	Means of Compliance
MPD	Maintenance Planning Document
MSN	Manufacturer serial number
No./Nº	Number
NOTAC	*Notice to Aerodrome Certificate Holders*
NPRM	Notice of Proposed Rulemaking
OM-A	The Operator's *Operations Manual- Part A*
PA	Public address
PEMS	Passenger Evacuation Management
PBE	Protective breathing equipment
PMA	Part Manufacturing Authority
psi	pounds per square inch (pressure unit)

QRH	The Operator's *Quick Reference Handbook*
QTP	Qualification Test Plan
QTR	Qualification Test Report
RAT	Ram Air Turbine
RTCA	Radio Technical Commission for Aeronautics
SAE	Society of Automotive Engineers
SDCU	Smoke Detection Control Unit
S/N	Serial number
TSB	Transportation Safety Board of Canada
TSO	Technical Standard Order
UAE	The United Arab Emirates
UTC	Coordinated Universal Time

Synopsis

On 4 October 2014, Emirates Airline flight EK609, from Jinnah International Airport (JIAP), Karachi, Pakistan, to Dubai International Airport (OMDB), the United Arab Emirates, with 14 crewmembers and 68 passengers onboard was operated by an Airbus A330 Aircraft, registration A6-EAQ. As preparations for departure were completed the flight crew sensed an odor accompanied by a yellow hydraulic system low pressure indication on the electronic centralized aircraft monitoring (ECAM) system.

The odor was due to hydraulic fluid mist that entered the cabin and cockpit through the airconditioning system. The source of the hydraulic fluid mist was leakage from a fractured hose that provides hydraulic pressure to the rudder yellow system actuator. The leaking hydraulic fluid entered the auxiliary power unit (APU) from where it entered the airconditioning system. Examination of the hose concluded that the cause of the fracture was, most probably, fatigue failure of the metal braiding, followed by fracture of the hose PTFE core pipe.

The mist filled the cockpit and cabin and caused difficulty in breathing, throat discomfort, and eye irritation for some occupants.

In an attempt to determine the source of the mist, which was perceived as smoke, the cabin crewmember located at the L3 door handed a fire extinguisher and protective breathing equipment (PBE) to the cabin crewmember stationed at door L1A, and after the latter had donned the equipment and pulled the lanyard to activate the PBE oxygen generator, the PBE caught fire. The crewmember removed the PBE immediately and threw it on the floor next to the L3 door. This caused a localized fire that was suppressed by other crewmembers.

Based on initial information, the Commander decided to return the Aircraft to the stand and disembark the passengers and crew using steps. The Commander requested information about the situation in the cabin from the L4 cabin crewmember, who stated that visibility in the cabin was now limited to four rows. On receiving this information, the Commander decided to order an evacuation while the Aircraft was at its final pushback position.

The evacuation of the Aircraft was well-managed with only minor injuries to some of the passengers. Following the evacuation, the passengers stayed close to the Aircraft as they were not given directions as to what to do or where to go. On becoming aware of the evacuation of the Aircraft, ATC did not issue any instruction to halt airside operations, and several aircraft and vehicles continued moving.

The Air Accident Investigation Sector (AAIS) determined that the cause of the dense mist was the failure of a yellow hydraulic system rudder servo hose that allowed leaking hydraulic fluid to enter the APU, become heated and atomized, and then to be fed into the Aircraft airconditioning system. The cause of the hydraulic hose failure was not determined by the Investigation. The AAIS determined that it is probable that manufacturing defects in the PBE candle caused the candle to ignite abnormally when the cabin crewmember pulled the activation lanyard.

A contributing factor to the Incident was that the flight crew were unable to identify the source of the mist/smoke and decided to leave the APU running in case it became necessary to shutdown both engines.

Nine safety recommendations are issued with this Report and addressed to Emirates Airline, Airbus, Karachi Airport Authority, the General Civil Aviation Authority (GCAA) of the United Arab Emirates, and the International Civil Aviation Organization (ICAO).

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1. Factual Information

1.1 History of the Flight

On 4 October 2014, at 1405:11 UTC, the cabin preparation of Emirates flight EK609, operated by an Airbus A330, registration A6-EAQ, was completed for departure from Jinnah International Airport (JIAP), Karachi, Pakistan, to Dubai International Airport (OMDB), the United Arab Emirates, with 14 crewmembers and 68 passengers onboard.

At 1405:32, the copilot completed the necessary clearances with air traffic control (ATC) and advised the controller of engine start in three minutes.

At approximately 1406, the Commander asked the ground crew whether or not both ground power units (GPUs) were still connected for engine start and the ground personnel confirmed that they were.

At 1406:39, the Commander asked the copilot to request ATC clearance to start one engine on the stand and the copilot did so. Minutes later, the copilot observed difficulties in the APU and informed the Commander accordingly. At 1406:54, the 'engine start on stand' was approved by ATC. At 1407:040, the Commander called for the *Engine Start* checklist. The Commander then asked the ground crew to clear No.1 engine for start. At 1407:18, the Commander announced No.1 engine start.

At 1408:41, the Commander informed the ground crew that the Aircraft had a good engine start. The Commander cleared the ground crew to remove the GPUs and the ground crew acknowledged the clearance. He then requested ATC clearance to pushback and the Aircraft was cleared to push at 1410:12. The Commander requested the ground crew to change the final position to which the Aircraft would be pushed in compliance with an amended ATC clearance. The ground crew acknowledged the request and the pushback started at 1410:34.

During the pushback, the Commander asked the ground engineer to advise when the Aircraft was cleared for No.2 engine start, and the ground engineer replied by asking if the Commander wished to start by using engine cross-bleed or normal start. The Commander advised that it would be a normal start.[1]

At 1410:58, the Commander announced No.2 engine start. In the meantime, the copilot noted that the Aircraft had reached the pushback stop position and he informed the Commander.

At 1411:42, the Commander requested the copilot to obtain taxi clearance from ATC. At 1421:12, ATC read the clearance to the crew and the copilot read back the clearance correctly.

At 1412:42, a chime was recorded on the CVR and the chime repeated after three seconds. The Commander enquired as to the reason for the chime. The copilot informed him that the yellow system hydraulic reservoir air pressure was low. The Commander told the copilot to let the engine start and it "Will sort itself out." Seconds later, the copilot commented that the yellow system hydraulic electrical pump was OFF, and that the hydraulic pressure was fluctuating.

At 1413:09, a master caution chime was recorded on the CVR due to low hydraulic pressure, and the yellow hydraulic system was indicating low pressure on the Electronic Centralized Aircraft Monitoring (ECAM). The problem was discussed by the Commander and the copilot.

[1] Normal start is by using the bleed air from the APU

At 1413:50, the Commander asked the copilot to review the ECAM system page and to see whether any indications relevant to the yellow system low pressure and low quantity were present. At this time, the copilot observed that the yellow hydraulic system had lost pressure, as indicated by several ECAM messages.

At 1413:54, 1 minute 12 seconds after the first chime, the Commander and copilot sensed 'terrible' smoke, and the copilot suggested going back to the stand. At the same time, the ground engineer called the flight crew informing them that the pushback was completed and requesting that the parking brake be set. The Commander confirmed that the parking brake was set.

The senior cabin crewmember (SCCM) had already finished the cabin safety briefing and announced, through the public address (PA), that the lights were being dimmed for a night takeoff.[2]

The Commander informed the ground engineer that the cockpit had experienced some "Smoke" and he asked the ground engineer to check if there was any indication of smoke outside. The ground engineer replied that he did not notice anything and asked the Commander what type of indications had appeared.

The Commander asked the SCCM[3] whether there was any smoke in the cabin and the SCCM replied: "Yes, all the cabin is smoke[y] and smelly." The Commander asked the SCCM to standby for one second and the copilot again suggested going back to the stand.

The Commander requested that the yellow pump be switched to OFF, and the copilot switched both the engine driven and electrical hydraulic pumps to OFF. In a few seconds, the copilot observed yellow system low pressure.

The Commander and copilot donned their oxygen masks, cross-checked communications and confirmed that the oxygen mask microphones were functioning.

At 1415:07, 1 minute 13 seconds after the first report of smoke, the Commander called the SCCM who informed him that there was very thick smoke in the cabin and the passengers were "Agitated." The Commander acknowledged this information and informed the SCCM that the flight crew also had smoke in the cockpit.

At 1415:28, the Commander called the ground engineer and informed him that the Aircraft had a problem with the yellow system: low pressure, low level, and low air pressure. A chime was recorded by the CVR and the Commander announced that there was smoke in the lavatory. The ground crew asked the Commander to standby as they would call the ground engineer, but the Commander requested a return to the stand and the ground crew acknowledged. The ground crew requested a tug to return the Aircraft to the stand. The flight crew repeated the request for the tug several times, informing the ground crew that the Aircraft was experiencing a technical problem. In the meantime, the Commander called the SCCM asking for an update, and she replied: "The situation is very very bad."

At 1416:49, 2 minutes 55 seconds after the first report of smoke, (3 minutes and 40 seconds after the master caution for the low hydraulic pressure), the Commander informed the SCCM that the Aircraft was going back to the stand, and she informed the Commander that the occupants of the cabin “Cannot breathe.” In the meantime, an announcement was made by one of the cabin crewmembers requesting that the passengers remain seated.

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2 The sunset time at Karachi was 1318 UTC

3 All communication with the *SCCM*, positioned at the L1 position, was via the Aircraft communication system

At 1417:13, the Commander told the copilot to keep the APU running, and that he would shut the engines down. At that time, the cabin crew requested the passengers, through the PA, to sit down and remain in their seats.

At 1417:25, the copilot informed ATC that the Aircraft was proceeding back to the stand, and ATC requested confirmation. The copilot confirmed the information and the Commander declared that the engines had been shut down. In the meantime, the cabin crew used the PA to request the passengers to remain seated and calm, and to place handkerchiefs over their mouths and noses. The cabin crew informed the passengers that the situation was under control.

At 1417:39, the Commander called the ground engineer and informed him that the smoke seemed to be “Okay in the front [cockpit].” but the cabin still had smoke. The Commander also informed the ground engineer that the problem was related to the hydraulic system.

At 1418:08, the Commander said that he was going to turn OFF the APU bleed in order to stop the air circulation. A few seconds later, the Commander said that the smoke indication in the lavatory had ceased.

At 1418:24, 4 minutes 14 seconds after the first report of smoke, the cabin crewmember positioned at L4 door called the cockpit and informed the flight crew that the situation in the cabin was "Really, really bad." and that they would have to evacuate the Aircraft. During this communication between the Commander and the cabin crewmember, a master warning chime was recorded by the CVR. The Commander asked the same cabin crewmember: "How far can you see[?]" and she informed the Commander that the visibility was up to four rows. Subsequently, the Commander asked the cabin crewmember whether she considered that it was necessary to evacuate the Aircraft, and she replied "Yes." The Commander then decided to disembark the passengers and crew and he informed the ground crew of his decision.

At 1419:24, the copilot called ATC and informed the controller that the Aircraft was being “Evacuated.”[4] The Commander asked the ground crew if passenger steps were available immediately. The ground crew asked the Commander if it was possible to open the doors from the inside.

At 1419:45, 5 minutes 58 seconds after the first report of smoke, another cabin crewmember, positioned at R3 door, called the cockpit and informed the flight crew that there was a fire at L3 door coming from the protective breathing equipment (PBE). The PBE had ignited after the cabin crewmember had donned it and activated it by pulling sharply on the adjustment straps, as per the procedure. The cabin crewmember immediately removed the burning PBE and dropped it on the floor adjacent to L3 door.

In an attempt to suppress the fire, four onboard Halon fire extinguishers were used without success, as the fire was self-sustaining due to its continuous production of oxygen. Three seconds after ignition of the PBE fire the Commander issued the command to the cabin crew to evacuate the Aircraft via the escape chutes.

At 1420:03, a sound similar to the removal of a flight crew oxygen mask was recorded on the CVR, followed by the Commander saying: "Let's go." The crew opened the cockpit windows. At 1429:26 the copilot called for the emergency evacuation checklist.

At 1420:19, the cabin crewmember positioned at L4 door called the cockpit asking the Commander if she could evacuate, and the Commander informed her to evacuate the Aircraft.

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[4] At times, the flight crew used the terms ‘disembark’ and ‘evacuate’ interchangeably

At 1420:45, the Commander called ATC and informed the controller that there was a fire onboard and requested the fire service to attend the Aircraft. ATC confirmed that the fire service was responding.

Passengers had already left their seats and started to assemble at the mid-cabin area close to L2 door, through which they had boarded the Aircraft. A number of passengers were screaming, carrying their hand-held baggage, and demanding to exit the Aircraft.

At 1421:02, 7 minutes 8 seconds after the first report of smoke, and 1 minute 10 seconds after ignition of the PBE fire, the Commander announced over the PA: "This is the Commander, evacuate, evacuate, evacuate."

All passenger doors, except L3 door, were opened by the cabin crewmembers. Because the Aircraft passenger doors had been armed for the departure, the escape chutes were automatically deployed, and all persons onboard exited the Aircraft via the chutes.

The evacuation resulted in minor injuries to some passengers. Neither the Aircraft interior nor exterior structure sustained heat damage, except to the cabin crewmember seat, carpet, and floor panels adjacent to L3 door.

The fire service personnel accessed the Aircraft by removing their shoes and climbing up the escape chute extending from R1 door.

Post-event inspection of the external fuselage of the Aircraft showed signs of hydraulic fluid leakage from the vertical fin which had flowed down around the aft fuselage and entered the APU air inlet located at the six o'clock position on the aft fuselage.

The Operator's maintenance crew found that the yellow hydraulic system pressure hose that supplies hydraulic pressure to the rudder yellow actuator, located in the vertical fin, was leaking fluid.

1.2 Injuries to Persons

Table 1. Injuries to persons

Injuries	Flight Crew	Cabin Crew	Other Crew Onboard	Passengers	Total Onboard	Others
Fatal	0	0	0	0	0	0
Serious	0	0	0	0	0	0
Minor	0	7	0	1	8	0
None	2	5	0	67	74	0
TOTAL	**2**	**12**	**0**	**68**	**82**	**0**

1.3 Damage to Aircraft

Damage to the Aircraft was limited to the area adjacent to L3 door. The cabin floor between fuselage frames 53.5 and 53.7, and seat tracks Y1456-Y1959, sustained burn damage.

Three floor panels (including one heated panel) were found badly damaged and required replacement (figure 1).

The cabin crewmember L3 seat was burnt.

Figure 1. Aircraft damage [Source: Karachi Airport]

1.4 Other Damage

There was no other damage to property, or the environment.

1.5 Personnel Information

1.5.1 Flight crew information

The flight crew consisted of the Commander and copilot. Table 2 illustrates the qualifications of the flight crewmembers.

Table 2. Qualifications of the flight crew

	Commander	Copilot
Age	40	41
Type of license	ATPL	ATPL
Valid to	January 2021	October 2019
Rating		
Issuing State	UAE	UAE
Medical class	1	1
Valid to	May 2015	April 2015
Total flying time (hours)	9,512	8,754
Total commands on all types	4,883	---
Total on type	3,909	1,657
Total last 30 days (hours)	48	75
Total last 24 hours (hours)	0	2:30
Total on type last 30 days (hours)	48	75
Last line check	December 2013	July 2014
Last proficiency check	May 2014	June 2014
English language proficiency	6	6

The Commander had rested for the previous 24 hours and the flight from Dubai to Karachi was his first flight following the rest period. The copilot’s flying time was about 2:10 during the previous 24 hours.

1.5.2 Cabin crew information

Each of the twelve cabin crewmembers possessed a valid cabin crew license and medical certificate issued by the General Civil Aviation Authority (GCAA) of the United Arab Emirates.

The ages of the crewmembers were within the range from 24 to 50 years. Their total flying experience varied between two and a half to twelve and a half years. All cabin crewmembers were type rated on Airbus A330, Airbus A340, and Boeing 777 types.

The 50 year old SCCM, positioned at L1 door, was also the most experienced cabin crewmember, with 10 years of her total experience as a senior cabin crewmember.

The 30 year old cabin crewmember, positioned at L4 door, had four and a half years total experience.

The 29 year old cabin crewmember, positioned at R3 door, had two and a half years total experience.

The 30 year old cabin crewmember positioned at L1A door, had two years and nine months experience total experience. This crewmember moved to R3 door area to identify the source of the lavatory smoke. She carried a fire extinguisher and donned a PBE.

1.6 Aircraft Information

1.6.1 General

The Airbus A330 is a wide body, twin-engine, twin-aisle aircraft. The normal flight crew compliment is two pilots. Operation of the aircraft is supported by cathode ray tube (CRT) displays, electrically signaled flight controls, sidestick controllers, Full Authority Digital Engine Control (FADEC), and a centralized maintenance system.

Table 3 shows general Aircraft data.

Table 3. Aircraft data

Manufacturer:	Airbus Industrie
Model:	A330-243
MSN:	0518
Year of manufacture:	2003
Date of delivery:	April 2003
Nationality and registration mark:	United Arab Emirates, A6-EAQ
Name of the owner:	Emirates
Name of the operator:	Emirates
Certificate of registration	
Number:	08/03
Issuing Authority:	General Civil Aviation Authority, UAE
Issuance date:	9 July 2003
Valid to:	Open
Certificate of airworthiness	

Number:	EAL/67
Issuing Authority:	General Civil Aviation Authority, UAE
Issue date:	29 April 2003
Valid to:	Open – Airworthiness Review Certificate (ARC) expiry date: 28 April 2015
Total hours since new:	48440:22
Total cycles since new:	13944
Last inspection type, date and hours/cycles:	A-Check, 16 August 2014, 47897:53 hours, 13775 cycles
Total hours since last inspection:	542:29
Total cycles since last inspection:	169
Engines:	Two Turbofan, RR Trent 772B-60
Maximum takeoff weight (kg):	230,000.00
Maximum landing weight (kg):	182,000.00
Zero fuel weight (kg):	140,211.00

1.6.2 Maintenance records

A review of the maintenance records submitted to the Investigation indicated that all of the hydraulic system flexible hoses, including the affected yellow system rudder hose, were installed on the Aircraft during manufacture. None of the hoses had been replaced during the service life of the Aircraft.

During the previous flight from Dubai to Karachi (EK608), an APU fault message was generated and the APU had shut down automatically. The maintenance corrective action undertaken was to cycle the APU switch. Following this maintenance action the APU started normally, and all APU indications were observed to be normal.

1.6.3 The hydraulic system

The Airbus A330 hydraulic system consists of three fully independent systems: Green, Blue, and Yellow. The operational pressure is 3000 psi.

The three hydraulic systems are powered by four engine-driven pumps (EDP). Two EDPs power the Green system, and there are three electrical pumps that can act automatically as backup for each hydraulic system.

