ARAB REPUBLIC OF EGYPT
MINISTRY OF CIVIL AVIATION
EGYPTIAN AIRCRAFT ACCIDENT INVESTIGATION DIRECTORATE

جمهورية مصر العربية
وزارة الطيران المدنى
الادارة المركزية لحوادث الطيران

Final Report

EgyptAir A320 Aircraft crash in the Mediterranean, registered SU-GCC, flight number MSR804, from Charles De-Gaulle Airport, Paris to Cairo International Airport, on 19/05/2016

EGAI2016-01

October 2024

This report issued in Arabic and translated into English. In the event of any discrepancy between the two texts, reference is made to the original text written in Arabic .

Foreword

The investigation procedures were conducted in accordance with the Egyptian Civil Aviation Law and Annex 13 of the Convention on International Civil Aviation.

This report is released in accordance with Annex 13 and the investigation was conducted with the sole objective to prevent accidents and incidents and not to apportion blame or liability.

Accordingly, using this report beyond the intended objective could lead to misinterpretation.

Synopsis

On May 18th 2016, an EGYPTAIR Airbus A320-232, registered SU-GCC, took off at 21:21 UTC on a scheduled flight from Paris - Charles-de-Gaulle Airport (France) to Cairo International Airport (Egypt) with 66 persons onboard including crew and passengers.

At 23:22, and altitude of 37,000 feet the aircraft entered the Greek airspace where it was cleared to proceed direct to position KUMBI the point between the Greek and the Egyptian airspace.

At 00:30, about seven nautical miles south of the position KUMBI and after entering the Egyptian airspace the aircraft disappeared from the Greek and Egyptian radar. Several failed attempts were made by the Greek and Egyptian ATC to contact the aircraft.

A signal from the aircraft Emergency Locator Transmitter (ELT) was transmitted and Search and Rescue were deployed.

Egypt, the state of registry and operator, instituted and conducted the investigation in accordance with ICAO Annex 13.

The Egyptian Aircraft Accident Investigation Directorate (EAAID) invited states that have the right to participate in the investigation (France, USA and Greece) and accredited representatives were appointed. The states that have citizens among the accident victims were also notified.

After coordinating with the French side (BEA), The Egyptian government leased a ship for search and retrieval.

Sea search located human remains, wreckage and flight recorders were recovered. The data from the Flight Data Recorder (FDR) and the Cockpit Voice Recorder (CVR) was extracted and analyzed.

The CVR indicated the co-pilot calling out "Fire" followed by a cabin flight attendant, present in the cockpit at the time, calling out "fire" and simultaneously the captain calling out "fire" and requesting fire extinguisher.

The FDR revealed that "lavatory smoke warning" was triggered first followed by "avionics smoke warning" 46 seconds later. Few minutes later, several computers failed sequentially.

Extensive data gathering and analysis of the aircraft technical records, crew and maintenance personnel was completed, found compliant with local and international standards.

Wreckage examination was carried out and documented.

Based on gathered data and information a sequence of events was established.

The EAAID received the report of the forensic medicine authority indicating the presence of explosive material on human remains and attached wreckage pieces.

In the course of investigation several reports and statements were issued from the Egyptian and the French sides; Debris survey - Part identification report (Airbus), Technical statement report (EAAID), A contribution report (BEA), A study on the oxygenated fire (BEA) and interim statements (EAAID).

The BEA oxygen fire study assumed that fire started in the co-pilot's mask storage box and was fueled by a leak of pressurized oxygen. However, the study neither identified the source of ignition nor determined which came first: the fire or the oxygen leak.

The investigation committee received a report from the Egyptian judicial authority, which had formed a committee headed by a forensic evidence expert and included an aviation expert and a forensic medicine expert. The report concluded that an explosive device had been placed inside catering trolleys, in the galley behind the cockpit.

The investigation committee examination of the cabin wreckage parts surrounding the area of the forward galley showed an exposure to thermal effects suggesting fire outside the cockpit.

Based on FDR and CVR correlation, the fire was first announced by the co-pilot call out then 44 seconds later the lavatory smoke warning came in followed by avionics smoke warning after 46 seconds indicating that the fire originated outside the cockpit before triggering the lavatory smoke warning followed by the avionic smoke warning.

The forensic medicine report also indicated that some remains were affected by heat.

The investigation committee concluded that fire and smoke due to explosive materials located at the forward galley just aft of the rear section of the cockpit, pressure generated was propagated and affected the cockpit right hand side crew oxygen system. The oxygen flow enriched the fire. The aircraft flight path was uncontrollable as the aircraft and the flight crew were severely affected by fire and smoke.

The aircraft crashed into the sea with no survivals.

The investigation committee issued four safety recommendations to enhance aviation safety.

Glossary

A	
A/C	Aircraft
A/P	Auto Pilot
ACARS	Aircraft Communication Addressing and Reporting System.
ACC	Area Control Center
ACC.	According
ACCREP	Accredited representative
ACP	Area Call Panel
ACP	Audio Control Panel.
ADF	Automatic Direction Finder
ADIC	Air Defense Information Center
AED	Automated External Defibrillator
AIC	Air Intake Cowl
AIP	Attendant Indication Panels
AIRMAN	Aircraft Maintenance Analysis
ALC	After landing Check
ALS	Airworthiness Limitation Sections
AMM	Aircraft Maintenance Manual
AMU	Audio Management Unit
APU	Auxiliary Power Unit
ARINC	Aeronautical Radio Incorporated
ATC	Air Traffic Control
ATPL	Airline Transport Pilot License
ATS	Air Traffic Services
ATSEPS	Air Traffic Safety Electronics Personnel
ATSU	Air Traffic Service Unit

B	
BEA	Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation Civile (French Investigation Authority)
BITE	Built-In Test Equipment
BMC	Bleed Monitoring Computer
BPS	Bit per second
BSCU	Braking /Steering Control Unit

C	
C	Celsius
C/O	Carried Out
CAA	Civil Aviation Authority
CAM	Cockpit Area Microphone
CAPT	Captain
CB	Cumulonimbus
CCA	Circuit Card Assembly
CCQ	Cross Crew Qualification
CDCCL	Aircraft Critical Design Configuration Control Limitations
CDG	3 letter code for Charles De-Gaulle Airport
CDSS	Cockpit Door Surveillance System
CFDIU	Central Fault Data Interface Unit
CFDS	Centralized Fault Display System
CH	Chapter

CIDS	Centralized Intercommunication Data System
CKPT	Cockpit
cm	centimeter
CP	Control Panel
CRC	Continuous Repetitive Chime
CRM	Crew Resource Management
CRT	Cathode Ray Tubes
CSMU	Crash Survivable Memory Unit
CTL PNL	Control Panel
CVR	Cockpit Voice Recorder

D	
DD	Deferred Defect
Deg	Degree
DFDR	Digital Flight Data Recorder
DIFF	Difference
DIM	Detailed Investigation Manual
DLU	Download Unit (File format from Honeywell)
DMC	Display Management computer
DU	Display Unit

E	
E	East
E.E	Engineering Entry
EAAID	Egyptian Aircraft Accident Investigation Directorate
EASA	European Union Aviation Safety Agency
ECAA	Egyptian Civil Aviation Authority
ECAM	Electronic Centralized Aircraft Monitor
EEC	Engine Electronic Control
EEPROM	Electrically Erasable Programmable Read Only Memory
EIS	Electronic Instrument System
ELT	Emergency Locator Transmitter
ENG	Engine
ESD	Electro Static Discharge
EVMU	Engine Vibration Monitoring Unit
EWD	The Engine /Warning Display

F	
F	Fahrenheit
F/O	Frist Officer
FAA	Federal Aviation Administration
FAC	Flight Augmentation Computer
FAP	Forward Attendant Panel
FC	Flight Cycle
FCDC	Flight Control Data Concentrator (used in Electrical Flight Control System)
FCOM	Flight Crew Operating Manual
FCU	Flight Control Unit

FDIMU	Flight Data Interface Management Unit.
FDIU	Flight Data Interface Unit
FDR	Flight Data Recorder
FH	Flight Hour
FIN	Functional Identification Number
FIR	Flight Information Region
FL	Flight Level
FLT	Flight
FMGC	Flight Management And Guidance Computer
FR	Frame
FSK	Frequency Shift Keying
ft	Feet
FWC	Flight Warning Computer
FWD	Forward

G	
g	Gram
GIS	Geographic Information Systems
GPS	Global Positioning System
GRS	Geodetic Reference System

H	
h	Hour
HECC	CAIRO Flight Information Region
HHMPI	Hand Held Multi-Purpose Interface
HP	High Pressure
hpa	Hectopascal

I	
IAW	In Accordance With
IIC	Investigator In Charge
IM	Investigator Manual
INDOC	Indoctrination
IOCC	Integrated Operations Control Centre
IOE	Initial Operating Experience

J	
JRCC	Joint Rescue Coordination Center

K	
Kg	Kilo Gram
Km	Kilo Meter

L	
L/G	Landing Gear
LA	Linear Accelerometer
lat	Latitude
LCD	Liquid Crystal Display
LFPG	four letter code for Charles De-Gaulle Airport
LGEL	Eleusis Airport - Greece
LH	Left Hand
Long	Longitude
LP	Low pressure

M	
M	Minute
MAMBO	2nd Area Control Center Of The Hellenic Tactical Air Force
MCDU	Multifunction Control And Display Unit
MHZ	Megahertz
Mic / Mike	Microphone
Min	Minute
MLG	Main Landing Gear
MMEL	Master Minimum Equipment List
MP	Maintenance Program
MP	Maintenance Program
MPD	Maintenance Planning Document
MRBR	Maintenance Review Board Report
MSN	Manufacture Serial Number

N	
N	North
N1	Refers to the Low Pressure Rotor Speed of an engine
N2	Refers to the high Pressure Rotor Speed of an engine
NAOP	National Air Operation Center (Greece)
NM	Nautical Mile
NVM	Non Volatile Memory

O	
OXY	Oxygen

P	
P/B	Push Button
P/N	Part Number
PAL /PAL chip	Programmable Array Logic chip /Programmable Semiconductor Logic Circuits
PALLAS	Phased Automation of the Hellenic ATC System
PATS	Playback And Test Station (Honeywell product)
PAX	Passenger
PBE	Portable Breathing Equipment
PC	Proficiency Check
PF	Pilot Flying
PFR	Post Flight Report
PIC	Pilot In Command
PM	Pilot Monitoring
Png file	Portable Network Graphic file
POB	Persons On Board
PPM	Policy and Procedure Manual
PRES	Pressure
PSI	Pounds per Square Inch
PSR	Primary Surveillance Radar
PTT	Push-to-talk,

Q	
QAR	Quick Access Recorder
QRH	Quick Reference Handbook
QTY	Quantity

R	
R	Right
Reg	Registration
REGUL LO PR	Regulator Low Pressure
RHS	Right Hand Side
RMP	Radio Management Panel
ROV	Remotely Operated Vehicle
RPGSE	Recorder Potable Ground Support Equipment
RTV	Room Temperature Vulcanizing sealant/adhesive/silicon
RVSM	Reduced Vertical Separation Minimum

S	
S	Second
S/N	Serial Number
SAR	Search And Rescue
SDAC	System Data Acquisition Concentrator
SDCU	Smoke Detection Control Unit
Sec.	Second
SEC2	Spoiler and Elevator Computer NO2
SELCAL	Selective Calling
SMS	Safety Management System
SPI	Short Power Interruptions
SSCVR	Solid State CVR
SSFDR	Solid State FDR
SSR	Secondary Surveillance Radar
STA	Station
STBY	Stand By

T	
TCAS	Traffic Alert and Collision Avoidance System
TLB	Technical Log book
TR	Transformer Rectifier

U	
UAE	United Arab Emirates
UIR	Upper Information Region
ULB	Under water Locator Beacon
USA	United States of America
UTC	Universal Time Coordinates
UTM	Universal Transverse Mercator

V	
VCC	voltage, common collector
VHF	Very High Frequency

W	
WBT	Web Based Training
WGS	World Geodetic System
WHC	Window Heat Computer
WR	Weather Radar

Z	
ZFT	Zero Flight Time

* All Times in UTC unless specified.

Organization of the Investigation

- At 02:45 UTC, on 19/05/2016, the Egyptian Aircraft Accidents Investigation Directorate (EAAID) received a notification about the loss of communication with the aircraft registered SU-GCC, Airbus 320, operated by EgyptAir , flight number MSR804, from Charles De-Gaulle Airport, Paris to Cairo International Airport.
- The EAAID initiated the documented initial procedures after receiving the notification and until the aircraft crash was confirmed inside the Flight Information Region (FIR) of the Arab Republic of Egypt in the Mediterranean Sea.
- The EAAID instituted and conducted the investigation as the state of registration and operator according to the Egyptian Civil Aviation Law and in accordance with Annex 13 to the Convention of International Civil Aviation.
- The aircraft accident investigation authorities of the states that have the right to participate in the investigation according to Annex 13 were informed, including:
    - France: State of design, State of manufacturing.
    - Greece: State that offered information and investigation actions.
    - United State of America: Engines manufacturer.

Also, the states that have citizens among the accident victims were notified.

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1. Factual information

1.1 History of the Flight

- At 15:17 UTC[1] on May 18, 2016, the Airbus A320, registered SU-GCC, operated by EgyptAir departed from Cairo to perform its scheduled flight number MSR803 to Charles De-Gaulle Airport.
- At 20:10 UTC same day, the aircraft landed safely and parked at stand number V5. Procedures for receiving and dispatching the aircraft have been carried out.
- At 21:21 UTC same day, the aircraft took off for its return flight to Cairo from LFPG airport flight number MSR804 with its cockpit crew (PIC and F/O), five cabin crew, three security officers and 56 passengers.
- The aircraft planned route for the return flight starts with the departure from Charles De-Gaulle Airport in Paris, exiting the French airspace to the German airspace, then passing through the Swiss, the Italian, the Croatian, the Serbian, the Albanian, the Greek airspace, and finally the Egyptian airspace to destination Cairo International Airport.

Figure 1.1/1: Planned Flight Path

- At 23:22:27 UTC same day, the aircraft entered the Greek airspace HELLAS UIR at the point PINDO, at flight level FL370, the area sector started communicating with the aircraft on frequency 132.375 MHZ, the aircraft was allowed to fly direct to the point KUMBI (The boundary point between Greek and Egyptian airspace) . The crew acknowledged receiving this information.
- At 00:27:25 UTC the radar traffic controller AC5 allowed the aircraft to transfer to Cairo area control frequency 124.7 MHZ. the crew did not acknowledge this information.

[1]Cairo local time = UTC +2

- When the aircraft was at 14.8 nm north of KUMBI, the Greek air controller repeated his call to the aircraft without acknowledgement from the crew.
- At 00:28 the AC5 planner inquired Cairo area control if they could communicate with the aircraft. Whereas, no communication was established with the aircraft.
- At 00.29 the radar controller of the Greek traffic control AC4 started calling the aircraft to instruct them to communicate with Cairo area control without any response.
- At 00:29:57 UTC according to the radar information from the Greek air traffic unit AC5, it was shown that the aircraft was lost at a distance of 7.1 nm south of the point KUMBI.
- At 00:30:08 UTC, the aircraft disappeared from the radar screen of Cairo area control.
- At 00:31 UTC, Cairo air traffic control was informed that the aircraft was lost from the Greek radar screen.
- At 00:32 UTC the Greek air traffic control unit AC5 contacted the unit MAMBO that belongs to the Greek Air Force to inform them about the loss of the aircraft.
- At 00:36:59 UTC, signal from the Aircraft's Emergency Locator Transmitter (ELT) was transmitted.
- At 01:13 UTC, the area control unit in Cairo contacted the aircrafts flying in the area where the aircraft was lost, without obtaining any information about the accident aircraft.
- At 01:40 UTC, the area control unit in Cairo contacted the Search and Rescue Center, to inform them about the loss of the aircraft. At the same time, the Greek Search and Rescue aircrafts reached the site where the aircraft was lost.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	7	59	-
Serious	-	-	-
Minor	-	-	

1.3 Damage to Aircraft

- The Aircraft was completely destroyed.

1.4 Other Damages

- The accident did not cause any other damage.

1.5 Personnel Information

1.5.1 Pilot in Command (PIC)

1.5.1.0 General Information

Gender	Male
Age	36 years
Nationality	Egyptian
License	Airline Transport Pilot License, ATPL No 1912, Issued by Egyptian Civil Aviation Authority dated 15/08/2010, renewed and valid the period from 22/12/2015 to 30/06/2016 on the A/C type A320, A321
Total Flying hours	6639:30 hrs:min
Total flight time on A320 type	2108:10 hrs:min
Total Flight time as a PIC	2236:05 hrs:min
Total Flight time as a F/O	4403:25 hrs:min
Total flight time for day flight	1316:45 hrs:min
Total flight time for night flight	791:25 hrs:min
Flight time during the last month	44:20 hrs:min
Flight time during the last 7 days	13:40 hrs:min
Flight time during the last 24 hours	Zero
Total number of flights on A320 type	429 flight

1.5.1.1 Main Courses /Training/Checks

No.	Course /Training/Check	Location	Completion Date	Remarks
1	Ground Training (A320)	Egypt Air Training Center	24/3/2013	Initial
2	Type rating (A320) written exam	Egypt Air Training Center	31/3/2013	
3	Certificate Oral	Egypt Air Training Center	24/4/2013	Initial
4	Simulator Training	Egypt Air Training Center	9/5/2013	
5	Simulator Proficiency Check	Egypt Air Training Center	11/5/2013	
6	Type base training /ZFT	Egypt Air Training Center	12/5/2013	
7	A320 /A321 CCQ Ground Training	Egypt Air Training Center	13/5/2013	
8	A320-321 Type Endorsement	ECAA	20/5/2013	
9	Line Training / IOE	Training flights	20/6/2013	
10	Final Line Check	Check flight	21/6/2013	
11	Company Oral	Egypt Air flight Operations	23/6/2013	
12	Approved as a type A320 Captain	Egypt Air flight Operations/ECAA	23/6/2013	
13	CAT II Initial qualification	Egypt Air Training Center	7/11/2013	
14	A320 Refresher Lessons / Jet Performance Refresher Lesson	WBT	22/5/2015	Latest Refresher before accident date
15	Recurrent Training /Proficiency check (PC)	Egypt Air Training Center	15/11/2015	Latest Recurrent /PC before accident date
16	Annual Line Check	Check flight	16/11/2015	Latest Annual line check before accident date

1.5.1.2 Others Courses /Training/Checks

No.	Course /Training/Check	Location	Completion Date	Remarks
1	English Language Proficiency	Egypt Air Training Center	15/9/2013	Valid to 14/9/2016
2	Dangerous Goods	WBT	22/12/2014	Latest Recurrent before accident date
3	Crew Resource Management (CRM)	Egypt Air Training Center	16/4/2015	Latest Recurrent before accident date
4	Joint / General Safety	Egypt Air Training Center	25/11/2015	Latest Recurrent before accident date
5	Security Awareness	WBT	30/4/2016	Latest Recurrent before accident date
6	– Meteorology – De-Icing / Anti icing – Cold Weather Operation – All Weather Operations	WBT	30/4/2016	Latest Recurrent before accident date
7	Safety Management System (SMS)	WBT	30/4/2016	Latest Recurrent before accident date

1.5.2 First Officer (F/O):

1.5.2.0 General Information

Gender	Male
Age	25 years
Nationality	Egyptian
License	Airline Transport Pilot License, ATPL No 2363, Issued by Egyptian Civil Aviation Authority dated 13/01/2015, renewed and valid the period from 17/01/2016 to 31/07/2016 on the Aircraft type A320, A321
Total Flying hours	2966:10 hrs:min
Total Flying hours on A320	2771:01 hrs:min
Total Flight time as a PIC	77:09 hrs:min
Total Flight time as a F/O	2889:01 hrs:min
Total flight time for day flight	1558:02 hrs:min
Total flight time for night flight	1182:59 hrs:min
Flight time during the last month	54.20 hrs:min
Flight time during the last 7 days	07:25 hrs:min
Flight time during the last 24 hours	Zero

1.5.2.1 Main Courses /Training

No.	Course /Training/Check	Location	Completion Date	Remarks
1	Ground Training (A320)	Egypt Air Training Center	21/8/2011	Initial
2	A320-A321 Type Difference	Egypt Air Training Center	22/8/2011	
3	Instrument Flying Course	Egypt Air Training Center	29/8/2011	FMST
4	Type rating (A320) written exam	Egypt Air Training Center	12/9/2011	
5	New Hired Pilots Observer Flights	Training flights	9/9/2011 19/9/2011 24/9/2011 28/9/2011 13/10/2011	
6	Certificate Oral	Egypt Air Training Center	11/12/2011	
7	Simulator Training	Egypt Air Training Center	24/12/2011	
8	Simulator Proficiency Check	Egypt Air Training Center	26/12/2011	
9	Type base training /ZFT	Egypt Air Training Center	27/12/2011	
10	A320-321 Type Endorsement	ECAA	5/1/2012	
11	Line Training / IOE	Training flights	9/4/2012	
12	Final Line Check	Check flight	12/4/2012	
13	Company Oral	Egypt Air flight Operations	12/4/2012	
14	Approved as a type A320 F/O	Egypt Air flight Operations/ECAA	12/4/2012	
15	CAT II Initial qualification	Egypt Air Training Center	27/9/2013	
16	Recurrent Training /Proficiency check (PC)	Egypt Air Training Center	12/12/2015	Latest Recurrent/PC before accident date
17	A320 Refresher Lessons / Jet Performance Refresher Lesson	WBT	21/4/2016	Latest Refresher before accident date

1.5.2.2 Others Courses /Training

No.	Course /Training/Check	Location	Completion Date	Remarks
1	English Language Proficiency	Egypt Air Training Center	21/12/2015	Valid to 20/12/2020
2	Dangerous Goods	WBT	17/11/2015	Latest Recurrent before accident date
3	Crew Resource Management (CRM)	Egypt Air Training Center	23/4/2015	Latest Recurrent before accident date
4	Joint / General Safety	Egypt Air Training Center	7/5/2015	Latest Recurrent before accident date
5	Security Awareness	WBT	6/9/2015	Latest Recurrent before accident date
6	– Meteorology – De-Icing / Anti icing – Cold Weather Operation – All Weather Operations	WBT	1/8/2015	Latest Recurrent before accident date
7	Safety Management System (SMS)	WBT	2/8/2015	Latest Recurrent before accident date

1.5.3 Flight Purser

1.5.3.0 General Information

<table>
<tr><td>Gender</td><td colspan="2">Female</td></tr>
<tr><td>Age</td><td colspan="2">53 years</td></tr>
<tr><td>Nationality</td><td colspan="2">Egyptian</td></tr>
<tr><td rowspan="5">License</td><td>Type</td><td>Cabin Crew License</td></tr>
<tr><td>No</td><td>982</td></tr>
<tr><td>Authority</td><td>Egyptian Civil Aviation Authority</td></tr>
<tr><td>Issue Date</td><td>06/09/1988</td></tr>
<tr><td>Validation</td><td>Renewed and valid the period from 12/04/2016 to 21/04/2017 on aircraft types B777, A330/340 ,B737-800/500, A320/321.</td></tr>
<tr><td colspan="2">Proficiency check validation</td><td>From 18/03/2016 to 17/03/2017</td></tr>
<tr><td colspan="2">Medical check validation</td><td>From 22/04/2015 to 21/04/2017</td></tr>
</table>

1.5.3.1 Courses /Training

No.	Course	Training Organization	Course completion date	Remarks
1	Cabin Attendant Type B737-800/500	Egypt air training center	19/7/2012	Requalification.
2	Cabin Attendant Type A320/321	Egypt air training center	26/12/2012	A320(Transition) A321(DIFF.)
3	Cabin Attendant Type A330/340	Egypt air training center	30/1/2013	A330 Transition A340 DIFF.
4	Cabin Attendant Type B777-200/300	Egypt air training center	20/3/2013	Transition
5	CRM&SMS	Egypt air training center	4/9/2014	Recurrent
6	Safety – First Aid For Aircraft Types (B777, A330/340 ,B737-800/500, A320/321)	Egypt air training center	20/5/2015	Recurrent 12 Month
7	Air Carrier Access Act	Egypt air training center	3/1/2016	Recurrent
8	Security flight deck & Cabin Crew.	Egypt air training center	8/2/2016	
9	Automated External Defibrillator (AED)	Egypt air training center	11/4/2016	Recurrent
10	Safety Practical First Aid / Dangerous Good For Aircraft Types (B777, A330/340 ,B737-800/500, A320/321)	Egypt air training center	14/4/2016	Recurrent 24 Month

1.5.4 Cabin Crew 1

1.5.4.0 General Information

Gender	Male	
Age	38 years	
Nationality	Egyptian	
License	**Type**	Cabin Crew License
	No	4339
	Authority	Egyptian Civil Aviation Authority
	issue date	03/7/2003
	Validation	renewed and valid the period from 17/04/2015 to 07/05/2018 on aircraft types : B777,B737−500/800,A330/340 ,A320/321
Proficiency Check Validation		From 17/04/2016 to 16/4/2017
Medical Check Validation		From 8/5/2016 to 7/5/2018
Types endorsed before joining Egypt air		MD-83,B757-200,A320

1.5.4.1 Courses /training

No.	Course	Training Organization	Course completion date	Remarks
1	Basic Indoc.	EgyptAir training center	24/9/2012	Initial
2	Cabin Attendant Type A320/321	EgyptAir training center	25/9/2012	A320(recurrent) A321(DIFF.)
3	Cabin Attendant Type B737-800/500	EgyptAir training center	12/12/2012	Transition
4	Cabin Attendant Type A330/340	EgyptAir training center	22/5/2013	Transition
5	Cabin Attendant Type B777-200/300	EgyptAir training center	12/2/2014	Transition
6	Safety –Practical First Aid Dangerous Good A/C Types	EgyptAir training center	18/12/2014	Recurrent 24 Month
7	CRM&SMS	EgyptAir training center	12/5/2015	Recurrent
8	Air carrier access act	EgyptAir training center	25/5/2015	Initial
9	Automated External Defibrillator (AED)	EgyptAir training center	25/11/2015	Recurrent
10	Safety – First Aid A/C Types	EgyptAir training center	26/11/2015	Recurrent 12 Month
11	Security flight deck & cabin crew. Restraint Devices &Self Defense Training	EgyptAir training center	15/2/2016	

1.5.5 Cabin Crew 2

1.5.5.0 General Information

Gender	MALE	
Age	40 years	
Nationality	Egyptian	
License	**Type**	Cabin Crew License
	No	3033
	Authority	Egyptian Civil Aviation Authority
	Issue Date	23/5/2005
	Validation	Renewed and valid the period from 8/11/2015 to 13/9/2017on aircraft types : A330/340, B777,B737−500/800, A320/ 321
Proficiency check validation		From 15/10/2015 to 14/10/2016
Medical check validation		From 14/09/2015 to 13/09/2017
Types endorsed before joining Egypt air		B777-200/300

1.5.5.1 Courses /training

No.	Course	Training Organization	Course Completion Date	Remarks
1	Cabin Attendant Type B777-200 Cabin Attendant Type B777-300	Emirates training collage EgyptAir training center	6/7/1997	Transition DIFF.
2	Cabin Attendant Type A320/321	EgyptAir training center	29/9/2004	A320(recurrent) A321(DIFF.)
3	Cabin Attendant Type A330/340	EgyptAir training center	23/12/2004	A340 Transition A330 DIFF.
4	Cabin Attendant Type B737-800/500	EgyptAir training center	13/1/2010	Transition
5	Cabin Attendant TypeB777-200 Cabin Attendant Type B777-300	Emirates training collage EgyptAir training center	23/1/2011	Transition DIFF.
6	Security flight deck & cabin crew.	EgyptAir training center	13/2/2014	
7	Air carrier access act	EgyptAir training center	9/7/2014	Recurrent
8	Security flight deck & cabin crew.	EgyptAir training center	16/12/2014	
9	Safety – First Aid A/C Types	EgyptAir training center	1/1/2015	Recurrent 12 Month
10	CRM&SMS	EgyptAir training center	17/9/2015	Recurrent
11	Safety Practical First Aid Dangerous Good A/C Types	EgyptAir training center	1/10/2015	Recurrent 24 Month
12	Automated External Defibrillator (AED)	EgyptAir training center	4/10/2015	Recurrent
13	Security flight deck & cabin crew.	EgyptAir training center	21/12/2015	

1.5.6 Cabin Crew 3

1.5.6.0 General Information

Gender	Female	
Age	26 years	
Nationality	Egyptian	
License	**Type**	Cabin Crew License
	No	6965
	Authority	Egyptian Civil Aviation Authority
	Issue Date	19/10/2014
	Validation	renewed and valid the period from 06/12/2015 to 21/05/2016 on aircraft types : B737-800/500, A320/321,A330/340
Proficiency check validation		From 20/9/2015 to 19/9/2016
Medical check validation		From 29/11/2015 to 21/05/2016

1.5.6.1 Courses /training

No.	Course	Training Organization	Course Completion Date	Remarks
1	Basic Indoc.	EgyptAir training center	19/6/2014	Initial
2	Cabin Attendant Type B737-800/500	EgyptAir training center	19/6/2014	Initial
3	Security flight deck & cabin crew.	EgyptAir training center	1/6/2014	Initial
4	Cabin Attendant Type A320/321	EgyptAir training center	24/12/2014	Transition
5	Security flight deck & cabin crew.	EgyptAir training center	20/5/2015	Recurrent
6	Safety – First Aid A/C Types	EgyptAir training center	28/5/2015	Recurrent 12 Month
7	Cabin Attendant Type A330/340	EgyptAir training center	9/12/2015	Transition
8	Cabin Attendant Type B777-200/300	EgyptAir training center	17/2/2016	Transition (Type not added)
9	Security flight deck & cabin crew.	EgyptAir training center	1/3/2016	Recurrent
10	CRM&SMS	EgyptAir training center	29/3/2016	Recurrent
11	Automated External Defibrillator (AED)	EgyptAir training center	6/4/2016	Recurrent
12	Safety –Practical /First Aid/Dangerous Good Aircraft Types B737-800/500,A320/321,A330/340,777-200/300	EgyptAir training center	7/4/2016	Recurrent 24 Month
13	Air carrier access act	EgyptAir training center	4/5/2016	Initial

1.5.7 Cabin Crew 4

1.5.7.0 General Information

Gender	Female	
Age	27 years	
Nationality	Egyptian	
License	**Type**	Cabin Crew License
	No	7009
	Authority	Egyptian Civil Aviation Authority
	Issue Date	20/1/2015
	Validation	renewed and valid the period from 3/3/2016 to 27/2/2018 on aircraft types B737-800/500 ,A320/A321
Proficiency check validation		From 18/2/2016 to 17/2/2017
Medical check validation		From 28/2/2016 to 27/02/2018

1.5.7.1Courses /training

No.	Course	Training Organization	Course Completion Date	Remarks
1	Basic Indoc.	EgyptAir training center	3/7/2014	Initial
2	Cabin Attendant Type B737-800/500	EgyptAir training center	3/7/2014	Initial
3	Air carrier access act	EgyptAir training center	25/6/2014	Initial
4	Security flight deck & cabin crew.	EgyptAir training center	10/7/2014	Recurrent
5	Cabin Attendant Type A320/321	EgyptAir training center	8/4/2015	Transition
6	Security flight deck& cabin crew.	EgyptAir training center	4/6/2015	Recurrent
7	Safety – First Aid A/C Types	EgyptAir training center	10/6/2015	Recurrent 12 Month
8	Cabin Attendant Type B777-200/300	EgyptAir training center	9/3/2016	Transition (type not added)
9	Cabin Attendant Type A330/340	EgyptAir training center	13/4/2016	Transition (type not added)
10	Automated External Defibrillator (AED)	EgyptAir training center	18/4/2016	Recurrent
11	Safety –Practical First Aid Dangerous Good Aircraft Types B737-800/500 ,A320/A321	EgyptAir training center	21/4/2016	Recurrent 24 Month
12	CRM&SMS	EgyptAir training center	28/4/2016	Recurrent
13	Security flight deck & cabin crew.	EgyptAir training center	5/5/2016	Recurrent

1.5.8 Maintenance engineer dispatched the accident flight

1.5.8.0 General Information

Gender	Male	
Age	58 years	
Nationality	Egyptian	
License	**Type**	Aircraft Maintenance Engineer (Airframe & Engines) License
	No	1005
	Authority	Egyptian Civil Aviation Authority
	Issue Date	10/01/1982,
	Validation	Renewed and valid the period from 0٩/0١/201٦ to 09/01/2017 on the aircraft type A320, A321

1.5.8.1 Ratings valid at time of accident

Types	Addition Date	Remarks
A319/320/321(V2500)A&C	22/5/1991	(No limitation)
A340-200/300 (CFM56-5C)A&C	28/12/1996	(No limitation)
B777-200(PW4090)	20/1/2004	(PDC only)
A319/320/321 (CFM56-5A) A&C	7/3/2007	(up to weekly check)
A319/320/321 (CFM56-5B) A&C	7/3/2007	(No limitation)
B737 6/7/8/900 (CFM56-7)	28/5/2010	(PDC only)

1.5.8.2 Training /courses

No.	Course	Duration	Training Organization	Period	
				From	To
1	Aircraft Maintenance Engineering (Airframe & Engines)	100 weeks	Civil Aviation Training center -National Training Institute - Ministry of civil aviation	24 /12/ 1977	31 /7/ 1980
2	Fokker 27 technical training (A&C)	- 8 weeks (theoretical) - 3 weeks (practical)	EgyptAir training center	July 1985	
3	Refreshing A&C Fokker 27 course	1 DAY	EgyptAir training center	6 /8/ 1990	
4	Theoretical Airbus A320 Airframe and power plant (A&C)	4 weeks	(EM 40) AB320 at AIRBUS	18 /11/ 1990	21 /12/ 1990
5	Theoretical training on Engine V2500	2 weeks	Rolls Royce -Derby - England. (operation , maintenance and troubleshooting-V2500)	5/11/ 1990	16/ 11/ 1990
6	Engine Run-up practical	1 week	Aeroformation /Airbus - Toulouse , France	21/12/ 1990	27 /12/ 1990
7	Practical Airbus A320 (A&C)	2 weeks		14 /1/ 1991	26 /1/ 1991
8	Airbus A320-231 (Engine IAE V2500) On Job Training	2 weeks	Aeroformation Airbus Industries flight safety	25 /3/1991	5 /4/ 1991
9	A340 CFM56-5C CBT line maintenance training course AND on job training for Airframe technicians	2 weeks	CFM international training in Frankfurt	7 /10/1996	18 /10/ 1996
10	A320/A321 (V2500-A5) difference maintenance course for airframe / power plant engineers according to ATA 104 level 3	2 days	EgyptAir training center	1 /6/ 1997	3 /6/ 1997

11	A321 Maintenance practical training ((airframe and power plant)	1 day	EgyptAir training center	09 /6/ 1997	
12	A340 to A330 mechanics differences (ATA 104 level 3)	4 days	Airbus training center	15 /3/ 2004	19 /3/ 2004
13	Engine Run up course on A330 (Trent 700)	2 days	Airbus training center	22 /3/ 2004	25 /3/ 2004
14	A340 to A330 difference practical training for mechanics on A330 (Trent 700) by Airbus training	4 days	Additional certificate issued by Emirates training college -Dubai for the same period	24 /4/ 2004	28 /4/ 2004
15	Difference course for maintenance engineers Airbus 318(CFM56) from Airbus 319/320/321 (CFM56) Airframe and power plant	3 days	EgyptAir training center	18 /2/ 2007	21 /2/ 2007
16	A330 (Trent 700) ETOPS training	1 day	EgyptAir training center	28 /1/ 2009.	
17	A320(IAE V 2500) Engine Run Up Accelerated course for airframe and power plant engineers	1 day	EgyptAir training center	14 /5/ 2009	
18	Aircraft Critical Design Configuration Control Limitations (CDCCL) course for engineers	1 day	EgyptAir training center	12 /10/ 2009	
19	B737-800 familiarization & preflight check course	2 weeks	EgyptAir training center	19 /5/ 2010	28 /5/ 2010
20	Classic to enhanced and ATA 28 (ATA 104 level 3) on Airbus A33 (Trent 700)	2 weeks	Airbus training	18 /7/ 2010	22 /7/ 2010

21	A330(GECF6-80E1)from A330(RR TRENT 700) difference maintenance course for airframe and power plant engineers (practical only)	3 DAYS	EgyptAir training center	10/12/ 2010	14/12/ 2010
22	A330(GECF6-80E1)from A330(RR TRENT 700) difference maintenance course for airframe and power plant engineers (practical only)	1 day	EgyptAir training center	15 /12/ 2010	
23	Boeing 777 familiarization & Preflight check	2 weeks	EgyptAir training center	9 /1/ 2011	20 /1/ 2011
24	Boeing 777 familiarization & Preflight check training course	2 days	EgyptAir training center	27 /5/ 2013	
25	Fuel Tank Safety recurrent course	1 day	EgyptAir training center	21 /1/ 2015	
26	Reduced Vertical Separation minimum (RVSM) familiarization for maintenance	1 day	EgyptAir training center	25 /2/ 2015	

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1.5.8.3 Previous experience in EgyptAir out Stations

1- Kuwait, 3 months starting from November 2007.