The systems are managed by the Hydraulic System Monitoring Unit (HSMU) which controls all automatic functions (electrical pumps, Ram Air Turbine (RAT), monitoring, etc.). A manual override is available on the cockpit overhead panel.

A schematic of the hydraulic power supply to the various flight controls is illustrated in figure 2.

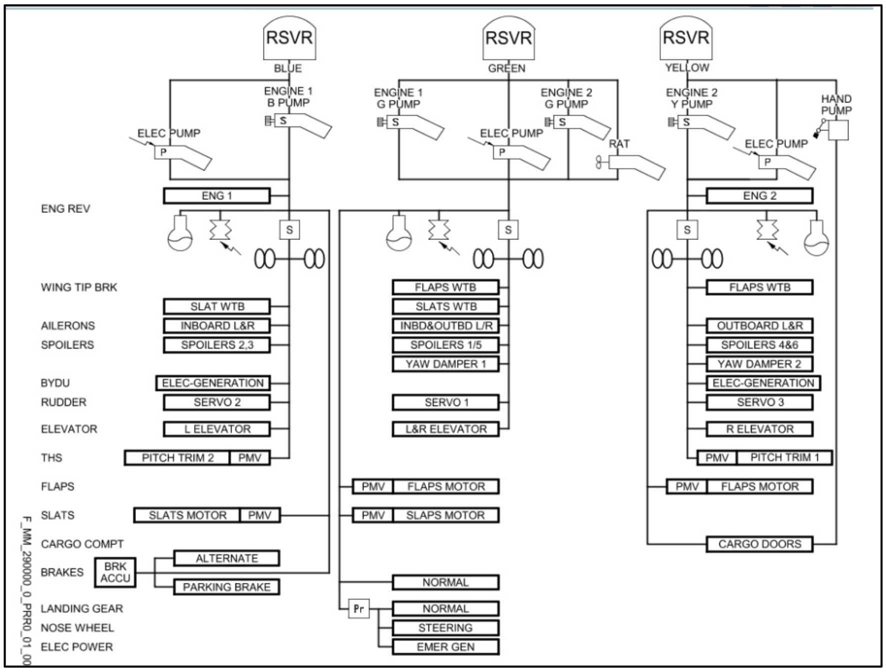

Figure 2. Hydraulic system architecture

1.6.4 The hydraulic leak

The mist that filled the cabin was generated by heated atomized hydraulic fluid leaking from the yellow hydraulic system hose which was connected to the center rudder servo (figure 3). The atomized hydraulic fluid was drawn into the APU intake, and then entered the cabin through the airconditioning system. This vaporized hydraulic fluid generated a "mist like" cloud that filled the cabin.

Figure 3. Traces of hydraulic fluid leak
[Source: Karachi Airport]

The hydraulic leak was caused by a fractured hose connected to the rudder hydraulic servo powered by the yellow system. The Aeroquip, high pressure hose, was fitted with straight-to-single elbow (45°) end fittings, and was constructed of three layers: a thin wall Teflon inner tube, a Hi-Pac outer braid consisting of densely packed small diameter stainless steel wires, and a fabric sleeve.

The hose is tested according to the requirements of *MIL-H-38360A*[5], at pressures of 4,000 to 5,000 psi, the test temperature varies between room temperature to 400°F (204°C).

[5] *MIL-H-38360A* is a United States standard Military Specifications for hose assemblies, tetrafluoroethylene, high-temperature, high pressure, 3,000 psi, hydraulic and pneumatic

Table 4 shows the general specifications of the affected hose, and figure 4 shows a hose similar to the one which failed.

The hose assembly drawing indicates that an identification tag is fixed to the side of the elbow end fitting. This tag shows the hose manufacturer's name, the hose manufacturer part number (P/N), the customer P/N (if available), the month and year of manufacture, the manufacturer code, the material of the hose inner tube (Teflon), and the operating pressure (3,000 psi). This tag was not found on the affected hose after removal from the Aircraft.

The Investigation did not determine the mean time between failures (MTBF) of this part number.

Table 4. Hose general specifications

O.D. tube size	1/2
Hose I.D	0.40
Hose O.D.	0.67
Operating pressure (psi)	3,000
Proof pressure (psi)	6,000
Min. high temperature burst pressure (psi)	10,500
Minimum room temperature burst pressure (psi)	14,000
Minimum bend radius	2.88
Weight per foot (lbs.)	0.235
Length of the assembly	31.75

Figure 4. Similar hose to the failed hose [Source: Airbus]

1.6.5 The auxiliary power unit (APU)

1.6.5.1 The APU Installation

The location of the Airbus A330 APU air intake prevents the ingestion of the main engine exhaust gases, or APU exhaust gases, into the APU. The APU air intake is also fitted with the following components to drain or divert fluids flowing along the fuselage while the aircraft is on the ground or in flight:

- <u>Air intake diverter</u>

  On the ground and inflight, the diverter diverts fluids that could flow along the fuselage, so that they do not enter the APU air intake.

- <u>Fluid gutters</u>

  The fluid gutters are installed on both sides and to the rear of the air intake inlet. Together with the diverter, the fluid gutters form a frame which extends from the fuselage skin level to the area around the inlet opening of the APU air intake. This frame is designed to prevent fluids that could flow along the fuselage from entering the air intake.

The function of the two components is to minimize fluid ingestion into the APU air intake but the frame is not capable of preventing all of the fluid resulting from a large hydraulic leak, occurring on the ground, from entering the intake.

1.6.5.2 APU bleed system description (figure 5)

The APU load compressor supplies APU bleed air to the pneumatic system. The electronic control box (ECB) monitors the bleed airflow to the pneumatic systems and maintains stable pressure.

The APU power section supplies the mechanical energy, which is necessary to drive the load compressor impeller. Centrifugal force causes the air between the blades to increase air speed in the direction of the blade tips. This increases the air velocity causes a low pressure area at the impeller hub. This causes a continuous airflow from the APU inlet plenum chamber (air taken from the air intake) into the compressor. The airflow is controlled by the inlet guide vanes (IGVs), which also impart an initial swirl to the air. Downstream of the impeller, the air enters the radial diffuser. The radial diffuser changes most of the kinetic energy of the air into pressure. There is also an increase in the temperature of the air. The scroll, which is around the diffuser, collects the diffuser outlet air and guides it to the bleed air duct.

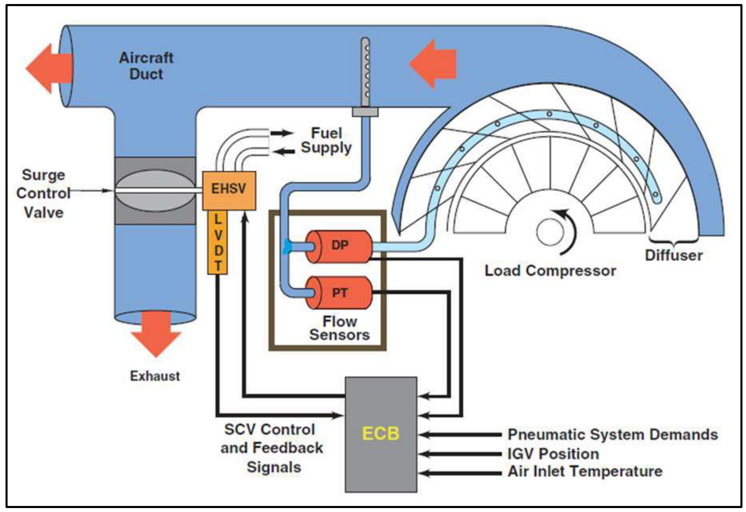

Figure 5. Bleed system schematic

The leaking hydraulic fluid that entered the APU inlet had been heated and atomized as it passed through the load compressor and diffuser.

The APU bleed air is not filtered of any contaminants, or fluid, before it enters the Aircraft airconditioning system. In addition, the APU bleed air is not monitored for contaminants.

1.6.6 The Airconditioning system (figure 6)

The A330 airconditioning system is fully automatic and supplies a continuous flow of controlled air to the aircraft.

Two airconditioning packs fitted to the Aircraft operate automatically and independently of each other. Pack operation is controlled by the pack controller.

The air supplied by the APU is initially cooled in the packs and the temperature is regulated by two hot air pressure regulating valves and trim air valves for fine temperature adjustment. Temperature regulation is controlled by a zone controller and two pack controllers. Cockpit and cabin temperature can be selected from the AIR panel in the cockpit. In addition, a control panel is provided on the forward attendant panel (FAP). During cruise, the cabin crew can modify each cabin zone temperature from the FAP, with a limited authority of ±2.5°C.

The temperature control valve can modify the pack outlet temperature by adding uncooled air to the turbine outlet flow. Trim air valves, associated with each zone, adjust the temperature by adding hot air from the two hot air manifolds. The trim air valves are electrically-controlled by the zone controller.

For the cockpit supply, one trim air valve is fitted to regulate air from hot air manifold. Air from hot air manifold 1 passes through a restrictor.

The cockpit is supplied with fresh air from the mixer unit, but no recirculation fans are dedicated to it. The cabin recirculation fans can be selected from the CAB FANS button in the cockpit. The unit mixes cold fresh air from the packs with the cabin air being recirculated through the recirculation fans. The mixer unit is also connected to the emergency ram air inlet, and the low pressure ground inlets. The recirculated air flows through filters and valves to remove any polluting contaminants.

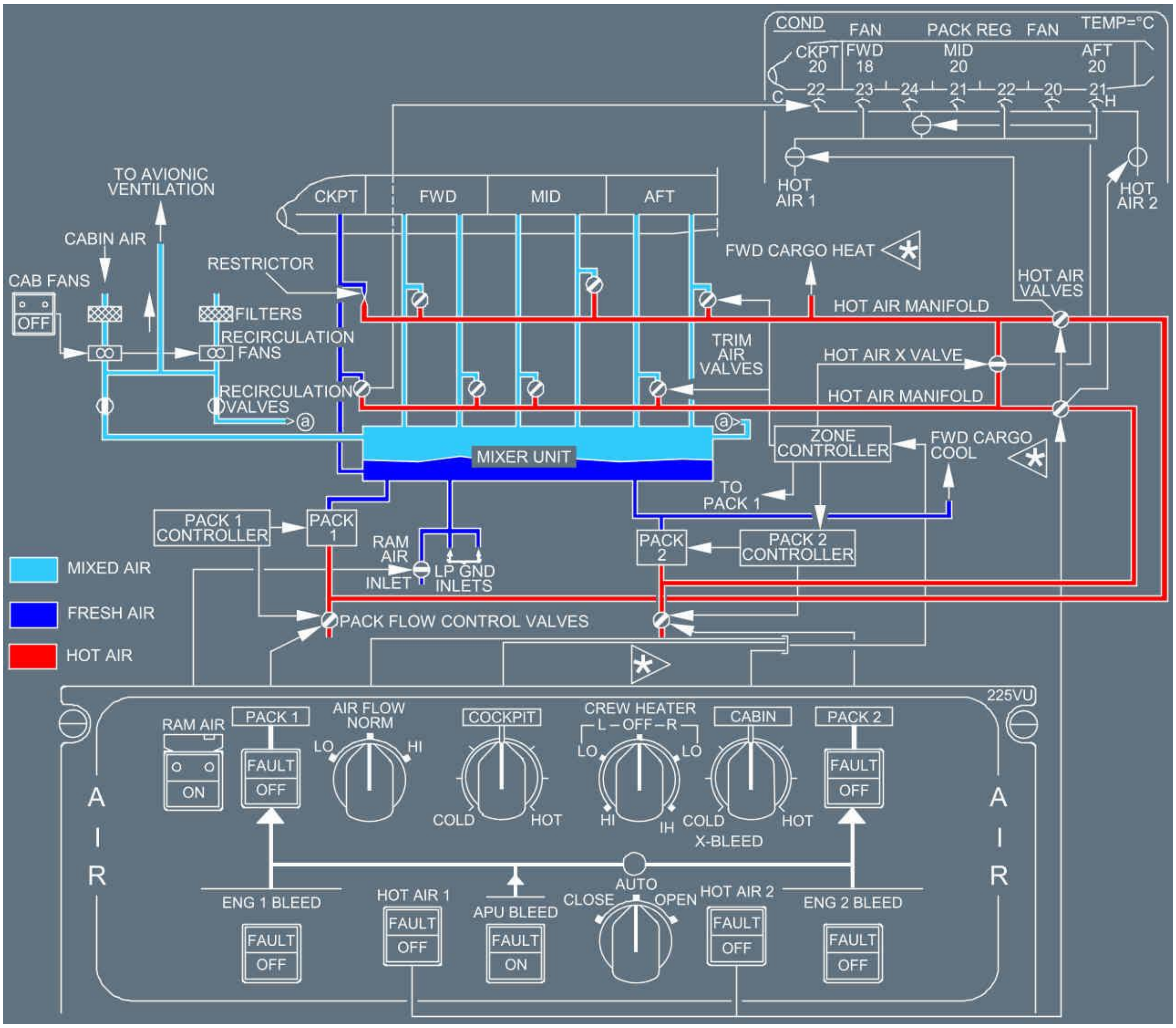

Figure 6. Architecture of the air-conditioning system [Source: *FCOM*]

In normal operations, with the engines shutdown, and APU bleed air on, the cross-bleed valve is set to 'AUTO' mode, therefore air will flow to both packs.

There is no filter that can totally purify any contaminated air in the APU, APU bleed line, airconditioning packs, mixer unit, or cabin air distribution duct. However, the airconditioning system is fitted with filters at the recirculation system level which filter the cabin air recirculated by fans, and the air is finely filtered before being injected into the mixer unit.

1.6.7 Smoke/evacuation warning system

The Aircraft evacuation horn is designed to sound at each cabin crewmember station. The evacuation command can be initiated either from the cockpit, or from the cabin. The CAPT and PURS/CAPT switch selection on the cockpit overhead panel determines whether the alert can be activated from the cockpit and the cabin, or only from the cockpit.

In addition, the lavatories are equipped with a smoke detection system that consists of:

- Smoke detectors in the air extraction duct of each lavatory
- A double-channel Smoke Detection Control Unit (SDCU).

If smoke is detected in a lavatory, the smoke detector sends a signal to the SDCU. The SDCU then transmits this information to the flight warning computer (FWC) to display a warning in the cockpit, and to the Cabin Intercommunication Data System (CIDS) to display a warning in the cabin.

Visual indications appear to the cabin crew in the 'All Attendant Indication Panels (AIP)', the applicable 'Area Call Panel (ACP)', the associated lavatory wall light, the 'Forward Attendant Panel (FAP)', and the 'Additional Attendant Panel (AAP)'. Two repetitive chimes also trigger simultaneously to the visual indications: from the cabin loudspeakers, and from all attendant station loudspeakers.

1.6.8 Emergency lights

The emergency lighting (escape path and exit markers, overhead emergency lights, and EXIT signs) is controlled by the EMER EXIT LT switch located on the overhead panel in the cockpit, and the EMER pushbutton on L1 door CIDS panel in the cabin. The emergency lighting system, in particular the Electrical Emergency Escape Path Marking System (EEPMS), is activated according to a system functional logic.

As per the *Flight Crew Operating Manual (FCOM) PRO-NOR-SOP-06- Cockpit Preparation*, the flight crew is required to set the EMER EXIT LT switch to the “ARM” position at each transit stop.

In the *SMOKE/FUMES/AVNCS* Abnormal and Emergency Procedures, and if airconditioning smoke is suspected, the QRH requires the APU bleed be switched to OFF. In the *Emergency Evacuation* section, the *QRH* procedure requires that all ENG and APU FIRE pushbuttons be pressed before starting the evacuation. This means that the aircraft is no longer in the normal electrical configuration. Electrical power is being supplied by the batteries only. (Appendix A).

As per the above logic, if the EMER EXIT LT switch is in the ARM position (as per *SOP*), the emergency lighting will automatically go to ON, if the EMER EVAC procedure is initiated.

1.6.9 Protective breathing equipment (PBE)- Operations principles[6]

The Aircraft was equipped with PBE units manufactured by B/E Aerospace. According to section 121.337 (b)(1) of the *Federal Aviation Regulations* of the United States: ”The (protective breathing) equipment must protect the flight crew from the effects of smoke, carbon dioxide, or

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[6] Reference: B/E Aerospace Engineering Report Nº 3500-15-025, dated 3 June 2015- *CT Scan Inspection of Annex 13 PBE Candles.*

other harmful gases or oxygen deficient environment caused by other than an airplane depressurization while on flight deck duty and must protect crewmembers from the above effects while combatting fires onboard the airplane."

Each PBE unit is preserved in a hermetically sealed pouch that ensures the serviceability of the PBE appliance. It is stored in a compartment next to each cabin crewmember position including the cockpit. The compartment is fixed in position by either straps or fasteners depending on the location.

The *TSO C116* approval of P/N 119003-11 was established based on the use of fasteners to positively secure the compartment to a vertical or horizontal surface. At no time was B/E Aerospace, or Puritan-Bennett Aero Systems (Legacy Company) required to support any compliance finding for a strap method of installation.

The PBE is equipped with a hood which fits over the user's head, sealing against the user's neck to protect against the ingress of smoke and fumes, and has polycarbonate visors on its front and sides that allow the user to identify and combat the fire. (Figure 7).

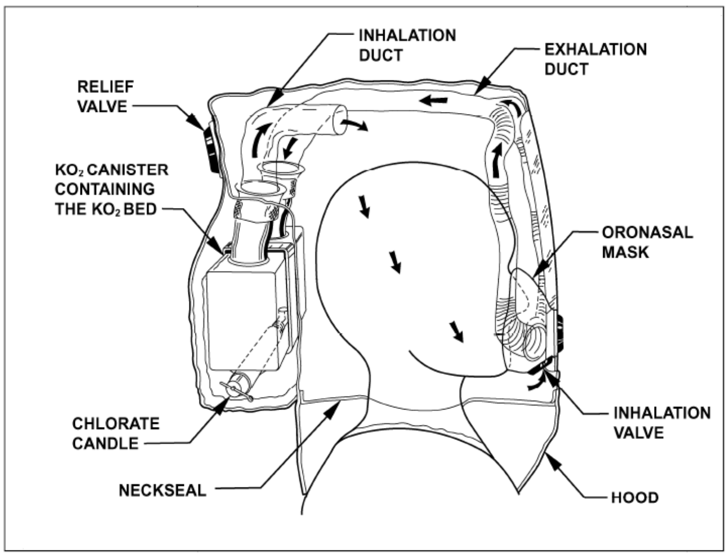

Figure 7. PBE schematic
[Source: B/E Aerospace CT scan report]

The hood is equipped with an oronasal face piece, inhalation valve, and speaking diaphragm assembly, which channels the user's exhaled breath to a canister containing potassium dioxide (KO_2) granules. Water vapor and carbon dioxide in the user's exhaled breath react with the KO_2 to produce breathable oxygen. By-products from this initial process react further with residual carbon dioxide to prevent it from being returned to user's breathing environment. This reaction continues for as long as available KO_2 remains in the canister. In order to prevent premature depletion of the KO_2 material, the PBE is packaged and hermetically sealed in a Mylar[7] lined bag. The PBE remains sealed in the bag for the 10-year life of the PBE unit.

The chlorate starter candle is designed to deliver a fixed volume of approximately eight liters of oxygen over duration of less than 20 seconds by the chemical decomposition of sodium chlorate. The starter candle is contained in a small stainless steel cylinder affixed to the base of the KO_2 canister (figure 8).

7 Mylar is a clear material made from polyester resin

The starter candle is actuated by pulling the release pin. The release pin is pulled automatically by a lanyard when the user adjusts the straps that tension the oronasal mask against the user's face during the donning sequence.[8]

The discharge of the chlorate starter candle is directed into the interior of the KO_2 canister on the same side of the PBE where the user's exhaled breath enters the canister from the PBE's exhalation duct. The duct is fabricated from 0.1 mm thick polyurethane film. Some of the oxygen from the starter candle provides an initial fill of the exhalation duct, while the bulk of the oxygen emitted by the starter candle travels through the KO_2 canister and provides an initial oxygen-rich environment within the confines of the hood that surrounds the user's head.

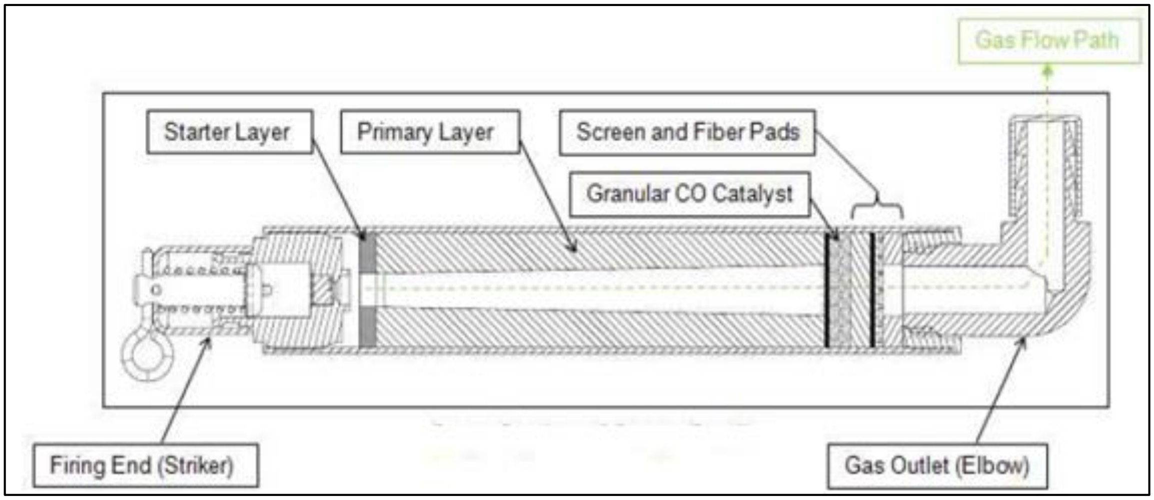

Figure 8. Cross section of the starter candle [Source: B/E Aerospace CT scan report]

Once the starter candle is consumed and ceases to emit oxygen, oxygen is then supplied to the user from the PBE's KO_2 canister. During operation, the user exhales into the oronasal mask.

A pair of one-way valves connects the oronasal mask to two branches of the PBE's exhalation duct. A user's exhaled breath travels through the exhalation duct and enters the KO_2 canister. Within the KO_2 canister, carbon dioxide and water vapor, which have been exhaled by the user, are absorbed by the chemicals within the canister, causing a chemical reaction which supplies replacement oxygen to the user.

The regenerated oxygen passes through the inhalation duct, and enters the main compartment of the hood. This interior hood volume serves as a breathing reservoir for the user. When the user inhales, a second one-way valve (the inhalation valve) allows the regenerated oxygen contained within the interior volume of the hood to enter the oronasal mask for inhalation by the user. This repeating breathing cycle continues until the KO_2 canister is exhausted and can no longer convert the user's exhaled breath into oxygen, the cycle may last for about 15 minutes.

1.7 Meteorological Information

The prevailing meteorological conditions were not a factor in this Incident.

The sunset time at Karachi was 1318 UTC. The flight was a 'night' flight.

8 The chemical reaction of the starter candle is: $2NaClO_3 + Heat \rightarrow 2NaCl + 3O_2$

1.8 Aids to Navigation

Ground-based navigation aids, onboard navigation aids, aerodrome visual ground aids and their serviceability were not a factor in this Incident.

1.9 Communications

The quality of communications between the Aircraft and ATC was good.

1.10 Aerodrome Information

Jinnah International Airport (JIAP), Karachi is a certificated aerodrome under the *Civil Aviation Regulations* of Pakistan*.*

The Airport is equipped with two runways: runway 25R/07L measuring 3,200 m in length and 46m in width, and runway 25L/07R measuring 3,400m in length and 45m in width.

The runways can accommodate simultaneous landing and takeoff. Runways 25R and 25L are equipped with ILS CAT-I.

Although it was requested, the Investigation could not obtain the Karachi Airport Emergency Plan.

1.11 Flight Recorders

Both flight recorders were offloaded form the Aircraft and forwarded to the flight recorder downloading entity.

Visual inspection of the flight recorders did not reveal any damage.

The CVR was downloaded and revealed clear intra- and inter- cockpit and cabin communication. A transcript was made and formed a good source of data that assisted the Investigation to assess the flight and cabin crew performance.

The Investigation did not consult the FDR data.

1.12 Wreckage and Impact Information

Other than the floor area adjacent to the L3 door that was affected by the PBE fire, the Aircraft was undamaged.

1.13 Medical and Pathological Information

No medical or pathological investigation was conducted as a result of this occurrence, nor was any required.

1.14 Fire

After the cabin crewmember had donned the PBE, it ignited upon activation of the two lanyards. The crewmember immediately removed the PBE and dropped it on the floor adjacent to the L3 door. The burning PBE caused the fire damage described in section 1.3 of this Report.

1.15 Survival Aspects

Based on the initial available information, the Commander decided to return the Aircraft to the stand and disembark the passengers and crew using steps. Immediately before his decision to evacuate, the Commander requested information about the situation in the cabin from the L4 cabin crewmember, who stated that visibility in the cabin was limited to four rows. On receiving this information, the Commander decided to order an evacuation while the Aircraft was at its final pushback position.

The cabin crew managed the emergency by using the Aircraft's PA system. The megaphones were not used to provide evacuation instructions. The PBE unit that caught fire had been installed next to the L3 door, but the cabin crewmember who was positioned at L3 door handed the PBE to the cabin crewmember who was positioned at door L1A and had gone to the aft cabin to assist the other crewmembers. As the L1A crewmember was having difficulties with breathing and seeing, she was handed the PBE that had now been removed from its sealed package, and immediately donned it and pulled the straps as per the procedure. Figure 9 illustrates the time line of events relevant to the emergency management.

Some passengers had already left their seats before the evacuation announcement was made and had started to assemble at the mid-cabin door area especially near the L2 door through which they had boarded the aircraft. A number of passengers were screaming, carrying their hand-held baggage, and demanding to exit the Aircraft.

When the Commander ordered the evacuation, the cabin crewmembers did not recall seeing the illuminated floor path lighting, and the cabin crewmembers stated that the evacuation call was not easily audible.

In their interviews, the female cabin crewmembers stated that they were reluctant to slide down the escape chutes. They provided two reasons for this: the first was that they were wearing skirts and so sliding down the chute could place them in an embarrassing situation and secondly that they were required to remove their medium-heel shoes[9] before sliding on the chute, whereas they would have preferred to protect their feet by keeping their footwear on. It was noted that several of the female cabin crewmembers were wearing shoes that should be worn only during passenger boarding and disembarkation.

The evacuation of the Aircraft was well-managed with only minor injuries to some of the passengers. Following the evacuation, the passengers wandered close to the Aircraft as they were not given directions as to what to do or where to go. Figure 10 illustrates the doors used during the evacuation and the slides deployed, and from which doors the crew and passengers evacuated.

On becoming aware of the evacuation of the Aircraft, ATC did not issue any instruction to stop airside operations, and several aircraft and vehicles continued moving.

[9] Medium-heel shoes height is: 4.5cm (1.8 inches)

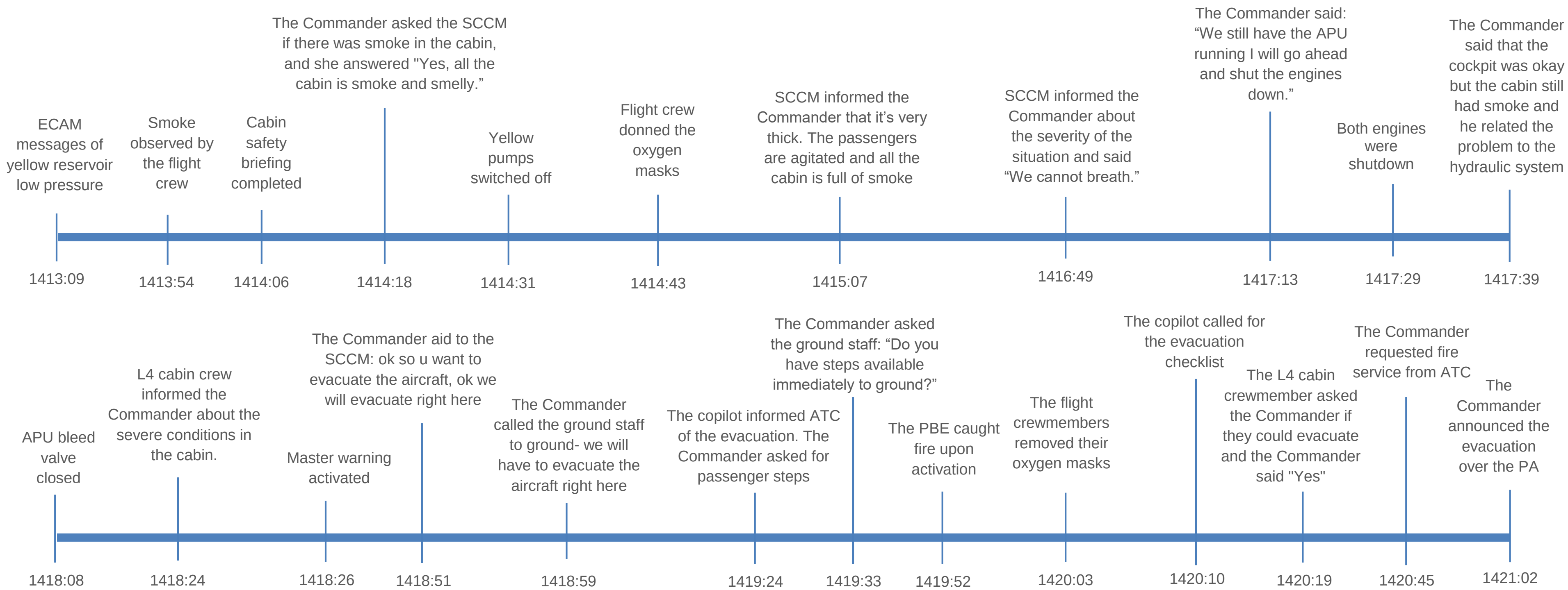

Figure 9. Timeline of emergency related events

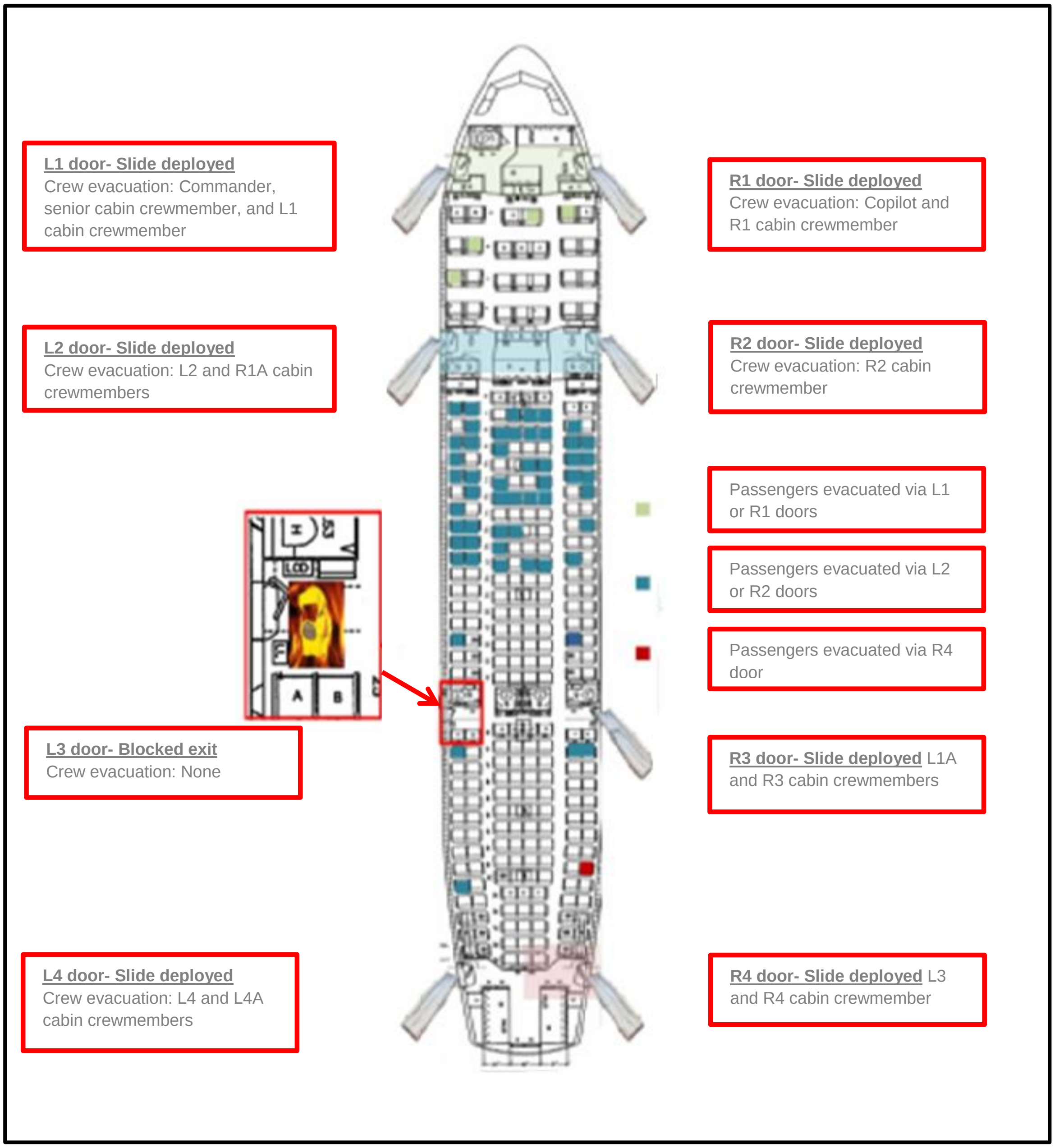

Figure 10. Evacuation doors [Source: the Operator]

1.16 Tests and Research

1.16.1 The hydraulic hoses

The ruptured yellow system rudder servo hydraulic pressure hose (P/N AE2464373H0316) and the return hose (P/N AE3663864J0332) were shipped to the Aircraft manufacturer for forensic laboratory investigation. A report titled *Failure Analysis of a Damaged Hydraulic Hose* was provided to the Investigation.[10]

A visual inspection of the hose revealed a torn textile sleeve and abrasion marks on the metal braiding. The crack on the PTFE[11] pipe surface was opened in the laboratory and no obvious evidence of fatigue was found on the crack surface (figure 11). Microscopic analysis showed striations and beach marks on the braiding, indicative of fatigue failure. The microscopic examination also showed dirt on the surfaces of the failed braiding wires. The fractographic examination did not show any signs of corrosion on the surfaces of the failed braiding wires (figure 12).[12]

The report concluded that the main failure cause was, most probably, fatigue failure of the metal braiding which caused the failure of the PTFE pipe.

The return hose did not show any evidence of failure.

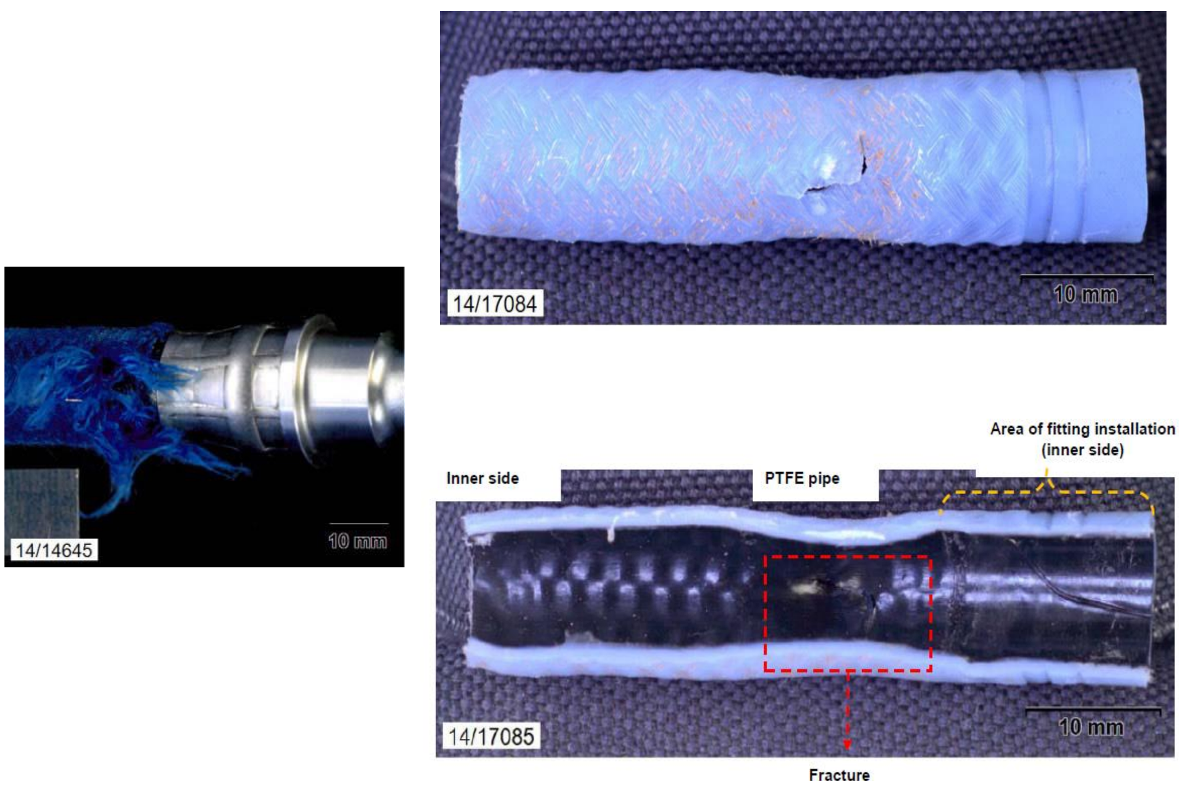

Figure 11. The torn textile and cross section of the failed tube. [Source: Airbus]

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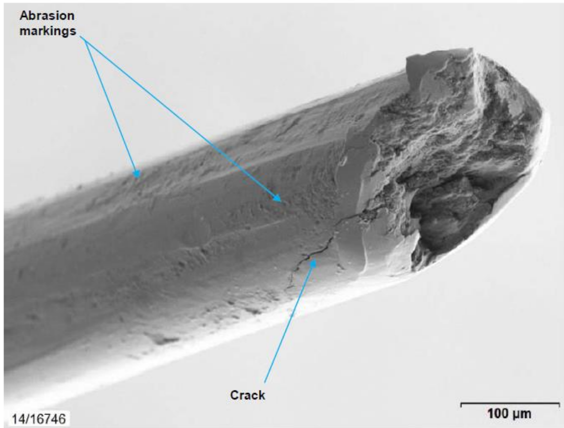
10 Reference: Airbus *Technical Report No. G29RP1503928*, dated 11 March 2015

11 PTFE is a fluorocarbon solid compound consisting wholly of carbon and fluorine

12 Fractographic examination is to determine the cause of failure by studying the characteristics of a fractured surface.