2- Kuwait, 3 Months starting from September 2008.

3- Kuwait, 3 months starting from 6 April 2011.

4- Paris /France ; from 30 September 2012 to 29 November 2012

5- Abu-Dhabi, UAE, Starting 5 April 2013 to 23 May 2013.

6- Paris / France; from 28 January 2014 to 29 March 2014.

7- Baghdad, Iraq, From 8 June 2014 to 24 July 2014.

8- Paris /France ; from 29 April 2015 to 21 may 2015

9- Paris / France; 3 months from March 2016.

1.5.9 Maintenance Engineer replaced the F/O oxygen box on 16/5/2016

1.5.9.0 General Information

Gender	Male	
Age	32 years	
Nationality	Egyptian	
License	**Type**	Aircraft Maintenance Engineer (Airframe & Engines) License
	No	2991
	Authority	Egyptian Civil Aviation Authority
	Issue Date	29/04/2008,
	Validation	Renewed and valid the period from 28/04/2016 to 27/04/2017 on the aircraft type A320, A321

1.5.9.1Ratings valid at time of accident

Types	Addition Date	Remarks
A319/320/321 (V2500) A&C	3/2/2011	No limitation
A319/320/321 (CFM56-5A) A&C	9/8/2011	No limitation
A330-200 / -300 (Trent 700)	15/4/2013	ETOPS

1.6 Aircraft Information

1.6.0 General information

Registration Marks	SU-GCC
Type	A320-232
Operator	EgyptAir
Manufacturer	Airbus
Manufacture Serial Number (MSN)	2088
State of Registration and state of Operator	Egypt
State of design and state of Manufacturer	France
Engine , State of design and manufacturer	USA
Certificate of Registration	Egyptian registration certificate no 1155, from the Egyptian Civil Aviation Authority on 12/10/2014
Certificate of Airworthiness	No. 998, issued by the Egyptian Civil Aviation Authority on 27/10/2015, renewed and valid for the period from 03/11/2015 to 02/11/2016.
Flight approval	Flight approval number 461 for year 2015 issued by the Egyptian Civil Aviation Authority to fly or land on the Arab Republic of Egypt territories on 28/10/2015, renewed and valid for the period from 01/11/2015 to 31/10/2016
First Flight	on 03/11/2003
Number of flying hours	48052 since new
Total number of cycles	20773 since new

Engines: Two Turbofan IAE V2527-A5 manufactured by International Aero Engines with the following information:

	Engine No.1	Engine No.2
Serial number	V11539	V11509
Flight hours since new	42974	38650
Flight cycles since new	18718	17319
Flight hours since last overhaul	6005	3378
Flight cycles since last overhaul	2247	1249
Flight hours since installation	6004	1482
Flight cycles since installation	2247	649
Installation date	04/09/2014	19/12/2015
Last shop visit date	03/04/2014	27/12/2014

Auxiliary Power Unit (APU):

Manufacturer	Pratt &Whitney Aero Power.
P/N	4500001B
Manufacturer Serial Number	1084
Total FH/FC since new	29096/44682
FH/FC since last overhaul	4198/6430
FH/FC since installation	1734/2839

1.6.1 Maintenance works carried out on the aircraft

1.6.1.1 Scheduled Maintenance program

Aircraft was maintained according to maintenance program revision (13) dated March 2015 which is based on Airbus A320 MPD Rev 40 issued Nov. 2014, MRBR revision 19 issued Nov. 2014 and other Airworthiness Limitation Sections ALS updates. The maintenance program is approved by the Egyptian Civil Aviation Authority (ECAA).

Types of Checks:

1- Line Checks :

a) Pre-Flight Check (Transit Check): The pre-flight "Transit "check is intended to assure continuous serviceability of a transiting aircraft. The check is performed at each en-route stop. Transit check is valid for (4) elapsed clock hours.

b) After Landing Check: The "ALC" Check is intended to be performed after each arrival for 4 hours and more stops.

c) Daily Check: Tasks to be carried out every day not to exceed 36 hours elapsed time (aircraft in service).

d) Weekly (Ramp) Check: Tasks to be carried out every 8 calendar days (aircraft in service).

2- Grouped phase (A check): represents phases to be grouped every 750 FH interval.

3- Scheduled Maintenance Checks (base checks) the scheduled maintenance checks, identified by cycle / segment, are performed every 750 flight hours. Egypt Air creates its own C check and multiples to be accomplished every 24 Month which contains tasks at 24 Month and multiples.

1.6.1.2 Last carried out maintenance checks

Last "C" check:

- Type: 7C
- Start date: 28/04/2015
- End date: 25/06/2015
- Flying Hours FH: 44726
- Flying Cycles FC: 19423

Last "A" check:

- Type: 4A
- Start date: 26/03/2016
- End date: 28/03/2016
- Flying Hours FH: 47493
- Flying Cycles FC: 20531

Last "weekly" check:

- Performed on 16/05/2016

Last "Transit" check:

- Performed on 18/05/2016 (Time: 20:30 CDG)

1.6.2 Technical log book information

TLB information covering the past 7 days before the accident flight. It covers the time from 13/05/2016 till the accident flight (27 flights).

ITEM	DATE	Flt NO.	FROM	TO	TLB PAGE NO.	DEFECT	ACTION TAKEN
1	13/05/2016	MSR061	HELX	HECA	0023140	ADF #1 AIR APU BLEED LEAK	• ADF #1 RESET C/O, TEST C/O AS PER 34-53. • BMC #1 RESET C/O, BMC1 BITE TEST C/O FOUND OK AS Per 36-22.
2	13/05/2016	MSR747	HECA	LGAV	0023141	AIR ENG 2 HIGH PRES VALVE FALUT	• BOTH BMC TEST C/O, SATIS IAW 36-11-00 WITH NO FAULTS • TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
3	13/05/2016	MSR748	LGAV	HECA	0023142	NIL	NIL NOTED
4	13/05/2016	MSR182	HECA	HEBA	0023143	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
5	13/05/2016	MSR618	HEBA	OKBK	0023144	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
6	13/05/2016	MSR619	OKBK	HEBA	0023145	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
7	14/05/2016	MSR151	HEBA	HECA	0023146	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
8	14/05/2016	MSR725	HECA	EBBR	0023147	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
9	14/05/2016	MSR726	EBBR	HECA	0023148	NIL	NIL NOTED
10	14/05/2016	MSR916	HECA	OMAA	0023149	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
11	15/05/2016	MSR917	OMAA	HECA	0023150	NIL	• E.E: TRANSIT CHECK C/O IAW MP REV 13 MAR 2015

12	15/05/2016	MSR 737	HECA	LTBA	0074726	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
13	15/05/2016	MSR738	LTBA	HECA	0074727	NIL	• E.E: TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
14	15/05/2016	MSR 711	HECA	OLBA	0074728	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
15	15/05/2016	MSR 712	OLBA	HECA	0074729	TAXI LIGHT U/S	• TAXI LAMP REPLACED C/O , CHECKED FOUND OPERATING NORMAL , • E.E: CONSIDER DD PAGE 21411 CLEARED • E.E: TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
16	16/05/2016	MSR180	HECA	HEBA	0074730	NIL	• TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
17	16/05/2016	MSR 181	HEBA	HECA	0074731	VENT AVNCS SYS FAULT	• BITE TEST C/O SEVERAL TIME FOUND OK ,ACC TO AMM 21-26-00 • E.E: REPLACE F/O O2 BOX C/O ACC TO AMM 35-12-00& OPERATIONAL CHECK OK , • AIC REPLACED ACC TO AMM 71-11-11 DUE TO DENT OUT OF LIMIT , LEAK TEST C/O ACC TO AMM 30-21-49
18	16/05/2016	MSR 803	HECA	LFPG	0074732	ENG 2 HP VALVE FAULT	• BOTH BMC 1&2 BITE TEST C/O , NO FAULTS , • TRANSIT CHECK C/O IAW MP REV 13 MAR 2015

19	16/05/2016	MSR 804	LFPG	HECA	0074733	NIL	• NIL NOTED • MLG WHEEL # 3 WORN WITHIN LIMIT ACC TO AMM 32-41-00
20	17/05/2016	MSR 725	HECA	EBBR	0074734	NIL	TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
21	17/05/2016	MSR 726	EBBR	HECA	0074735	NIL	E.E :TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
22	17/05/2016	MSR 833	HECA	HHAS	0074736	NIL	TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
23	18/05/2016	MSR 834	HHAS	HECA	0074737	NIL	E.E:TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
24	18/05/2016	MSR 843	HECA	DTTA	0074738	NIL	NIL NOTED
25	18/05/2016	MSR 844	DTTA	HECA	0074739	NIL	TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
26	18/05/2016	MSR 803	HECA	LFPG	0074740	NIL	TRANSIT CHECK C/O IAW MP REV 13 MAR 2015
27	18/05/2016	MSR 804	LFPG	HECA	ACCIDENT FLIGHT		

1.6.3 Flight Crew Oxygen System

The oxygen system supplies oxygen to the flight crew. It supplies oxygen to the Captain, the First Officer, the third Occupant and the fourth occupant stations.

The flight crew oxygen-system supplies supplement oxygen and gives protection to the eyes and respiratory system of the crew members. It is used in the following conditions:

- Loss of cabin pressurization (hypoxia protection)
- Smoke and poisonous fumes
- If one pilot remaining on station (applicable regulations)
- Pre-flight checks by the pilots.

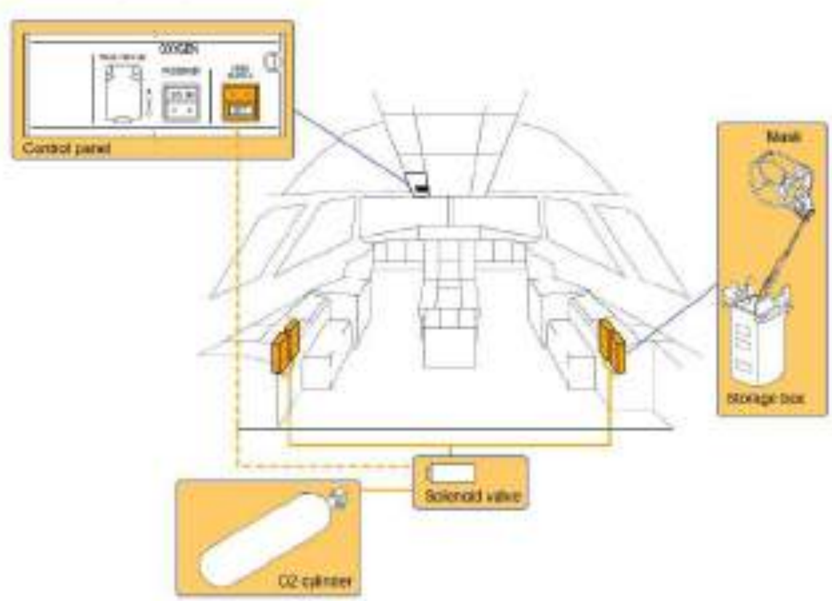


Figure 1.6/1: Flight Crew Oxygen System

Figure 1.6/2: Fixed breathing equipment (quick-donning)

Figure 1.6/3:Portable breathing equipment (PBE)

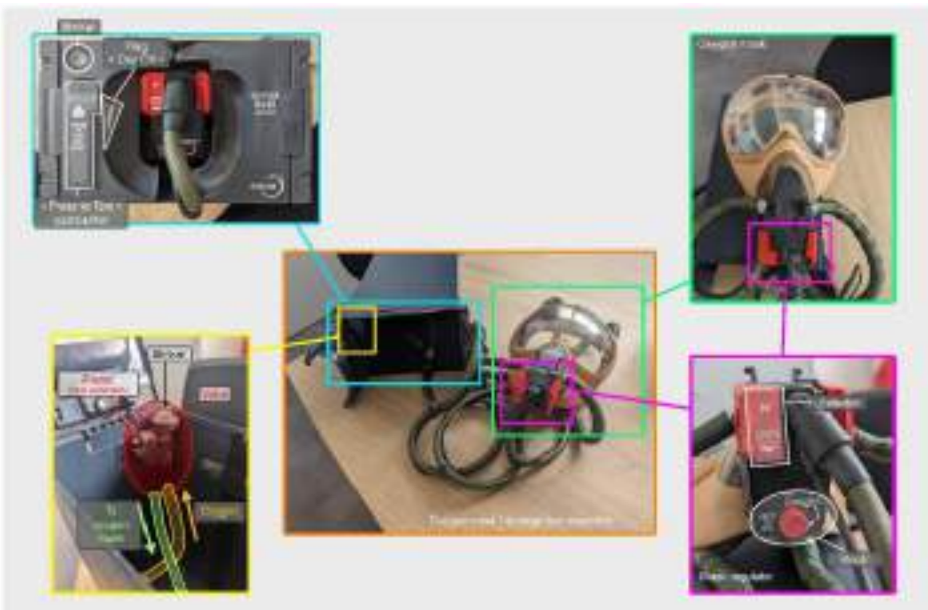


Figure 1.6/4: oxygen box

A320 (FCOM and AMM)

GENERAL

Ident.: DSC-35-20-10-00001449.0002001 / 09 DEC 09
Applicable to: ALL

The cockpit's fixed oxygen system consists of :
- A high-pressure cylinder, in the left-hand lower fuselage.
- A pressure regulator, connected directly to the cylinder that delivers oxygen, at a pressure suitable for users.
- Two overpressure safety systems to vent oxygen overboard, through a safety port, if the pressure gets too high.
- A supply solenoid valve that allows the crew to shut off the distribution system.
- Four full-face quick-donning masks, stowed in readily-accessible boxes adjacent to the crewmembers' seats (one at each seat).

OPERATION

Ident.: DSC-35-20-10-00001450.0001001 / 09 DEC 09
Applicable to: ALL

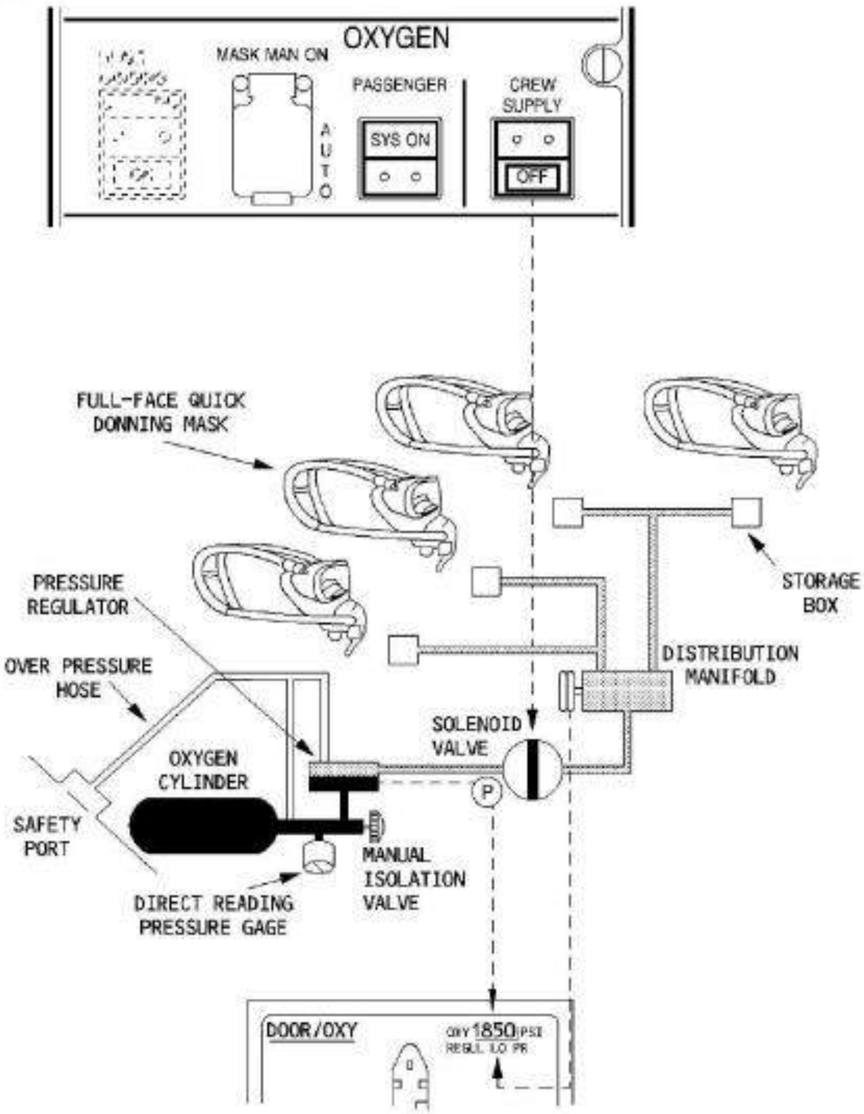
The crewmember squeezes the red grips to pull the mask out of its box, and this action causes the mask harness to inflate.
A mask-mounted regulator supplies a mixture of air and oxygen or pure oxygen, or performs emergency pressure control. With the regulator set to NORMAL, the user breathes a mixture of cabin air and oxygen up to the cabin altitude at which the regulator supplies 100 % oxygen. The user can select 100 %, in which case the regulator supplies pure oxygen at all cabin altitudes.
If the situation calls for it, the user can use the emergency overpressure rotating knob and receive pure oxygen at positive pressure.
The storage box contains a microphone lead, with a quick-disconnect, for connection to the appropriate mask microphone cable.

<u>Note:</u> *Each mask may have a removable film that protects the visor against scratches. This strip is optional and may be removed from the mask at any time.*

A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	AIRCRAFT SYSTEMS OXYGEN FIXED OXYGEN SYSTEM FOR COCKPIT - DESCRIPTION

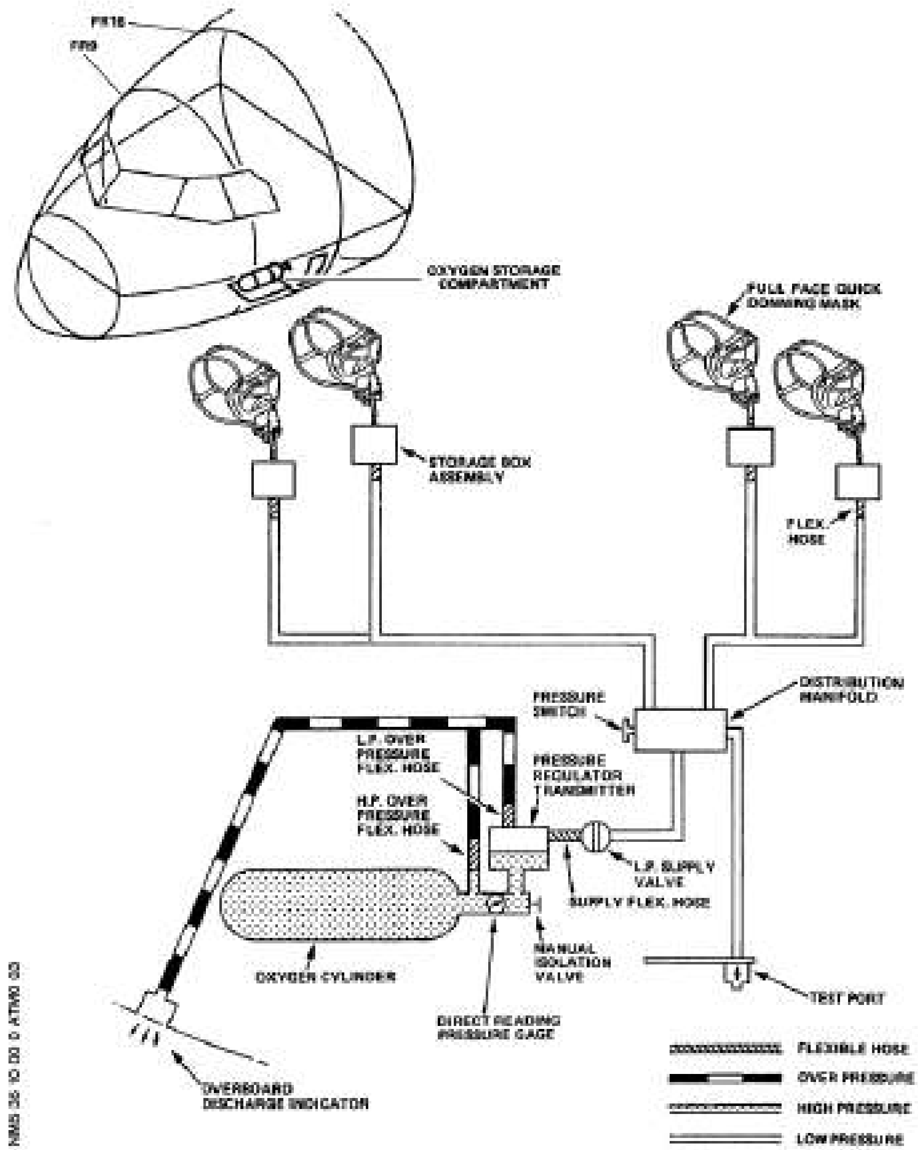
SCHEMATIC

Ident.: DSC-35-20-10-00001451.0002001 / 14 FEB 11
Applicable to: ALL



A320

AIRCRAFT MAINTENANCE MANUAL



Crew Oxygen System - Schematic
Figure 001

EFF : ALL	**35·10·00**	Page 2 Feb 01/96
MS.R		

Printed in France

1.6.3.1Oxygen Storage

The High Pressure (HP) oxygen cylinder supplies oxygen to the flight crew. The HP oxygen cylinder is installed on a support that has two quick release clamps in the left part of the avionics compartment between frames 11 and 13.

The valve assembly is installed on the oxygen cylinder head. A pressure regulator/transmitter is connected to the valve assembly. The regulator located on the head of the cylinder reduces the pressure between 4.48 bar and 6.48 bar in the downstream system. The HP oxygen cylinder and its pressure regulator/transmitter have an overboard discharge system which prevents too much pressure in the HP oxygen cylinder and/or in the Low Pressure (LP) chamber of the pressure regulator/transmitter.

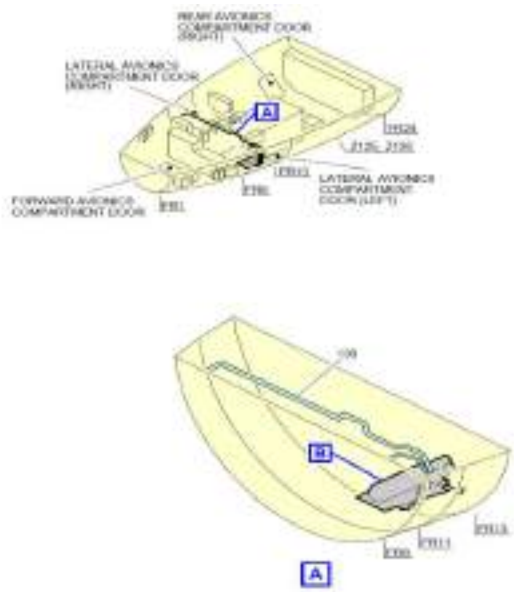


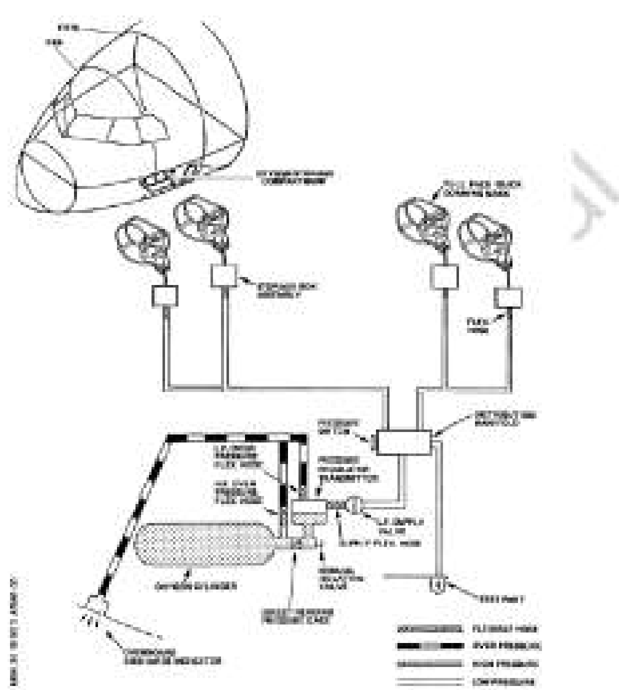
Figure 1.6/5:Oxygen Storage

1.6.3.2 Oxygen Distribution

The oxygen then travels from the regulator, under the cockpit floor parallel to frame 11 through rigid stainless steel lines to four mask storage boxes located on the left and right side of the cockpit (two on each side). The boxes are connected to the rigid line by flexible hoses (soft hoses protected by a metal braid tube). This connection is in the cockpit’s side compartments where the boxes are housed.

Oxygen is supplied to the flight crew stations through a distribution circuit. The distribution circuit has the components that follow:

- An LP solenoid supply-valve
- A distribution manifold
- The LP stainless-steel distribution-pipes
- The Supply hoses and stowage boxes
- The Full-face/quick-donning oxygen masks with a demand regulator.



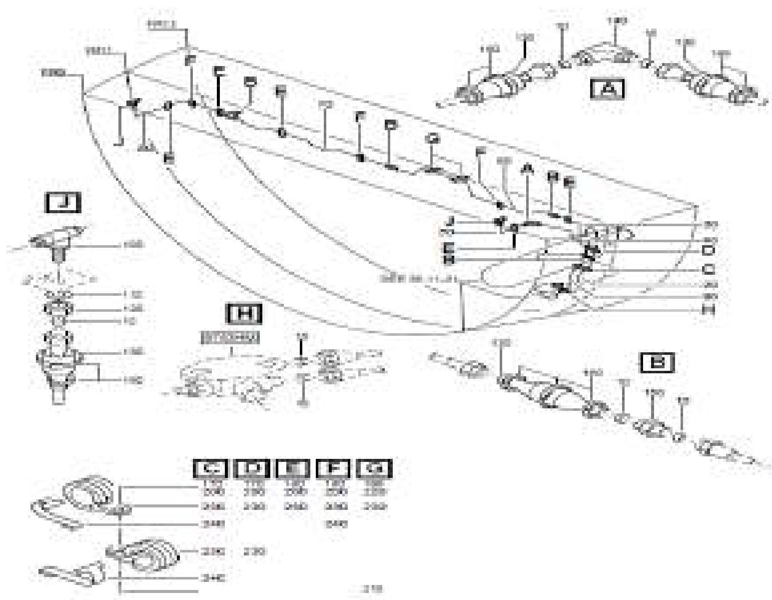


Figure 1.6/6:Oxygen Distribution

In the mask storage box, a first hose (Dekabon-aluminum tubing in a nylon sheath) connects the box inlet to a valve. Inside the valve, a piston is mechanically held in the closed position. It prevents the flow of pressurized oxygen (between 4.48 bar and 6.48 bar) to the mask. When the PRESS TO TEST pushbutton is pressed or the box door is open, the mechanical stop is moved. The piston slides and oxygen flows through the lines to the mask. In the same way, this piston presses a micro switch which activates the mask microphone.