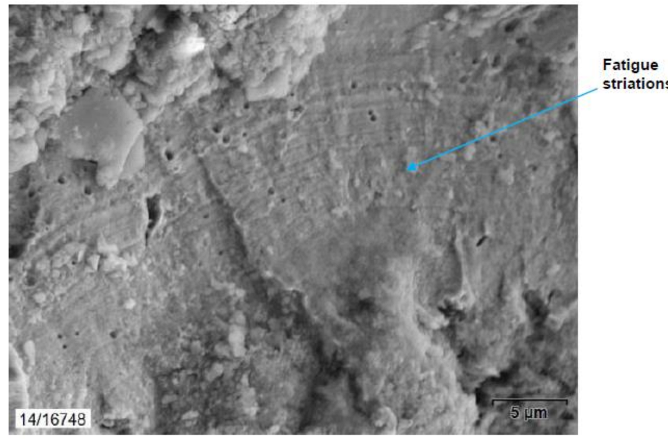


Figure 12. Microscopic image of the fractured braiding wires. [Source: Airbus]

1.16.2 The protective breathing equipment (PBE)- Tests and forensic examination

1.16.2.1 Tests

A sample of 59 PBE units installed on the Operator's fleet were tested[13] at the Operator’s facilities on 14 October 2014. The 59 units contained seven units from the same lot as the Incident affected PBE (P/N 119003-11, S/N 003-35283M). These seven units did not exhibit any anomalies.

According to records provided to the Investigation, a total of 580 PBE units (between S/N 003-34983M and 003-35563M, manufactured in June 2007) were equipped with suspect chlorate candles from the same production lot of the Incident PBE. Out of the 580 PBE units, 48 units had been delivered to the Operator.

On 19 October 2014, during tests of 14 additional units from the questionable lot, one PBE made a 'popping' sound and generated black deposits (S/N 003-35280M), which is inconsistent with its normal operation, and another PBE caught fire (S/N 003-35282M)[14].

Out of the 48 units, 22 units were selected to be shipped to the PBE manufacturer facilities for examination as the vacuum sealed pouches containing the PBE had been removed from the Operator aircraft and were therefore presumed to be in a serviceable condition. The aim of the examination was to assess the possible effects of added environmental exposure which are considered specific to, or may affect the activation, and resulting behavior of the PBE.

The PBE manufacturer test method was proposed to and accepted by the Federal Aviation Administration (FAA). The purpose of these PBE tests was to examine structural effects on the integrity and state of the candle contents, directly through operational shock or vibration, and indirectly through exposure to high and low temperatures and temperature variations that could induce stress on the core, due to thermal expansion and contraction of the candle stainless steel housing. Also, testing was carried out on PBE units having breached pouches to examine the results of exposure of the candle contents to moisture accruing from a combination of humidity and variations in cabin pressure typical of normal aircraft service.

Out of the 22 units, nine units were subjected to the following testing:[15]

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13 The sample was selected from the various Operator's aircraft

14 Both tests were carried out at the Operator's facilities

15 Reference: B/E Aerospace Report, *DOC: 3500-14-115,* issued on 16 December 2014

- A 'vibration and shock test' was performed on three units contained in stowage containers as per Airbus' strap installation method but loosely secured to the test fixture in a manner intended to be representative of the condition of the PBE stowage containers observed on some of the Operator's aircraft. The PBE container was resting on a flat solid metal surface. Each of the units selected for these tests were serviceable with regard to pouch vacuum. The test concluded that all the three units were opened and then activated without issue.
- A 'temperature/temperature variation test' was also performed on three other units. The units were subjected to combined high and low temperature and temperature variation tests, while installed in a free standing stowage container. The test concluded that all three units were opened and then activated without issue.
- A 'combined humidity and altitude test' was performed on three units subjected to 'combined humidity and altitude tests' while installed in a free standing stowage container. Two of the units selected for these tests were serviceable with regard to pouch vacuum. The third PBE had a compromised pouch seal. The test concluded that all three units were opened and then activated without issue.

In the case of the three tests, candle discharge was observed in the hood exhalation ducts in a limited number of cases and circumstance. However, there were no observable effects or hazardous conductions associated with or resulting from the CT scan examination.

The following three candles obtained from the PBE tests articles discussed in section 1.16.2.1 were examined in a third party laboratory[16]:

- The candle from the PBE unit that caught fire during activation by the cabin crew on the Incident Aircraft (S/N 003-35283M) (figure 13).
- The candle from a PBE unit (S/N 003-35282M) tested at the Operator's facility that had caught fire.
- The candle from a PBE unit (S/N 003-35280M) tested at the Operator's facility that had generated some black deposits after activation.

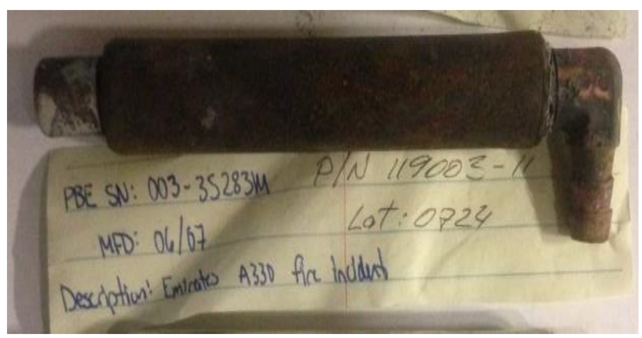

Figure 13. The candle from the PBE unit involved in the Incident [Source: B/E Aerospace CT scan report]

The objective of the CT scan was to provide a means to understand the structure and state of the internal features of the candle, and if possible, draw a correlation between this and the candle's subsequent activation performance.

The CT scan[17] showed that the three selected candles displayed evidence of filter disruption and penetration. The sodium chlorate based primary layer had fully reacted, but was

[16] Microvista, is located in Blankenburg (Harz), Germany

[17] Reference: B/E Aerospace Engineering Report Nº 3500-15-025, dated 3 June 2015- *CT Scan Inspection of Annex 13 PBE Candles*

largely intact and undisturbed. There were signs of localized discoloration on the surface of the candle stainless steel tubes. These areas discoloration were immediately adjacent to the starter layer consistent with the effects associated with elevated heat. This could not be seen on the candle involved in the Incident because of surface damage due to the fire.

The two PBE units that had been exposed to fire (S/N 003-35283M and 003-35282M), exhibited residues of the core and filter in the oxygen path. The candles also showed evidence of localized outlet elbow burning and material loss in the vicinity of these compacted core/filter materials, or in the preceding flow path. In addition, residue from the perchlorate based starter layer of the candle, that is the region normally occupied by the starter layer, was essentially void and the starter layer residue assumed a displaced position in the direction of the candle outlet. (Figure 14a, 14b, 14c, 14d).

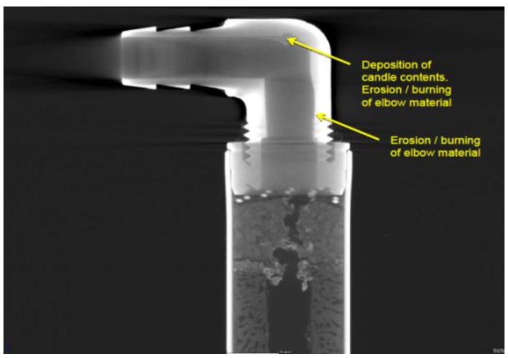

Figure 14a. The candle outlet end elbow

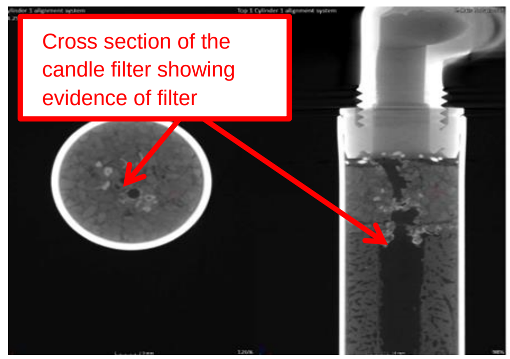

Figure 14b. Cross section of the candle

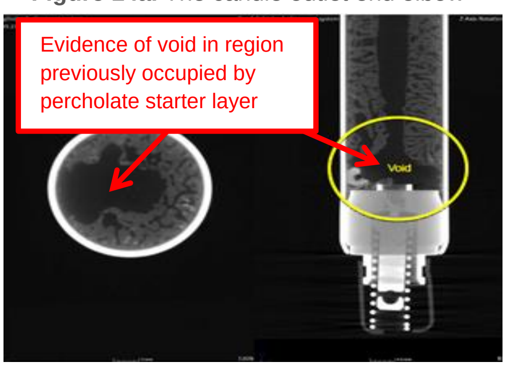

Figure 14c. The candle activation end

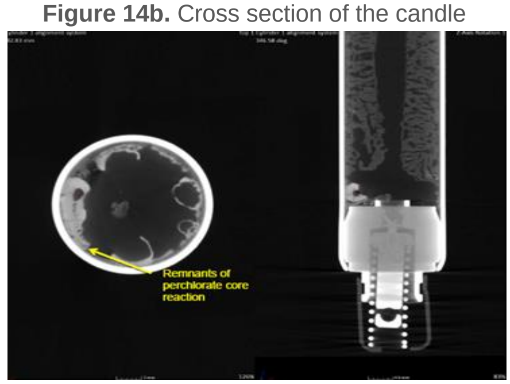

Figure 14d. The candle activation end

Photos related to the Incident PBE unit candle. [Source: B/E Aerospace CT Scan Report]

1.16.3 Emergency lighting operational test

After the return of the aircraft to Dubai International Airport, the Investigation, in the presence of representatives of the Operator, performed an operational test of the emergency lighting. The results showed that all emergency lights were operational.

1.17 Organizational and Management Information

1.17.1 The Operator's evacuation procedure

The Operator's *operations manual, part A (OM-A)*, refers to the *FCOM* and applicable *Cabin Crew Operating Manual (CCOM*) for emergency policies and procedures.

According to the *FCOM* (*PRO-ABN-90*), if it is possible to reach the passenger cabin, the Commander is the last person to leave the aircraft from the rear door or any other available exit if the rear door is not reachable. Once on the ground, the Commander shall take command of operations until rescue units arrive.

The copilot is required to proceed to the cabin and take the emergency equipment, evacuate the aircraft using any available exit, help passengers on the ground, and direct them away from the aircraft.

The cabin crew is responsible for evacuation, each for his or her assigned door area.

The *FCOM* states that an on-ground evacuation is triggered by notification from the flight crew to the cabin crew of the nature of the emergency, and the Commander's stated intentions. The cockpit crew uses the PA system, to make an appropriate announcement, such as: PASSENGERS EVACUATE, and the EVAC COMMAND pushbutton is pressed.

When the cabin crew receive the order to evacuate, each cabin crewmember must stand up and shout: "Unfasten seatbelts." The cabin crew check the outside conditions. If the outside conditions are safe, the cabin crewmember assigned to the applicable station shall open the door firmly and shout: "Come this way." The cabin crewmember shall then deploy the escape chute and order the passengers to evacuate with expediting statements.

The Operator's *CCOM* requires the cabin crew to be alert for any indication of possible emergency while waiting for takeoff and landing. According to the *CCOM*, the cabin crew may initiate an evacuation in a catastrophic situation. This includes the presence of dense smoke. The cabin crew must attempt to contact the flight crew to inform them of the situation in the cabin if he, or she, has decided to initiate an evacuation.

All cabin crewmembers must be informed that a life-threatening situation exists. There are many ways to inform cabin crewmembers, such as via:

- evacuation alarm
- public address
- interphone
- megaphone.

The *CCOM* explains that the cabin crew may use body language and gestures to assist the passengers to understand the evacuation practice. The cabin crew may request able-bodied persons to assist them with safety-related tasks during an evacuation.

The cabin crew are trained to control the evacuation by understanding the various possible reactions of passengers such as:

- panicking (screaming, crying, hysteria)
- freezing up (not able to react)
- not being aware that danger exists
- pushing
- exiting with carry-on baggage.

The cabin crew must monitor the evacuation progress, and maintain an even flow of passengers from each exit to avoid congestion at the end of the slides and they must continually monitor the slide to ensure that it remains safe for use.

The Operator's *Quick Reference Handbook (QRH)* had no specific procedure for crew preparedness from the time the doors are closed to before takeoff in the case of smoke/fire.

According to Airbus, some steps in the *SMOKE/FUMES/AVNCS SMOKE QRH* procedure are not fully applicable to emergency conditions which occur on the ground. However, the philosophy that has been chosen to cover any non-ECAM smoke/fume events is to have a single paper procedure, whatever the smoke source (and the flight phase), in order to facilitate the flight crew management of such a critical situation. This procedure is written in a larger font compared to the typical font used in the *QRH* in order to improve the legibility of the procedure in a smoke environment.

1.17.2 Cabin smoke awareness

The *CCOM* contains a *Cabin Smoke Awareness* chapter under the *Abnormal/Emergency* Procedure.

The procedure highlights the importance of cabin crew awareness of any smoke indication and all crewmembers should take any report about smoke seriously and identify the source and take the appropriate actions. The procedure calls for dealing with smoke as a sign of potential fire.

The procedure lists the smoke that is generated by the airconditioning as difficult to be detected by the cabin crewmember, and attributes it to more than one area, including the APU.

The procedure lists possible consequences if the cabin crewmembers are not able to detect the source of smoke; amongst these consequences is an emergency evacuation.

The procedure classifies the detection of the source of smoke between 'easy' and 'difficult', and classifies the airconditioning area under the 'difficult' class. In such a circumstance, the cabin crewmembers must: "Inform the flight crew, closely monitor the situation, search for hot spots using the back of the hand, and prepare a fire extinguisher, protective breathing equipment, and fire gloves in case the situation deteriorates."

For the protection of persons onboard, the cabin crewmembers shall not open the cockpit door, shall move the passengers away from the smoke source or direct them to bend forward in case movement is not possible, and use wet towels or something similar to aid breathing. During these actions the cabin crewmembers should use the PBE.

The procedure calls for the cabin crewmembers to use their senses to detect smoke. The chapter indicates that a 'skydrol smell' would indicate engine hydraulic material.

The procedure mentions that the ineffective detection of smoke can occur due to re-circulation through airconditioning system and that important information from the cabin may not be taken into account by the flight crew. These reasons, and others, may degrade the effectiveness of detecting the source of smoke.

The Investigation attended a training session carried out at the Operator's cabin crew training facility. The following points were observed:

- According to the Operator's training procedure, the cabin crew training on firefighting uses an already opened dummy PBE unit. There was no specific training on picking up the PBE from a similar compartment to the one fitted onboard the aircraft, nor was it required to open the PBE pouch and don the PBE.

- From the evacuation training aspect, the cabin crewmembers were not dressed in the actual uniform during their use of the escape chute. The choice was left to the cabin crew as to what to wear, and they were free to wear their own cloths.

1.17.3 History of cabin crew uniform change

The Operator, introduced a change to the cabin crew uniform in 1985 and the new uniform required the female cabin crewmembers to wear skirts.

In 1997, the Operator provided the female cabin crewmembers with the option of wearing trousers or skirts. In August 2008, a revision of the uniform took place for all Airbus A380 cabin crewmembers and this was then introduced across all aircraft types in 2009. This change in uniform continued to offer the wearing of trousers as an option for female crewmembers.

From 1 August 2013, the option for female cabin crewmembers to wear trousers was withdrawn, and the wearing of skirts became mandatory for female crewmembers.

Regarding footwear, and according to the Operator's policy, the female cabin crew have to wear medium-heel shoes during the flight preparation and receiving the embarking passengers. The shoes are then replaced by service flat shoes at some time after takeoff as a preparation for passengers service.

1.17.4 The Operator's safety management system (SMS)

The Operator's safety management system (SMS) was approved by the GCAA in 2012. No risk assessment of the uniform change was carried out based on the new SMS. At the time of the last uniform change of August 2013, the Operator considered that the skirts would continue to achieve the same safety standard. Therefore, the Operator did not undertake a safety case study to determine any risk associated with the wearing of skirts.

Paragraph 1.6- *Subcontracting and Purchasing,* in the Operator's *safety management manual (SMM)* states that:

> "Where products or services that may have an impact on the level of safety are purchased or contracted, the Group[18] shall ensure that the product or service meets the applicable requirements (Group, regulatory, and legal), and that suppliers are periodically evaluated to ensure continued compliance with requirements. These procedures shall be documented in the relevant departmental documents, and are subject to SMS Audit and Oversight."

Paragraph 1.7- *Safety Risk Management,* states: "Safety Management is centered on a systematic approach to Hazard Identification and Risk Assessment (HIRA) and management." Generic HIRA processes are detailed in Section 2 of the *SMM*, and in the *Group Safety Procedures Manual*.

Paragraph 1.7.1- *Hazard Identification,* states:

> "Hazard identification includes those processes used to collect, record, and classify identified hazards. The process includes reactive, proactive and predictive methods of safety data collection. The

[18] SMS is a group manual is the reference of Emirates Group which comprises: Emirates Airline, Dnata, and associated companies

reporting systems include mandatory, voluntary and confidential reporting elements, within a non-punitive reporting culture as defined in the Safety Policy."

Paragraph 1.7.2- *Safety Risk Management*, states:

"Safety Risk Management is implemented through processes that ensure the classification, analysis, assessment and control of risks to an acceptable level. Safety Risks are analyzed in terms of probability of occurrence and severity of outcome, and then assessed for their tolerability.

Decisions regarding tolerability of identified safety risks are made at an appropriate management level, as defined within the Safety Risk Management process detailed in Section 2 of this manual, and the applicable departmental manuals.

Recognizing that individual departmental needs may present special requirements in respect of Safety Risk Management, the standardized methodology presented in this manual may need to be modified or supplemented to meet a specific need. Any alternative arrangement must be developed and implemented in consultation with Group Safety to ensure that the regulatory, data management and monitoring requirements continue to be met."

Paragraph 1.8.2- *Management of Change*, states:

"Safety Assurance processes include change management processes that ensure;

a. changes which may affect established processes and services, and have a safety impact are identified;

b. the arrangements to ensure continued safety performance are described before change is implemented; and

c. safety risk controls are in place, and are applicable to, and appropriate for the new arrangements.

The formal change management processes are documented in section 2 of this manual [*SMM*].

Recognizing that individual departmental needs may present special requirements in respect of Change Management, the standardized methodologies presented in this manual may need to be modified for individual departmental usage. Any alternative arrangement must be conducted in consultation with Group Safety, to ensure that the regulatory, data management and monitoring requirements continue to be met."

Paragraph 2.3.2- *Conduct of Formal Safety Risk Assessment,* states that: "A formal Safety Risk Assessment may be initiated in response to an identified hazard/risk, or from a change management initiative. The Safety Risk Assessment should be conducted by an individual or team with subject area knowledge and training in the conduct of risk assessments." The level of complexity of any risk assessment should be appropriate to the operational significance of the risk.

According to the Operator's policy, hazard identification can occur from experiencing safety incidents in the operational environment, near-miss events, assessing potential outcomes based on possible threats/procedures, and the experience of other operators/industries which could pose a similar hazard to the operations.

Paragraph 2.3.6- *Management of Change*, states: "Change to policies, procedures, equipment, operating environment, etc. may have an impact on the level of safety of the operation. It is a requirement of the SMS that such changes are identified, and managed in a way to ensure that safety performance is not negatively impacted by the change."

1.17.5 The UAE civil aviation requirements

CAR–OPS 1.780- Crew Protective Breathing Equipment, states

"(a) An operator shall not operate a pressurized aeroplane or, after 1 April 2000, an unpressurised aeroplane with a maximum certificated take-off mass exceeding 5700 kg or having a maximum approved seating configuration of more than 19 seats unless:

(1) It has equipment to protect the eyes, nose and mouth of each flight crew member while on flight deck duty and to provide oxygen for a period of not less than 15 minutes. The supply for Protective Breathing Equipment (PBE) may be provided by the supplemental oxygen required by CAR–OPS 1.770(b)(1) or CAR–OPS 1.775(b)(1). In addition, when the flight crew is more than one and a cabin crew member is not carried, portable PBE must be carried to protect the eyes, nose and mouth of one member of the flight crew and to provide breathing gas for a period of not less than 15 minutes; and

(2) It has sufficient portable PBE to protect the eyes, nose and mouth of all required cabin crew members and to provide breathing gas for a period of not less than 15 minutes.

(b) PBE intended for flight crew use must be conveniently located on the flight deck and be easily accessible for immediate use by each required flight crew member at their assigned duty station.

(c) PBE intended for cabin crew use must be installed adjacent to each required cabin crew member duty station.

(d) An additional, easily accessible portable PBE must be provided and located at or adjacent to the hand fire extinguishers required by CAR–OPS 1.790(c) and (d) except that, where the fire extinguisher is located inside a cargo compartment, the PBE must be stowed outside but adjacent to the entrance to that compartment.

(e) PBE while in use must not prevent communication where required by *CAR-OPS 1.313*, *CAR–OPS 1.685, CAR–OPS 1.690, CAR–OPS 1.810 and CAR–OPS 1.850.*"

1.18 Additional Information

1.18.1 The PBE design requirements

The PBE was required to comply with the design requirements mentioned in the *Federal Aviation Regulations (FAR) section 121.337 (b1)- Protective Breathing Equipment, FAR 25.1450 (a)(b)- Chemical oxygen generators, Technical Standard Order TSO-C116- PBE Design Requirement,* standards of Radio Technical Commission for Aeronautics (RTCA), document No. *DO-16OC- Environmental Conditions and Test Procedures for Airborne Equipment*, dated 4 December 1989, and the requirements of the Society of Automotive Engineers (SAE).

Section 6 of the current FAA *Advisory Circular (AC) No. 21-16G*[19]*- RTCA Document DO-160 versions D, E, F, and G- Environmental Conditions and Test Procedures for Airborne Equipment,* contains specific requirements for using *RTCA/DO-160* for TSOs. The *AC* states: "b. If the TSO does not specify the environmental qualification, the applicant may choose any environmental standard conditions and test procedures appropriate for their airborne equipment. Although an applicant may choose any environmental standard, we [the FAA] recommend that you [the applicant] use *RTCA/DO-160G*." The PBE P/N 119003-11 obtained TSO approval against the requirements of *RTCA/DO-160D,* which was current at the time of application for the TSO approval obtained on 24 July 2002.

The function of the PBE is to protect the crewmembers from the effects of smoke, carbon dioxide, or other harmful gases, or an oxygen deficient environment caused by other than an aircraft depressurization and the PBE must protect crewmembers from the above effects while combating fires onboard the aircraft.

TSO-C116 requires the PBE to be marked properly including information about the face size. In addition, certain technical data is required to be provided to the FAA Aircraft Certification Office (ACO) such as operating instructions, equipment limitations, typical installation procedures and any limitations, schematic drawings as applicable to the installation procedures, and wiring diagrams as applicable to the installation procedures, list of the major components (by P/N) that make up the system complying with the standards prescribed in this *TSO*, manufacturer's *TSO* qualification test report, nameplate drawing, and instructions for periodic maintenance and continued airworthiness.

Appendix 1 to the *TSO* requires the manufacturer to provide a means for any crewmember to check the serviceability of the unit in its stowed condition. Any failure of the unit to operate, or to cease operation, shall be readily apparent to the user.

The unit shall not present a hazard when stored, in use, or during inadvertent operation. The unit shall not be adversely affected by environmental extremes. The unit shall have a stated reliability with an appropriate confidence level to conform to the stated shelf life, operational limit, and/or maintenance interval.

The unit shall wear comfortably in use, leaving both hands free. It shall not be displaced during the normal tasks of locating and combating a fire.

Chapter 5 of *TSO-C116- Construction Requirements*, requires that the PBE unit and its stowage be constructed of materials that are flame resistant in compliance with *the FAR Section*

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[19] FAA website states: "This *advisory circular (AC)* [*No. 21-16G*] identifies RTCA Document No. *(RTCA/DO)-160 versions D, E, F, and G*, Environmental Conditions and Test Procedures for Airborne Equipment, dated July 27, 1997, December 20, 2005, December 6, 2007, and December 8, 2010, respectively, as containing acceptable environmental qualifications to show compliance with certain airworthiness requirements. The FAA strongly encourages the use of *RTCA/DO-160G* for new articles."

25.853. Any exposed portions of the unit and stowage shall withstand and remain functional when exposed to a radiant heat flux of 1.0 BTU/ft^2 per second for 60 seconds.[20] The unit shall also protect the head and neck of the user from dripping 200°C plastic materials and withstand a 1000°C flame for five seconds without material penetration while operational.

Reviewing *TSO-C116*, the Investigation did not find a reference to test or design features for fire protection of the PBE candle.

1.18.2 Unit and installation certification

1.18.2.1 The PBE unit certification

In 1998, B/E Aerospace acquired the business formerly known as Puritan Bennett Aero Systems Co. Although the business name changed, products of the same P/N bearing the old company name and new company name are treated as identical.

The original version of the PBE, identified as P/N 119003, was issued FAA design approval under *Action Notice A8150.2* by the ACO on 27 October 1988. The unit was initially manufactured by the former remanufacturer under *Part Manufacturing Authority (PMA)* based on this design approval. [21]

On 1 March 1990, the FAA published *TSO-C116*, which replaced *Action Notice A8150.2.* The FAA issued *TSO* Approval to B/E Aerospace for P/N 119003 on 24 April 1990, covering both the original model 119003 and a second version, 119003-01. Subsequently, a third version of the PBE, P/N 119003-11, was issued FAA *TSO-C116* approval on 24 July 2002. A fourth version of the PBE, P/N 119003-21, was issued FAA *TSO-C116* approval on 21 April 2014. The -11 and -21 versions are the only versions currently produced by B/E Aerospace, and the only versions in service with a 10-year life.

The four part numbers are considered by the FAA to be variations of the same model. All four part numbers utilize the same operating principle and the same breathing circuit design, and all four comply with the same performance standard (*TSO-C116*), and are donned and operated in the same way by a user.

The main difference between the -11 and -21 versions is the installation on the PBE -21 of a spark arrester in the exhalation port of the canister. The -21 candle was modified by the implementation of a spark arrester that is physically capable of preventing PBE fires when subjected to the operation of a perturbed PBE candle that was previously shown to consistently produce fires in the existing -11 design.[22]

The B/E Aerospace qualification test for *TSO-C116* approval was documented in the 'Qualification Plan and Procedure of Protective Breathing Equipment' report issued on 13 May 2002. It stated that the purpose of the report was to present a *Qualification Test Plan (QTP)* that would result in analysis and tests demonstrating that the PBE would meet the requirements of *TSO-C116*.

The report states that: "This design of 119003-11 is derived from previous versions of the 119003 series PBE. This unit provides enhanced visibility and other improvements to the hood component, while retaining the proven, previously qualified breathing circuit, atmosphere regenerating system, and donning procedure."

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[20] BTU: British Thermal Unit, heat intensity unit

[21] Reference: B/E Aerospace Report, *DOC: 3500-14-115,* issued on 16 December 2014

[22] B/E Aerospace report, *Document No. 3500-15-029, revision A*, issued in June 2015

The scope of the *QTP* was "[To] site applicable portions of the original certification documents of PBE P/N 119003 series in combination with certain additional tests to demonstrate that the PBE P/N 119003-11 manufactured by B/E Aerospace conforms to *TSO C116* when installed in combination with the existing stowage boxes (P/N 119063-XX & 119065-XX)."

Among other tests, test #17 in the *QTP* was to test the various materials used in the construction of the major components of the hood for their flammability under a 12 second burn condition. Test #18 was to fill a number of hoods with oxygen and expose them to a 1000°C source for 5 seconds.

The *Qualification Test Report (QTR)*, issued by B/E Aerospace on 21 June 2002, states: "To pass this test the hood must sufficiently retain the volume of oxygen so that oxygen does not contribute to the flames and would not present a hazard to the wearer."

According to the *QTR*, the new hood material passed the '#17 vertical burn test', and the hood assembly satisfactorily passed the '#18 flame lick test'.

A supplemental *QTP* was issued by B/E Aerospace on 28 February 2006 and contains a change of #18 test as there was a new supplier of the hood material. The relevant *QTR*, issued on 15 March 2006, stated that: "Three units were subjected to the exposure per 11.1.1 [flame lick test procedure]. In all cases the hood withstood the exposure with the hood able to retain the gaseous oxygen stored within."

The *QTP* and the supplemental *QTP* did not contain changes to the starter candle and canister performance criteria, and also did not contain tests for a PBE self-generated fire such as those caused by the candle.

1.18.2.2 The PBE installation on the Airbus A330- Certification

Airbus had no specific requirements for qualification testing of the PBE to be fitted on the Airbus A330 type, nor was this testing required as part of the type certification requirements. No documentation was submitted by Airbus to the European Aviation Safety Agency (EASA) for the PBE installation as part of the Airbus A330 type certification process. According to Airbus, the PBE units installation in the cockpit was done over a modification (MOD) which was classified as 'minor' where no EASA approval was required. The installation of PBE units in the cabin was done over a cabin layout MOD which was also a 'minor MOD'. Therefore, there was no requirement for Airbus to get approval from EASA with respect to PBE installation.

In its policy, Airbus relies on the *TSO* standards and requirements and considers that equipment manufactured under *TSO*s are airworthy. Therefore, Airbus is not required to perform any post-production tests on the PBE units as the design, production and testing criteria are the responsibility of the *TSO* holder.

According to Airbus, PBE P/N 119003-11 is a *TSO C116*-approved component which was included in the Airbus certification document with a *Mean of Compliance (MOC)- Equipment Qualification* in reference to a *Declaration of Design and Performance (DDP) 4407107-914*.

During the time of delivery, the original PBE P/N 119003-01 was installed on the Aircraft with stowage box 119063-01 according to the cabin layout customization (*Cabin Layout MOD 51226*) prepared by Airbus. According to Airbus, this installation is compliant with the current *Joint Aviation Requirements (JAR) Certification Specification (CS)25.789 and CS25.1301*. Then, PBE P/N 119003-11 (interchangeable with P/N 119003-01) was introduced with the same installation and stowage box according to MOD 51226.

1.18.2.3 The PBE testing criteria

PBE P/N 119003-11 is required to meet the *TSO-C116* standard. To conform to the TSO, the PBE shall meet the environmental conditions of *RTCA/DO-160C.* Prior approval to *TSO-C116* is issued based on testing completed to *RTCA/DO-160D*.

Testing detailed within this document was conducted in accordance with B/E *Document No. 3500-14-106*, using the current industry standard *RTCA/DO-160G*. As such, some conditions and/or procedures may differ from the original certification referring to the FAA *AC 21-16G* for a detailed description of the changes from revision D to revision G of *DO-160*.

According to the production acceptance test procedure of the PBE manufacturer, the KO_2 canisters are manufactured in lots of 500 units. Up to eleven canisters are tested from each lot for leakage, maximum temperature, duration, O_2 production, and CO_2 absorption. If any test fails, the entire lot is scrapped.

All tests in support of the Investigation were performed under the following ambient environmental conditions unless mentioned otherwise:

- Ambient temperature: 25°C±10°C
- Ambient pressure: local standard, 840 to 1070 mbar
- Relative humidity: not to exceed 85%
- Deviations from these conditions shall be stated in the test report.

1.18.2.4 PBE continuous airworthiness

The current Airbus *Maintenance Planning Document (MPD)* contains different check intervals for the PBE units on different types of Airbus aircraft. The interval for the Airbus A330 was eight days/weekly checks.

Two *MPD* references were assigned for the PBE checks: one for the cockpit PBE units, and the other for the cabin.

The cabin PBE check required the following:

> "1) Check Cabin Attendants portable protective breathing equipment tamper seal/serviceability indication i.a.w [in accordance with] AMM [aircraft maintenance manual] 353000/601 at locations defined on the A330 Emergency Equipment Check List (QA/F/0091).
>
> 2) Without removing PBE from box, visually inspect through the box transparent door for vacuum seal. Check expiry date.
>
> Note: A tight pouch indicates a good vacuum seal. A slack or inflated pouch indicates a degraded vacuum seal."

B/E Aerospace *Document 2499-200* was provided to aircraft manufacturers, including Airbus, and operators to support the PBE life cycle in terms of installation, training, use and disposal. The document specifies the requirements and instructions as to the inspection and maintenance of the PBE.

1.18.2.5 Post-Incident service bulletins (SBs) and airworthiness directives (ADs)

A modification plan was initiated by B/E Aerospace for the -11 model, and discussion was continuing between B/E Aerospace and the Federal Aviation Administration (FAA) for further testing of the candles towards more 'volatile' candles by utilizing an accelerant inside the candle and restricting flow to likely produce a consistent method that builds heat and pressure and could consistently produce a fire when assembled in the PBE hood."

On 4 February 2015, B/E Aerospace issued *SB No. 119003-35-011*, Rev. 000, and *SB 119003-35-009, Rev. 009*, was released on 9 November 2015. The first SB (applicable to PBE P/Ns 119003-11 and 119003-21) contained procedures for inspecting the relevant PBE P/Ns: "To determine if the vacuum seal of the pouch containing the PBE is compromised.", whereas the second SB contained procedures "For replacing PBE, P/N 119003-11, with P/N 119003-21."

On 6 January 2016, the FAA published a *Supplemental Notice of Proposed Rule Amendment (SNPRM)*[23] for issuing an *Airworthiness Directive (AD)* related to the PBE ignitor candles. The NPRM mentions that:

> "Further investigation into the fire of the PBE, part number (P/N) 119003-11, found that the ignitor candles from the PBE units that caught fire had a breach of the filter in the candle assembly.
>
> The breach of the filter in the candle assembly allowed hot particles from the igniter candle to enter the oxygen rich environment of the PBE hood, which could cause a fire. All ignitor candles that were examined after fire events showed a breach in the filter. Due to the complexities involved with the chemical reaction within the candle, a definitive cause for the breached filters has not been identified. B/E Aerospace PBE, P/N 119003-21, contains a stainless steel mesh in the outlet path of the igniter candle. It has been established that the installation of the stainless steel mesh will prevent hot particles from entering the PBE hood as a result of a breached filter. Also, it was initially believed that the fire events occurred only with PBEs that had compromised vacuum sealed pouches.
>
> Two recent events occurred with PBEs that were reported by the operators to be in serviceable conditions, although the FAA and PBE manufacturer could not verify the condition of the pouch or PBE before the event. Therefore, we [the FAA] can no longer conclude that a PBE, P/N 119003-11, with an intact vacuum seal will prevent the possibility of spark and fire.
>
> This condition, if not corrected, could result in the PBE catching fire."

The *SNPRM* called for comments on or before 29 February 2016. Paragraph (g) of the *AD* requires inspection on PBE P/N 119003-11 based on *SB No. 119003-35-011,* within 3 months after the effective date of the AD. Paragraph (h) requires replacement based on *SB 119003-35-009* if the PBE pouch is found not to have an intact vacuum seal, the replacement can be by P/N 119003-21, or it may be replaced with another FAA-approved serviceable PBE. The *SNPRM* also also requires: "2) If a PBE pouch is found during the inspection required in paragraph (g) of this AD where the vacuum seal is intact: Within 18 months after the effective date of this AD, remove PBE, P/N 119003- 11, and replace the PBE with PBE, P/N 119003-21, following paragraphs III.C., III.D.(4), III.D.(6), and III.D.(7) of the Accomplishment Instructions in B/E Aerospace Service

[23] This *SNPRM* was issued after *NPRM* published on 16 June 2015 proposing AD to "Require inspecting the PBE to determine if the pouch has the proper vacuum seal and replacing if necessary."

Bulletin No.119003-35-009, Rev. 000, dated November 9, 2015, or replace it with another FAA approved serviceable PBE."

1.18.2.6 Previous PBE incidents

Aviation accidents/incidents literature contains other occurrences in which PBE units did not operate as expected. Table 5 illustrates information about each incident.