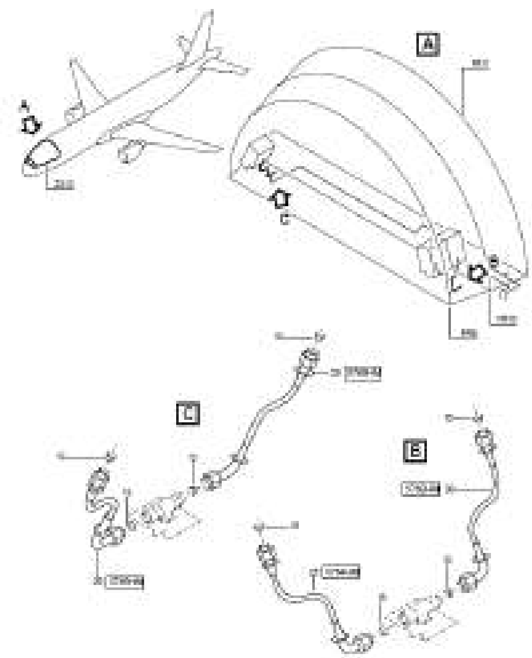


Figure 1.6/7:Oxygen Distribution

1.6.3.3 Oxygen System Controls and Indications.

In the cockpit, on the OXYGEN section of overhead control and indicating panel 21VU, the CREW SUPPLY pushbutton switch (2HT) controls the opening of the Low Pressure (LP) oxygen-supply solenoid valve (3HT). The status and the warnings related to the system pressure are shown on:

- The ECAM Display Units (DUs) (the DOOR/OXY page on the lower ECAM DU and warning/resolution messages on the Engine/Warning Display (EWD)):

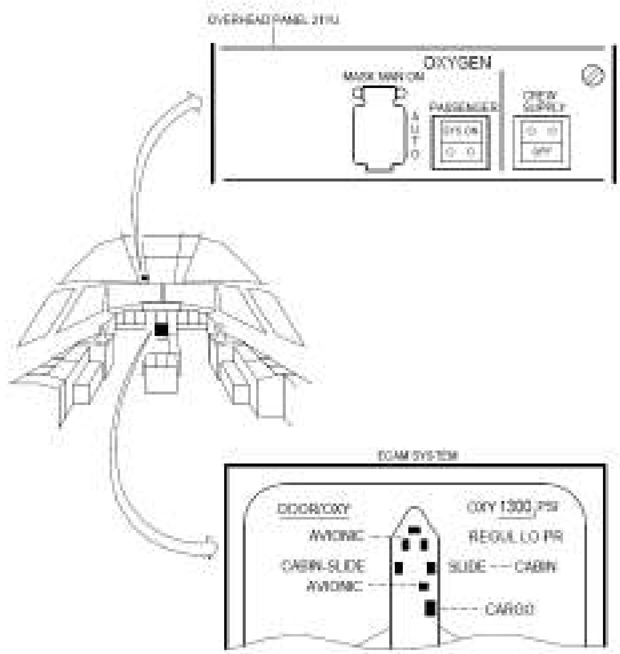


Figure 1.6/8:oxygen System Controls and Indications

A direct-reading pressure gage installed on the crew oxygen-storage cylinder gives an indication of the cylinder high-pressure level

An overboard discharge indicator.

(1) OXY pressure indication

It is in green, when the pressure is ≥ 400 PSI.

It is in amber, when the pressure is < 400 PSI.

On ground, an amber half frame appears when oxygen pressure is < 1 500 PSI.

In this case, the flight crew must check that the remaining quantity is not below the minimum

(2) REGUL LO PR indication

It is in amber, if oxygen pressure on the low-pressure circuit is low (50 PSI).

(3) OXY indication

It is normally in green.

It becomes amber, when:

- Pressure goes below 400 PSI
- Low oxygen pressure is detected
- The OXYGEN CREW SUPPLY pushbutton switch on the overhead panel is OFF.

1.6.3.4 Maintenance activities carried out on the Oxygen System

- On 16 May 2016 (10 flights, 32hr:46mn flight time prior to accident)

  During a scheduled weekly check the first officer oxygen box press to test / reset button was found stuck. The oxygen mask stowage box was replaced by the maintenance engineer according to Aircraft Maintenance Manual.

  – Part Number: MXP801-11.
  – Serial Number: SE35850.
  – Manufacturer: Inter technique S.A. Manufacturing (EROS EQUIPMENT).
  – Manufacturing Date: July 2009.
  – First installation date for unit: 9/12/2009 (on aircraft Reg. YI-AGS, TYPE A321-231, MSN: 4044) The unit was removed from Aircraft due to "LH door reset mechanism faulty" and was deemed for overhaul which was carried out by AVIA TECHNIQUE LTD where an EASA form 1 was issued on 22 April 2016 after overhaul completion.
  – The unit was installed on SU-GCC on 16 May 2016 after removing the previous unit due to inspection found F/O oxygen box test (press to test push button unserviceable).
  – Unit total flight hours at date of installation on SU-GCC: 7558:23.
  – Unit total flight cycles at date of installation on SU-GCC: 3754.

  The aircraft flew 10 flights, 32hr: 46mn flight time prior to accident after the replacement without complaint regarding the crew oxygen system.

- On 21 March 2016 (262 flights prior to accident)

  Captain reported in TLB that "Oxygen mask cover is broken Capt. Side" and was corrected before further flight as "Capt. Oxygen Mask cover repaired".

- On 20 March 2016 (268 flights prior to accident)

– Captain reported on TLB "Please check oxygen quantity decreasing every sector". Oxygen bottle was replaced as per TLB "E.E. crew oxygen cylinder has been replaced due to low pressure ACC to AMM 35-11-41 and leakage check c/o found no leak".
– It was noted that by reviewing earlier flights to this one, there was no TLB entry regarding flight crew oxygen bottle pressure decrease.

- The aircraft flew 268 flight cycles (60 days) after this replacement without log book complaint.

- On 17 February 2016 (414 flights prior to accident)

It was reported in the TLB as engineering entry that "fourth seat crew oxygen mask is INOP. This was deferred in DDL (page 0010691) and cleared on the same day.

1.6.4 Lavatories

Lavatory smoke Detection System:

A smoke detection system is installed to detect smoke and/or fire in the lavatories. The lavatory smoke detectors are installed in a loop system, together with the cargo-compartment smoke detectors. If smoke is detected, the system gives a visual and aural warning to the flight crew. This system is made-up of:

- One smoke detector for each lavatory,
- The Smoke Detection Control Unit (SDCU).

Smoke or fire in one of the lavatories causes a detector to signal the SDCU. The SDCU sends signals to the Centralized Intercommunication Data System (CIDS) and the Flight Warning Computer (FWC). The FWC gives indications on: - the ECAM upper display unit, The CIDS gives indications on: - The FWD attendant panel,

- The area call panel.

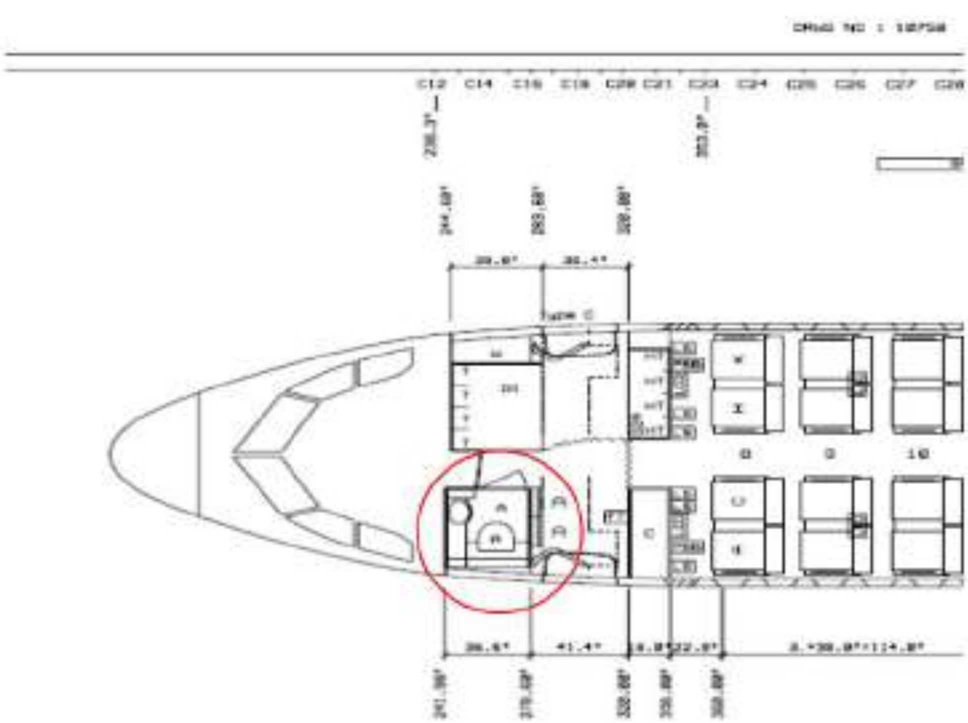


Figure 1.6/9: Forward Lavatory

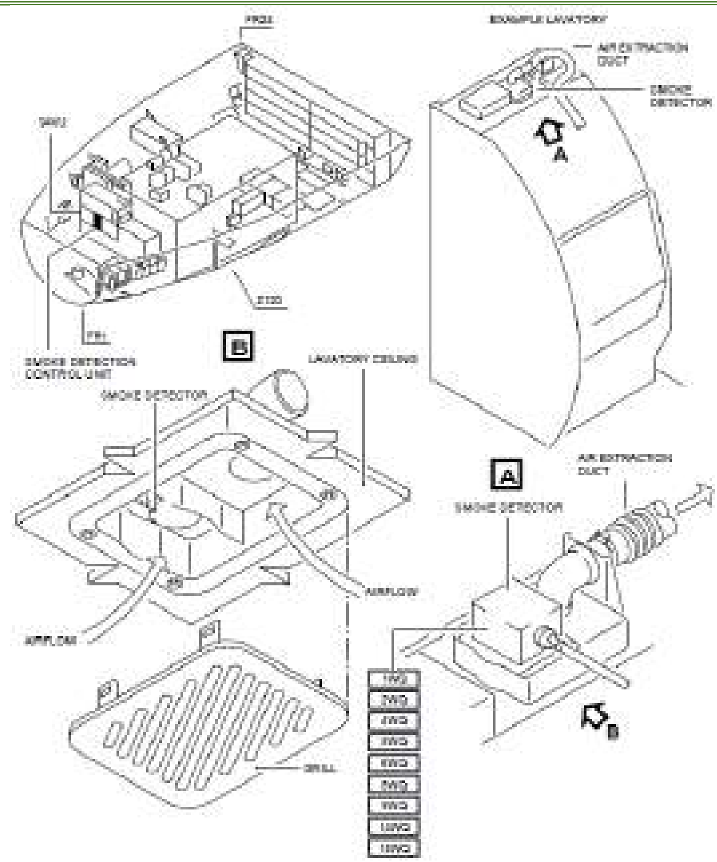


Figure 1.6/10: Lavatory Smoke Detection System

1.6.4.1 Smoke Detectors

The smoke detector operates on the principle of scattered light. The light source, the labyrinth and the photocell are set out in a horizontal plane so that the photocell cannot receive light. When there is smoke, the smoke particles reflect and scatter a part of the light beam. The photocell receives this light and gives an analog signal and sets off the alarm.

1.6.4.2 Smoke Detection Control

The smoke detection control unit (SDCU) 10WQ has two channels, which make it a fail-safe unit. The system will operate normally if one channel fails. The Built in Test Equipment (BITE) detects and isolates failures in the SDCU. It also makes sure that the smoke detectors function correctly. Most of the system functions are monitored continuously. The line key switch (on the Centralized Fault Display System (CFDS) and the Multifunction Control and Display Unit (MCDU)) simulates a smoke condition when pressed. Information of faulty equipment is signaled to the CFDS.

1.6.4.3 Smoke Warning Facilities

Smoke warnings are given in the cockpit and the cabin. The cockpit warnings are:

- A repetitive chime.
- A red master warning light
- A smoke warning indication on the ECAM upper display unit.

The cabin warnings are:

- A chime from all cabin loudspeakers or from the attendant station loudspeakers
- A pink flashing indicator light and a steady text on all Attendant Indication Panels (AIP)
- An amber flashing light on the related Area Call Panel (ACP)
- An amber flashing call light on the related lavatory wall
- A common red lavatory smoke indicator on the forward attendant panel.

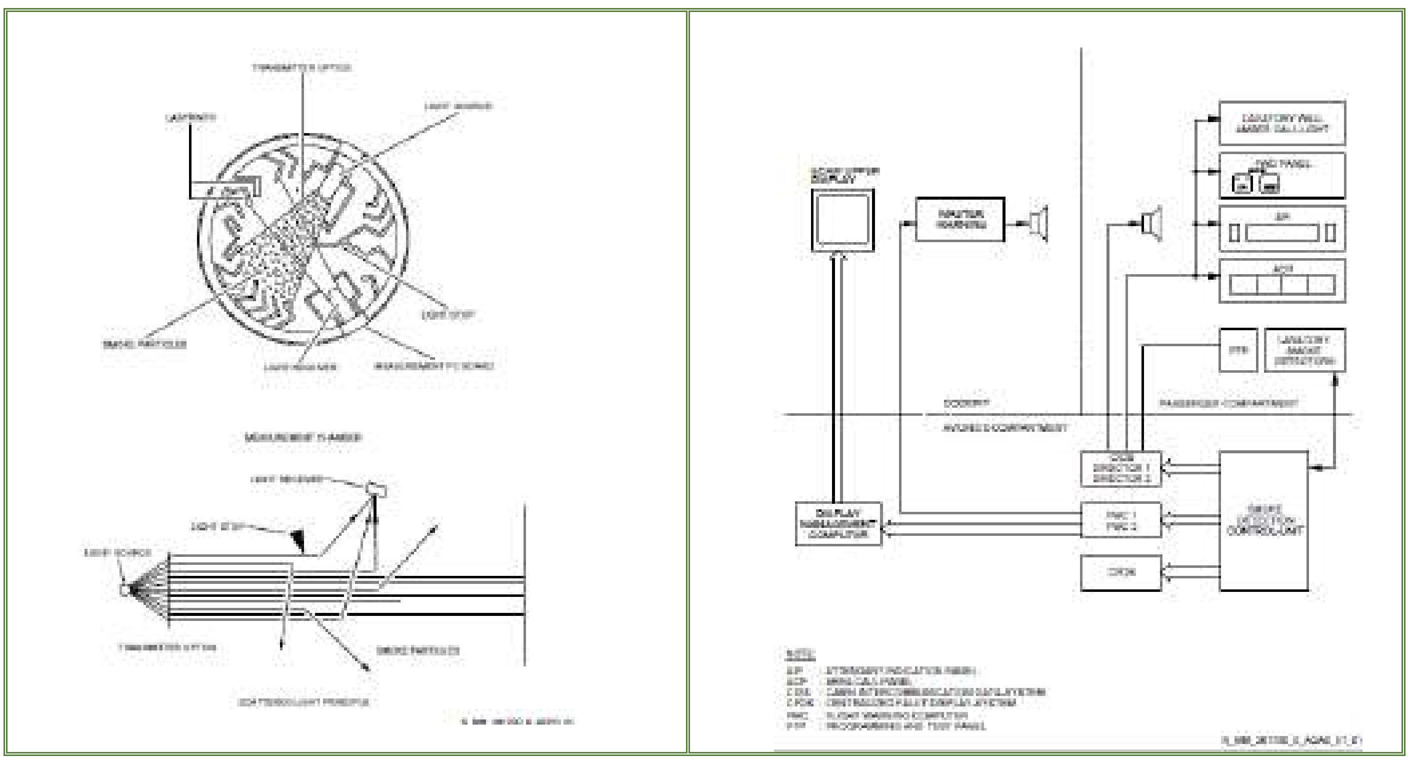


Figure 1.6/11: Smoke Warning Facilities

Smoke Condition:

Smoke that enters the measurement chamber of the smoke detector, gives a warning signal to the SDCU. The SDCU transmits the signal to the CIDS and FWC via data buses. The CIDS directors send the signal to the FAP (Forward Attendant Panel), AIP (Attendant Indication Panel) and ACP (Area Call Panel). The aural and visual warning reset switch on the FAP stops the warning indications on the ACP and AIP. Smoke indication cannot be switched off on the FAP. This indication goes off, when the density of the smoke drops below the threshold of the respective smoke detector.

1.6.4.4 ARINC Raw Data Messages during the accident

At time 00:26 the "Smoke Lavatory Smoke" was recorded in the ARINC Raw Data report.

1.6.4.5 Lavatory Ventilation

The largest quantity of air for ventilation of the lavatories and galleys comes from the cabin. Extraction causes the air to flow from the cabin into the lavatories and galleys. The air flows into the lavatories through grilles in the door and into the galleys through grilles and filters which are installed in the galley walls and the ceiling. A small quantity of air for ventilation of the lavatories flows from individual air outlets. Conditioned air from the cabin air distribution and recirculation system flows into the supply ducts of the lavatory/galley ventilation system. The supply ducts are installed in the ceiling area of the cabin. The air flows from the supply ducts into each lavatory through an individual air outlet. There are also supply ducts to the galleys. The extraction fan removes air from the lavatories and the galleys through a duct which is installed above the cabin ceiling. The air flows through filters into the duct. This duct extends the length of the cabin from the FWD utility area to the left-hand AFT lavatory. The air is then removed overboard through the outflow valve. The extraction fan operates continuously during flight and also on the ground when electrical power is available to the aircraft.

1.6.5 Electrical Wiring

Failed computers according to FDR download

1.6.5.1 Computers Locations

No.	Computer	Computer	Location	Time of Loss
1	SEC3	Spoiler and Elevator Computer No.3	93VU	00:29:26
2	TCAS	Traffic Collision Avoidance System Computer	82VU	00:29:28
3	RUDER PEDAL FORCE SNSR	Ruder Pedal Force Sensor	Cockpit	00:29:28
4	SEC2	Spoiler and Elevator Computer No.2	84VU	00:29:34
5	SDCU CHANNEL B	Smoke Detector Control Unit	94VU	00:29:35
6	FAC2	Flight Augmentation Computer	84VU	00:29:36
7	WR 1 & 2	Weather Radar	109VU	
8	FMGC2	Flight Management and Guidance Computer	84VU	Between 00:29:37 and 00:29:42
9	EEC2 CHANNEL B	Engine Electronic Control	ENG 2	
10	DMC3	Display Management Computer No.3	80VU	
11	FCDC2	Electrical Flight Control System No.2	84VU	
12	EVMU	Engine Vibration Monitoring Unit	86VU	00:29:45

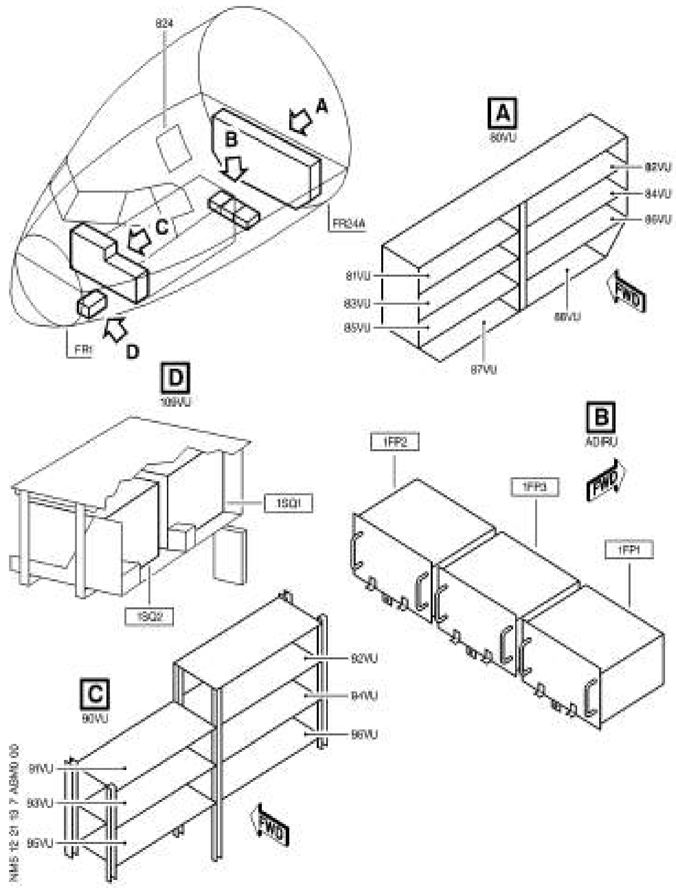


Figure 1.6/12: Computers Locations

1.6.5.2 Affected Computers by Main Power Supply Circuit Breakers

	Power Supply CB	Location	Computer
1	1XN1	123VU	WR1
2			DMC3
3			EVMU
4			TCAS
5	3PN2	124VU	SEC2
6			SEC3
7			SDCU B
8			FCDC2
9	1XN2	124VU	DFDR
10			WR2
11	6PN	124VU	FAC2
12			FMGC2
13	1PN2	124VU	EEC2

1.6.5.3Affected Computers by Terminal Block

	Terminal block	Location	computer
1	2252VT	120VU	SEC3
2			SEC2
3			SDCU
4			FAC2
5			FMGC2
6			EEC2
7			FCDC2
9			WR2
10			DFDR
11	2244VT	120VU	WR1
12			DMC3
13			EVMU
14			TCAS

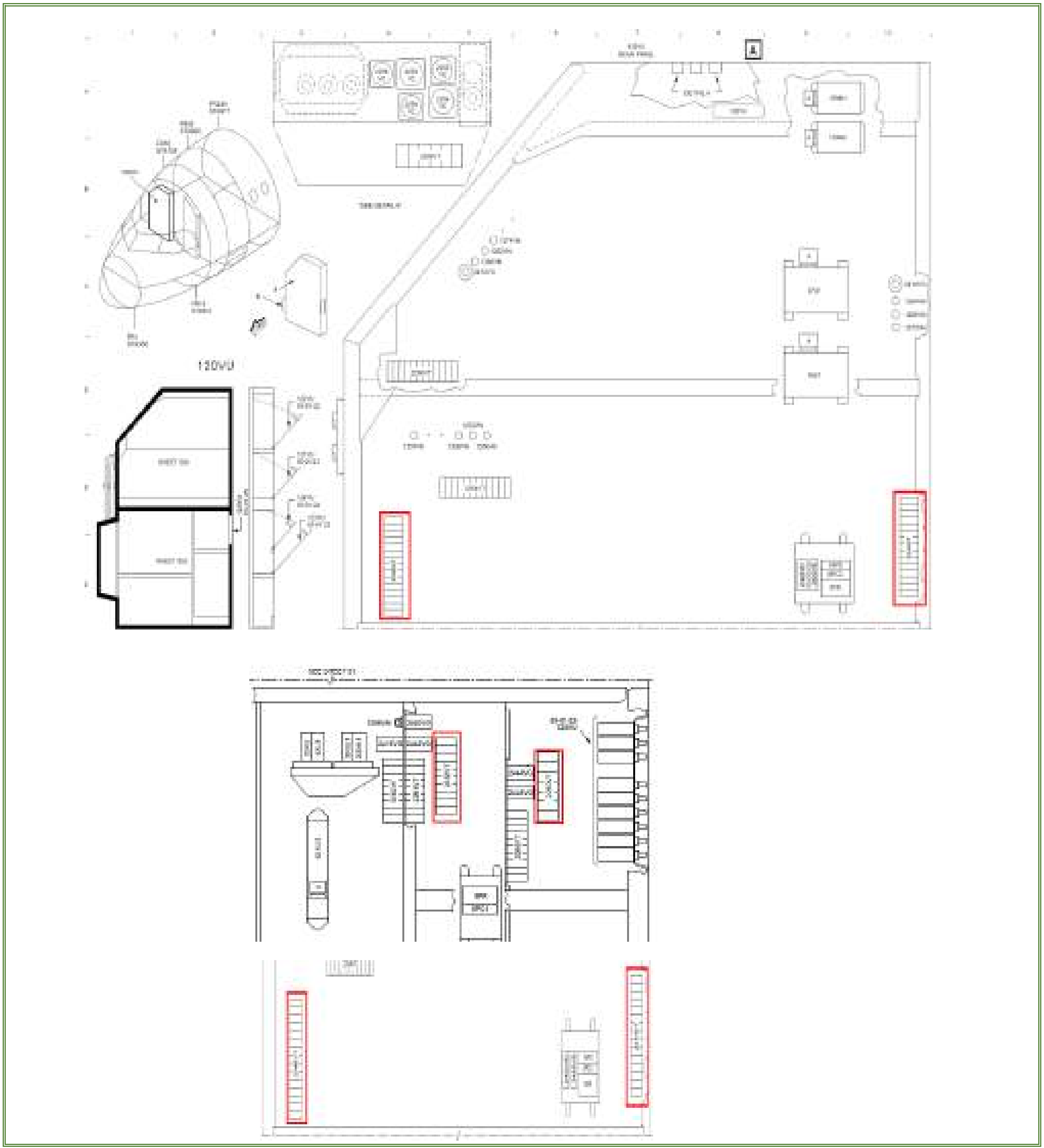
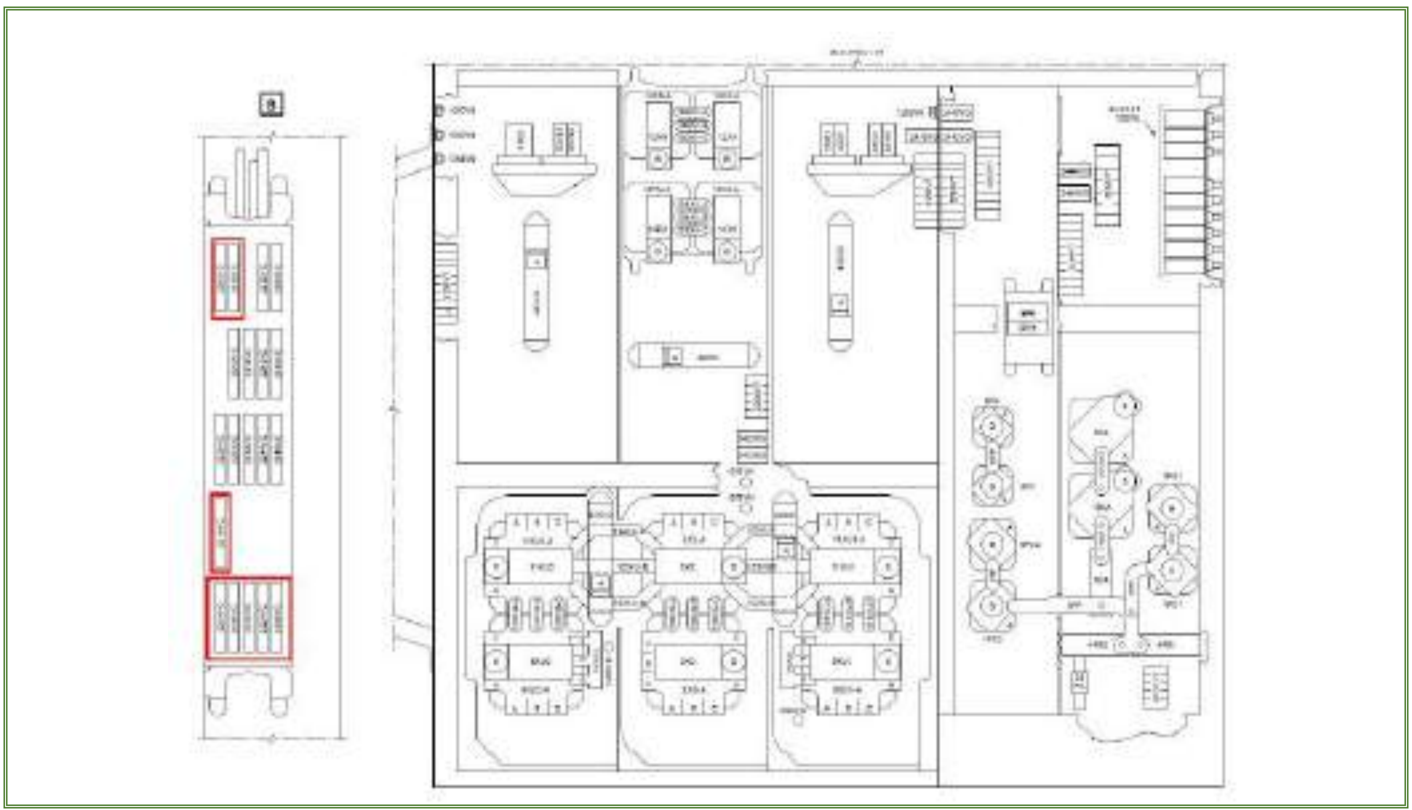


Figure 1.6/13: Affected Computers By Main Power Supply Circuit Breakers

1.6.5.4Affected computer by Connectors

No.	Connector	Location	Computer
1	2200VC	120VU	EVMU
2			BSCU
3	2250VC	120VU	TCAS
4	2204VC	120VU	FAC2
5			FAC2
6			WR2
7	2206VC	120VU	FMGC2
8			DFDR
9	2210VC	120VU	SEC3
10			SEC2
11			FCDC2
12	2226VC	120VU	SDCU
13	2202VC	120VU	WR1
14			DMC3
15	2216VC	120VU	EEC2



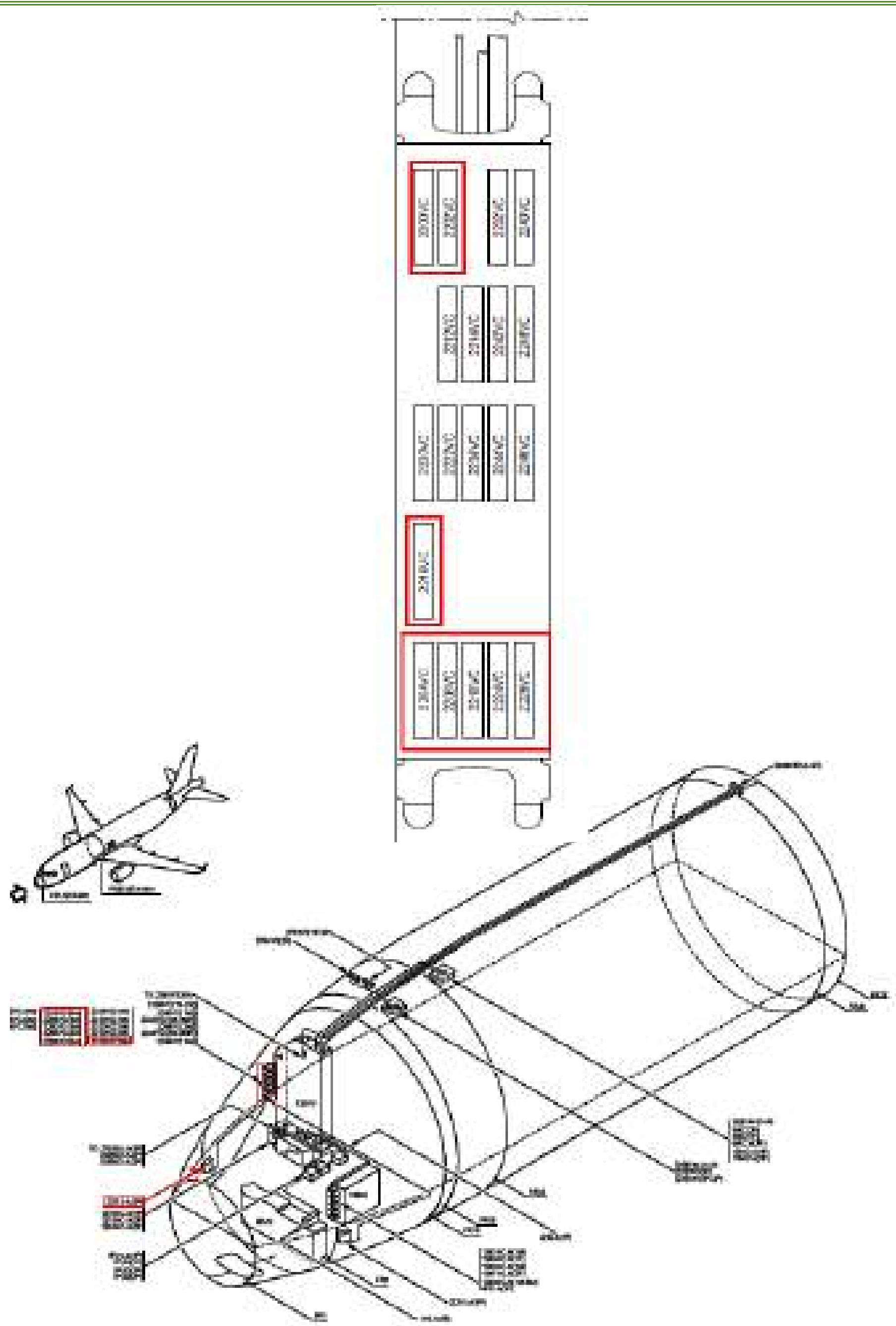
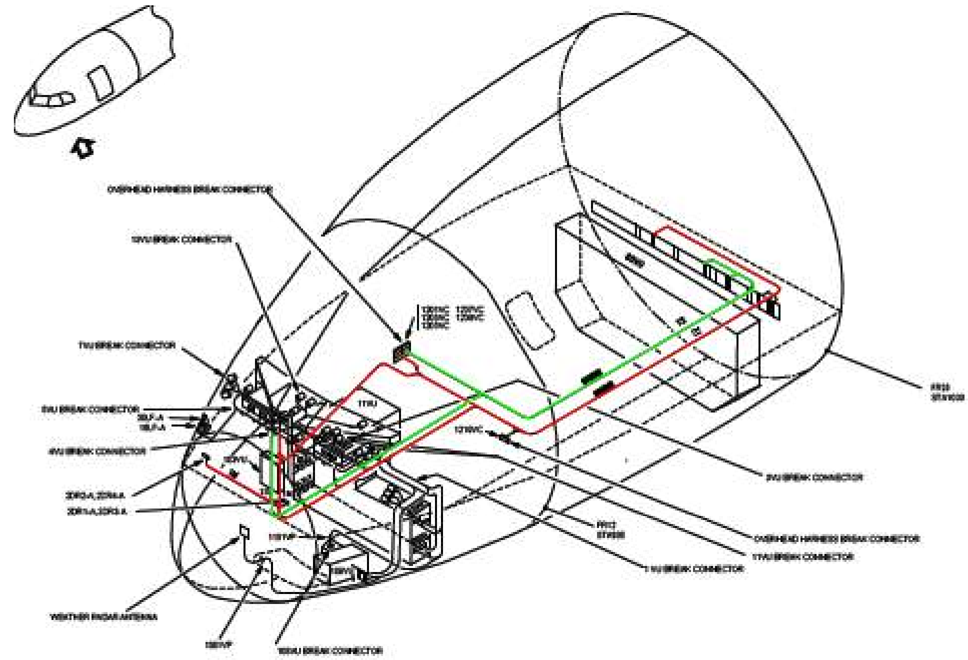


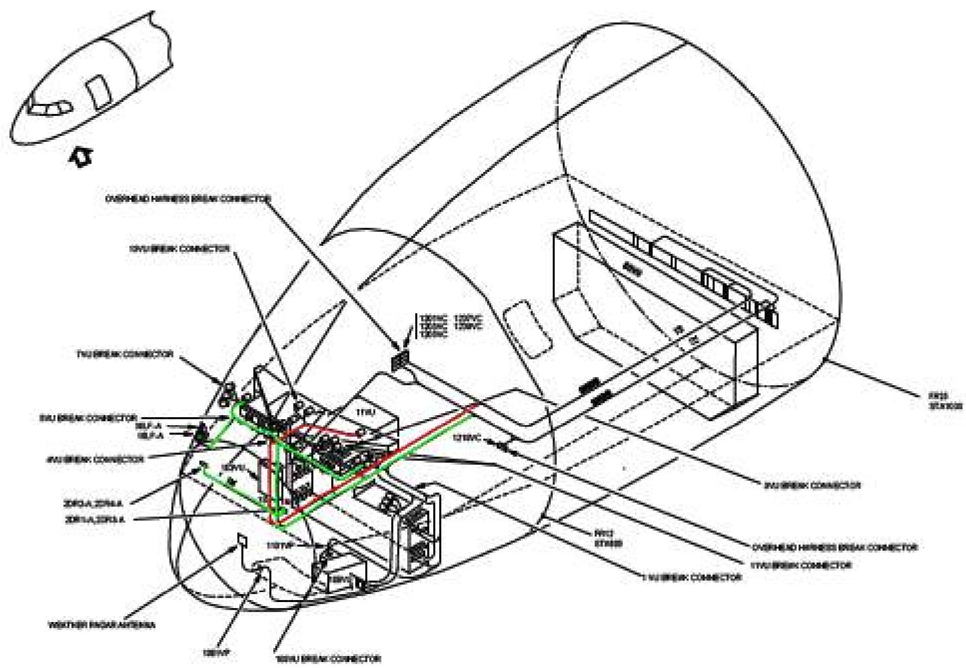
Figure 1.6/14: Affected Computer By Connectors

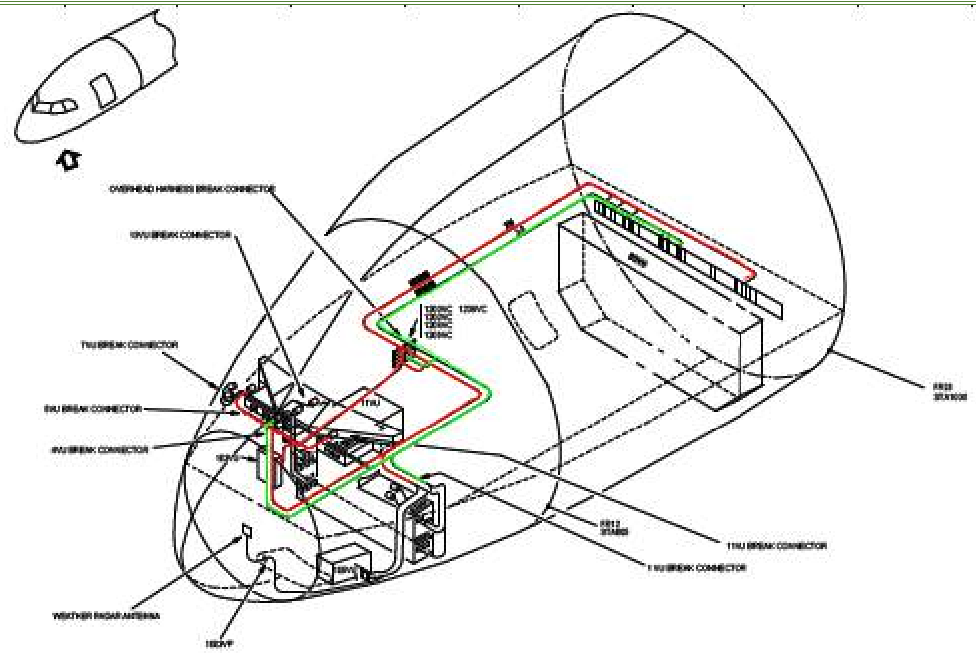
Notes:

1- All of the above CB supply another A/C systems.
2- All of the above terminal blocks (VT) supply another A/C systems.
3- All of the above electrical connectors (VC) contain another A/C systems wires.

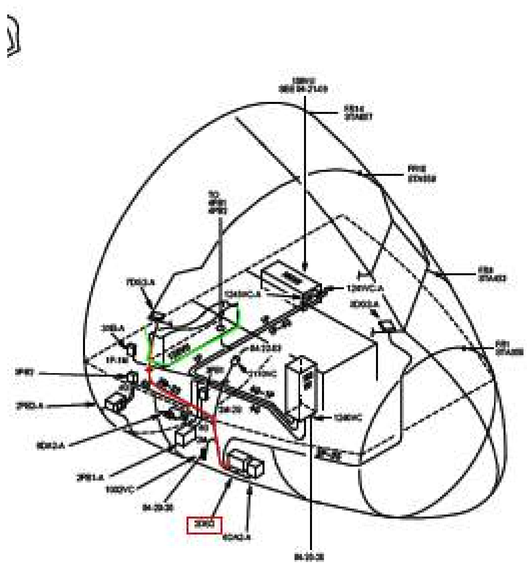
1.6.5.5 Routing Identification: The affected wires route as follow 1M, 2M, 8M, 1S, 2S, 7S, 8S

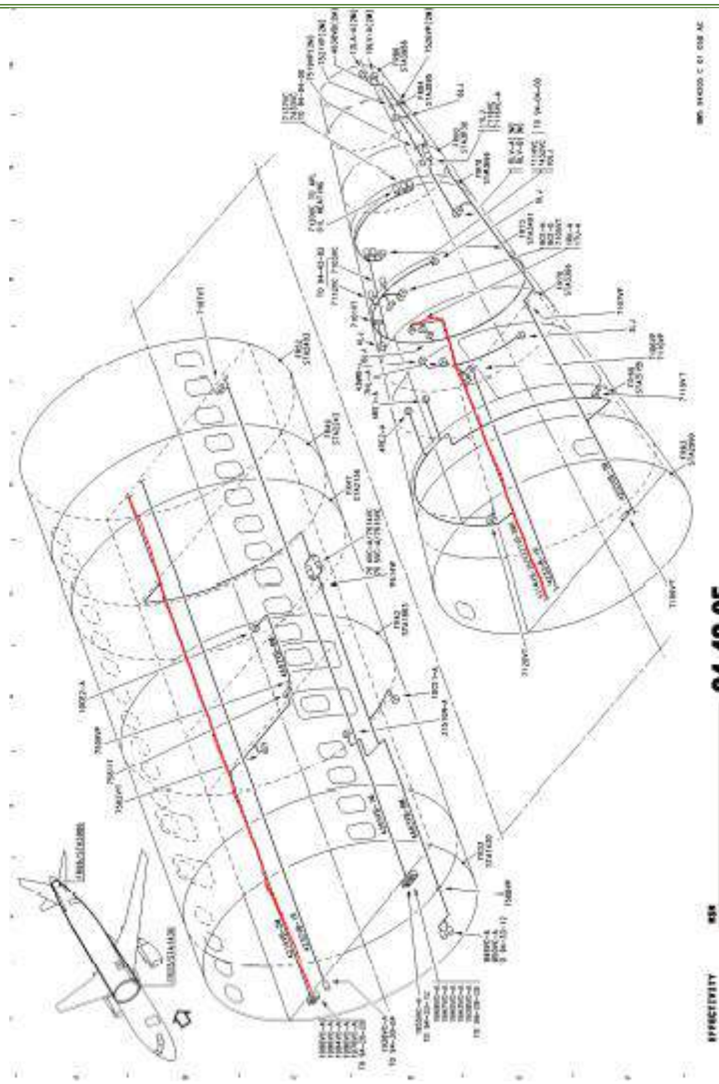






OVERHEAD HARNESS BREAK CONNECTOR
WEATHER RADAR ANTENNA





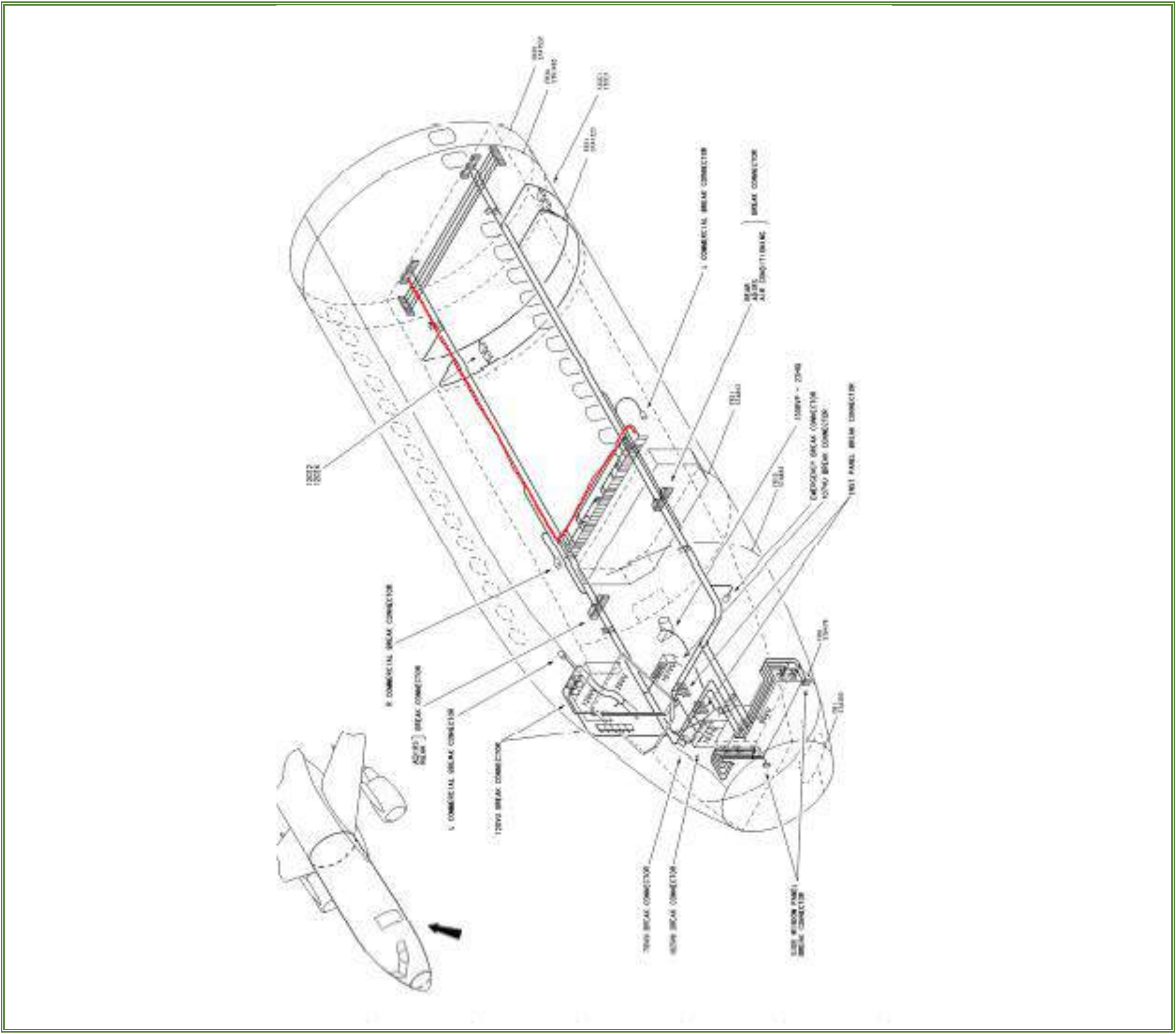


figure 1.6/15: Affected Wires Route

1.6.6 Air Traffic Service Unit (ATSU)/ ARINC Raw Data

Air Traffic Service Unit (ATSU) is an electronic system located in the avionics compartment. The ACARS uses VHF3. This system is connected to the CFDIU and serves to send reports to the ground.

The CFDIU is a computer that is used as the interface between the system BITEs and the MCDUs.

The purpose of the onboard maintenance is to provide maintenance personnel with an aid to fault diagnosis further to a complaint of the crew.

The ECAM messages downlinked from ATSU can be retrieved as raw data through ARINC Hermes web based application or viewed on AIRBUS AIRMAN Web based application.

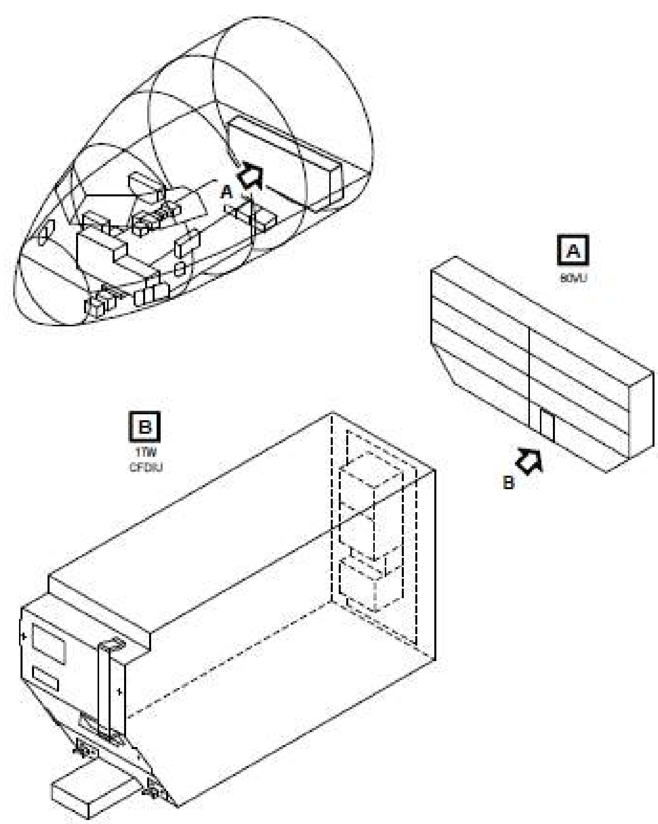


figure 1.6/16: Air Traffic Service Unit

1.6.6.1 System BITE Functions

General:

Each electrical or electronic system of the aircraft includes a fault detection, isolating and storing device called a BITE.

The BITE system reacts to any fault affecting operation, whether internal or external to the system.

The BITE permanently transmits maintenance messages in real time (in flight).

These maintenance messages cover internal and external faults of the current flight or of the last flight.

1.6.6.2 ARINC Raw Data messages

The Following ARINC Raw Data messages were generated during cruise of the crash flight:

Message	Time Generated
SMOKE LAVATORY SMOKE	00:26
ANTI ICE R WINDOW	00:26
R SLIDING WINDOW SENSOR/IDWHC 2	00:26
AVIONICS SMOKE	00:27
R FIXED WINDOW SENSOR/IDWHC 2	00:28
AUTO FLT FCU 2 FAULT	00:29
F/CTL SEC 3 FAULT	00:29

1.6.6.3 The AIRMAN application provides priority level next to most of the messages

Three pre-defined priority levels are available, based on the Airbus MMEL:

- Low – Low Maintenance impact / No operational impact.
- Medium – Medium operational impact
- High – No Go.

The above levels can be customized by the operator.

Fault Tracking	Leg	A/C ID	Flight Number	Flight phase	Date Time	Transmission Date	ATA	Source	Title	Priority	Correlated	Rate	Airline rate	Airbus rate	Report	Work
OCCURRENCE	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:22	18 May 16 - 19:24	316022	EIS 1	DU NDI		No	6.7%	3.4%	2.2%	CFR,PFR	
	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:31	18 May 16 - 19:31	3611		AIR ENG 2 HP VALVE FAULT	Low	Yes				CFR	
OCC / REP	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:31	18 May 16 - 19:32	361151	BMC 2	HP BLEED-V 4000HA2 OR SENSE LINE		Yes	48.3%	10.7%	6.1%	CFR,PFR	
OCCURRENCE	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:31	18 May 16 - 19:36	3611		AIR ENG 2 HP VALVE FAULT (2)	Low	Yes	15.2%	7.9%	2.7%	PFR	
	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:37	18 May 16 - 19:37	3200		WHEEL TYRE LO PR	Low	Yes				CFR	
OCCURRENCE	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:37	18 May 16 - 19:38	324033	TPIS	CHECK TIRES 1/2 PRESS 2649/2650GM		Yes	16.7%	18.8%	5.7%	CFR,PFR	
OCCURRENCE	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:37	18 May 16 - 19:38	3200		WHEEL TYRE LO PR (4)	Low	No	3.3%	1.9%	1.7%	PFR	
OCCURRENCE	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:38	18 May 16 - 19:38	3611		AIR ENG 2 HP VALVE FAULT	Low	No	18.7%	11.8%	4.7%	CFR,PFR	
OCCURRENCE	-1	SU-GCC	MS804	06-CRUISE	18 May 16 - 19:38	18 May 16 - 19:39	3200		WHEEL TYRE LO PR	Low	Yes	15.3%	10.3%	4.3%	CFR,PFR	
	-1	SU-GCC	MS804	09-80 KTS	18 May 16 - 19:54	18 May 16 - 19:55	228934	AFS	AFS FMGC2		No	3.3%	2.4%	1.0%	CFR,PFR	

1.6.6.4 Spurious Messages

Spurious messages in PFR occur because any of the following reasons:

1. System BITE monitoring too tight/sensitive.
2. Optional systems not installed.
3. Monitoring activated although system not started yet.
4. System selection in flight.
5. Airline procedures.

Spurious item definition / correction

Conditions of occurrence are precise/known and reproducible

Statistical survey shows a high number of occurrences:

→ More than 1 occ. every 5 flights per A/C without logbook complaint

•Based on in-service experience, airline's feedback:

→ Systematic analysis of BITE deviations is conducted:

- To confirm an item is or not spurious, and may or not be filtered
- To determine the condition(s) of occurrence, for example:

•Permanent / Intermittent (Failure messages)

•Only during a given flight phase. Ex: Eng. Start, Landing, etc.

•BITE improvement is a continuous process

→ BITE deviations generally corrected at each Standard upgrade, unless the deviation has a major operational impact.

1.6.7 Anti-Hijack Camera

The Cockpit Door Surveillance System (CDSS) uses cameras in the cockpit entrance, and left and right door 1 areas. They let the flight crew monitor the door 1 area and identify persons who request access to the cockpit.

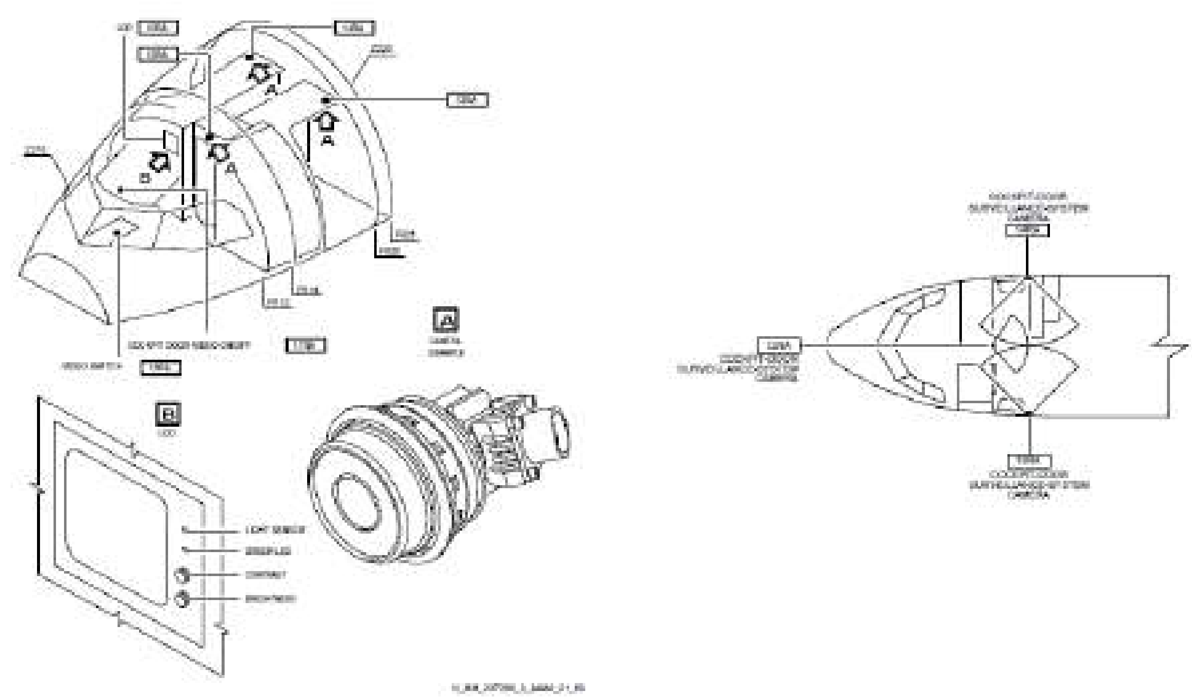


Figure 1.6/17: Anti-Hijack Camera

The Cockpit Door Surveillance System (CDSS) consists of the following components:

- 3 Cameras
- 1 LCD (with a system controller)
- 1 CKPT DOOR VIDEO switch
- 1 VIDEO pushbutton

The three cameras are installed in the ceiling panels in the cockpit entrance and the door 1 area:

- Camera 1 (has a 105 degree lens) is installed above the cockpit door. It gives images of the area directly in front of the cockpit door.

- Camera 2 is installed in the ceiling of the right door 1 area. It gives images of the area directly below camera 2 (has a 90 degree lens) in the right door 1 area.
- Camera 3 (has a 90 degree lens) is installed in the ceiling of the left door 1 area. It gives images of the area directly below camera 3 in the left door 1 area.
- The LCD is installed on the aft wall of the cockpit. It lets the flight crew see the picture from the cameras. The image from camera 1 is shown as a full screen on the LCD and the image from camera 2 and 3 are shown as a split screen.

After five minutes the images go off (power-down mode).

1.6.8 Avionics Compartment

The avionics compartment is located in the underfloor nose section between Frames 1 and 24. Its structure is as follows:

- Frames 1 to 9: the avionics compartment forward part, forward of the nose landing gear well, under the cockpit.
- Frames 0 to 20, R side and L side: the avionics compartment lateral left and lateral right parts, on each side of the nose gear well, under the cockpit and the forward passenger compartment. Frames 20 to 24 the avionics compartment aft part, aft of the nose gear well, under the forward passenger compartment. The total capacity of the ventilated racks is 415 MCU. Each part is fitted with a door allowing access from the outside. An access panel in the aft part of the avionics compartment allows communication with the passenger compartment.

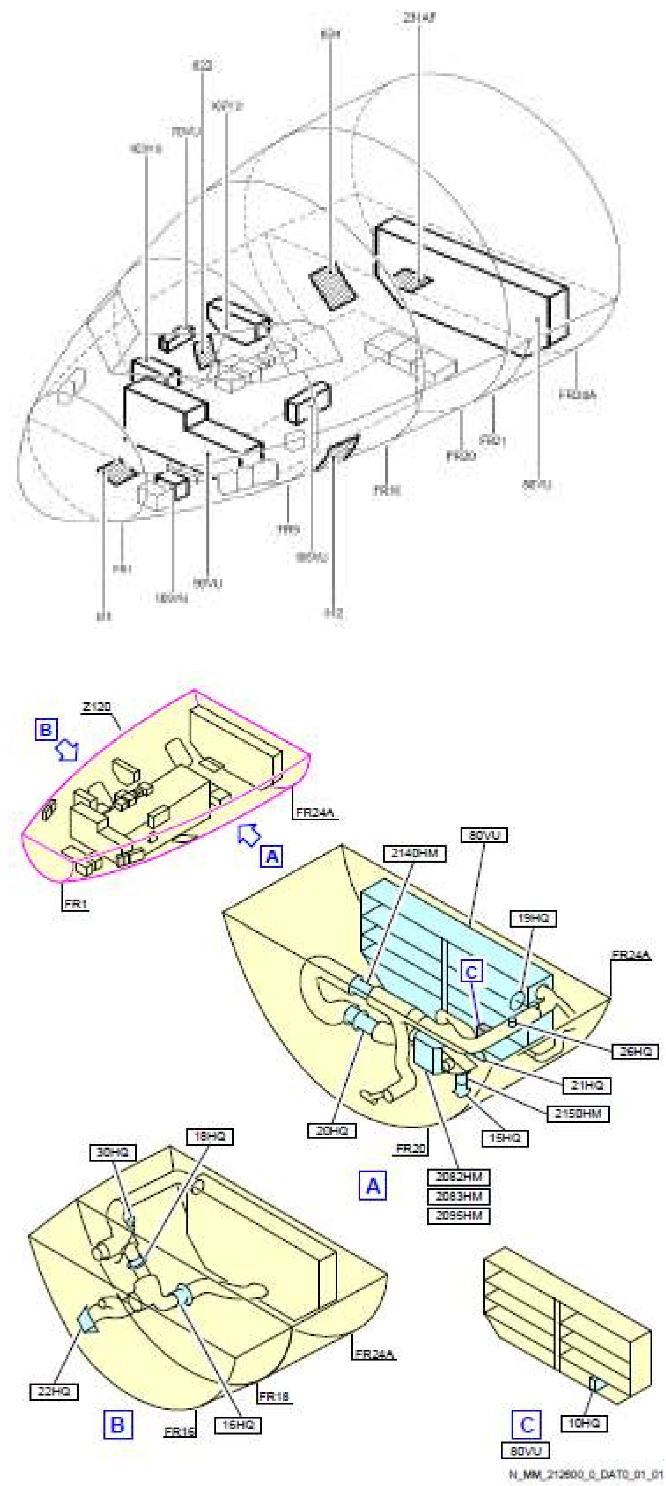


Figure 1.6/18: Avionics Compartment

1.6.8.1 Avionics Compartment Ventilation

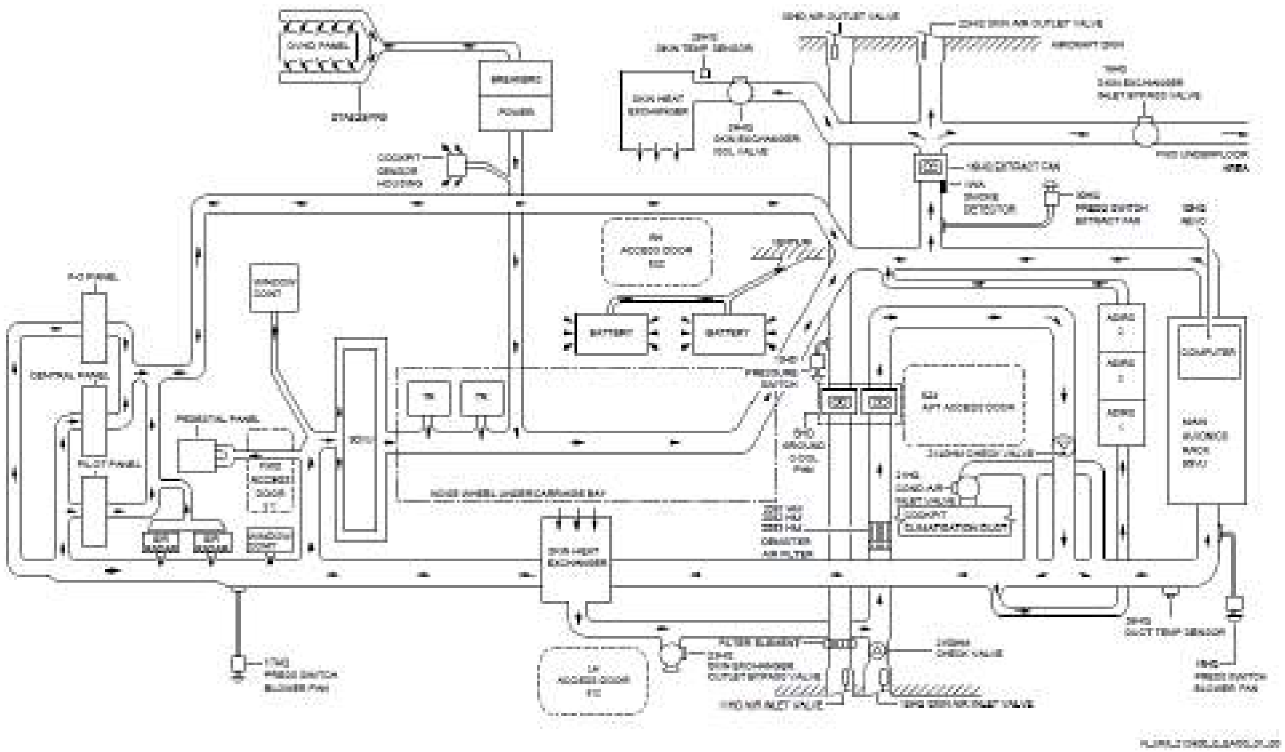


Figure 1.6/19: Avionics Compartment Ventilation Diagram

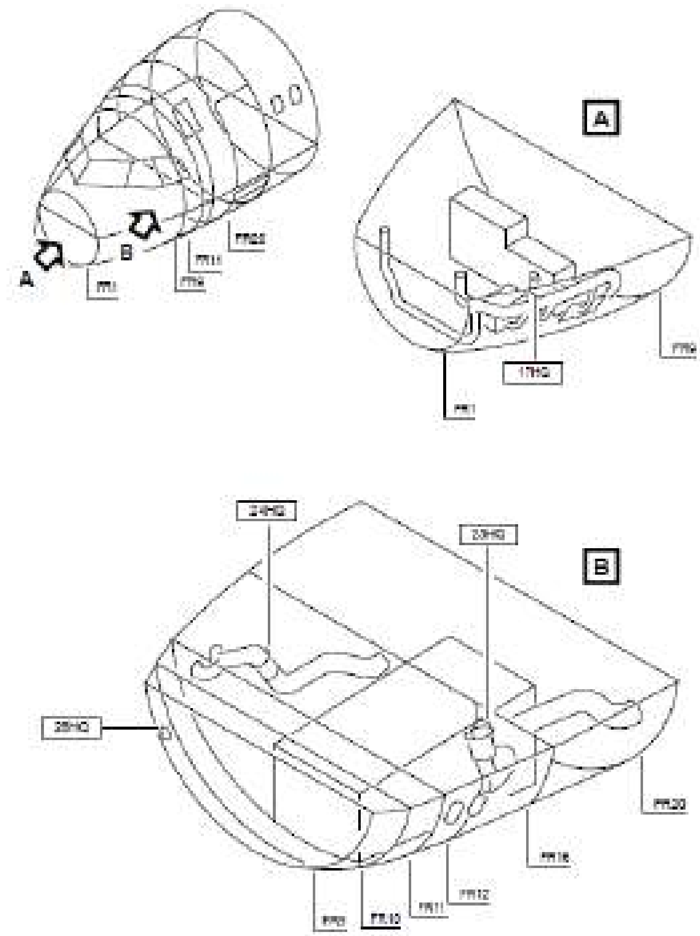
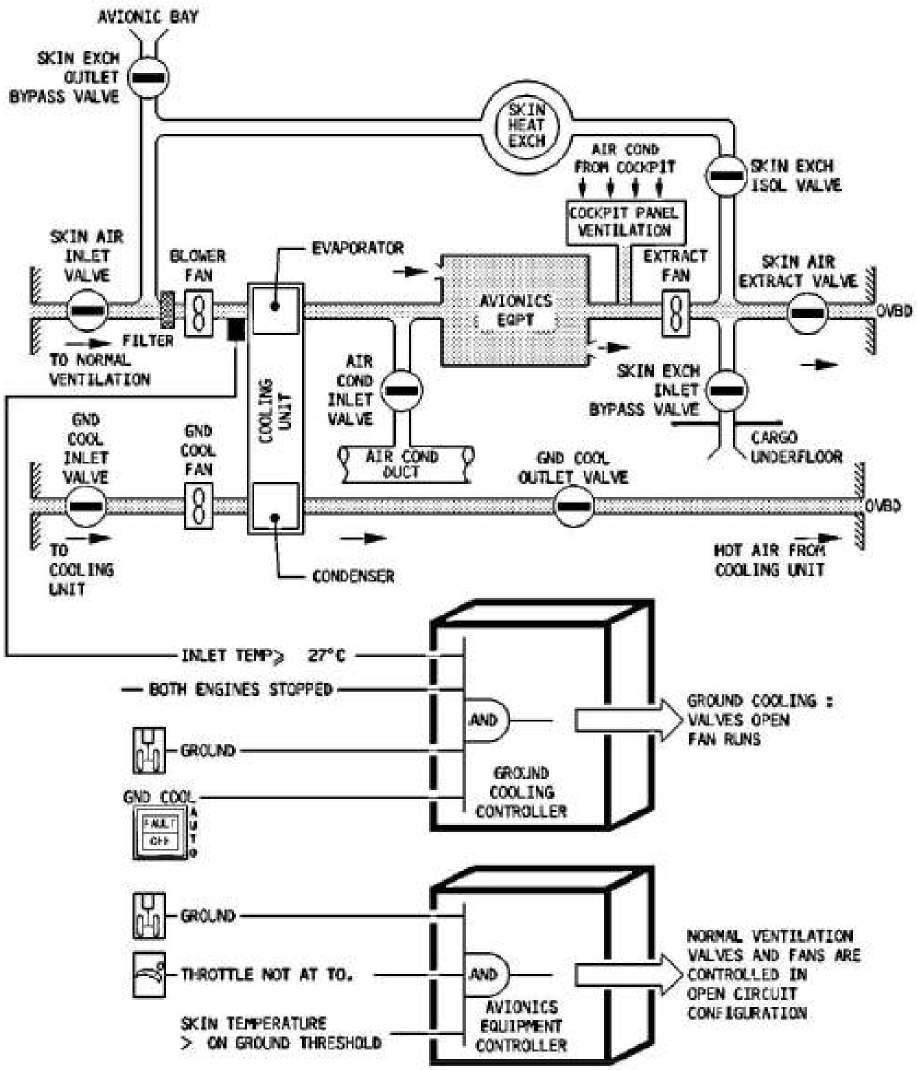