Table 5. Historical PBE-related incidents

Nº	Incident Date	Operator	Manufacture Date	Conclusion
1.	23 August 2000	Qantas	Pre- 2001	Bushing separation
2.	11 August 2003	Spirit	October 2002	Bushing separation
3.	12 October 2007	Hawaiian	October 2002	Bushing separation
4.	7 January 2009	VLM	October 2005	External contamination
5.	1 April 2009	SR Technics	June 2005	External contamination
6.	26 April 2011	Finnair	August 2006	Internal contamination
7.	22 November 2011	Qantas	October 2006	External contamination
8.	10 April 2012	West Jet	October 2002	Bushing separation
9.	21 February 2013	Qantas	August 2006	Ongoing
10.	21 May 2013	RSAF	November 2002	Bushing separation
11.	21 May 2013	RSAF	May 2003	Nominal operation
12.	9 January 2015	Qantas	July 2007	Ongoing

The twelve reported events took place during disposal or training. Four events were conclusively attributed to short bushing design. Subsequently, the PBE candle design changed in January 2003 and all PBE units with short bushings have been purged from the fleet. Four events investigated by the B/E Aerospace concluded contamination as the probable cause.

1.18.3 Previous occurrences involving passenger evacuation

On 4 November 2013, a Boeing 767 landed on runway 06 left of Montreal Airport. The aircraft taxied towards the assigned gate. A fire broke out under a belt loader positioned under the left aft cargo door. The smell of the smoke from the fire penetrated the cabin, prompting the Commander to order the evacuation of the aircraft. Some passengers evacuated the aircraft through the boarding bridge while others used the evacuation slides. The airport firefighting service arrived on site at 1649:50 and brought the fire under control.

The Final Report issued by the Transportation Safety Board (TSB) of Canada found that:

> "Passengers who found themselves on the apron without designated staff to help them wandered around looking for instructions and direction. The ground crew working around the aircraft at the time of the evacuation had clearly not been trained on how to deal with such an influx of passengers from the evacuation slides. Nevertheless, some employees reacted quickly by redirecting the wandering passengers towards the door leading to the boarding gate. If ground crew on the apron are not trained to manage

passengers following an evacuation, there is risk of injury both for evacuated passengers and ground crew." [24]

1.18.4 UAE requirements on aerodrome

Taking into account the circumstances of the Incident, the Investigation reviewed the UAE aerodrome related regulations, in order to verify whether or not the regulatory system had adequate provisions in place, regarding an aircraft incident response. In more detail the Investigation looked into the 'rescue and firefighting', and 'passenger evacuation from aircraft and buildings' along with the associated procedures and training of the relevant personnel.

CAR Part XI- [25] states:

> "1.3 Rescue and firefighting equipment and services shall be provided at all certificated aerodromes.
>
> Aircraft Rescue: - is defined as actions taken to save or set free persons involved in an aircraft accident/incident by safeguarding the integrity of the aircraft fuselage from an external / internal fire. To support self-evacuation, and to undertake the removal of injured and trapped persons.
>
> 12.2.11 It is important to provide the fire service with the facility to communicate with flight crew members in certain types of incidents, particularly where undercarriage/engine fire situations are involved or aircraft evacuation may be proposed.
>
> 24.5 Facilities and procedures shall be established by the aerodrome for a designated survivor holding area (Survivor Reception Centre). Those people responsible for the operations of this facility shall be appropriately trained.
>
> Prearrangement shall be made for the immediate transportation by bus or by other suitable transport of the "walking survivors" from the accident site to the Survivors Reception Centre.
>
> Occupants departing an aircraft using evacuation slides may be barefoot, without proper clothing and without required entry documents. These problems shall be anticipated by the aerodromes and appropriate procedures formulated."

Furthermore, *CAR Part XI* required aerodromes operators to include in the emergency exercises Passenger Evacuation Management (PEMS) and crowd control of passengers after aircraft or building evacuation.

Prior to the latest *CAR Part XI* amendment, the GCAA issued a *Notice to Aerodrome Certificate Holders (NOTAC)* under the title *Aircraft Incident Response*. The *NOTAC* was issued to provide guidance for aerodrome certificate holders on:

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24 Reference: TSB Aviation Investigation Report A13Q0186, page 14

25 AERODROME EMERGENCY SERVICES, FACILITIES AND EQUIPMENT" Issue number 03 revision number 00 dated April 2015

"a) Developing training and development programs for Aerodrome Emergency Service and responding airport operational personnel, and

b) The development of procedures for leading passengers, evacuated from an aircraft, to secure areas away from the scene of an incident."

The *NOTAC* also provided detailed guidance to be included in the aerodrome emergency plan procedures for 'Leading Passengers Evacuated From Aircraft, and to Secure Areas Away from the Scene of an Incident' such as PEMS and in more detail how to lead persons who have evacuated and are directly affected by the incident, away from the incident or accident scene to an area that is safe and secure. Regarding crowd control and passenger assembly, the guidance includes coordination of the required actions in order to organize, arrange and coordinate the available resources in an effective manner that would take into consideration their safety and security.

1.19 Useful or Effective Investigation Techniques

No new investigation techniques were used during this Investigation.

2. Analysis

2.1 General

The Investigation into this Incident collected data from various sources for the purpose of determining the causes and contributing factors.

This section of the Report explains the contribution of each investigation aspect to the occurrence of the Incident and to the severity of the consequences. The analysis also contains safety issues that may not be contributory to the Incident but are significant in adversely affecting safety.

This section discusses the following aspects:

- The hydraulic hose failure
- The performance of the Aircraft environment control system
- The performance of the protective breathing equipment (PBE)
- The Airbus A330 and the PBE certification
- The flight and cabin crewmembers performance in the emergency
- The Operator's procedures
- The airport emergency management.

Nothing in this section is to be understood as apportioning blame or liability.

2.2 The Hydraulic Hose Failure

According to Airbus, hydraulic hoses are approved to be installed on Airbus aircraft relying on the part manufacturer's approved design and manufacture standards.

The affected hose was a straight-to-single elbow (45°) end fittings, high pressure hose that is constructed of three layers: a thin wall Teflon inner tube, a Hi-Pac outer braid consisting of densely packed small diameter stainless steel wires, and a fabric sleeve.

The *MIL-H-38360A* testing criteria for the hose are universally recognized and the probability of reaching the extremes of these test parameters during operation is remote. The location of the hose in the Aircraft and the operational hydraulic pressure (3,000 psi) do not create elevated environmental conditions such as those applied during testing.

The Investigation approached the analysis of the hose failure working from the outer construction layer to the inner construction layer. The outermost layer was a fabric sleeve which exhibited inhomogeneous damage to the fabric which indicated that the textile was exposed to tensile force from the internal direction.

The layer inside the fabric sleeve was the steel braiding which displayed abrasion marks on the surface of the steel wires, and fatigue marks on the cross section of the damaged wires.

The crack on the PTFE pipe surface did not exhibit fatigue indications.

The examination showed that the damaged braiding wires, the fabric sleeve, and the damage of the PTFE tube were correlated. The location of the damage was also the location of the hose identification tag. This identification tag was not found on removal of the hose from the Aircraft.

The hose damage was in the area very close to where the elbow end fitting is crimped to the hose. The outer part of the end fitting is crimped to the hose outside the fabric sleeve, but the dust and the abrasion marks noticed on the outside of the damaged braiding wires revealed that the wires had been exposed some time before the sudden failure took place. Although the damaged wires were the cause of the textile rupture, the wires sudden fracture occurred after the textile rupture.

The sudden failure of the wires took place after the fatigue reached the critical phase where the remaining diameter of the wires was unable to withstand the force exerted by the hydraulic pressure transferred from the interior PTFE tube.

The purpose of the braiding is to re-enforce the PTFE tube. Normally, the braiding should not fail before the tube failure. In addition, there were no corrosion indications on the braid wires which, if present, would have adversely affected the life of the wires and, subsequently, the hose.

According to the *MIL-H-38360A* standard, the inner tube shall be reinforced by corrosion-resistant steel wires conforming to defined specifications. The wires shall be arranged over the inner tube so as to provide sufficient strength to ensure conformance with the requirements specified in the same standard.

The Investigation could not determine the age of the failed hose since the hose was installed on the Aircraft during production and the identification tag was missing, but, by checking the dates of manufacture for other hydraulic hoses located in the rudder area, the Investigation believes that the life of the damaged hose was approximately 14 years, within the same life range as the other hoses.

MIL-H-38360A does not specify limited service, or shelf lives, for the hydraulic hoses. Therefore, if the post-production testing, storage, and handling conform to the standards, the hose life can continue without any service life constraint.

The failure of the hose may have occurred for any one, or a combination, of the following reasons:

1. The manufacturing process was not well protected from contamination;
2. The postproduction testing of the hose was not carried out correctly to comply with the design testing standards;
3. The design testing standards were not adequate to cover the spectrum of actual operational conditions, and vulnerability to other conditions, that may not have been anticipated during the development of the testing standards;
4. Handling of the spare part after production, including the storage conditions, was not appropriate; and/or
5. The in-service conditions were beyond the published limitations.

The precedence of the braiding failure to the tube failure indicates that the braiding was holding its part of the internal hydraulic pressure. The scratches and the imprint marks left on the tube by the braiding wires indicate that the braiding was properly fitted to the hose assembly. Accordingly, it is believed that the hose assembly step in the manufacturing was carried out properly, but the Investigation could not determine whether or not the fabrication of each component in the hose was according to that specific component-manufacturing standard.

No records were discovered by the Investigation indicating that the hose in-service limitations, in terms of operating pressure, or burst pressure, had been exceeded. There were also no indications on the exterior of the hose that indicated that the bend radius had been exceeded. There was no indication that inappropriate physical force had been applied to the hose, or that the environment was contaminated, or that the fixing clamps were out of place. Therefore, the Investigation believes that the in-service conditions were within the published standards.

Since the part was installed by the Aircraft manufacturer, and the manufacturing standards were properly implemented, the Investigation believes that handling of the hose before and after installation was proper.

The Investigation could not determine the exact cause of the braiding fatigue failure, but the Investigation believes that the hose postproduction testing could not predict the failure at this service life, or was not sufficient to cover other conditions that the hose was subjected to, within the spectrum of the testing parameters. The loss of the identification tag prevented the Investigation from determining the date of production of the hose, and made it impossible to check the documentation related to the post-production inspection.

2.3 The Protective Breathing Equipment (PBE)

2.3.1 The PBE fire

From the 'vibration and shock test', 'temperature/temperature variation test' and 'combined humidity and altitude test', all units, including one with a compromised pouch seal, were opened and they activated normally. Evidence of some candle discharge was observed in the hood exhalation ducts.

Considering the results of the tests, and assuming that the tests accurately reflected the PBE operational conditions, the Investigation believes that it was unlikely that the installation operational conditions had contributed to the candle fire.

In order for a PBE fire to occur, it is necessary that active/energetic core materials, such as those emanating from the perchlorate starter layer, be ejected from the candle. The CT-scan report[26] concluded that the absence of the perchlorate based starter layer residues in the candle core, combined with more significant temperature effects on the candle tube surface, and the presence of core materials in the candle elbow outlet, were indicative of exceptionally high temperature conditions, and a high rate of reaction of these elements. Such temperature and pressure conditions caused an increase in the rate of reaction of the remaining sodium chlorate core materials complementing, or perpetuating, the effects associated with a discharge of energetic material from the candle.

The relative lack of primary layer core disruption implies that the material observed in the candle elbows of the two PBE units exposed to fire, was a by-product of the starter layer reaction.

The CT scan report referred to a military study that addresses physical and chemical factors that may affect the desired result (e.g. rate of reaction) from a pyrotechnic piece as being:

- The purity of each substance used
- The chemical balance of the composition as a whole
- The amount of moisture present

[26] B/E Aerospace Engineering Report Nº 3500-15-025, dated 3 June 2015- *CT Scan Inspection of Annex 13 PBE Candles*

- The age of the composition, taking into account the slow chemical reactions, which may take place with the lapse of time
- The relation of the proportions of the various substances used, as compared with the ideal relation experimentally determined as producing the greatest efficiency
- The relative fineness of the various constituents
- The degree of compression used in the formation of the composition
- The thoroughness with which the various constituents have been mixed
- The shape and size of the finished piece in which the composition functions
- The hydroscopic properties of the composition as a whole
- The efficiency and adaptability of the container as regards the maximum effect to be produced.

A number of these factors could be considered to have an attenuating effect (such as moisture, or ageing).

The report listed factors specific to the processes by which the candle is manufactured and that could directly affect, or accrue in a manner that could influence, an increase in the reaction rate of the starter layer:

1. The purity of each substance used (either pre-existing or introduced contamination)
2. The degree of compression used in the formation of the composition, (i.e. control the application of forces during the core forming/molding process)
3. The thoroughness with which the various constituents have been mixed, (i.e. consistent mixing)
4. The shape and size of the finished piece in which the composition functions.

The Investigation determined that it is highly probable that at least one of the listed production-based defects had led to the uncontrolled reaction in the EK609 PBE S/N 003-35283M and in the PBE S/N 003-35282M that caught fire during the post-Incident test carried out in the Operator's facility.

2.3.2 The Airbus A330 and the PBE certifications

The B/E Aerospace *Qualification Test Report (QTR)* contained a compliance statement indicating that there were no issues related to compliance with *TSO-C116*.

Airbus had no specific requirements for qualification testing of the PBE to be fitted on the Airbus A330 type, nor was this required as part of the type certification requirements. Airbus had not submitted any document to EASA for the PBE installation as part of the Airbus A330 type certification process. According to Airbus, the PBE units were installed in the cockpit under a modification (MOD) which was classified as minor, and no EASA approval was required. The installation of PBE units in the cabin was accomplished under a cabin layout MOD which was also a minor MOD. Therefore, there was no requirement for Airbus to obtain approval from EASA with respect to PBE installation.

The potential fire hazard of the PBE candle was not mentioned in the *TSO,* or the relevant *RTCA*. Furthermore, the Airbus modification did not request any on-board fire hazard test to be conducted by either the supplier, or by the Airbus safety team.

2.4 The Aircraft Environment Control System (ECS)

The design of the airconditioning intake did not completely prevent the ingress of hydraulic fluid into the airconditioning system. The airconditioning filtering system was unable to completely decontaminate the treated air.

Operationally, and according to the *FCOM* procedure, the first action to be carried out in case of airconditioning smoke is to switch off the APU BLEED. This action would have stopped the introduction of hydraulic fluid mist into the cabin.

The temporary influence of the mist generated by heating the hydraulic fluid in the airconditioning system on the health of people onboard could not be exactly determined, but the Investigation believes that the level of contaminants in the mist was below the published limitation that could cause drowsy situation. However, the mist concentration still affected the respiratory system causing difficulty in breathing, throat discomfort, and eye irritation to some occupants.[27]

The build-up of mist in the cabin was a significant indicator to the crew that they should anticipate the potential need for an evacuation. The Operator's policy is that the Commander may order an evacuation or, in an extreme situation, a cabin crewmember may initiate an evacuation, but with continuous updates on the situation from the other crewmembers. For the Incident flight, from the initial report of smoke to the point when the Commander decided to disembark the passengers using steps, a period of approximately five minutes elapsed. The Commanders decision to evacuate using the slides was made based on the information provided by the L4 cabin crewmember regarding the very limited visibility in the cabin. The Commander called for the evacuation two minutes after he had requested that the passenger be disembarked using steps.

The hydraulic fluid mist buildup and dissipation is dependent on the airconditioning system. Normally, and according to the procedure, the on-ground setting is to open the APU-bleed valve and cross bleed valve. Therefore, the air coming from the APU will enter the system through the pack 1 and pack 2 flow control valves. But after engine start, the APU shall be switched to OFF. (Appendix B).

The correct functioning of the cabin ECS is vital for the occupants' safety. However, considering the limits of the ECS, a supply of pure air is not always guaranteed, and a certain level of contamination is acceptable, as long as the contaminants are not hazardous.[28]

According to a published study "Concerns have been raised by organizations representing pilots and cabin crew about the possible effects on aircrew health of oil/hydraulic fluid smoke/fume contamination incidents in pressurized aircraft. Specific concerns have been

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[27] Reference: Air Quality in Airplane Cabins and Similar Enclosed Spaces, by Prof. Martin B. Hocking, Department of Chemistry, University of Victoria, Canada.

The hydraulic fluid is fire resistant fluid including a proprietary phosphate ester mixture composed principally of dibutyl phenyl phosphate and tributyl phosphate.

Tributyl phosphate is a colorless to pale-yellow, odorless liquid. The existing standards for tributyl phosphate are:

- According to the Occupational Safety&Health Administration (OSHA) General Industry, the permissible exposure limit (PEL) is 5.0 mg/m^3 Time Weighted Average (TWA).
- According to the American Conference of Governmental Industrial Hygienists (AGGIH), the Threshold Limit Value (TLV) is 0.2 parts per million (ppm) (2.2 mg/m^3 TWA).

The international published revised Immediately Dangerous to Life or Health Concentrations (IDLH) is 30 ppm

[28] *Certification Specification, CS 25.831- Ventilation*

raised with respect to organophosphate compounds (OPs) in the cabin air environment and the perceived effects on health of long term low-level exposure."[29]

The same study defined the irritation as: "A state of over-excitation and undue sensitiveness of the nervous system in response to a stimulus. For example, irritant receptors in the lungs stimulate reflex constriction of the bronchioles in response to smoke and smog. Similarly, sneezing, sniffing and coughing may be stimulated by irritant receptors in the nose, larynx and trachea.

Individuals vary in their response to sensory stimuli, including smells. Genetic differences are thought to cause some people to have enhanced sensitivity to low levels of some volatile chemicals; they experience a range of irritant symptoms affecting well-being."

In a study titled *Contamination of aircraft cabin air by bleed air – a review of the evidence*[30], the Introduction states that: "Cabin air in commercial aircraft can be contaminated with hydraulic fluids, synthetic jet oils or the compounds released when these fluids are heated or pyrolysed. The incidence of contaminated air events and the nature of contaminants within the cabin air are difficult to determine as commercial aircraft do not have air quality monitoring systems onboard […]. The immediate effects of exposure to contaminated air have been well documented but debate continues about causation, diagnosis and treatment of long-term effects." [31]

The exposure of the passengers onboard the Incident flight to the hydraulic mist, and of some of the passengers to the following PBE fire led them to complain of irritation. However, the exposure did not lead to ill effects to the Central Nervous System (CNS) of which known symptoms are loss of recent memory, poor concentration, increased lethargy, neuromuscular incoordination, confusion, and headaches.

There are no design features incorporated into any in-service aircraft that measure contamination of the cabin air in relation to the total environment. In addition, measuring the concentration of such contaminants to the total volume of air is not an easy task.

An international specified database managed by the International Civil Aviation Organization (ICAO) can be a good mechanism for data collection from the various States, and improvement of the Aviation Data Reporting Program (ADREP) system utilizing the European Co-Ordination Centre for Aviation Incident Reporting Systems (ECCAIRS), is a good tool for containing a comprehensive checklist for incidents related to the aircraft interior environment and the human body symptoms after exposure to such contaminated environments.

2.5 The Flight and Cabin Crew Performance during the Emergency

2.5.1 Crew decision-making

Crewmembers are required to make decisions to safeguard passengers and fellow crewmembers. In their day-to-day operation, they need to choose between possible solutions to a problem. They need to identify as many alternatives as possible, but to choose one. Their selection should have the highest probability of effectiveness. Before a final decision is made, they project their selected best solution into the future, in order to understand whether or not the selected course of action will solve their specific problem, while maintaining their situational

[29] Reference: Health Effects of Contaminants in Aircraft Cabin Air, Summary Report v2.5, by Professor Michael Bagshaw, August 2013

[30] *Contamination of aircraft cabin air by bleed air – a review of the evidence*, by Expert Panel on Aircraft Air Quality (Expert Panel)

[31] The above reference

awareness of all other elements of the flight. Crewmembers respond to a situation as they perceive it at that specific moment. Given what they know at that moment, and within the limits of human information processing capability, they are called upon to make decisions.

Crewmembers training, experience, knowledge, personal goals, ancestry and culture, affect their characteristic limitations and human cognition, and determine how they will respond to the demands of the situation, and the tasks that have to be performed.

The EK609 flight crewmembers required information in order to make their decisions, but, in the beginning, multiple and conflicting information was presented to them regarding the smoke in the cabin. Although they did not have prior knowledge of hydraulic fluid entering aircraft, they managed the situation according to their training. It was evident that the Commander was unfamiliar with the situation in the cabin and he did not initiate the evacuation until he had acquired sufficient information to assess the situation.

In more detail due to the leak, in the fractured hydraulic hose located in the rudder the hydraulic fluid escaped from the Aircraft's yellow hydraulic system and entered the airconditioning system. Once the fluid entered the APU, it was heated and converted to small droplets which exited through the vents and ducts into the Aircraft interior.

The cabin was filled quickly with mist, and as long as the APU bleeds were 'open', the mist continued to enter the cabin. The crewmembers could see the mist, which they perceived as smoke and which was restricting their visibility. However, the crewmembers could not locate the source of the perceived 'smoke'.

The flight and cabin crewmembers are trained that smoke is associated with fire, which requires utilizing a PBE unit. Consequently, the crewmembers were trying to locate the source of the smoke to determine the origin of the fire. The crewmembers are also trained to determine the source and type of smoke, or fumes, by using their sense of smell, based on different types of fume events having differing material origins.

Furthermore, flight and cabin crewmembers had different perceptions of the situation. In an attempt to assess the situation, the Commander asked the copilot whether he had the same impression of a 'terrible smell' and the copilot replied in the affirmative. Then the Commander asked the senior cabin crewmember if she had the same impression and she confirmed this to be so.

At that time, the environment was contaminated by the hydraulic fluid mist, which was building up through the airconditioning system, and was circulated in the Aircraft cabin through the re-circulation system.

When the cabin crew felt that the hydraulic fluid mist became denser, and the lavatory smoke detector activated, the R3 cabin crewmember handed the fire extinguished and PBE to the crewmember who was originally stationed at L1A. This crewmember donned the PBE to start fighting the suspected fire source. It was logical to suspect that the source of the 'smoke', and therefore potential fire, was in the lavatory, and this was appropriate reasoning based on the training provided to the crewmembers.

When the cabin crewmember donned the PBE, the PBE ignited after she pulled the activation lanyard that is connected to the release pin of the starter candle; the cabin crewmember immediately removed the PBE and dropped it on the Aircraft floor, and she did not suffer any injury. The Investigation believes that the behavior of the cabin crewmember in such circumstances was a normal human reaction when facing a hazard.

The CVR indicated that the Commander's situational awareness was reinforced by effective CRM which included continuous updates from the cabin.

The influence of stress on human performance is of great importance, as individual reactions to stress, and its influence on attention control, is vital[32]. To counteract stress, among other things, crewmembers are trained in the utilization of all available resources. In EK609, all crewmembers utilized their past experiences, and their training, to better understand the developing situation.

A person's ability to draw conclusions by referring to previous experiences may serve as a guide to dealing with current events, which is an important ingredient of decision-making[33]. Emphasis on labeling previous cases assists with the most predictively useful indexes[34].

The review of the EK609 communication flow, the information and warnings transmitted to the flight crewmembers, and the actions taken by all crewmembers, indicate that the initial information was insufficient to enable the Commander's decision-making. When the Commander received the first indication of what he considered to be 'smoke', he verified the situation with the copilot and then started communicating with the cabin crewmembers. However, there was no critical information or significant indication to prompt the cabin crew to take action other than waiting for new information, or for direct instructions from the Commander.

The Commander decided to disembark the passengers, and to accomplish this by returning to the departure gate approximately 3 minutes and 40 seconds after receiving the first indication on the ECAM of the hydraulic system caution. Soon after, when the Commander asked for more information about the amoke and learned that the visibility in the cabin was now down to four seat rows, he decided to evacuate the passengers using the Aircraft escape chutes. By that time, a number of passengers had already left their seats with their personal belongings including their hand baggage and were demanding to exit the aircraft. The evacuation command was issued by the Commander seven minutes and eight seconds after the first indication of smoke.

It would be difficult to simulate the exact pattern of the hydraulic fluid mist dissemination and the reduction in visibility inside the cabin; the Investigation believes that the mist generated and vented through the Aircraft airconditioning system and condensed rapidly. The mist caused the Aircraft occupants to sense a disturbing odor and some occupants started to suffer from throat irritation.

While events were taking place in the cabin, the Commander needed information in order to complete his mental picture of the situation in the cabin. Therefore, the Investigation needed to identify when the Commander decided to evacuate.

A review of the crew communications indicated that there was information flow from the cabin to the cockpit, but that the terminology used by the cabin crew to describe the situation to the flight crew and assist decision-making, was not standard terminology. The use of phrases such as "The situation is very very bad" transfers a sense of urgency and a level of emotion, but lacks information as to details of what is actually happening, as bad could be perceived differently due to personal experience. However, "visibility one meter" or "I can see four seat rows." would have transferred critical information more accurately. The Commander spent valuable time trying to perceive the actual situation in the cabin, whereas there was an assumption that as the Aircraft

[32] Vine, Samuel J.; Uiga, Liis; Lavric, Aureliu; Moore, Lee J.; Tsaneva-Atanasova, Krasimira; Wilson, Mark R. Individual reactions to stress predict performance during a critical aviation incident Anxiety, Stress & Coping. Jul2015, Vol. 28 Issue 4, p467-477. 11p. DOI: 10.1080/10615806.2014.986722

[33] Schank, R. C. (1999). Dynamic memory revisited. Cambridge, UK: Cambridge University Press.

[34] O'Hare, D.,&Wiggins, M. (2004). Remembrance of cases past: Who remembers what, when confronting critical flight events? Human Factors, 46, 277–287

was on the ground near the terminal buildings, it could quickly be returned to the stand, or that an evacuation of the passengers and crew could be accomplished within seconds

Although the terminology used by the cabin crew was not standard, the flight crew could have better interrogated the cabin crewmembers and better interpreted the communication of information from the cabin. The flight crew heard the words from the outset “Very thick smoke” stated in an agitated tone of voice. Seventy four seconds later the cabin crew advised the flight crew that: “The situation is very, very bad”, and then a further communication from the cabin stated; “Cannot breathe…” All of these statements, which convey a sense of urgency or distress, were transmitted over a period of about three minutes, but it took the Commander a further four minutes to decide to order an evacuation of the Aircraft. The Investigation believes that the time spent in deciding to order the evacuation could have shortened if more weight had been given to key words and phrases used by the cabin crewmembers.

The flight crewmembers were attempting to gather information and manage the situation within a dynamic environment. The flight crew utilized the *SMOKE/FUMES/AVNCS SMOKE* checklist contained in the Operator's *QRH.* This checklist did not differentiate between smoke and mist, nor between inflight and on-ground smoke. The checklist was designed to cope with an inflight event rather than an on-ground event as this is the most critical scenario, but the philosophy and the efficiency of the overall procedure remains applicable for on-ground situations. The checklist contains three inflight fire items that are not applicable to an on-ground fire event. In a situation where the flight crew and cabin crew are busy with the many aspects of preflight preparation, the crew must be prepared to adjust their mindset and level of alertness rapidly to manage any unanticipated emergency situation.

2.5.2 Crew uniform

The Operator requires the female cabin crewmembers to wear medium-heel shoes during passenger embarkation and disembarkation for product branding purposes. According to the Operator's policy, the medium-heel shoes are more presentable in welcoming the passengers. The medium-heel shoes are usually replaced by flat shoes when the inflight service starts.

During the Aircraft pushback, the female crewmembers were still wearing the medium-heel shoes, and when the evacuation commenced, the crew were required to take the shoes off in order to evacuate using the chute. This type of shoes is not allowed to be worn during an evacuation because of the possibility of puncturing the chute.

The cabin crew were unsure, as stated during their interviews, whether to leave their shoes on, or remove them, as they were worried that their feet may be injured due to the impact with the ground when reaching the end of the slide. In addition, the female crew also added that they felt uneasy using the slides as they were wearing skirts.

Aircraft emergency evacuation is a time critical and procedure-sensitive practice that requires intensive training and good leadership. The crew must be able to manage the evacuation safely and efficiently, especially in cases where panicked passengers may influence the whole exercise by their uncontrolled behavior. Assertive cabin crew will inspire confidence among the passengers.

In the EK609 flight, the first experience of the crew in facing situations that require evacuation during pushback, the unassertive mindset of the female crew to slide with or without shoes, in addition to wearing an uncomfortable uniform, may trigger a need for evaluating and enhancing the training of the cabin crew to assertively manage an emergency situation. The flight and cabin crewmembers need to be indoctrinated in the on-ground emergency in order to be able to quickly assess the event, communicate vital information and, if necessary, commence an immediate and efficient evacuation.

The cabin crew directed the agitated passengers towards the doors for evacuation. However, these evacuation doors were not the same doors that the passengers had, shortly before, used to enter the cabin. The cabin crew tried to guide passengers to other unobstructed exits, without success due to the passengers' reluctance to follow the cabin crew directions. Although the passenger briefing contained information regarding all Aircraft exits, the majority of the 68 passengers exited the Aircraft by L2 door.

Following the evacuation, the passengers received no guidance on where to assemble outside of the aircraft.

2.6 The Operator's Safety Management System

When the Operator decided in August 2013 to change the uniform of the female cabin crewmembers from trousers to skirts, there was no associated safety risk study carried out. The Operator considered that the skirts would provide the same safety performance that it had throughout its history, therefore, no change management process and no safety case was considered necessary. The Operators safety unit was not consulted on the change, nor was it requested to prepare a risk analysis exercise on the change.

From the cabin crew training side, there was no specific requirement that the trainee crew use a packed PBE unit in the simulator class. The dummy, already opened PBE units used in the simulator training could not simulate the training as closely as possible to the real life. Similarly, there was no specific requirement in the Operator's training procedure that the female crewmembers wear clothing similar to that used in operation.

The Investigation believes that the lack of such requirements in the training procedure deprived the Operator from identifying hazards arising from testing the preset emergency procedure. Accordingly, the Operator did not have appropriate data that could have assisted in the decision as to whether to conduct a safety assessment on that specific area, or not.

The *Safety Management Manual* requires the Operator to assess the safety risks associated with any new product and to manage those risks "Through processes that ensure the classification, analysis, assessment and control of risks to an acceptable level. Safety Risks are analyzed in terms of probability of occurrence and severity of outcome, and then assessed for their tolerability."

The Operator's safety policy requires a formal safety risk assessment "In response to an identified hazard/risk, or from a change management initiative. The Safety Risk Assessment should be conducted by an individual or team with subject area knowledge, and training in the conduct of risk assessments." The level of complexity of any risk assessment should be appropriate to the operational significance of the risk.

The Operator's safety policy requires a review and analysis of safety impacts in case of changes to policies, procedures, equipment, operating environment, etc. The Operator's safety policy requires that such changes be identified and managed.

Although the Investigation believes that the uniform of the female cabin crew was not contributory to the Incident; the worry of the female cabin crewmembers of suffering skin burns due to friction with the chute, and potential embarrassment caused a moment of hesitation. That short loss of assertiveness might have a greater impact should a more time constrained incident occur where the number of passengers is greater, and/or the evacuation is subject to adverse conditions.

The probability of an evacuation on the ramp was not taken into account by the Operator, nor had there been a situation that might have required addressing the need for such a procedure. The Operator's evacuation procedure, checklists, as well as training, were all attuned to an in-flight fire, therefore, the cockpit and cabin crew were not experienced with, or trained for, an evacuation on the ramp.

The Investigation believes that the lack of anticipation of the possibility of an evacuation on the ramp , and the absence of a safety risk analysis of the cabin crew uniform, placed the cabin crew in a more passive, and less assertive, mindset than was optimal to control the evacuation. However, this did not significantly affect the EK609 evacuation, but could have exacerbated the situation should the occurrence have taken place in a more complex situation.

2.7 The Airport Emergency Management

When the Commander announced the passenger disembarkation initially, and then that he intended to evacuation the Aircraft using the escape chutes, the situation was not treated with an appropriate level of urgency by ATC. Other aircraft and vehicles continued to maneuver close to the EK609 Aircraft. No effective action was taken by ATC to assist in expediting the disembarkation of passengers and crew, or to protect the disembarked passengers by stopping movements on the ramp.

Although the evacuation took place without any unsafe consequences, the Investigation believes that a hazardous situation was created when ATC allowed other aircraft in the vicinity of EK609 to continue taxiing as the Aircraft was being evacuated. ATC could have managed the emergency by observing and directing other aircraft in such a way as to facilitate a safe evacuation, and minimize any potential hazards on the ramp.

From the airside operations aspect, the airport did not take sufficient action to facilitate the evacuation by protecting the area of the Aircraft and making personnel, equipment, and facilities available to safeguard and guide the evacuated passengers. The Investigation believes that the airport lacked efficient procedures to manage an aircraft evacuation on the ramp.

The fire service vehicles arrived at the site within a reasonable time, and were appropriately positioned. The fire officers entered the Aircraft by climbing R1 door chute barefoot to prevent damage to the chute. This was not in accordance with firefighting standard operating practice.

Other passenger evacuation investigation such as a Boeing 767 in Montreal and a Boeing 777 in San Francisco, show that there are many safety issues to be considered after successfully evacuating passengers from an aircraft.

For the purpose of identifying potential improvement opportunities for the UAE civil aviation system, the *Civil Aviation Regulations* should be revised regarding the safeguarding and guidance of passengers evacuated on the ramp. The Investigation believes that it is crucial that the GCAA assures that airport emergency manuals contain effective procedures for handling evacuated passengers, and that these procedures are practiced frequently to assure their effectiveness.

3. Conclusions

3.1 General

From the evidence available, the following findings, causes and contributing factors were made with respect to this Incident. These shall not be read as apportioning blame or liability to any particular organization or individual.

To serve the objective of this Investigation, the following sections are included in the conclusions heading:

- **Findings-** are statements of all significant conditions, events or circumstances in this Serious Incident. The findings are significant steps in this Serious Incident sequence but they are not always causal or indicate deficiencies.
- **Causes-** are actions, omissions, events, conditions, or a combination thereof, which led to this Serious Incident.
- **Contributing factors-** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of this Serious Incident occurring, or mitigated the severity of the consequences. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 Findings relevant to the Aircraft

(a) The Aircraft was certified, equipped and maintained in accordance with the existing requirements of the United Arab Emirates, General Civil Aviation Authority.

(b) The cause of the yellow hydraulic rudder servo hose failure was not determined.

(c) The hose failure initiated from a fatigue failure of the braiding which caused a fracture of the core tube.

(d) Most probably, the hose post-production testing did not predict this type of failure at this time in the service life of the hose.

(e) The loss of the hose identification tag prevented the Investigation from determining when the hose was manufactured, nor could post-production inspection be verified.

(f) The hose was classified under the 'on-condition' maintenance and inspection philosophy.

(g) The Yellow system hydraulic fluid leaked at a high rate from the fractured hose.

(h) A fine mist resulted from the ingestion of the leaking hydraulic fluid into the APU inlet.

(i) The mist entered the cockpit area first, before flowing to the aft cabin section.

(j) The Aircraft environment control system could not detect the mist and alert the crew at an early stage.

(k) The Aircraft environment control system could not prevent the mist from entering the cabin.

(l) The PBE was installed on the Aircraft during production.

(m) The PBE ignited when the cabin crewmember pulled on the activation straps.

(n) It is highly probable that the PBE caught fire because of manufacturing defects.

(o) The evacuation order was initiated by pressing the EVAC COMMAND guarded pushbutton on the cockpit overhead panel.

(p) The PBE unit was manufactured in accordance with *TSO-C116* issued by the Federal Aviation Administration (FAA) of the United States.

(q) Airbus had no special test requirements for the PBE fitted to the Airbus A330. Airbus relied on the unit certification requirements as mentioned in *TSO-C116*, listed in the B/E Aerospace *Qualification Test Plan (QTP)*, and verified by the *Qualification Test Report (QTR)* issued by B/E Aerospace on 21 June 2002.

3.2.2 Findings relevant to the crew

(a) The flight and cabin crewmembers were licensed and qualified for the flight in accordance with the existing requirements of the United Arab Emirates, General Civil Aviation Authority.

(b) The flight and cabin crew were well-rested.

(c) The reaction of the cabin crewmember who dropped the burning PBE on the Aircraft floor was normal human behavior, given the circumstances.

(d) The flight crew were not aware at an early stage that the source of the 'smell' that they detected was due to the presence of fine hydraulic fluid mist.

(e) At the beginning of the incident, the information available to the flight crew about the cabin situation was not sufficient to assist them in building a good mental model of the developing occurrence.

(f) After the situation became more severe, and explicit statements were transmitted to the Commander describing the severity of the situation in the cabin, the Commander took a further three minutes before ordering the evacuation.

(g) Some of the female cabin crewmembers were not comfortable wearing skirts while using the escape chutes. Some of them were also reluctant to slide without wearing their medium heel footwear. The absence of a ramp-evacuation mindset led to a less than optimally assertive crew attitude.

3.2.3 Findings relevant to the Operator and flight operation

(a) The cockpit and cabin inter- and intra-communication systems functioned correctly.

(b) Although the abnormal checklist included in the *Quick Reference Handbook (QRH)* requires the flight crew to shut down the APU immediately in case of smoke generation, the crew did not implement that step and the APU remained running which allowed more mist to enter the cabin.

(c) There was no dedicated on-ground emergency smoke or mist checklist. The checklists contained in the Operator's *CCOM* and *FCOM* are relevant to in-flight smoke, and these checklists include items that are not applicable to an on-ground smoke or mist emergency.