Figure 1.6/20: Avionics Compartment Ventilation

A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	AIRCRAFT SYSTEMS AIR CONDITIONING / PRESSURIZATION / VENTILATION VENTILATION - AVIONICS VENTILATION



NORMAL OPERATION, CLOSE-CIRCUIT CONFIGURATION

Applicable to: ALL

FLIGHT OPERATIONS

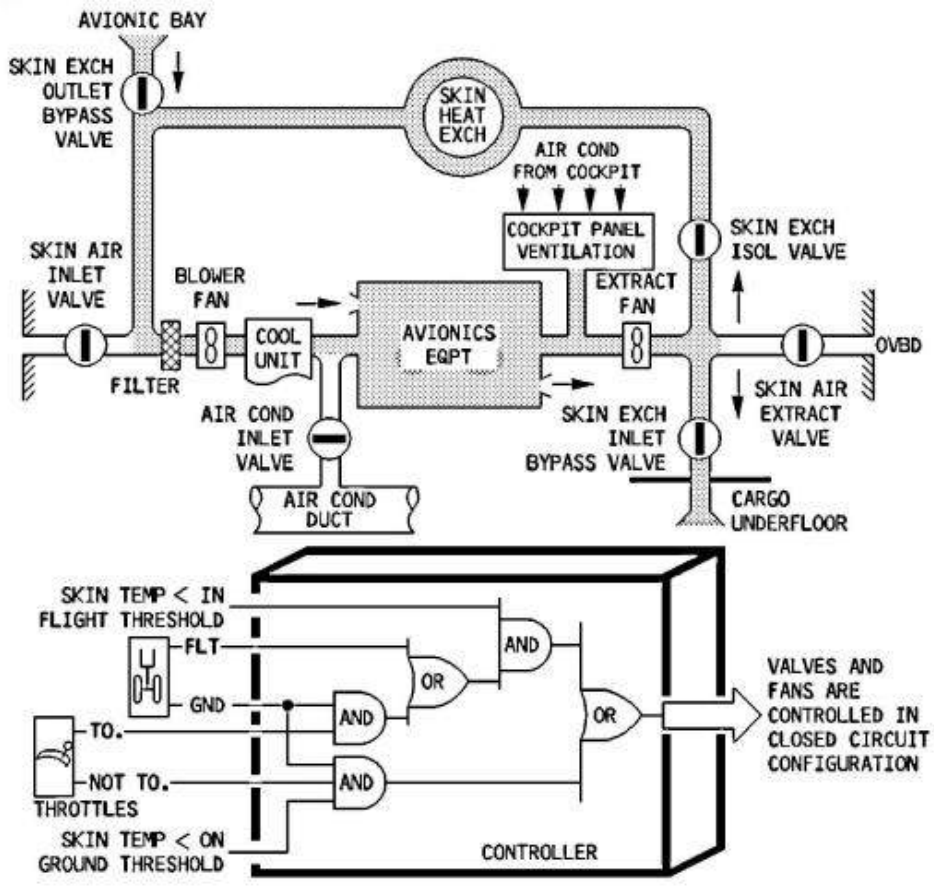
The close-circuit configuration operates when skin temperature is beneath the in-flight threshold.

In flight threshold = +35 °C (95 °F), temperature increasing, or
+32 °C (90 °F), temperature decreasing.

GROUND OPERATIONS

The close-circuit configuration operates when skin temperature is beneath the on-ground threshold.

On ground threshold = +12 °C (53 °F), temperature increasing, or
+9 °C (48 °F), temperature decreasing.



NORMAL OPERATION, INTERMEDIATE CONFIGURATION

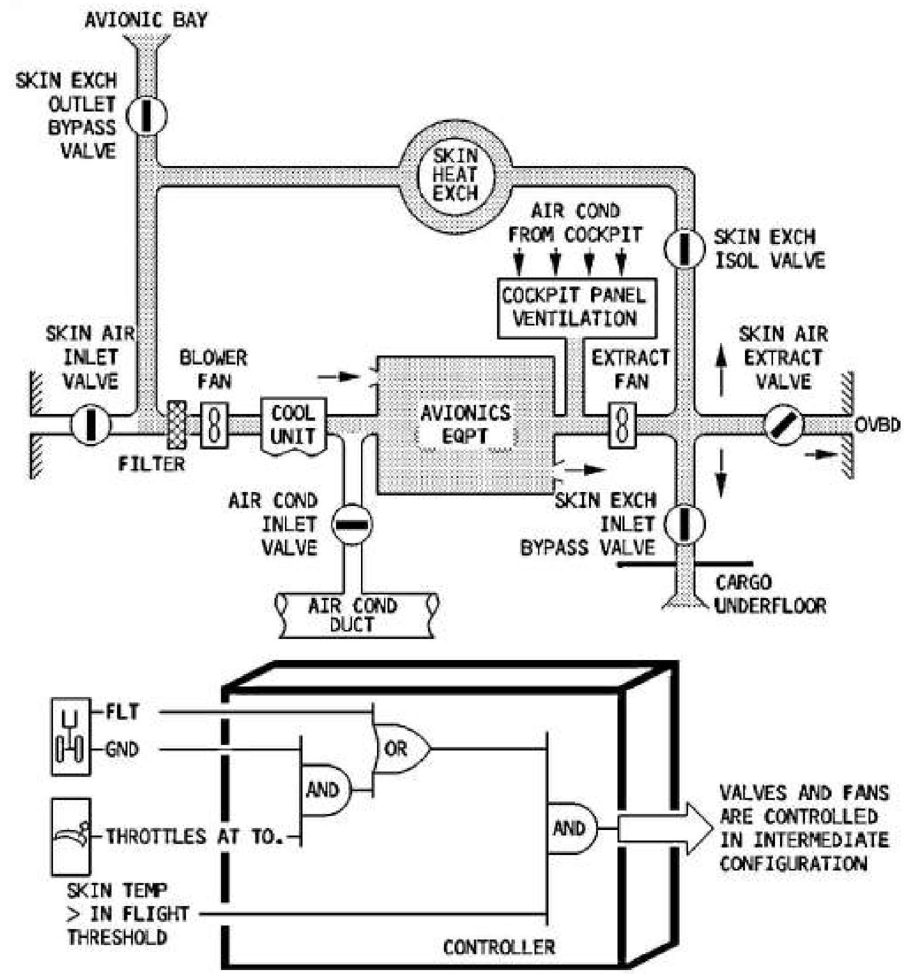
Applicable to: ALL

FLIGHT OPERATIONS

The intermediate configuration operates when skin temperature is above the in-flight threshold.

In flight threshold = +35 °C (95 °F), temperature increasing, or
+32 °C (90 °F), temperature decreasing.

A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	AIRCRAFT SYSTEMS AIR CONDITIONING / PRESSURIZATION / VENTILATION VENTILATION - AVIONICS VENTILATION

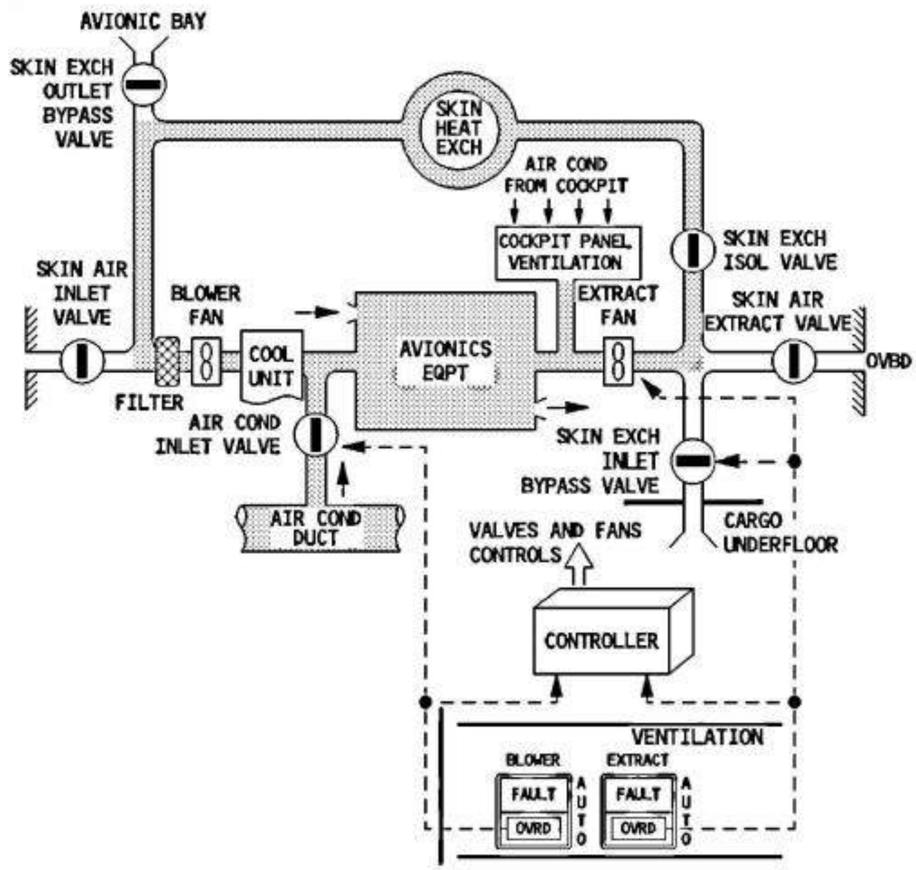


ABNORMAL OPERATION

Applicable to: ALL

BLOWER FAULT OR EXTRACT FAULT WARNING

When the BLOWER or the EXTRACT pushbutton switch is set at the OVRD (override) position, the system is in closed-circuit configuration and adds air from the air conditioning system to the ventilation air.



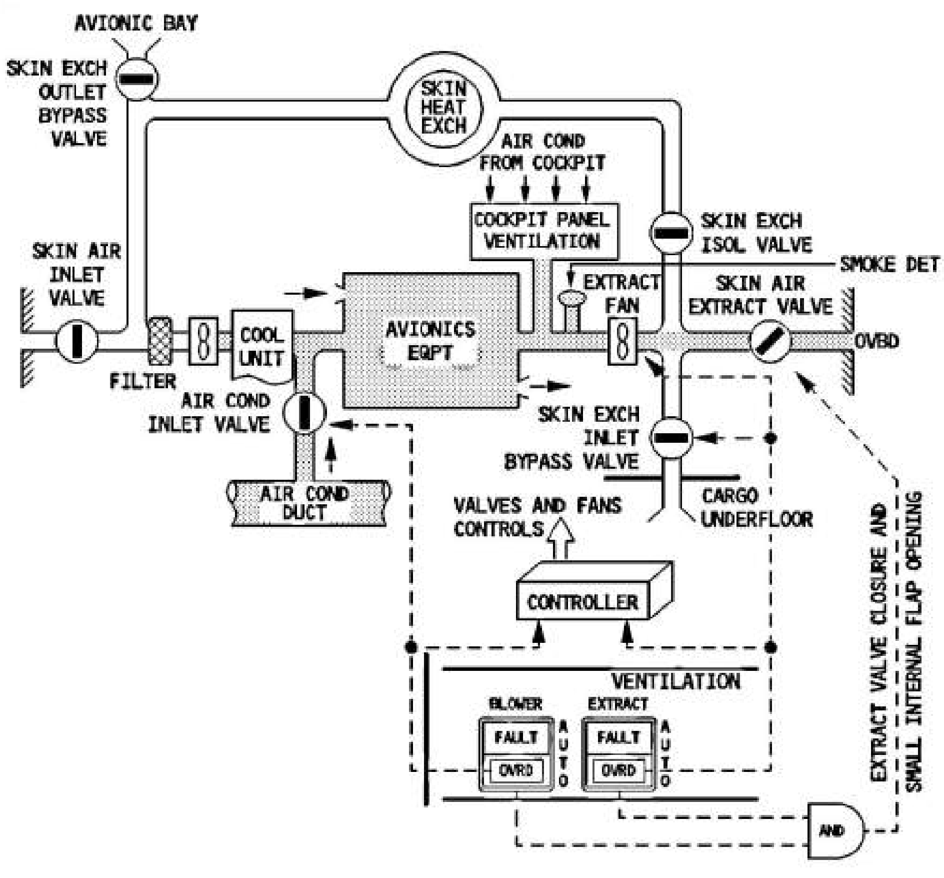
When the BLOWER pushbutton switch is set at OVRD, the blower fan is stopped and the extract fan continues to run.

When the EXTRACT pushbutton switch is set at OVRD, the extract fan is controlled directly from the pushbutton. Both fans continue to run.

2

SMOKE CONFIGURATION

When the smoke detector detects smoke in the avionics ventilation air the BLOWER and the EXTRACT FAULT lights come on.
When both the BLOWER and the EXTRACT pushbuttons are set to the OVRD position, the air conditioning system supplies cooling air, which is then exhausted overboard. The blower fan stops.



CONTROLLER FAILURE

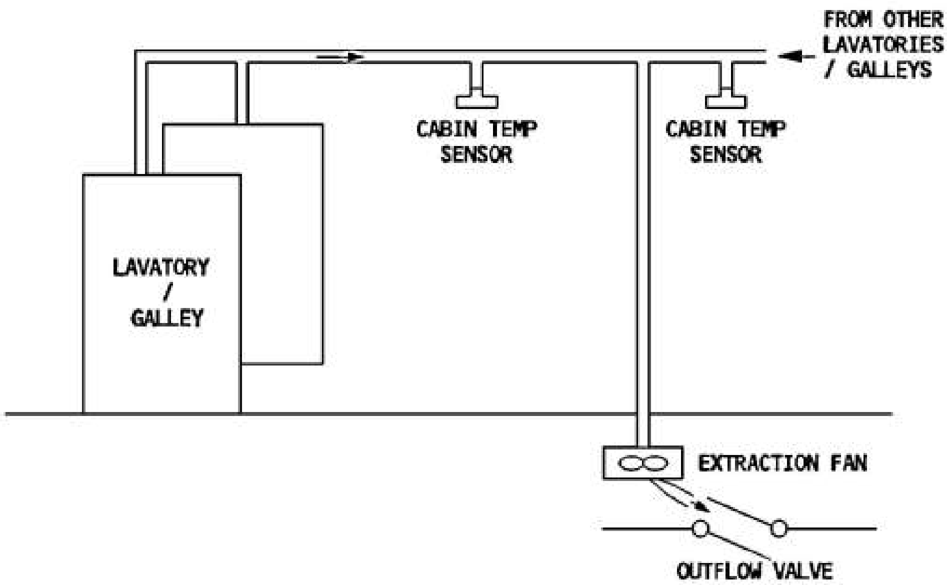
The system goes to the same configuration as above, except that the skin exchange isolation valve stays open.
The inlet valve and the skin exchange inlet bypass valve remain in the position they were in before the failure occurred.
The extract fan keeps running.

A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	AIRCRAFT SYSTEMS AIR CONDITIONING / PRESSURIZATION / VENTILATION VENTILATION - LAVATORY AND GALLEY VENTILATION

LAVATORY AND GALLEY

Applicable to: ALL

An extraction fan draws ambient cabin air through the lavatories and galleys and exhausts it near the outflow valve.
The extraction fan runs continually when electric power is available.



1.6.8.2 System Description

The avionics equipment is cooled as listed below:

A. Rack equipment

Equipment installed in the racks is cooled with air blown into the base of the racks through a sealed inlet. This air then flows through the equipment to the top of the racks and is then removed through an unsealed outlet. Other equipment installed on the racks is cooled with air blown into the base and then out at the top.

B. Cathode Ray Tubes (CRTs)

The CRTs located on the pilot's panel are cooled with air blown through a sealed inlet/outlet on the panel.

C. Pedestal Instruments

The pedestal instruments are cooled with air blown through the instruments on the upper panel and around the instruments on the lower panel. The air then goes into the avionics compartment through vents in the cockpit floor.

D. Cockpit Panels

The overhead circuit breaker and system control panels are cooled with cockpit air. This air is drawn around the back of the panels and into the avionics ventilation system.

E. Transformer Rectifiers (TR)

The transformer rectifiers are cooled with avionics compartment air. This air is drawn through the equipment into the avionics ventilation system.

F. Window Heat Controllers (WHC)

The WHCs are cooled with air blown through the equipment into the avionics compartment.

G. Radar

The radar is cooled by air blown into the equipment through a sealed inlet and blown out through an unsealed outlet.

H. Batteries (Independent Circuit)

The batteries are cooled with avionics compartment air drawn through an inlet, around the batteries and overboard through a venturi. The ventilation is only effective with cabin differential pressure.

1.6.8.3 Avionics compartment smoke detection

There are two types of smoke detection: the direct detection by the crew, the secondary detection by a smoke detector.

The avionics-compartment smoke-detection system confirms that there is smoke in the avionics compartment. The smoke detection system includes one smoke detector installed on the air extraction duct. The smoke detector triggers the smoke warnings to the cockpit when the alarm threshold is reached.

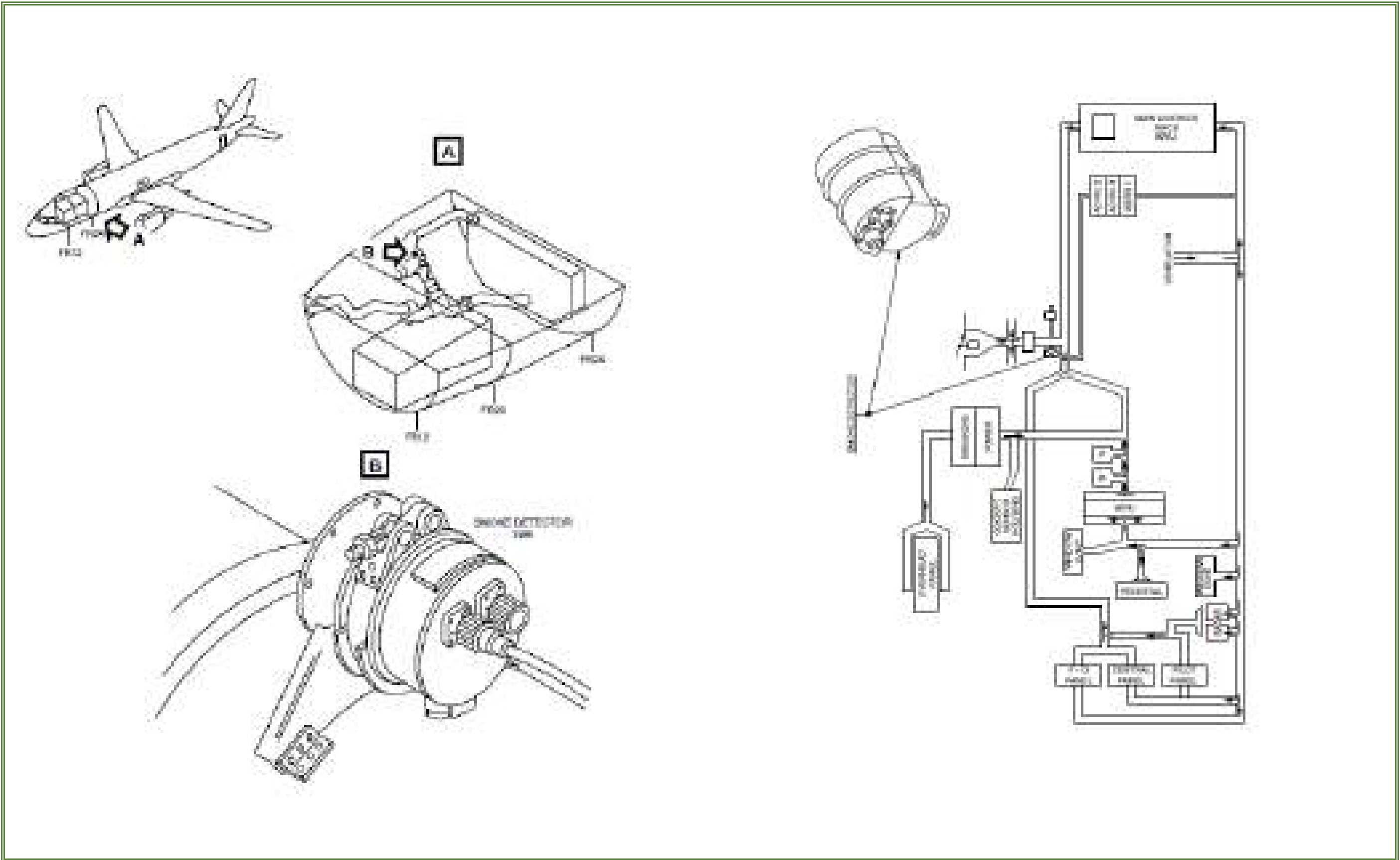


Figure 1.6/21: Avionics Compartment Smoke Detection

When the smoke concentration is above the alarm threshold, the smoke detector triggers the smoke warnings in the cockpit: on the EMER ELEC PWR section of the panel 21VU, on the VENTILATION section of the OVERHEAD CTL and IND panel 22VU, the MASTER CAUT light comes on, the warning message is shown on the lower ECAM display unit. The aural warning sounds.

DESCRIPTION

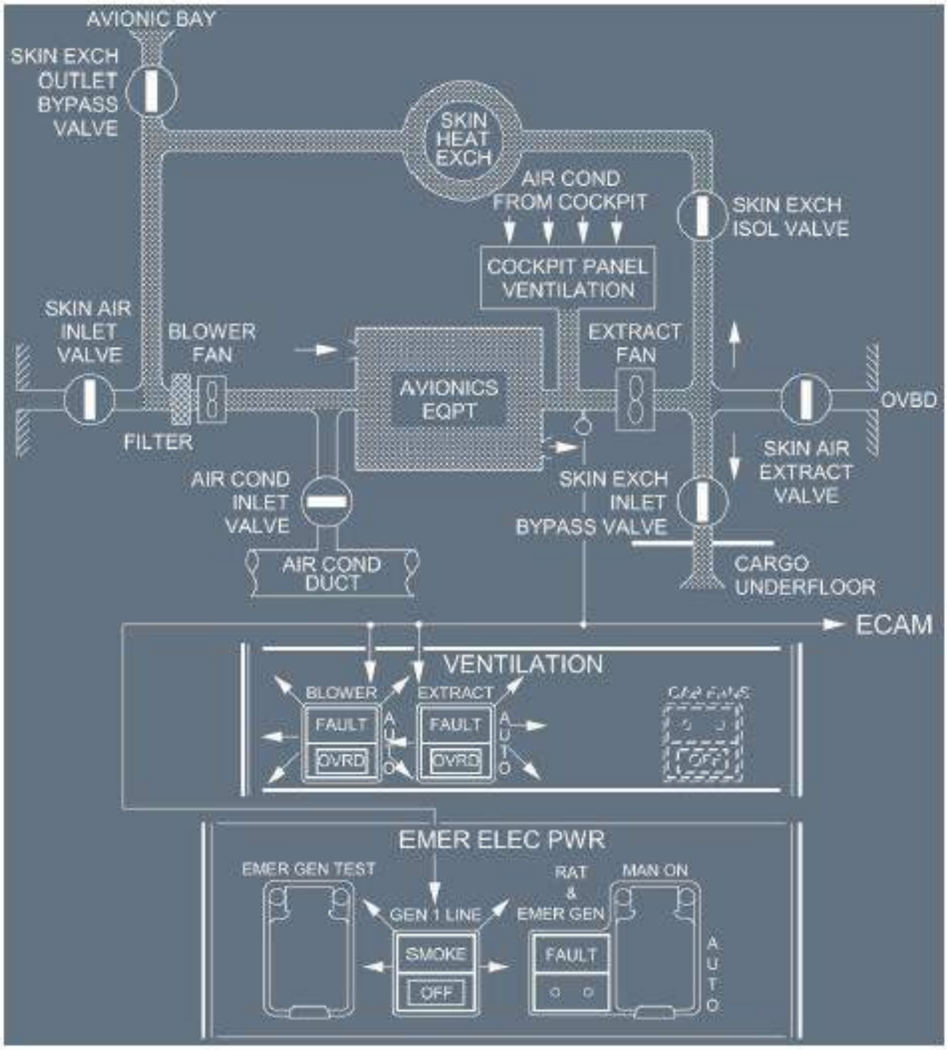
Ident.: DSC-26-30-10-00001030.0001001 / 22 MAY 12
Applicable to: ALL

One smoke detector in the air extraction duct of the avionics ventilation system detects smoke in the avionics compartment.
It signals the ECAM to display a warning in the cockpit.

When it detects smoke for more than 5 s:
- A single chime sounds
- The MASTER CAUTION lights, on the glareshield, light up
- The ECAM displays a caution on the E/WD
- The SMOKE light, on the EMER ELEC PWR panel, lights up
- The BLOWER and EXTRACT FAULT, on the VENTILATION panel, light up.

If smoke is detected for more than 5 min, the caution can be cleared; but, it remains latched, and can be recalled. On the ground, a dual FWC reset will unlatch the caution.

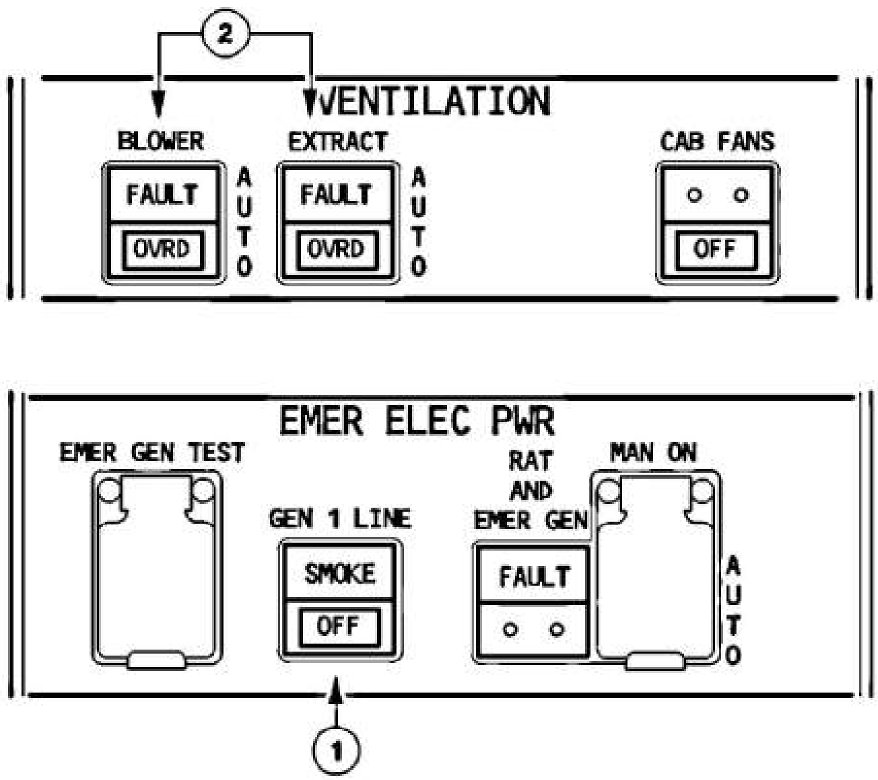
A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	AIRCRAFT SYSTEMS FIRE PROTECTION AVIONICS BAY - DESCRIPTION



A318/A319/A320/A321 FLIGHT CREW OPERATING MANUAL	AIRCRAFT SYSTEMS FIRE PROTECTION AVIONICS BAY - CONTROLS AND INDICATORS

OVERHEAD PANEL

Ident.: DSC-26-30-20-00001031.0001001 / 10 DEC 09
Applicable to: ALL



(1) GEN 1 LINE
(*Refer to DSC-24-10-20 AC Generators*)

SMOKE : lt — Comes on amber, along with a warning on ECAM, when smoke is detected in the avionics ventilation duct.

(2) BLOWER and EXTRACT pb sw
(*Refer to DSC-21-30-60 Overhead Panel*)

FAULT lts : Both FAULT lights come on amber, along with a warning on ECAM, when smoke is detected in the avionics ventilation duct.

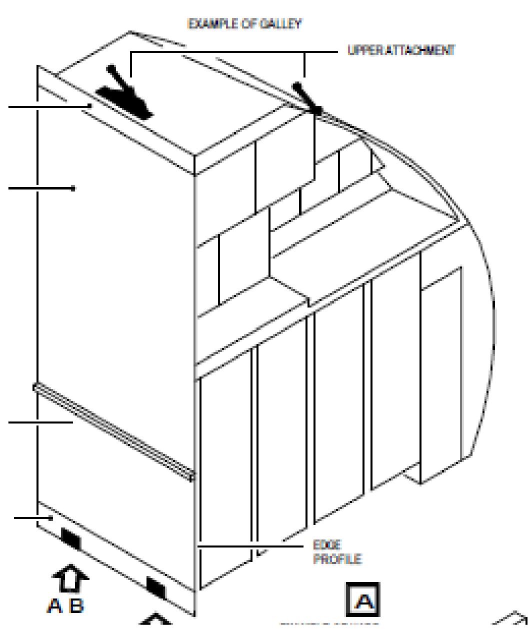
1.6.9 Galleys

The galleys are installed in the utility areas. The function of the galleys is to keep and prepare food and hot and cold drinks. Different installation configurations of the galleys are possible.

The galleys can be divided in to:

1- Forward Galleys: The forward galleys are installed in the FWD utility area of the aircraft.

2- Aft Galleys: The Aft galleys are installed in the Aft utility area of the aircraft.



Forward Galley removed, showing the back of the 120 Circut Breakers panel (120VU)

Figure 1.6/22: Forward Galley

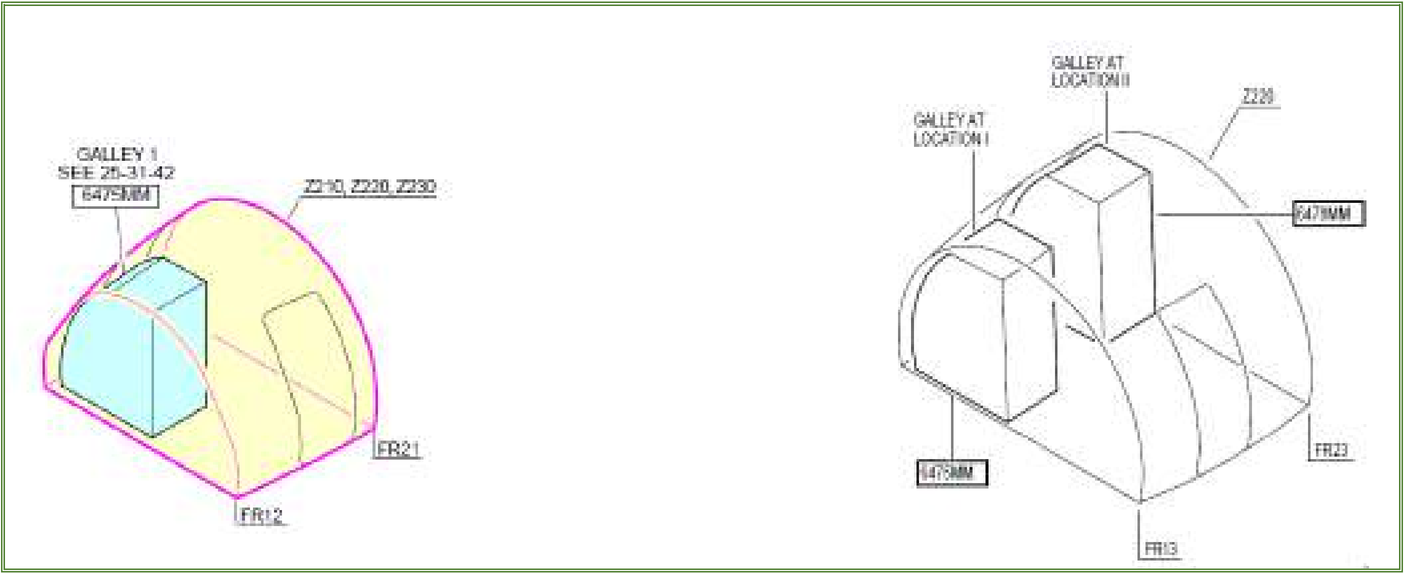


Figure 1.6/23: Galleys Location

Galley structure: The galley basic structure is made from sandwich panels. The sandwich panels are made from NOMEX with fiberglass cover plates. Extrusions are bonded and/or riveted to the panels. Edge profiles, stainless-steel kick strips and rub-strips are installed to prevent damage to the galley where applicable. The primary galley attachment points are hard point and/or seat rail attachments on the floor and tie rod attachments at the upper fuselage structure. B. Pelmet The pelmet is a cover structure on the top of the galley. Behind the pelmet there are all the top galley connections.

1.6.9.1 Galley Equipment

A. Preparation Galleys The preparation galleys are used to prepare the food and the drinks and have these items :

1- Ovens (QTY 2)
   The oven has a control box to select the temperature and time of operation, to heat the meals (2 selections 100 deg Celsius or 150 deg Celsius)
2- AIR CHILLER (QTY 1)
3- Waste Container (QTY 1) The waste trolley has a waste container with a flap
4- Standard Container (QTY 3) The container is used to keep trays, drawers, beverages and food
5- Water Boiler (QTY 1) The water boiler heats water supplied from the potable water system
6- Full Size Trolley (QTY 4) the trolley has trays or drawers for storage.
7- Folding trolley (QTY 1)

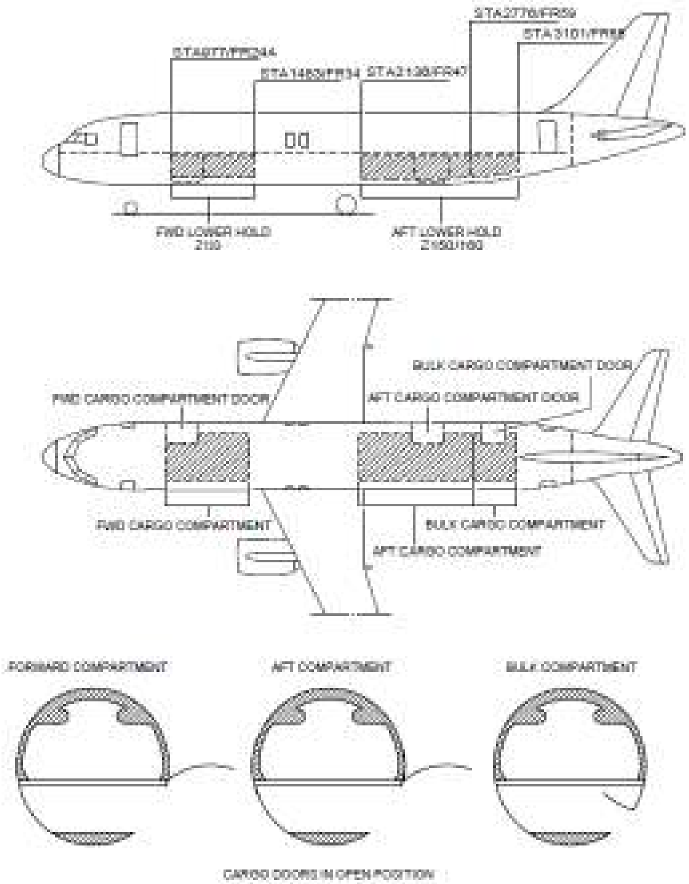
1.6.9.2 Galleys Ventilation

The largest quantity of air for ventilation of the lavatories and galleys comes from the cabin. Extraction causes the air to flow from the cabin into the lavatories and galleys. The air flows into the lavatories through grilles in the door and into the galleys through grilles and filters which are installed in the galley walls and the ceiling. A small quantity of air for ventilation of the lavatories flows from individual air outlets. Conditioned air from the cabin air distribution and recirculation system flows into the supply ducts of the lavatory/galley ventilation system. The supply ducts are installed in the ceiling area of the cabin. The air flows from the supply ducts into each lavatory through an individual air outlet. There are also supply ducts to the galleys. The extraction fan removes air from the lavatories and the galleys through a duct which is installed above the cabin ceiling. The air flows through filters into the duct. This duct extends the length of the cabin from the FWD utility area to the left-hand AFT lavatory. The air is then removed overboard through the outflow valve. The extraction fan operates continuously during flight and also on the ground when electrical power is available to the aircraft.

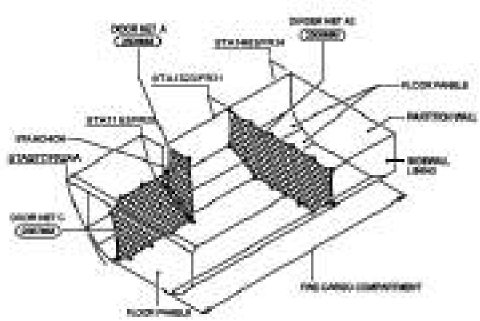
1.6.10 FWD Cargo Compartment

In the lower deck of the aircraft, there are two lower holds (Forward hold and AFT hold) which are divided into three underfloor cargo compartments. The forward hold is referred to as the forward cargo compartment. A net divides the aft hold into two cargo compartments. They are referred to as the aft cargo compartment and the bulk cargo compartment. The bulk cargo compartment has tie down/attachment points for the bulk door nets and for the nets and straps which keep the bulk cargo in place.

The forward lower hold (forward cargo compartment) is in zone 130 between STA977 (FR24A) and STA1483 (FR34). A hydraulically operated cargo door which opens to the outside is installed on the right side of the aircraft between STA977 (FR24A) and STA1163 (FR28). The cargo door gives access to the forward cargo compartment.



STA1483/FR34
STA2138/FR47
STA2776/FR59
FWD LOWER HOLD
AFT LOWER HOLD
BULK CARGO COMPARTMENT DOOR
FWD CARGO COMPARTMENT DOOR
AFT CARGO COMPARTMENT DOOR
FWD CARGO COMPARTMENT
BULK CARGO COMPARTMENT
AFT CARGO COMPARTMENT
FORWARD COMPARTMENT
AFT COMPARTMENT
BULK COMPARTMENT
CARGO DOORS IN OPEN POSITION



FLOOR PANELS
FWD CARGO COMPARTMENT

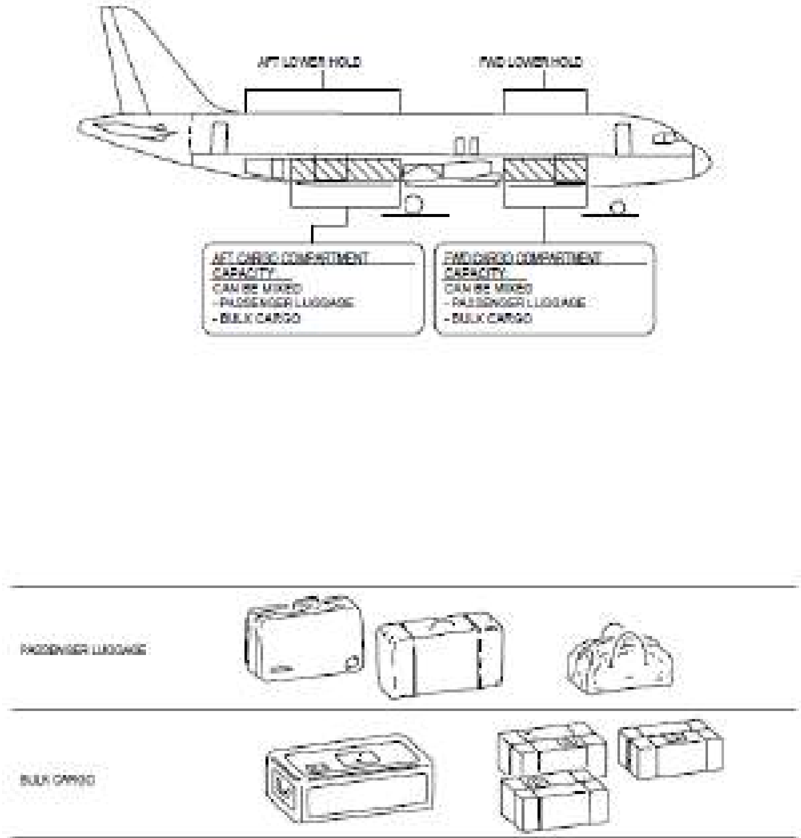


Figure 1.6/24: Cargo Compartments

1.6.10.1 Cargo Compartment Ventilation

Cabin air is drawn into the cargo compartment through ducts which are installed in the lower fuselage. Outlets along the compartment left-hand sidewall direct the air towards the cargo floor area. The air is extracted from the compartment through outlets which are located near the compartment ceiling. An extraction fan gives the necessary air flow.

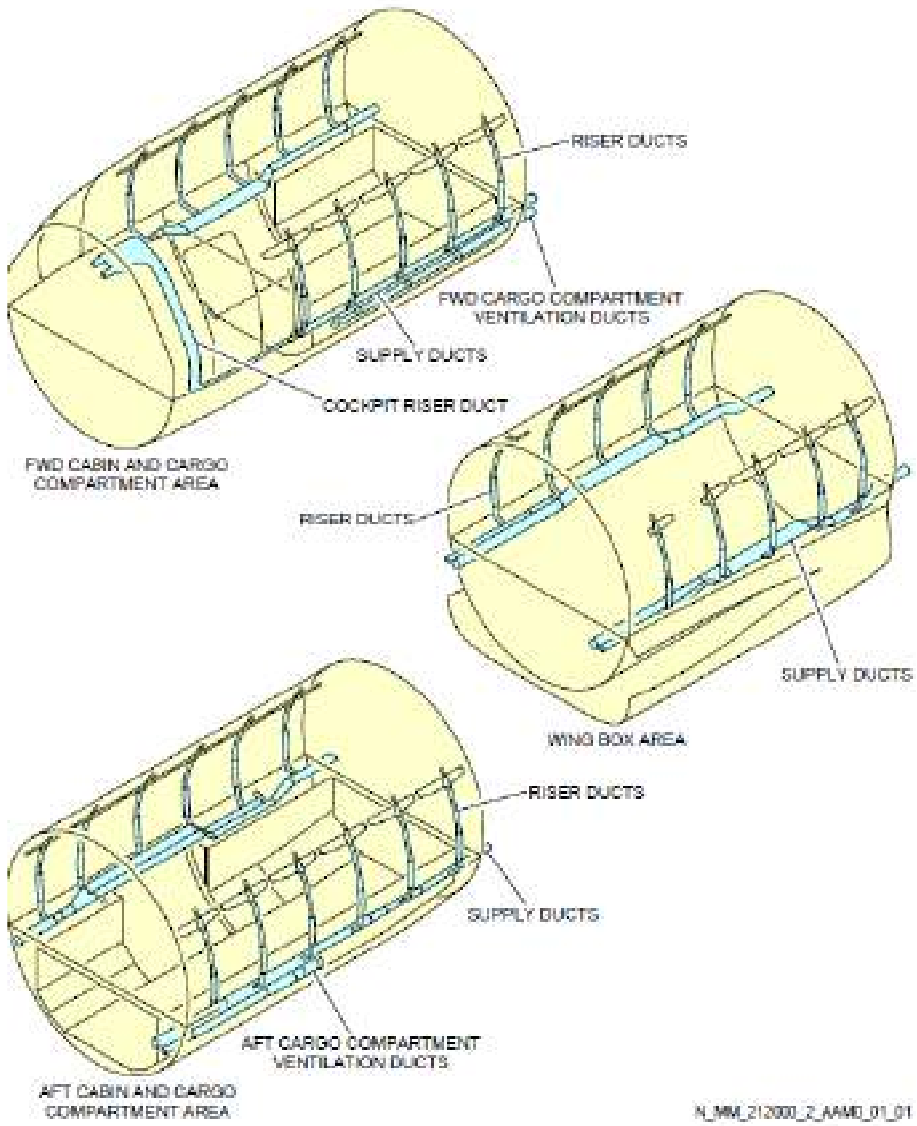


Figure 1.6/25: Cargo Compartments Ventilation

1.6.11 Fire Extinguishing

There are several different fire extinguishing methods. The methods depend on:

- The area in which the fire occurs,
- Whether the aircraft is in flight or on the ground.

The fire extinguishing systems are either fixed extinguishing bottle(s) or portable fire extinguisher(s). The fixed extinguishing bottle(s) are operated either automatically and manually and portable fire extinguishers are operated manually.

1.6.11.1 Fixed fire extinguishing bottles

The function of the fixed fire-extinguishing bottle(s) installed on board is to extinguish fire occurring in the following areas:

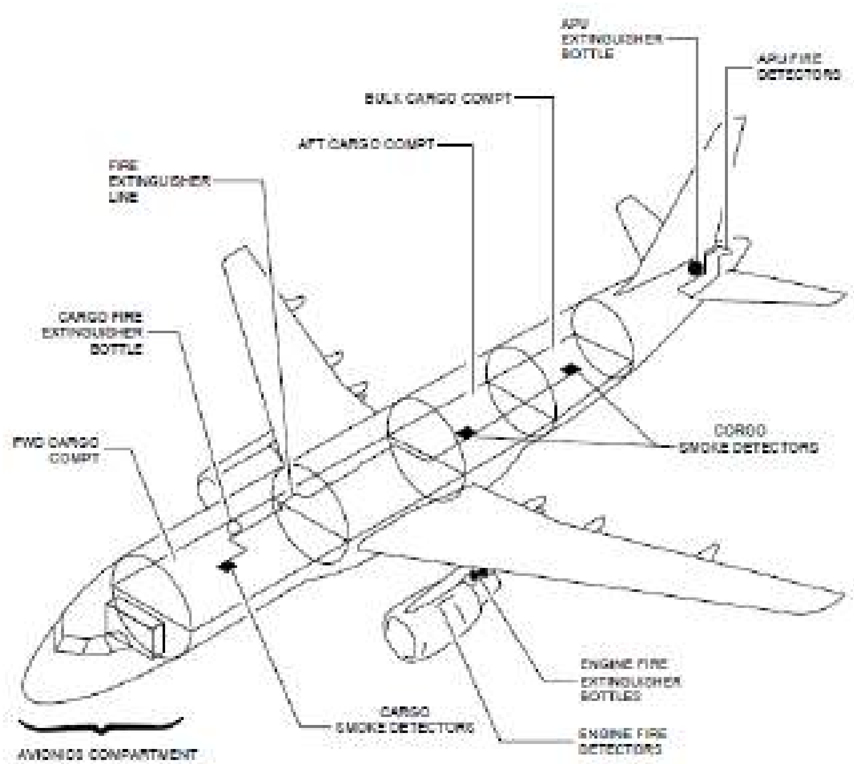


Figure 1.6/26: Fixed Fire Extinguishing Bottles Locations

1.6.11.2 Lavatories

A bottle located above the waste bin can extinguish a fire in the lavatory waste bin.

The lavatory fire-extinguishing system is installed in each lavatory service cabinet. The lavatory fire extinguishing system discharges its extinguishing agent automatically when heat activates it. Any fire in the waste is kept within the confines of the metal waste-paper bin. An inert gas floods the lavatory service cabinet and extinguishes the fire. Each lavatory fire-extinguishing system has an extinguisher bottle which is self-actuated.

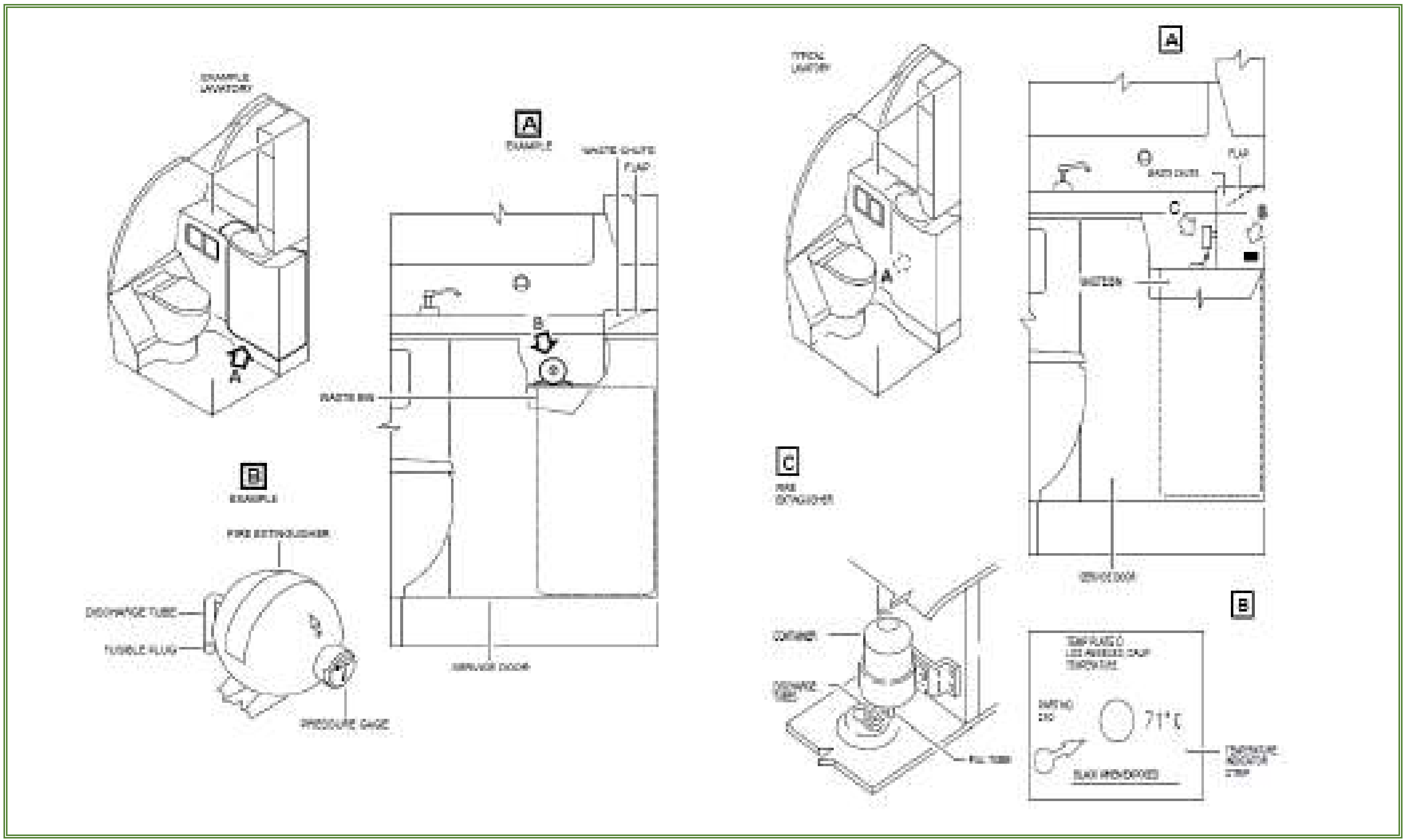


Figure 1.6/27: Lavatory Fire Extinguishing Bottle Location

The lavatory fire-extinguishing system is completely automatic and self-contained. A fire or overheat condition opens the release mechanism. When the temperature in the waste paper-bin area is approx. 79 DEG.C (174.20 DEG.F) the fusible material in the tip of the discharge tube melts. The lavatory fire extinguisher then discharges completely within 3 to 15 s. Each unit weighs 0.360 kg max. It stores and discharges 120 g of agent FE36 into the waste paper bin to extinguish the fire. As a fire extinguishing agent, HFC-236fa (1, 1, 1, 3, 3, 3-Hexafluoropropane) is referred to as FE-36™, It is a replacement to HALON 1211 in portable fire extinguishers.

1.6.11.3 Portable Fire Extinguishers

- The portable extinguishers are operated manually and are used if there is a fire in the cockpit or the cabin.

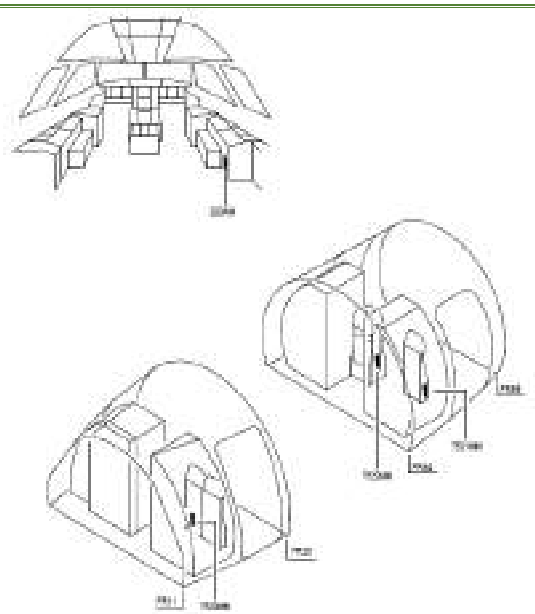


Figure 1.6/28: Portable Fire Extinguishers Cockpit Location

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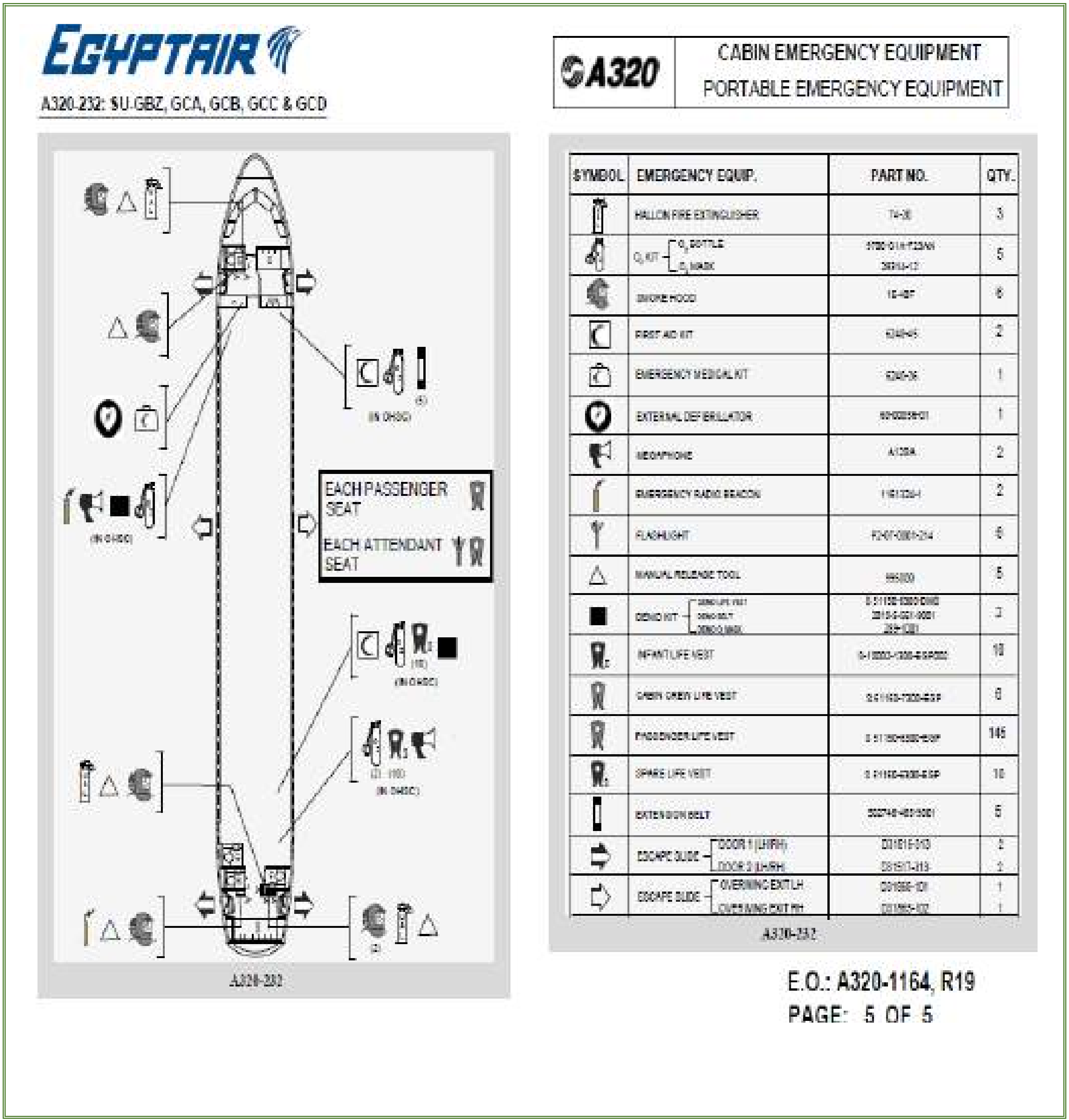
MINISTRY OF CIVIL AVIATION
EGYPTIAN AIRCRAFT ACCIDENT INVESTIGATION DIRECTORATE

جمهورية مصر العربية
وزارة الطيران المدنى
الادارة المركزية لحوادث الطيران



SYMBOL	EMERGENCY EQUIP.	PART NO.	QTY.
	HALLON FIRE EXTINGUISHER	[illegible]	3
	O_2 KIT – O_2 BOTTLE / O_2 MASK	[illegible] / [illegible]	5
	SMOKE HOOD	[illegible]	6
	FIRST AID KIT	[illegible]	2
	EMERGENCY MEDICAL KIT	[illegible]	1
	EXTERNAL DEFIBRILLATOR	[illegible]	1
	MEGAPHONE	[illegible]	2
	EMERGENCY RADIO BEACON	[illegible]	2
	FLASHLIGHT	P2-07-0001-214	6
	MANUAL RELEASE TOOL	9B5020	5
	DEMO KIT – DEMO LIFE VEST / DEMO BELT / DEMO O_2 MASK	[illegible] / [illegible] / [illegible]	3
	INFANT LIFE VEST	[illegible]	10
	CABIN CREW LIFE VEST	[illegible]	6
	PASSENGER LIFE VEST	[illegible]	145
	SPARE LIFE VEST	[illegible]	10
	EXTENSION BELT	[illegible]	5
	ESCAPE SLIDE – DOOR 1 (LH/RH) / DOOR 2 (LH/RH)	D31616-313 / D31617-313	2 / 2
	ESCAPE SLIDE – OVERWING EXIT LH / OVERWING EXIT RH	[illegible] / [illegible]	1 / 1

A320-232

Figure 1.6/29: Portable Fire Extinguisher Locations

The portable fire extinguishers are used to extinguish a fire in the cabin, in the cockpit or in the avionics compartment. There are two different types of portable fire extinguishers. Each type is filled with a different agent, Halon or liquid (water if installed). If a fire occurs, the crew can manually operate the portable fire extinguisher to extinguish the fire.

NOTE: The portable fire extinguishers are installed in different locations in the cabin and in the cockpit (as shown).

The portable fire extinguisher is filled with HALON agent and is pressurized with nitrogen. It can be used to extinguish an A, B and C classes of fire.

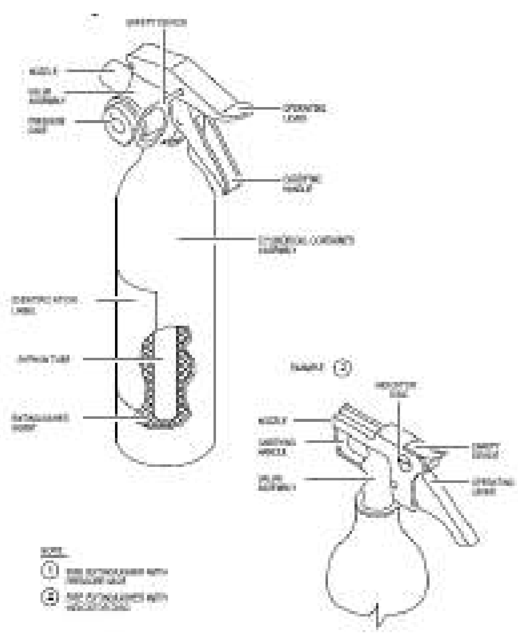


Figure 1.6/30: Portable Fire Extinguisher

Note (1):

CLASS A - Ordinary combustibles such as wood, cloth, and paper.

CLASS B - Flammable liquids such as gasoline, oil, and oil-based paint.

CLASS C - Energized electrical equipment, including wiring, fuse boxes, circuit breakers, machinery and appliances.

1.6.12 Description of the linear accelerometers (LA)

Basic recording system:

- Its function consists in the recording of the regulation mandatory parameters and additional basic parameters from the appropriate data systems.
- The installation comprises one Flight Data Interface Unit (FDIU), one Digital Flight Data Recorder (DFDR), one three axis Linear Accelerometer (LA) and one Control Panel (CP)
- The DFDR is installed at the rear of the aircraft behind the rear bulkhead in an unpressurized area.
- The FDIU is installed in the avionics compartment
- The LA near the aircraft center of gravity. LA is connected to SDACs.
- The parameters acquired by the EIS (FWC, SDAC, DMC) are transmitted on their ARINC 429 output buses to FDIU which composes the data frame transmitted to the DFDR.
- The FDIU is connected to different aircraft systems. Data (parameters) are received in discrete and digital form. The FDIU collects these parameters and converts them for internal processing.
- A standardized set of flight critical parameters are transmitted in serialized digital form to the DFDR. These parameters are stored on the recorder in data frame cycles.
- The QAR stores the same data as the DFDR.
- The FDIU generates aircraft data and sends them to the ARINC 429 output bus.
- A separate linear accelerometer is installed to provide the FDIU with acceleration data appearing in the center of gravity.
- The SDAC digitizes the analog signal of the LA and sends it to the FDIU via ARINC 429 bus.
- The DFDRs has:
    - A Flight Data Interface Unit (FDIU)
    - A Digital Flight Data Recorder (DFDR)
    - A Quick Access Recorder (QAR)

- A Linear Accelerometer (LA)
- A Control Panel (CTL PNL)
- An Event Marker Button (EVENT)
- The minimum equipment of a basic DFDRs (FDIU, DFDR, LA, CTL PNL and EVENT) must be installed on each aircraft. This is to meet the requirement of the authorities for recording of mandatory parameters.

– The three-axis Linear Accelerometer (LA) is installed between Frame 42 and 45 under a floor panel of the passenger compartment (center of gravity of the A/C).

– The LA generates acceleration data in analog format.

– The analog information from the LA is sent to the System Data Acquisition Concentrator (SDAC). The SDAC converts this information to a digital format and sends it to the FDIU part via an ARINC-429 data-bus.