(d) The abnormal checklist deals with mist under the generic term 'smoke'.

(e) The Incident was the first time that the crew had experienced a smoke event and subsequent evacuation during pushback.

(f) The transmission of communications among and between the flight and cabin crewmembers from the time of the mist/smoke generation until the end of the evacuation was were clear.

(g) The crew resource management (CRM) was effective and worked well in a dynamic situation practiced well.

(h) According to the Operator's procedure, the copilot is required to help the evacuated passengers on the ground, and direct them away from the aircraft.

(i) The Operator's cabin crew simulator training did not reflect actual operational conditions in terms of wearing clothing similar to the uniform and use of a sealed training PBE. The cabin crew training for slides escape chutes is performed using other clothing that is not besides the Operator's in-flight uniform, and the PBE used during training is not the same as that used during normal flight operations.

(j) No specific safety risk analysis had been carried out by the Operator of to risk assess the decision to change the female cabin crew uniform from trousers to skirts.

3.2.4 Findings relevant to air traffic services and airport facilities

(a) The evacuation was not treated with sufficient urgency by ATC. During the incident other aircraft continued to taxi close to the EK609 Aircraft.

(b) The passengers were not safeguarded and guided to a safe place after evacuating the Aircraft.

(c) The airport lacked effective procedures in dealing with an aircraft evacuation on the ramp.

(d) The firefighting vehicles arrived at the site within a reasonable time, and were appropriately positioned and stayed on standby.

(e) The fire officers climbed to R1 door using the deployed chute barefooted. This is not according to firefighting standard operating practice.

3.3 Causes

The Air Accident Investigation Sector determines that the causes of the dense mist entering the cabin, and the subsequent PBE fire onboard the EK609 Airbus A330 were:

3.3.1 The failure of a yellow hydraulic system rudder servo hose that allowed leaking hydraulic fluid to enter the APU where the fluid was heated and atomized and was then fed into the cabin airconditioning system. The cause of the hydraulic hose failure was not determined.

3.3.2 It is probable that manufacturing defects in the PBE candle caused a vigorous chemical reaction in the candle which resulted in abnormal ignition when the cabin crewmember, who had donned the equipment, pulled the activation lanyard.

3.4 Contributing Factor to the Incident

As the flight crew were unable to identify the source of the mist/smoke, they decided to leave the APU running in case it became necessary to shutdown both engines, but they did not close the APU bleed as required by the *SMOKE/FUMES/AVNCS SMOKE* checklist.

The result of this decision was that hydraulic fluid mist continued to enter the cabin. This decision was taken without having positively identified the sources of the smoke/mist.

4. Safety Recommendations

4.1 General

The safety recommendations listed in this Report are proposed according to paragraph 6.8 of *Annex 13* to the *Convention on International Civil Aviation*, and are based on the conclusions listed in heading 3 of this Report; the AAIS expects that all safety issues identified by the Investigation are addressed by the receiving States and organizations.

4.2 Corrective Actions Taken

4.2.1 Actions taken by the GCAA

Three *Director General Directives (DIR) Nº 07/2014, 08/2014, and 09/2014*, were issued and were applicable to all UAE civil registered aircraft equipped with B/E Aerospace PBE units, P/N 119003-11.

The purpose of the first *DIR 07/2014*, date of issue 14 October 2014, was to: "Arrest a potential fire risk from specific model of Protective Breathing Equipment.", with a requirement to inspect the "Integrity of PBE vacuum seal, expiry date, moisture ingress or any obvious damage or abnormality", and reject any suspect PBE unit at every pre-departure as per the applicable maintenance data.

DIR 09/2014, date of issue 23 October 2014, superseded *DIR 08/2014* and revised the PBE inspection frequency and required the: "Withdrawal from service of PBE P/N 119003-11 S/N 003-34983M to 003-35563M, all inclusive." within 72 hours.

4.2.2 Actions taken by B/E Aerospace

On 4 February 2015, B/E Aerospace issued *Service Bulletin (SB) No. 119003-35-011*, calling for inspection of the integrity of the vacuum-sealed pouch to assure that it protects the PBE from contamination and premature activation of the PBE air regeneration chemicals.

The *SB* requires visual and thorough physical inspection to check for looseness or bloating of the pouch.

A visual inspection is carried out before every flight, and a physical inspection is carried out every month. The visual check can be carried out by a cabin crewmember, whereas the physical inspection shall be carried out by maintenance personnel.

As stated in the B/E Aerospace post-incident report, B/E Aerospace is reviewing the main steps in the manufacturing process, as well as the conditions surrounding fabrication of the PBE.

Specific consideration was given to the following:

- The purity of each substance used (limit contamination, either pre-existing or introduced).
- The degree of pressing used in the formation of the composition (control of the application of forces during the core forming/moulding process).
- The thoroughness with which the various constituents have been mixed. (consistent mixing).

- The shape and size of the finished piece in which the composition functions. (controls implemented and maintained as per the pressing requirement).

On 9 November 2015, Mandatory SB 119003-35-009 was published by B/E Aerospace requiring: "All PBE PN 119003-11 shall be replaced with PN 119003-21 no later than February 28, 2017 or sooner if the PBE reaches the end of its original useful life or is deemed to be in an unserviceable condition."

4.2.3 Actions taken by Emirates

The consultation period for the draft Final Report ended on 3 June 2016. However, one month after this date, transmittal of safety actions taken was received by the Operator. As a result, the safety actions has been appended to the Final Report under Appendix C.

4.2.4 Prompt Safety Recommendations (PSR) issued by the AAIS

During the course of the Investigation, the AAIS addressed two Prompt Safety Recommendations (PSR) to the Federal Aviation Administration (FAA) of the United States, to:

PSR41/2014

Consider removing from service all suspected PBE units, P/N 119003-11, as identified by the manufacturer, between S/N 003-34983M and S/N 003-35563M.

PSR42/2014

Consider undertaking a review of the reliability of the in-service PBE P/N 119003-11.

4.2.5 Response of the FAA to the PSRs:

The initial response from the FAA to these PSRs was that the FAA is continuing to work with the National Transportation Safety Board (NTSB) and the manufacturer to investigate the issue and determine the best course of action.

On 6 January 2016, the FAA published a *Supplemental Notice of Proposed Rule Amendment (SNPRM)* calling for comments on proposed *Airworthiness directive (AD)* requiring:

"g) Inspection

Within 3 months after the effective date of this AD, while still in the stowage box, physically inspect the PBE pouch to determine if it has an intact vacuum seal. Do this inspection following paragraph III.A.1. of the Accomplishment Instructions in B/E Aerospace Service Bulletin No. 119003-35-011. Rev. 000, dated February 4, 2015.

(h) Replacement

(1) If a PBE pouch is found that does not have an intact vacuum seal during the inspection required in paragraph (g) of this AD: Before further flight or following existing minimum equipment list (MEL) procedures, replace the PBE with a PBE, P/N 119003-21, following paragraphs III.C., III.D.(4), III.D.(6), and III.D.(7) of the Accomplishment Instructions in B/E Aerospace Service Bulletin No. 119003-35-009, Rev. 000, dated November 9, 2015, or replace it with another FAA-approved serviceable PBE.

(2) If a PBE pouch is found during the inspection required in paragraph (g) of this AD where the vacuum seal is intact: Within 18 months after the effective date of this AD, remove PBE, P/N 119003- 11, and replace the PBE with PBE, P/N 119003-21, following paragraphs III.C., III.D.(4), III.D.(6), and III.D.(7) of the Accomplishment Instructions in B/E Aerospace Service Bulletin No. 119003-35-009, Rev. 000, dated November 9, 2015, or replace it with another FAA-approved serviceable PBE."

4.3 Final Report Safety Recommendations

4.3.1 Emirates Airline

It is recommended that Emirates Airline:

SR45/2016

In conjunction with Airbus, assess the risk of amending the existing *SMOKE/FUMES/AVNCS SMOKE* and *SMOKE/FUMES REMOVAL* checklists to distinguish between inflight and on-ground smoke or mist scenarios, and insert appropriate text in checklists.

SR46/2016

Conduct a safety risk analysis of cabin crewmembers' uniforms for appropriateness in dealing with onboard emergency situations.

SR47/2016

Consider a policy of initiating comprehensive safety risk assessments in cases of any addition to, or change of, existing processes or equipment that may have a significant effect on air safety.

SR48/2016

Address cabin crew simulator training to ensure that it accurately reflects actual operational conditions in terms of clothing worn and PBE use.

4.3.2 Airbus

It is recommended that Airbus:

SR49/2016

Assess the risk of amending the *existing SMOKE/FUMES/AVNCS SMOKE* and *SMOKE/FUMES REMOVAL* checklists to distinguish between inflight and on-ground smoke scenarios, and insert text in the checklists to differentiate between the aircraft be on the ground or inflight.

4.3.3 Karachi Airport Authority

It is recommended that Karachi Airport Authority:

SR50/2016

Review this incident with a view to improving procedures regarding care for passengers evacuated on the ramp.

4.3.4 The General Civil Aviation Authority (GCAA) of the United Arab Emirates

It is recommended that the GCAA:

SR51/2016

Ensure that all UAE aerodromes regularly exercise their procedures for controlling and guiding passengers, evacuated from an aircraft, terminal building or other building airside to a secure location away from the scene of the occurrence.

4.3.5 The International Civil Aviation Organization (ICAO)

It is recommended that ICAO:

SR52/2016

Establish a working group composed of regulatory authorities, aircraft manufacturers, and operators, assisted by research centers, to define the health effects of exposure of aircraft occupants to smoke/fumes/mist and to assist in determining the most appropriate treatment for any potential adverse impacts on occupant health.

SR53/2016

Form a taskforce to study the possibility of improving the international Aviation Data Reporting Program (ADREP) system utilizing the European Co-Ordination Centre for Aviation Incident Reporting Systems (ECCAIRS), to contain a comprehensive checklist for incidents related to the aircraft interior environment, and the potential symptoms that occupants could suffer after exposure to contaminated cabin air.

This Report is issued by:

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Appendix A. Abnormal and Emergency Procedures

Emirates A330/A340 QUICK REFERENCE HAND BOOK	ABN – ABNORMAL AND EMERGENCY PROCEDURES ABN-26 – FIRE PROTECTION	26.1 20-Sep-12

SMOKE/FUMES REMOVAL

EMER EXIT LIGHT .... ON
PACK FLOW .... HI
LDG ELEV ....10000 FT/MEA
DESCENT (FL 100 or MEA or minimum
obstacle clearance altitude) .... INITIATE
ATC ....NOTIFY
SMOKE/FUMES/ AVNCS SMOKE PROC... CONTINUE

While descending, continue applying the appropriate steps of the SMOKE/FUMES/AVNCS SMOKE paper procedure depending on the suspected smoke source.

- **At FL 100 or MEA :**

  PACK 1 + 2 ....OFF
  MODE SEL...MAN
  MAN VALVE SEL ....BOTH
  MAN V/S CTL.. FULL UP
  RAM AIR .... ON

- **If smoke persists in the cockpit, window opening:**

  MAX SPEED .... 230 KT
  COCKPIT DOOR ....OPEN
  HEADSET .... ON
  PNF COCKPIT WINDOW ....OPEN

- **When window is open:**

  NON-AFFECTED PACK(s) .... ON
  VISUAL WARNINGS (noisy CKPT) ....MONITOR
  SMOKE/FUMES/ AVNCS SMOKE PROC................
  ....CONTINUE

SMOKE/FUMES/AVNCS SMOKE

LAND ASAP

APPLY IMMEDIATELY

VENT EXTRACT .... OVRD
CAB FANS .... OFF
GALLEYS .... OFF
SIGNS .... ON
CKPT/CAB COM .... ESTABLISH

Emirates A330/A340 QUICK REFERENCE HAND BOOK	ABN – ABNORMAL AND EMERGENCY PROCEDURES ABN-26 – FIRE PROTECTION	26.3 20-Sep-12

SMOKE/FUMES/AVNCS SMOKE (CONT'D)

- **At ANY TIME of the procedure, if situation becomes UNMANAGEABLE:**
  IMMEDIATE LANDING .... CONSIDER

- **If AIR COND SMOKE SUSPECTED:**
  APU BLEED .... OFF
  VENT EXTRACT .... AUTO
  ALL CARGO ISOL VALVES .... OFF
  PACK 1 .... OFF
  - **If smoke continues:**
    PACK 1 .... ON
    PACK 2 .... OFF
    - **If smoke still continues:**
      PACK 2 .... ON
      VENT EXTRACT .... OVRD

  SMOKE/FUMES REMOVAL .... CONSIDER

- **IF CAB EQUIPMENT SMOKE SUSPECTED:**
  - **If smoke continues**
    EMER EXIT LT .... ON
    COMMERCIAL .... OFF
    SMOKE DISSIPATION .... CHECK
    FAULTY EQPT .... SEARCH/ISOLATE
    - **If smoke still continues or when faulty equipment confirmed isolated:**
      COMMERCIAL .... NORM

  SMOKE/FUMES REMOVAL .... CONSIDER

Continued on the next page

Emirates A330/A340 QUICK REFERENCE HAND BOOK	ABN – ABNORMAL AND EMERGENCY PROCEDURES ABN-26 – FIRE PROTECTION	26.4 07-Feb-13

SMOKE/FUMES/AVNCS SMOKE (CONT'D)

- **IF SMOKE SOURCE CANNOT BE DETERMINED AND STILL CONTINUES OR AVNCS/ELECTRICAL SMOKE SUSPECTED:**
  - **Shed AC BUS 1 as follows:**

    GEN 2 .... CHECK ON
    ECAM/ND SEL .... F/O
    ELEC/AC page .... SELECT
    BUS TIE .... OFF
    AC ESS FEED .... ALTN
    GEN 1 .... OFF
    SMOKE DISSIPATION .... CHECK

    - **If smoke continues:**

      GEN 1 .... ON
      AC ESS FEED .... NORM
      ECAM/ND SEL .... NORM

  - **Shed AC BUS 2 as follows:**

    GEN 1 .... CHECK ON
    BUS TIE .... CHECK OFF
    AC ESS FEED .... CHECK NORM
    ECAM/ND SEL .... CHECK NORM
    GEN 2 .... OFF
    SMOKE DISSIPATION .... CHECK

    - **If smoke continues:**

      GEN 2 .... ON
      BUS TIE .... AUTO

  SMOKE/FUMES REMOVAL .... CONSIDER

Continued on the next page

Emirates A330/A340 QUICK REFERENCE HAND BOOK	ABN – ABNORMAL AND EMERGENCY PROCEDURES ABN-26 – FIRE PROTECTION	26.5 20-Sep-12

SMOKE/FUMES/AVNCS SMOKE (CONT'D)

ELEC EMER CONFIG ....CONSIDER

TO SET ELEC EMER CONFIG

EMER ELEC PWR .... MAN ON

- **WHEN EMER GEN AVAIL:**

  GEN 1..OFF

  GEN 2..OFF

  APU GEN ....OFF

ELEC EMER CONFIG

APPLY ECAM PROCEDURE, BUT DO NOT RESET GEN, EVEN IF REQUESTED BY ECAM

- **AT 3 MIN OR 2 000 FT AAL BEFORE LANDING:**

  ATT HDG SWTG.................................... F/O ON 3

  ALL GEN .... ON

- **WHEN A/C IS STOPPED:**

  ALL GEN ....OFF

Appendix B. Engine Start and After Start Checklist

BEFORE PUSHBACK OR START

CM1	CM2
LOADSHEET .... CHECK/ENTER	
TO DATA .... ENTER/REVISE	TO DATA .... CHECK
SEAT BELTS .... ADJUST	SEAT BELTS .... ADJUST
MCDU .... AS RQRD	MCDU .... AS RQRD
	EXT PWR .... CHECK OFF
BEFORE START C/L DOWN TO THE LINE	
	PUSHBACK/START CLEAR .... OBTAIN
N/W STRG DISC .... CHECK AS RQRD	
WINDOWS/DOORS .... CHECK	WINDOW .... CHECK
BEACON .... ON	
THR LEVERS .... IDLE	
PARK BRK ACCU PRESS .... CHECK	
PARK BRK .... AS RQRD	
BEFORE START C/L BELOW THE LINE	
GRD CREW CLEARANCE .... OBTAIN	

ENG START

CM1	CM2
ENG START selector .... IGN	
ENGINE 1 START .... ANNOUNCE	
MASTER switch 1 .... ON	
START VALVE N2 IGNITER FUEL FLOW EGT N1 OIL PRESS START VALVE CLOSES AT OR ABOVE 50 % N3 — CHECK	
ENG IDLE PARAMETERS .... CHECK	
ENGINE 2 START .... ANNOUNCE	
REPEAT THE START SEQUENCE FOR ENG 2	

AFTER START

CM1	CM2
ENG START selector .... NORM	
APU BLEED .... OFF	GND SPOILERS .... ARM
ENG ANTI-ICE .... AS RQRD	RUD TRIM .... ZERO
WING ANTI-ICE .... AS RQRD	FLAPS .... SET
APU MASTER switch .... AS RQRD	PITCH TRIM .... SET
NWS TOWING FAULT LT .... CHECK off	
	ECAM DOOR PAGE .... CHECK
	•If STS label is displayed:
	ECAM STATUS .... CHECK
CLEAR TO DISCONNECT .... ANNOUNCE	
	FLT CTL .... CHECK
	GND CLRNC SIGNAL .... RECEIVED
AFTER START C/L	

Appendix C. Safety Actions taken by Emirates

The following safety actions are appended to the Final Report as transmittal of same was received one month after the draft Final Report consultation ended on 3 June 2016:

“

1. The operator conducted a review of available PBE systems and from this review conducted a fleet wide change to a new PBE which uses a gaseous system (which avoids candle ignition issues) and is significantly easier to unpack and doff. The changeover was completed by 31 Dec 15.
2. The operator, before transition to the deployment of the new PBE, ensured that training for all crew was completed which included training on stowage location, unpacking and doffing.
3. The operator has a documented safety risk assessment and mitigation programme linked to change management activities. With specific regard to Service Delivery (SD) activities, the introduction of new process or equipment or changes to existing processes or equipment is managed via the Service Delivery Safety Action Groups (SAGs) and the Service Delivery Safety Board. The safety risk assessment / change management activities are integrated into the Service Delivery Safety Risk Register which is reviewed prior to every Safety Board. All of the safety risk assessments for Service Delivery are housed in a dedicated library of safety risk assessments accessible to the SD-SAG with tracking of the status of safety risk assessments. They are reviewed at least monthly at the SD-SAG. In addition, safety risk assessment training includes the importance of initiating safety risk assessments for any new business process or equipment or additions, changes to existing processes or equipment.
4. The operator replaced the subject hydraulic hoses on the entire fleet of the same type of aircraft.”