– The FDIU part sends this acceleration data to the DFDR together with the other flight-parameters.

– On each flight the FDIU-part makes an integrity check of the acceleration-parameters.

– The status of the DFDR and the status of the FDIU part (failure/no failure) is monitored by the SDACs. If a failure occurs, it is shown on the ECAM display.

– For maintenance and test of the DFDRs, the FDIU part is connected with the Centralized Fault Display Interface Unit (CFDIU) of the Centralized Fault Display System (CFDS).

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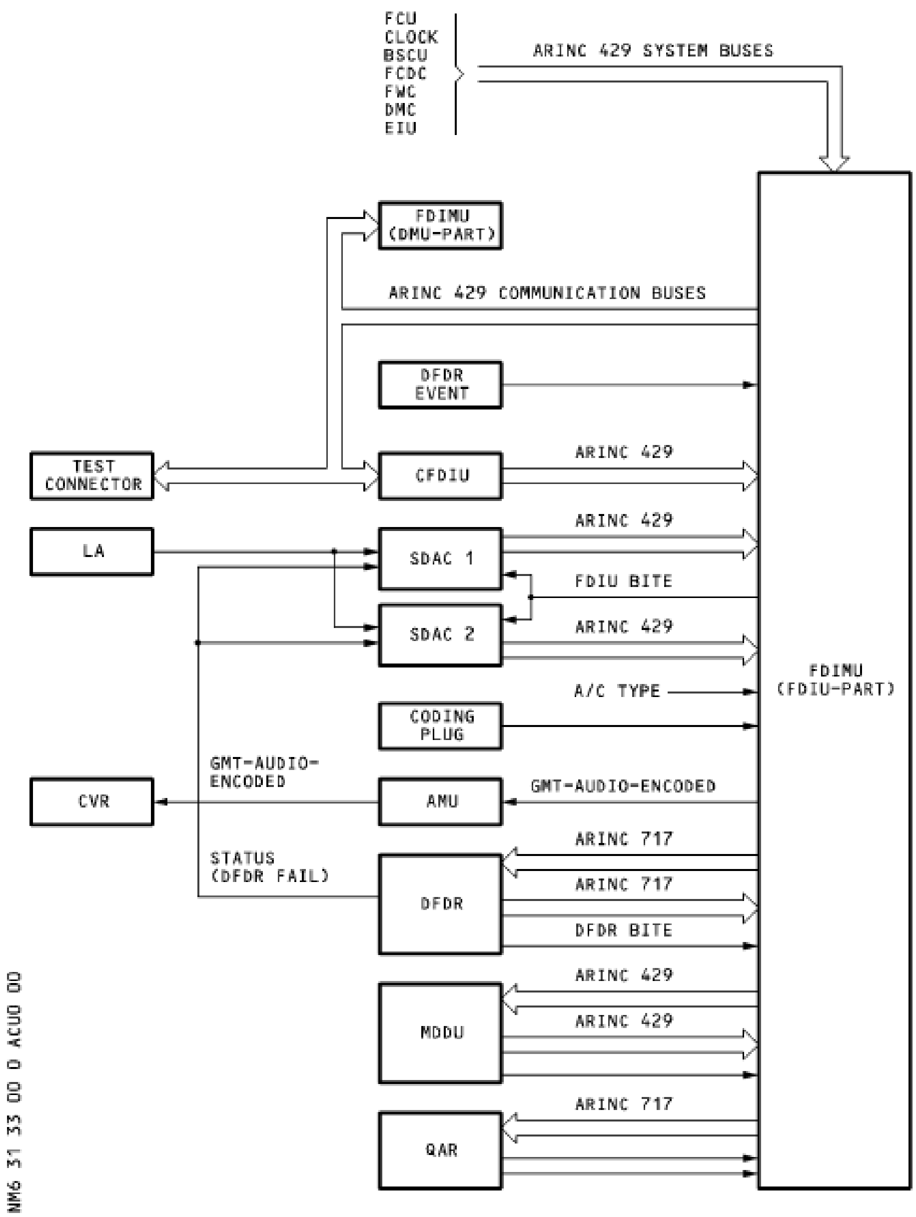

System Block Diagram
Figure 002A

1.6.13 ELT (Emergency Locator Transmitter)

1.6.13.1 ELT P/N, S/N

P/N	FIN
Portable ELT	
1151324-1 M622 (Forward)	7560 MM
1151324-1 M622 (Aft)	7559 MM
Fixed ELT	
S1819502-02	110MX

1.6.13.2 ELT Active Automatic Operation:

According to COSPAS-SARSAT standards, can be classified as Automatic Fixed (ELT-AF), Automatic Portable (ELT-AP), Survival (ELT-S) and Deployable (ELT-DT)

The ELT 406 ATP manufacturer (SAFRAN Electronic, formerly KANNAD) indicated that this type of emergency beacon is equipped with only one electronic G-Switch that triggers in the case of a +2.0 to +2.6G acceleration in the longitudinal axis only (i.e. the axis of the beacon installation on-board the A320).

The ELT system transmits on 3 frequencies, 121.5 MHz (Civil) and 243 MHz (Military) homing-signals and 406 MHz to the COSPAS-SARSAT satellite system. The battery-pack, installed in the ELT housing, supplies the power to operate the system.

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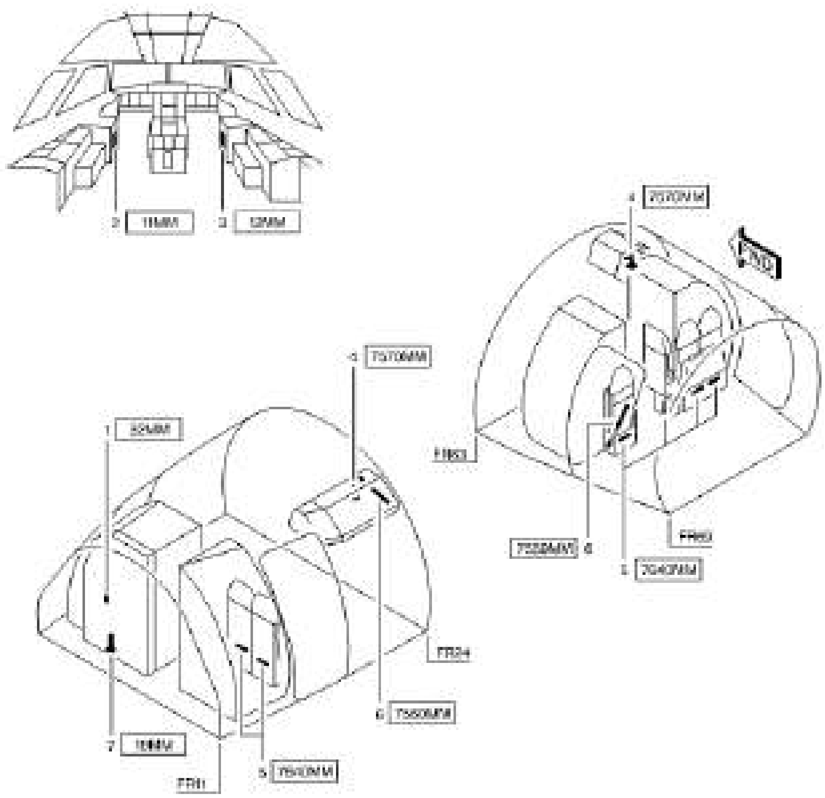

COMPONENT DESIGNATION

1 - GLOVES
2 - FLASHLIGHT CAPT
3 - FLASHLIGHT F/O
4 - MEGAPHONE
5 - FLASHLIGHT
6 - EMERGENCY LOCATION TRANSMITTER
7 - AXE

Miscellaneous Emergency Equipment - Component Location
R Figure 001B

R EFF : 201-299,

MSR

25-65-00

Page 6
May 01/06

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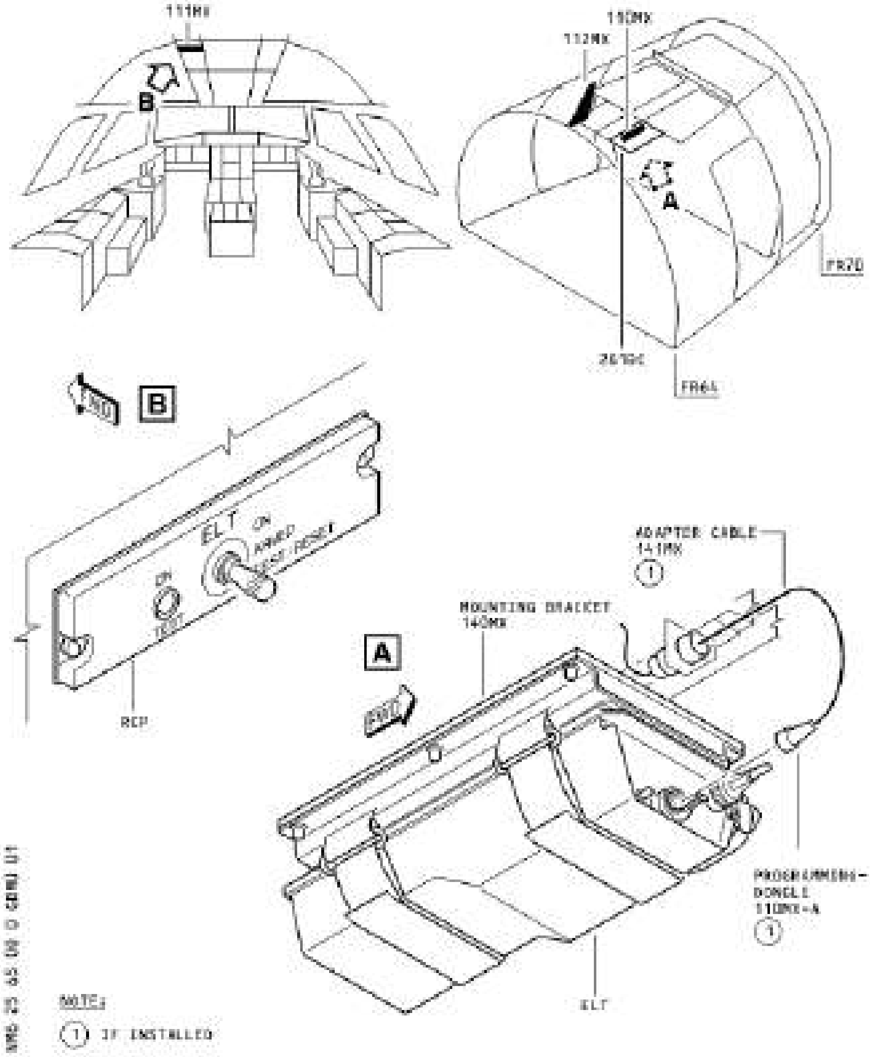
A320
AIRCRAFT MAINTENANCE MANUAL



ELT System - Component Location
Figure 002

EFF : ALL
MSR

R

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Page 8
Aug 01/07

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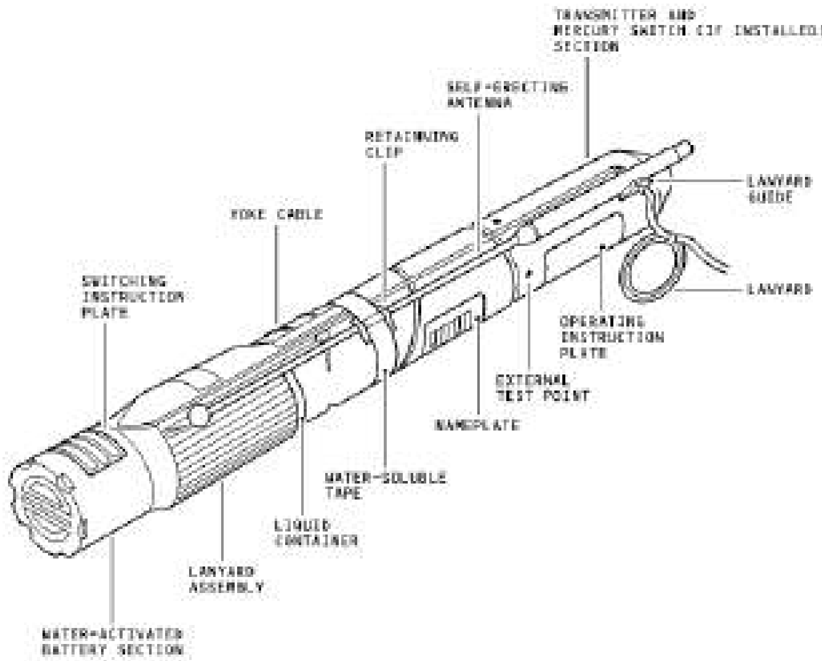
A320

AIRCRAFT MAINTENANCE MANUAL



ELT - Component Description
Figure 005

1.6.14 CVR System description:

Description of CVR and its connection with the audio system.

1.6.14.1 Audio Management Description And Operation

General:

A. The audio management system provides the means for using:

(1) All the radio communication and radio navigation facilities installed on the aircraft:

In transmission mode: it collects the microphone inputs of the various crew stations and directs them to the communication systems.

In reception mode: it collects the audio outputs of the communication systems and the navigation receivers and directs them to the various crew stations.

(2) The flight interphone system:

Telephone links between the various crew stations in the cockpit.

Telephone links between the cockpit and the ground crew from the external power receptacle.

(3) The SELCAL (Selective Calling) system:

Visual and aural indication of calls from ground stations equipped with a coding device used by the aircraft installation.

(4) Certain calls:

Visual and aural indication of the ground crew and the Cabin Attendants' calls.

System Description

AIRBUS

Customer : MSR Type : A318/A319/A320/A321 Rev. Date : Feb 01, 2018	Manual : AMM Selected applicability : 204-204
23-51-00-11400-00-F / SHEET 1/1 - Audio Management - Block Diagram	

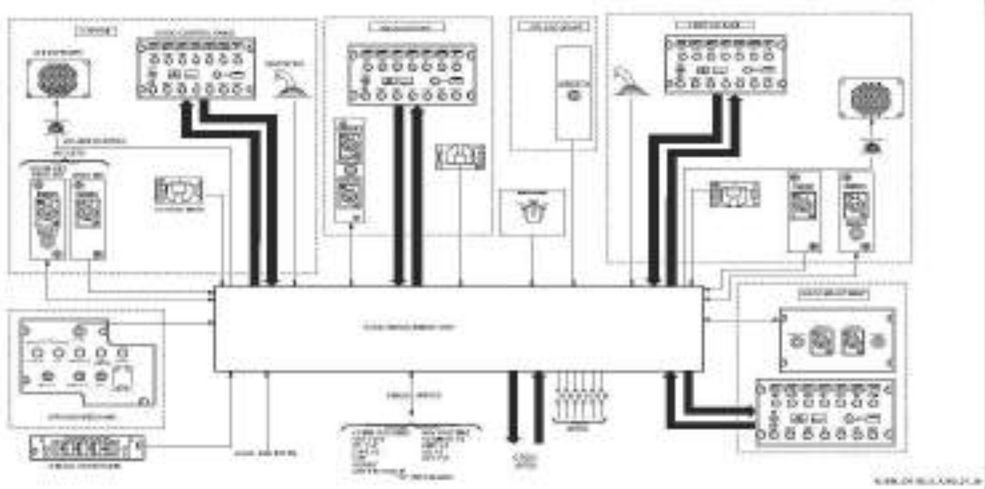


Figure 23-51-00-11400-F / SHEET 1/1 - Audio Management - Block Diagram
** ON A/C 001-007, 201-299

Print Date: November 21, 2018 | Page 1 of 1

The system comprises:

a. 1 AMU.
b. 2 hand microphone receptacles (CAPT and F/O).
c. 2 loud speaker potentiometers with incorporated switches.
d. 2 radio PTT switches.
e. 1 jack for the ground crew.
f. 1 AUDIO SWITCHING selector switch.
g. 1 SELCAL code panel.
h. 4 ACPs.
i. 1 headset jack (Fourth Occupant).
j. 3 oxygen mask stowage boxes.
k. 4 jack panels.

NOTE: In addition, the system uses:

- 2 loud speakers which are part of the central warning system.
- 3 oxygen mask microphones which are part of the oxygen system.
- 2 relay boxes which are part of the DMC system.
- FLIGHT/GROUND information from the LGCIU.

Customer : MSR Type : A318/A319/A320/A321 Rev. Date : Feb 01, 2016	Manual : AMM Selected applicability : 204-204

** ON A/C 201-298

A. Transmission Function - Transmission with Various Microphones
(Ref. Fig. Audio Management Unit - Simplified Schematic of Transmission Circuit SHEET 1)

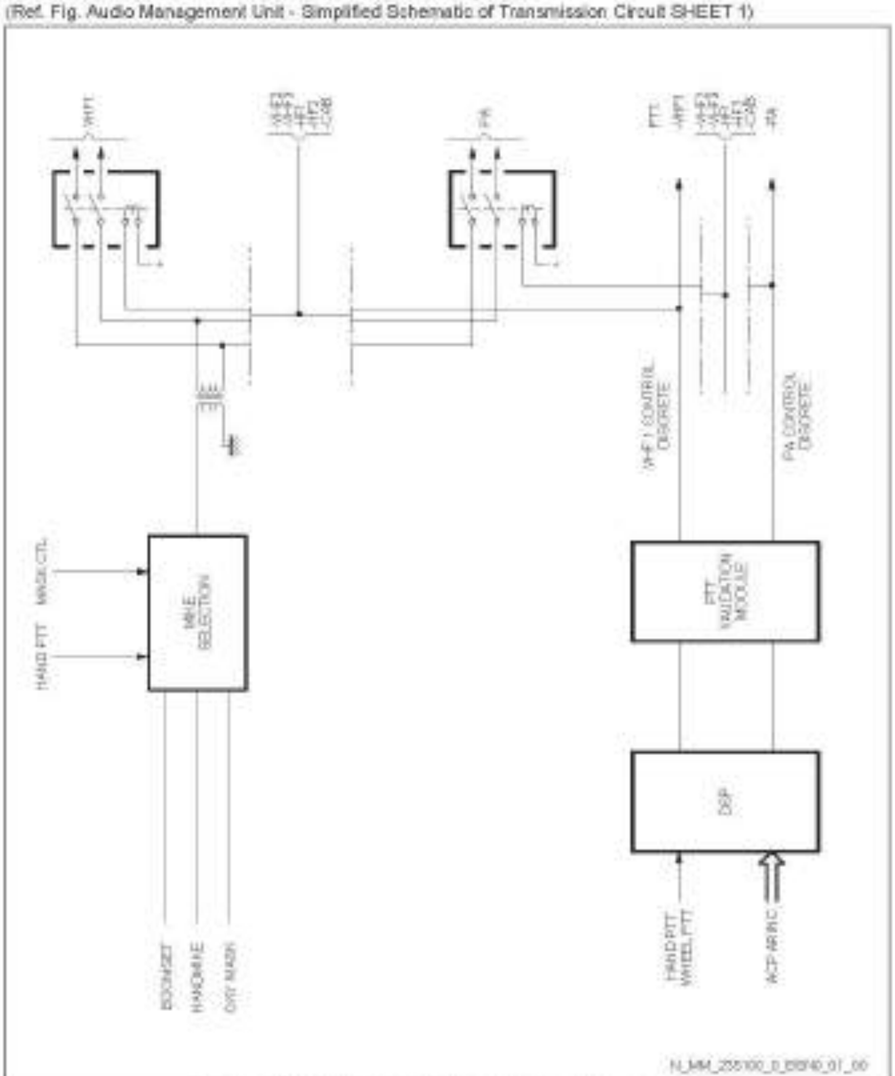


Figure 23-51-00-38300-B / SHEET 1/1 - Audio Management Unit - Simplified Schematic of Transmission Circuit
** ON A/C 201-298

Print Date: November 20, 2016	Page 1 of 2

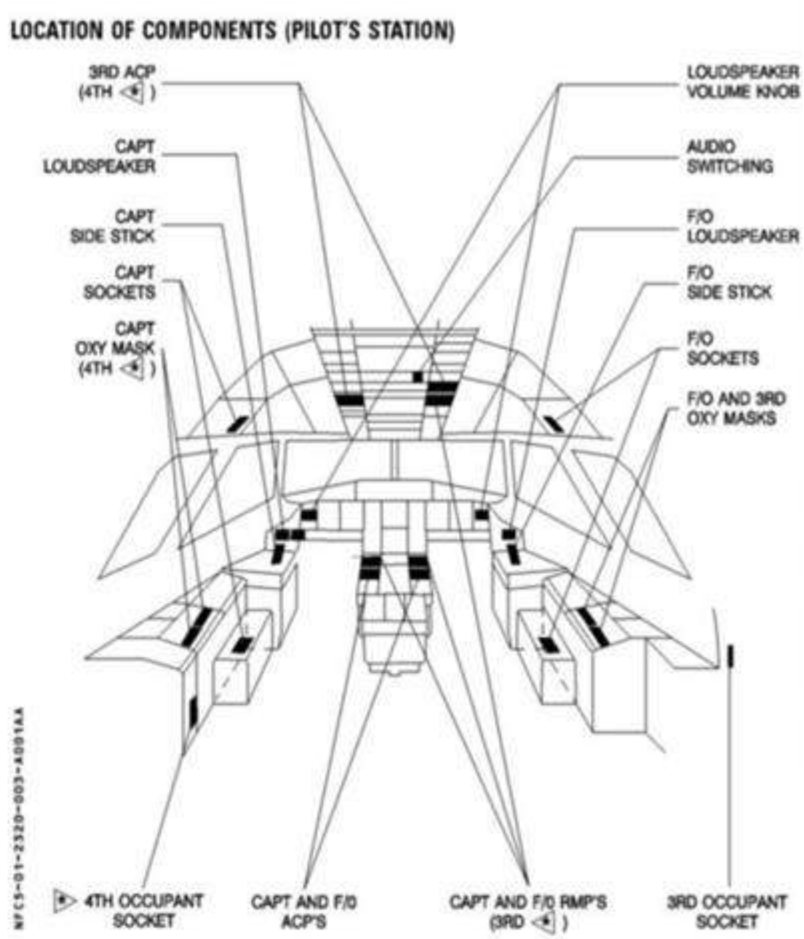
For transmission, each crew member can use either a hand microphone, a boomset or an oxygen mask.
The analog signals of these three microphones are adapted and filtered on the adaptation board of the AMU, which also receives the hand microphone PTT and oxygen mask control discretes.
The microphone selection is done by a dedicated circuit according to the following logic:

		OXYGEN MASK CONTROL DISCRETE	
		0	1
HANDMIKE PTT	0	Boomset signal valid	Boomset and oxygen mask signals valid
	1	Handmike signal valid	

NOTE: Input 6 microphone is valid when PTT6 is activated. Ground Mech microphone is valid when air/ground discrete is set to GND.

The selected microphone signal is then sent to an output transformer.
At the transformer output, this signal is switched to the transmitter selected by the operator on the ACP, in accordance with information received from the DSP.
This discrete information is consolidated with both hardware and software processings, to avoid permanent transmission.

1.6.14.2 CVR Components Location In The Cockpit



- Reference FCOM DSC-23-20-10, Issue 22 Mar 2016.

1.6.14.3 CVR Operational Modes

In CAA mode, the Captain, F/O, 3rd occupant boomset (headset) microphones are "HOT" at all times for voice/noise pick-up to reinforce the sounds picked-up by the area mic. The crew oxygen mask microphone circuit is open until the LH door opens which closes the circuit and activates the oxygen mask mic. The hand microphones are only "HOT" when the Push-To-Talk (PTT) switch on the microphone is activated.

Note:

FAA recording:

All the communications heard by the Captain (or the First Officer or the 3rd Occupant) are recorded.

This enables, at the same time, to record all the communications sent out by these crew members.

This is achieved by means of the side-tone controls on the various equipment.

The A/C is basically designed in accordance with this specification.

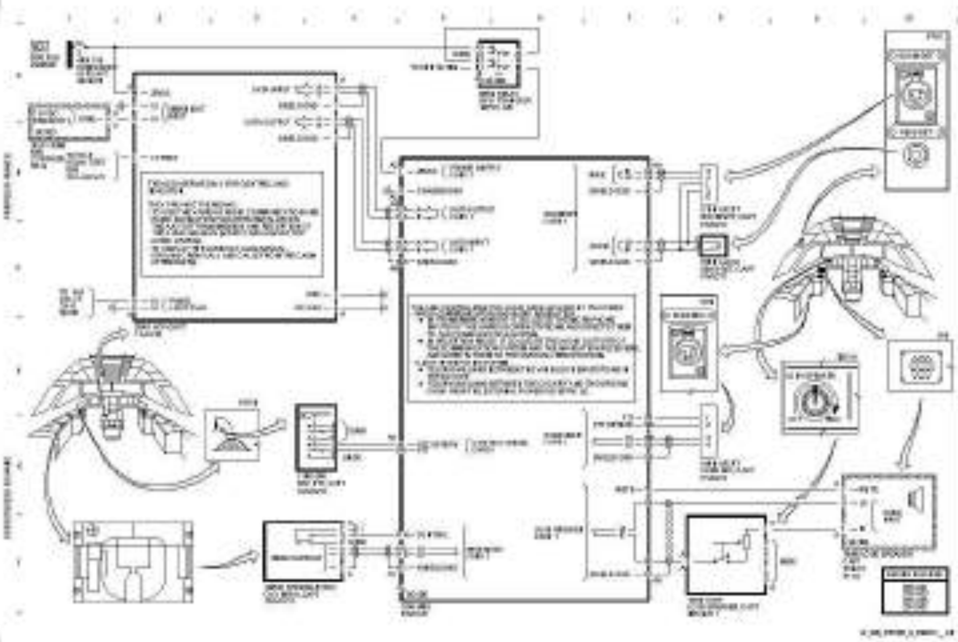
CAA recording:

The principle of CAA recording requires (in addition to the FAA recording principle) that the noises picked up by the boomset microphones be recorded even when these microphones are not active i.e. when the push-to-talk switches on the side-sticks or on the ACPs are not activated. This in order to reinforce the sounds picked-up by the area microphone. This configuration is named "hot-mike".

A shunt is installed on the pin-programming terminal of the AMU to activate the CAA recording.

AIRBUS

Customer : MSR Type : A318/A319/A320/A321 Rev. Date : Feb 01, 2016	Manual : ASM Selected applicability : 204-204
23-51-02 SCH 02 P 0011 SHEET 1 - CAPTAIN	



23-51-02 P 0011 SHEET 1 - COMMUNICATIONS - AUDIO MANAGEMENT - CAPTAIN
** ON A/C 201-299 | EMB SB 23-1333 for A/C 201-205 (A5 AB)

Print Date: November 21, 2016	Page 1 of 1

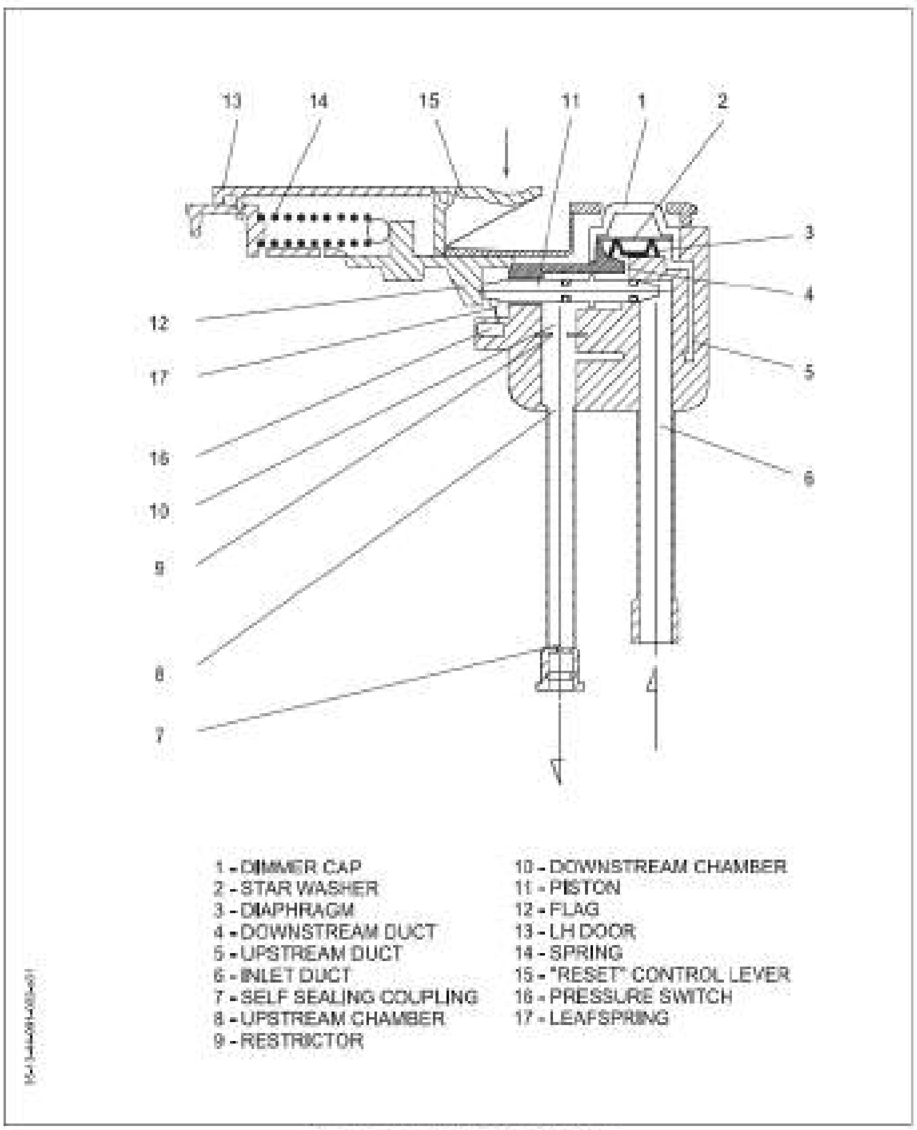
1.6.14.4 Crew Oxygen Mask Microphone Operation

The crew oxygen box microphone is activated when the micro switch closes the circuit to provide control to AMU.

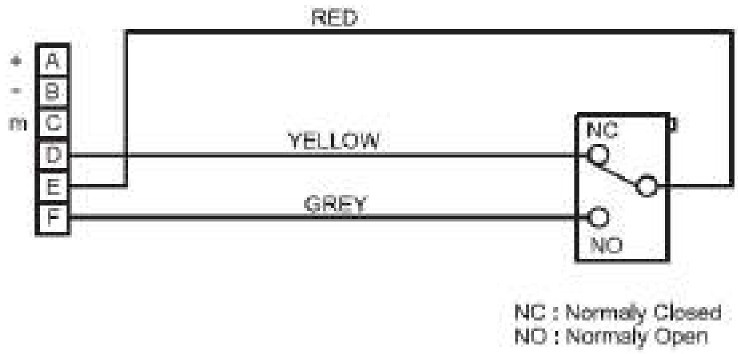
When the LH door is opened, the piston is in outlet position, then the leaf spring (item 17) linked to the piston (item 11) actuates a micro-switch (item 16) the circuit is:

- OPEN between pin contacts E and D,
- CLOSED between pin contacts E and F.

This is mechanical input related to LH door opening.



VALVE - BLINKER OPERATION



Micro switch operation

- Reference CMM 35-13-44, Issue 27 Nov 2014

1.6.15 Fire-smoke in cockpit procedures

Smoke/ Fumes/Avionics smoke procedure:

The philosophy of the procedure described in the FCOM is as follows: in the event of fire/smoke, a diversion must be considered as soon as smoke is detected. The aim is then to identify the source of the smoke/fire and to combat it. If the source is not identified, is not visible or not accessible, and cannot be extinguished, the diversion must be started immediately. If the smoke is detected by the crew and there is no procedure displayed on the ECAM, the crew must refer to the QRH.

The immediate actions are to:

- protect the crew, in particular by the wearing of oxygen masks,
- prevent further contamination (spread),
- Communicate with the cabin crew.

At all times, the elimination of smoke, the compliance with the ELEC EMER procedure and the immediate landing must be considered.

Specific procedure for lithium battery fires:

For lithium battery fires, the actions are specified in the FCOM as follows: The PF dons his oxygen mask while the PM dons the PBE/hood and if there is a flame, uses the Halon extinguisher.

It is indicated that Halon extinguishers are effective on flames but cannot stop a thermal runaway. It is also indicated that if necessary, the control of the airplane should be transferred to the pilot on the opposite side of the fire.

Protective Breathing Equipment (PBE):

A hood is located on the right-hand side at the rear of the cockpit.

1.6.16 Regulatory requirements

Reference BEA study; In the event of depressurization or smoke, the members of the crew and the passengers may need to use oxygen.

The A320 airplane is equipped with three separate oxygen systems:

- oxygen directly available in the cockpit for the crew's use,
- oxygen available in the cabin, above each seat, for the passengers and cabin crew,
- Portable oxygen equipment for the crew or passengers used in the event of an emergency or when giving first aid.

The potential external sources of ignition must be studied and the associated risks minimized.

The compartments in which oxygen systems are installed must provide adequate protection against possible contamination; these compartments must be adequately ventilated and the routing of the system must be insulated.

In addition, the oxygen hazard analysis must show that the oxygen systems and their components are designed in such a way that the occurrence of an uncontrolled oxygen fire in the aircraft is extremely unlikely and does not result from a single failure.

The oxygen system must be installed in such a way that:

1. The impacts of an external source of ignition are minimal.
2. The immediate environment is preserved, i.e. an oxygen leak cannot cause the ignition of substances close by.
3. And the system's design is such that a single failure of one of its components does not lead to an uncontrolled fire in the airplane and that in all cases, such a fire is extremely improbable.

The oxygen mask test procedure is designed to check:

That the oxygen mask storage box is supplied with oxygen; when the test pushbutton is pressed, oxygen is admitted into the hose up to the mask and the pressure is balanced at 5 bar in the box hoses upstream of the oxygen mask regulator. The visual indicator (called a blinker in the procedure) opens and a yellow dot appears when the pressure is balanced, then closes and turns black when the pressure is the same everywhere.

While the test pushbutton is being pressed, the piston that allows oxygen to flow to the pilot's mask moves and, via an electrical contractor, activates the link between the microphone and the audio system. During this basic test, there is no continuous noise of an oxygen flow.

The box is supplied with oxygen and that the mask and microphone are functional.

By simultaneously pressing the PUSH TO TEST pushbutton on the box and the EMERGENCY knob on the mask, a continuous flow of oxygen is established from the oxygen supply to the nose cup via the regulator. Oxygen is then released into the box. The microphone picks up the noise produced by this flow of oxygen and the sound can be heard on the cockpit loudspeaker.

That the box is effectively in the reset position (i.e. the piston that allows oxygen to flow to the mask is in the closed position, preventing oxygen from being delivered to the mask). Just pressing the mask's EMERGENCY knob does not release any oxygen and the blinker fed by the flow downstream of the piston does not change color (from black to yellow).

1.6.17 Mass and balance information

```
LOADSHEET                                  APPROVED          EDNO
WEIGHTS IN KILOGRAMS                                          01
        CAPTAINS NAME ..................
FROM/TO FLIGHT     A/C REG  VERSION       CREW       DATE      TIME
CDG HBE    MS804/18   SUEZC   16C125Y      2/5       18MAY16 2228

                      WEIGHT              DISTRIBUTION
LOAD IN COMPARTMENTS   1727      1/   629 2/   601 4/   497
                                 5/     0 0/     0

PASSENGER/CABIN BAG    4597  38/ 16/  1/  2 TTL  59 CAB 0
                             TOB  56
                             PAX   1/ 55     SOC   0/  0
                             BLKD  0

TOTAL TRAFFIC LOAD     6324
DRY OPERATING WEIGHT   44879
ZERO FUEL WEIGHT ACTUAL  51203 MAX  62500  L   ADJ
TAKE OFF FUEL          11900
TAKE OFF WEIGHT  ACTUAL  63103 MAX  77000      ADJ
TRIP FUEL               9000
LANDING WEIGHT   ACTUAL  54103 MAX  66000      ADJ

BALANCE AND SEATING CONDITIONS .      LAST MINUTE CHANGES
              DOI      104.1 .DEST  SPEC    CL/CPT  + - WEIGHT
      106.4    LIZFW   111.5 .
LITW    30.9
LAW   109.6    MACTOW   20.6 .
      FWD-LMT  ACTL   AFT-LMT .
ZFC   19.32    30.42   40.30 .
TOC   15.25    20.61   39.83 .
STANDARD               0,0  .
TRIM
THRU TRIP

UNDERLOAD BEFORE LMC     11297.              LMC TOTAL
MESSAGE AND CAPTAINS INFORMATION BEFORE LMC

TAXI FUEL 400 TAXI WGT  63503 MAX   77400

...0/18/1/2.0.T1727.1/629.2/601.4/497
1/1/56.0A0/0/3

CAI    FRE        0    POS         0    BAG   1727    TRA

LOAD IN CPTS 0/0 1/629 2/601 4/497 5/0
CHECKED BAGGAGE PIECES CAI 1/Y/30 2/Y/33 4/C/0/Y/17
PREPARED BY Philippe/FARGIER  33 174295412
... NO
FUEL IN TANKS 12300

FUEL DENSITY 0.795 KG/L
... TRE     0
... 17   10901

CI      FRE       0     POS         0    BAG     1727     TRA         0
```

Showler
21 jan

Figure 1.6/31: Weight and Balance Sheet

1.7 Meteorological Information

1.7.1 Accident area meteorological forecast

According to the information received from the "Egyptian Air Meteorological General Organization", regarding the actual meteorological forecast that prevailed the area of coordinates 33 35 13 N, 028 53 49 E the time between 2300 on 18/5/2016 to 0400 on19/5/2016 Cairo local time.

- On the surface of the Mediterranean:
  The prevailing wind direction was mostly North-West to West, with a speed of 18-20 knot, barometric pressure was 1015 hpa with no abnormal atmospheric phenomena.
- At the level of 500 hpa (5.5 km):
  The prevailing wind direction was mostly North-West to West, with a speed of 35-40 knot, with some moderate clouds.
- At the level of 200 hpa (13 km):
  The prevailing wind direction was mostly North-West associated with a jet stream of a speed 75-80 knots.

1.7.2 Maps presented to the flight crew at the departure airport

The maps that were presented to the flight crew at the departure airport (That were among the flight documents) included the following information:

- The flight path from Charles De-Gaulle Airport to Cairo, almost in the area between latitudes 40°- 50° N and longitudes 5°- 15° E contains isolated embedded CB up to FL280.
- The remaining flight path until the area of the aircraft crash did not have any other meteorological phenomena.

1.8 Aids to Navigation

1.8.1 Radar information study

A. Objective of the study

1. To develop the flight path of the aircraft specially after termination of the FDR recording
   For this purpose the radar lat, long information were used to create x-y plan view for the aircraft (using geodetic system algorithm), in addition to the flight path created by radar lat, long information
2. To check consistency of the last points of the aircraft flight path as defined by the FDR lat and long information with the first radar points as defined by the radar lat and long information
   For this purpose the FDR lat, long information were used to create x-y plan view for the aircraft (using geodetic system algorithm), in addition to the flight path created by FDR lat, long information
3. Locating ELT position on the aircraft path as defined by the radar information the moment the ELT sent the distress message

B. Source of information

Snapshots png files (29 file s1 to s29) (Greek Radar)

Explanation of the snapshots information details is included in the "EXPLANATION OF DIGITAL IMAGING.docx" file.

Information in snapshots png files was extracted and then established in a tabular form as follows:

Slide No	day	month	year	hr	min	sec	Run time	Lat North	Long East	altitude at the RADAR (FL)
s1	19	6	2016	0	28	48.19	1.00x 00.00:03:02:937	33:47:11	28:42:23	370
s2	19	6	2016	0	29	1.255	1.00x 00.00:03:16:001	33:43:45	28:43:48	370
s3	19	6	2016	0	29	24.42	1.00x 00.00:03:39:169	33:41:23	28:45:51	370
s4	19	6	2016	0	29	56.69	1.00x 00.00:04:11:439	33:38:15	28:49:41	370
s5	19	6	2016	0	30	25.51	1.00x 00.00:04:40:252	33:34:40	28:52:57	N/A*
s6	19	6	2016	0	30	44.48	1.00x 00.00:04:59:506	33:33:47	28:56:24	N/A
s7	19	6	2016	0	31	4.085	1.00x 00.00:05:18:831	33:32:08	28:59:06	N/A
s8	19	6	2016	0	31	25.64	1.00x 00.00:05:40:388	33:33:53	29:04:02	N/A
s9	19	6	2016	0	31	45.04	1.00x 00.00:05:59:783	33:33:19	29:07:29	N/A
s10	19	6	2016	0	32	4.593	1.00x 00.00:06:19:339	33:32:40	29:11:24	N/A
s11	19	6	2016	0	32	44.72	1.00x 00.00:06:59:469	33:26:28	29:13:59	N/A
s12	19	6	2016	0	33	4.574	1.00x 00.00:07:19:320	33:24:20	29:13:14	N/A
s13	19	6	2016	0	33	22.79	1.00x 00.00:07:37:534	33:23:31	29:12:17	N/A
s14	19	6	2016	0	33	32.48	1.00x 00.00:07:57:481	33:23:52	29:10:44	N/A
s15	19	6	2016	0	34	4.662	1.00x 00.00:08:19:673	33:22:48	29:05:36	N/A
s16	19	6	2016	0	34	33.95	1.00x 00.00:08:48:700	33:25:12	29:03:08	N/A
s17	19	6	2016	0	34	44.15	1.00x 00.00:08:59:153	33:24:55	29:01:06	N/A
s18	19	6	2016	0	35	3.977	1.00x 00.00:09:18:743	33:29:20	29:02:19	N/A
s19	19	6	2016	0	35	23.68	1.00x 00.00:09:38:428	33:31:59	29:03:43	N/A
s20	19	6	2016	0	35	44.07	1.00x 00.00:09:58:815	33:31:46	29:02:27	N/A
s21	19	6	2016	0	36	3.264	1.00x 00.00:10:18:010	33:32:36	29:03:18	N/A
s22	19	6	2016	0	36	22.88	1.00x 00.00:10:37:630	33:32:06	29:06:48	N/A

s23	19	6	2016	0	36	43.67	1.00x 00.00:10:58:412	33:31:52	29:08:13	N/A
s24	19	6	2016	0	37	24.1	1.00x 00.00:11:38:841	33:30:01	29:07:28	N/A
s25	19	6	2016	0	37	44.27	1.00x 00.00:11:59:269	33:29:49	29:08:36	N/A
s26	19	6	2016	0	38	4.639	1.00x 00.00:12:19:385	33:29:44	29:09:21	N/A
s27	19	6	2016	0	38	33.08	1.00x 00.00:12:47:829	33:29:09	29:12:09	N/A
s28	19	6	2016	0	38	43.2	1.00x 00.00:12:58:231	33:29:37	29:11:35	N/A
s29	19	6	2016	0	38	50.56	1.00x 00.00:13:05:306	33:29:47	29:11:32	N/A

*N/A: Not available

Raw data extracted from the snapshots png files Greek radar

C. Brief explanation about the Geodetic system

A geodetic system is a framework for accurately locating points on the Earth's surface. It provides a standardized reference system to describe the shape and size of the Earth, facilitating precise measurement and navigation. The Earth is not a perfect sphere but an oblate spheroid, and its irregularities make a simple coordinate system insufficient.

Key components of a geodetic system include:

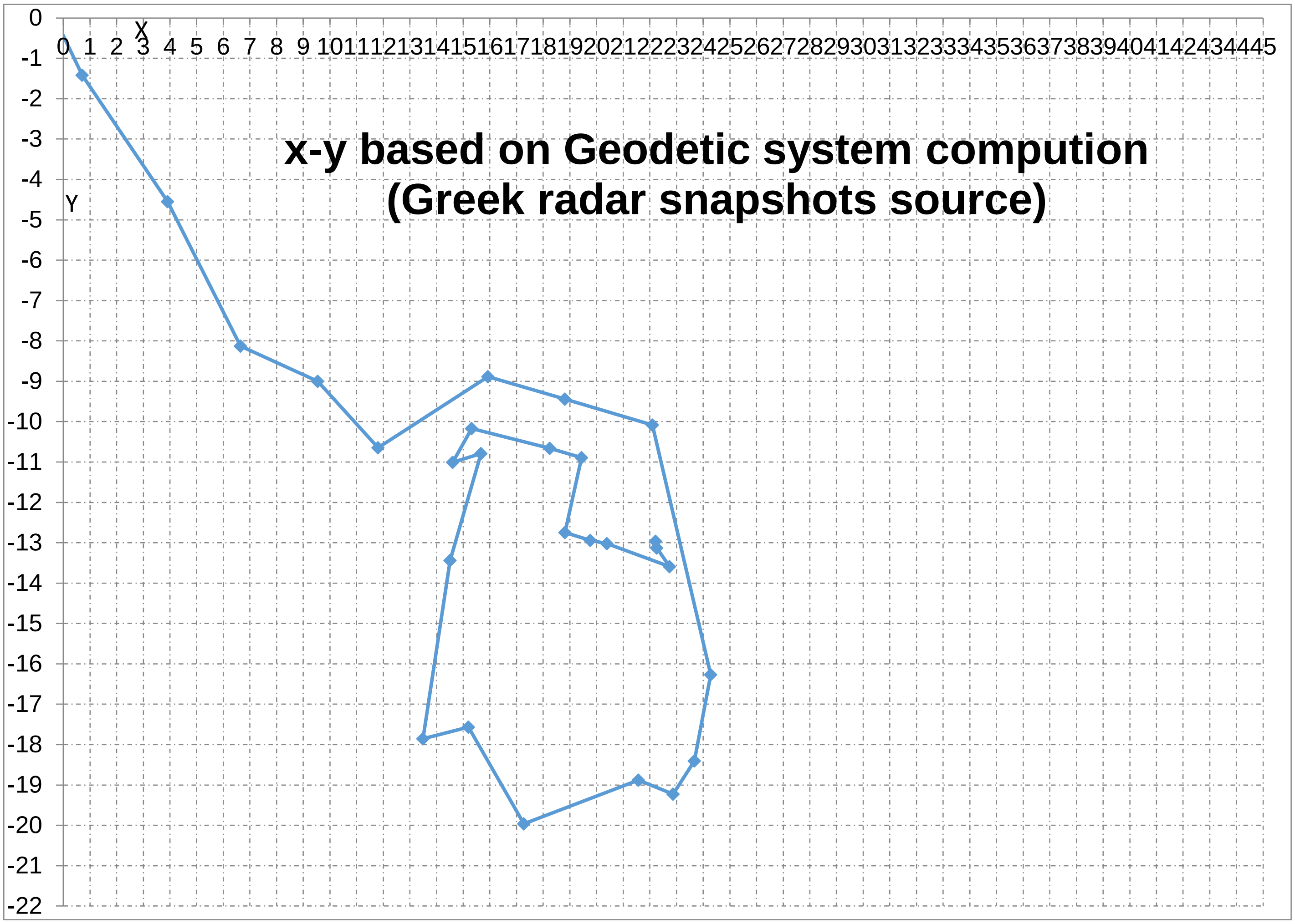
1. **Reference Ellipsoid:** Earth's shape is approximated by an ellipsoid, which is a three-dimensional, elliptical shape. Common ellipsoids include WGS84 (World Geodetic System 1984) and GRS80 (Geodetic Reference System 1980).
2. **Geodetic Datum:** A datum is a reference point and a set of parameters that define the coordinate system. It includes the origin, orientation, and scale factors. WGS84, for example, is a widely used geodetic datum.
3. **Coordinate System:** Latitude and longitude are commonly used geographic coordinates. Latitude measures north-south position, and longitude measures east-west position. Other coordinate systems, like Universal Transverse Mercator (UTM), use easting and northing values.
4. **Geoid:** The geoid is an equipotential surface representing the mean sea level. It serves as a reference for determining elevations. Gravity anomalies and irregularities in the Earth's mass cause deviations from a simple ellipsoid.

Geodetic systems are crucial for applications such as cartography, navigation, surveying, and geographic information systems (GIS). Advances in technology have led to more accurate measurements, with satellite-based positioning systems like GPS (Global Positioning System) playing a significant role in modern geodetic practices.

D. Plots

D.1 x-y plot for the Snapshots point of the Greek Radar as computed using Geodetic system algorithm:

Ser. No	UTC Time	seconds from 00:00:00	Δ time	X target	Y target	Lat degree North	Long degree East
1	0:28:48.191	1728.191		-2.183828209	4.381737248	33.78639	28.70639
2	0:29:1.255	1741.255	13.064	-1.002169653	0.94964996	33.72917	28.73
3	0:29:24.423	1764.423	23.168	0.710196292	-1.41594964	33.68972	28.76417
4	0:29:56.693	1796.693	32.27	3.915417179	-4.546365665	33.6375	28.82806
5	0:30:25.506	1825.506	28.813	6.651057458	-8.125196052	33.57778	28.8825
6	0:30:44.477	1844.477	18.971	9.538982946	-9.003593595	33.56306	28.94
7	0:31:4.085	1864.085	19.608	11.80195998	-10.64813993	33.53556	28.985
8	0:31:25.642	1885.642	21.557	15.92583712	-8.887950293	33.56472	29.06722
9	0:31:45.037	1905.037	19.395	18.81458871	-9.444664638	33.55528	29.12472
10	0:32:4.593	1924.593	19.556	22.09485916	-10.08141024	33.54444	29.19
11	0:32:44.723	1964.723	40.13	24.28583546	-16.26863473	33.44111	29.23306
12	0:33:4.574	1984.574	19.851	23.66709747	-18.40378296	33.40556	29.22056
13	0:33:22.788	2002.788	18.214	22.87434257	-19.22359985	33.39194	29.20472
14	0:33:32.477	2012.477	9.689	21.57339978	-18.87934095	33.39778	29.17889
15	0:34:4.662	2044.662	32.185	17.27348785	-19.96156009	33.38	29.09333
16	0:34:33.954	2073.954	29.292	15.19816407	-17.56924485	33.42	29.05222
17	0:34:44.151	2084.151	10.197	13.49470526	-17.85714513	33.41528	29.01833
18	0:35:3.977	2103.977	19.826	14.50216823	-13.43993382	33.48889	29.03861
19	0:35:23.682	2123.682	19.705	15.66661467	-10.78782931	33.53306	29.06194
20	0:35:44.069	2144.069	20.387	14.60698241	-11.00748537	33.52944	29.04083
21	0:36:3.264	2163.264	19.195	15.31602977	-10.17250675	33.54333	29.055
22	0:36:22.884	2182.884	19.62	18.24704809	-10.66277853	33.535	29.11333
23	0:36:43.666	2203.666	20.782	19.43368386	-10.89168769	33.53111	29.13694
24	0:37:24.095	2244.095	40.429	18.8126035	-12.74308849	33.50028	29.12444
25	0:37:44.265	2264.265	20.17	19.76235362	-12.93945992	33.49694	29.14333
26	0:38:4.639	2284.639	20.374	20.39071129	-13.02032072	33.49556	29.15583
27	0:38:33.083	2313.083	28.444	22.7379402	-13.59361421	33.48583	29.2025
28	0:38:43.199	2323.199	10.116	22.2613708	-13.12923946	33.49361	29.19306
29	0:38:50.56	2330.56	7.361	22.21878785	-12.96283555	33.49639	29.19222

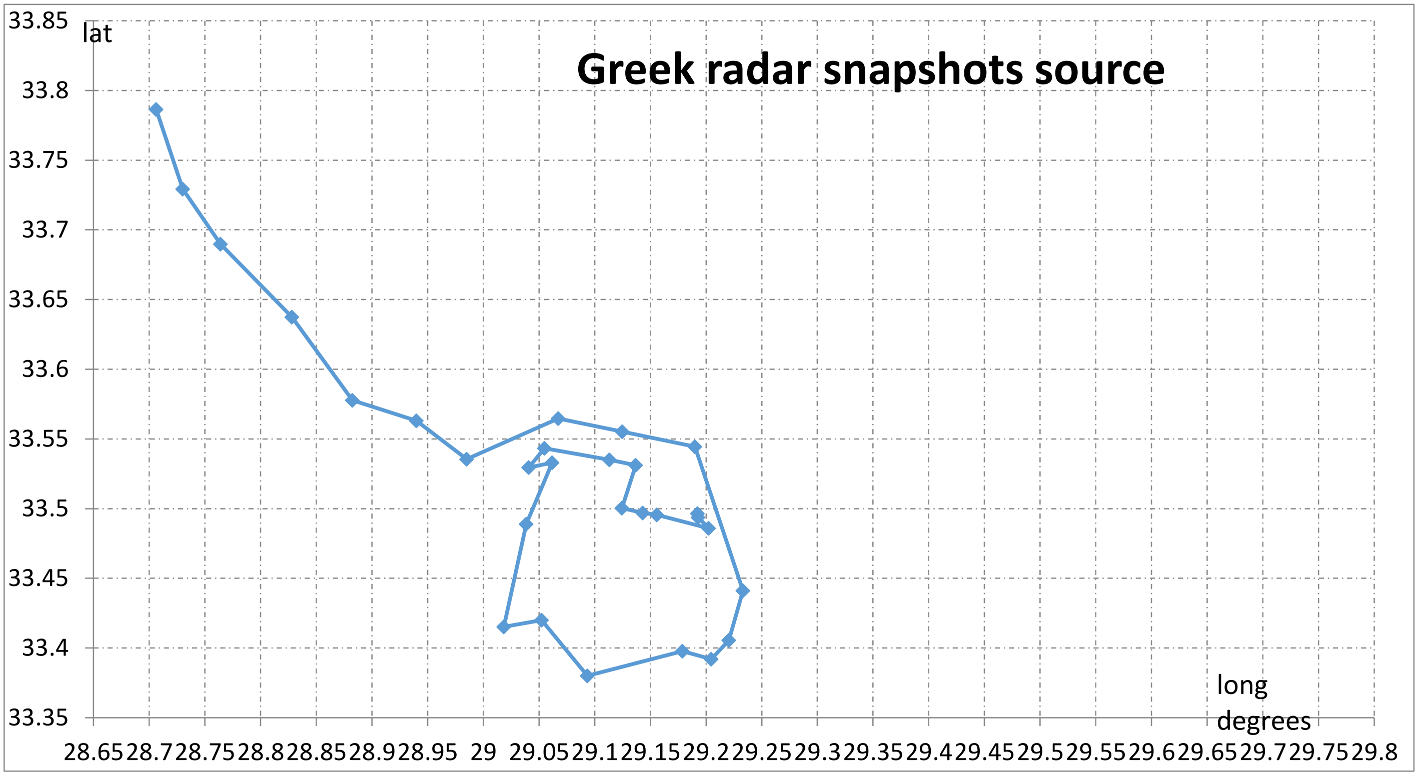


x-y plot (Greek radar snapshots source) using Geodetic system compution

Notes:

- All distances are referred to Kumbi point and in nautical miles:
  Kumbi Point coordinates:
  Lat = 33deg:42.8 min. = 33.7133 degrees
  Long= 28 deg:45 min. =28.75 degrees
  $X_{Kumbi} = 0$
  $Y_{Kumbi} = 0$
  On the above plot
- The altitude used for Kumbi point is sea level
- The altitude used for target (airplane) is 37000 ft (extracted from the snapshots file information)
- The altitude is available only for the four first points

D.2 lat-long plot for the Snapshots point of the Greek Radar:



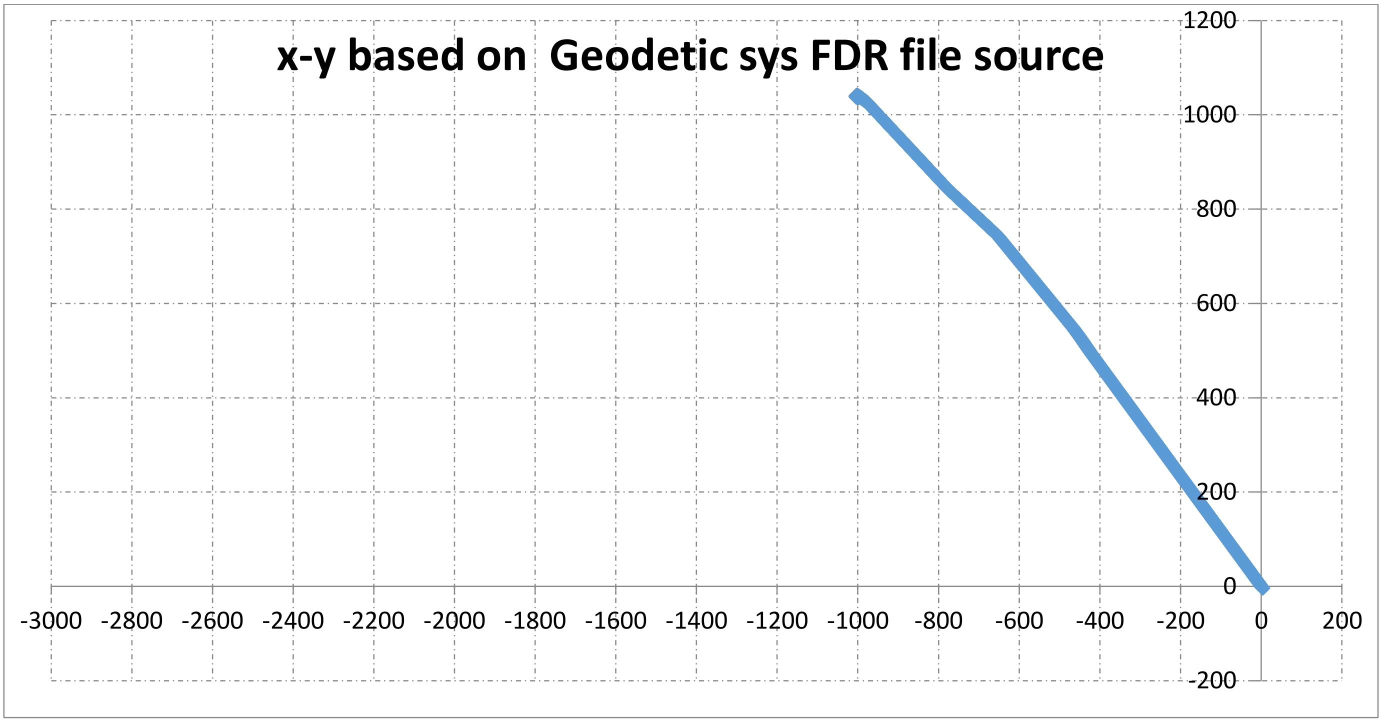
Latitude, longitude plot (Snapshots file source)

D.3 x-y plot based on FDR recorded lat, long as computed using Geodetic system algorithm:

FDR last points

UTC	Time seconds from raw data (frame number)	X based on Geodetic sys FDR	Y based on Geodetic sys FDR	Ør LAT degrees Target FDR reference North	ψr Long degrees Target FDR reference East
0:28:35	96172	-3.2659477	3.8162393	33.77695	28.6847861
0:28:37	96174	-3.076884	3.6000579	33.7733472	28.6885639
0:28:39	96176	-2.8706864	3.3940357	33.7699139	28.6926833
0:28:41	96178	-2.6902274	3.1570497	33.7659639	28.6962889
0:28:43	96180	-2.5012592	2.930561	33.7621889	28.7000639
0:28:45	96182	-2.3035039	2.7142372	33.7585833	28.7040139
0:28:47	96184	-2.1316134	2.4979316	33.7549778	28.7074472
0:28:49	96186	-1.9424572	2.2714633	33.7512028	28.711225
0:28:51	96188	-1.7447991	2.034504	33.7472528	28.7151722
0:28:53	96190	-1.555748	1.80805	33.7434778	28.7189472
0:28:55	96192	-1.3665383	1.5917649	33.7398722	28.722725
0:28:57	96194	-1.1515647	1.3754808	33.7362667	28.7270167
0:28:59	96196	-0.9624651	1.1387201	33.7323194	28.7307917
0:29:01	96198	-0.7732074	0.9121283	33.7285417	28.7345694
0:29:03	96200	-0.5839318	0.6958719	33.7249361	28.7383472
0:29:05	96202	-0.4119015	0.4797904	33.7213333	28.7417806
0:29:07	96204	-0.2141035	0.2532185	33.7175556	28.7457278
0:29:09	96206	-0.016149	0.0268207	33.7137806	28.7496778
0:29:11	96208	0.1816838	-0.199736	33.7100028	28.753625
0:29:13	96210	0.3795325	-0.4056282	33.7065694	28.7575722
0:29:15	96212	0.6032942	-0.6115098	33.7031361	28.7620361
0:29:17	96214	0.7925474	-0.8482059	33.6991889	28.7658111
0:29:19	96216	0.9992198	-1.0644013	33.6955833	28.7699333
0:29:21	96218	1.1971343	-1.270262	33.69215	28.7738806

0:29:23	96220	1.3950702	-1.4966055	33.688375	28.7778278
0:29:25	96222	1.5931595	-1.712946	33.6847667	28.7817778
0:29:27	96224	1.7997572	-1.9187809	33.6813333	28.7858972
0:29:29	96226	2.0062361	-2.1347694	33.6777306	28.7900139
0:29:31	96228	2.2130108	-2.350916	33.674125	28.7941361
0:29:33	96230	2.4369301	-2.5567179	33.6706917	28.7986
0:29:35	96232	2.6349697	-2.7830136	33.6669167	28.8025472
0:29:37	96234	2.8158875	-2.9991492	33.6633111	28.8061528
0:29:39	96236	3.0225975	-3.2255918	33.6595333	28.8102722
0:29:41	96238	3.2121777	-3.4313799	33.6561	28.81405
0:29:43	96240	3.4274137	-3.6474726	33.6524944	28.8183389
0:29:45	96242	3.6343156	-3.8737239	33.6487194	28.8224611

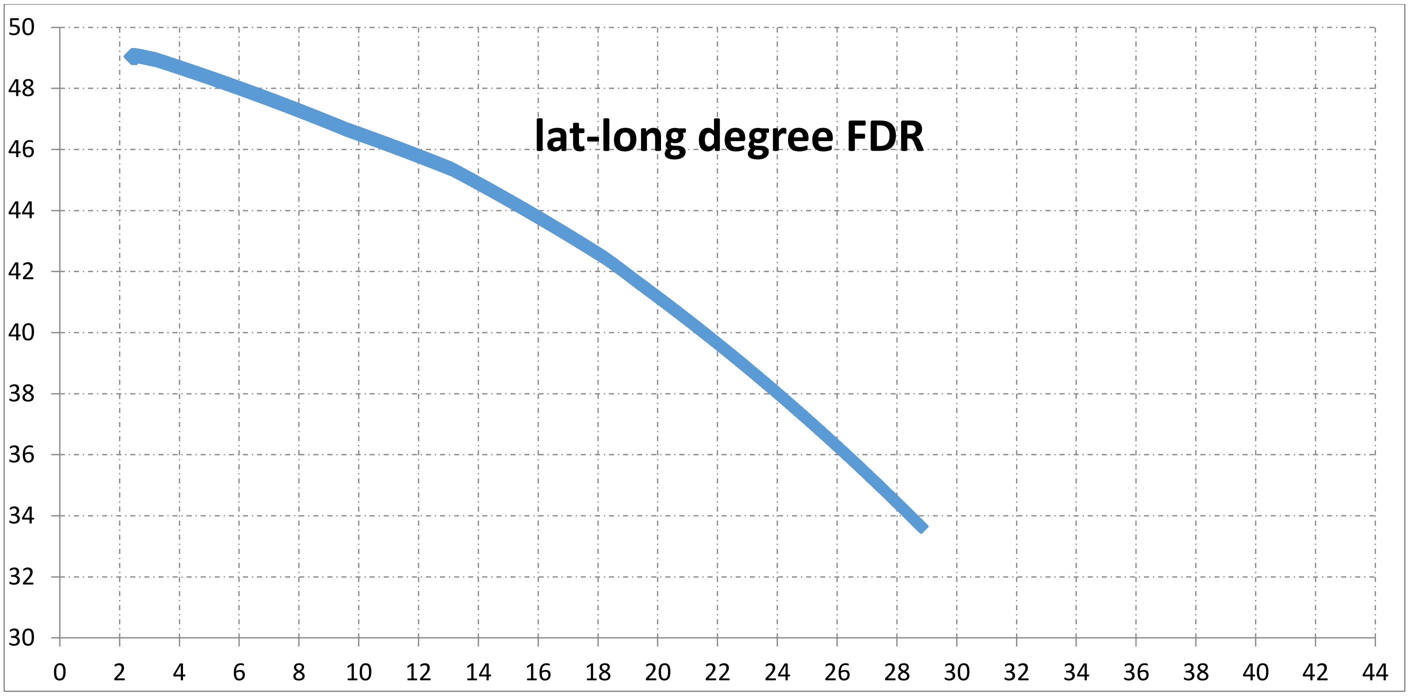


X-Y based on geodetic sys FDR file source plot

Notes:

- Altitude used for computation is 37000 ft. (reference FDR)
- Results are shown graphically above

D.4 lat-long plot based on FDR information:

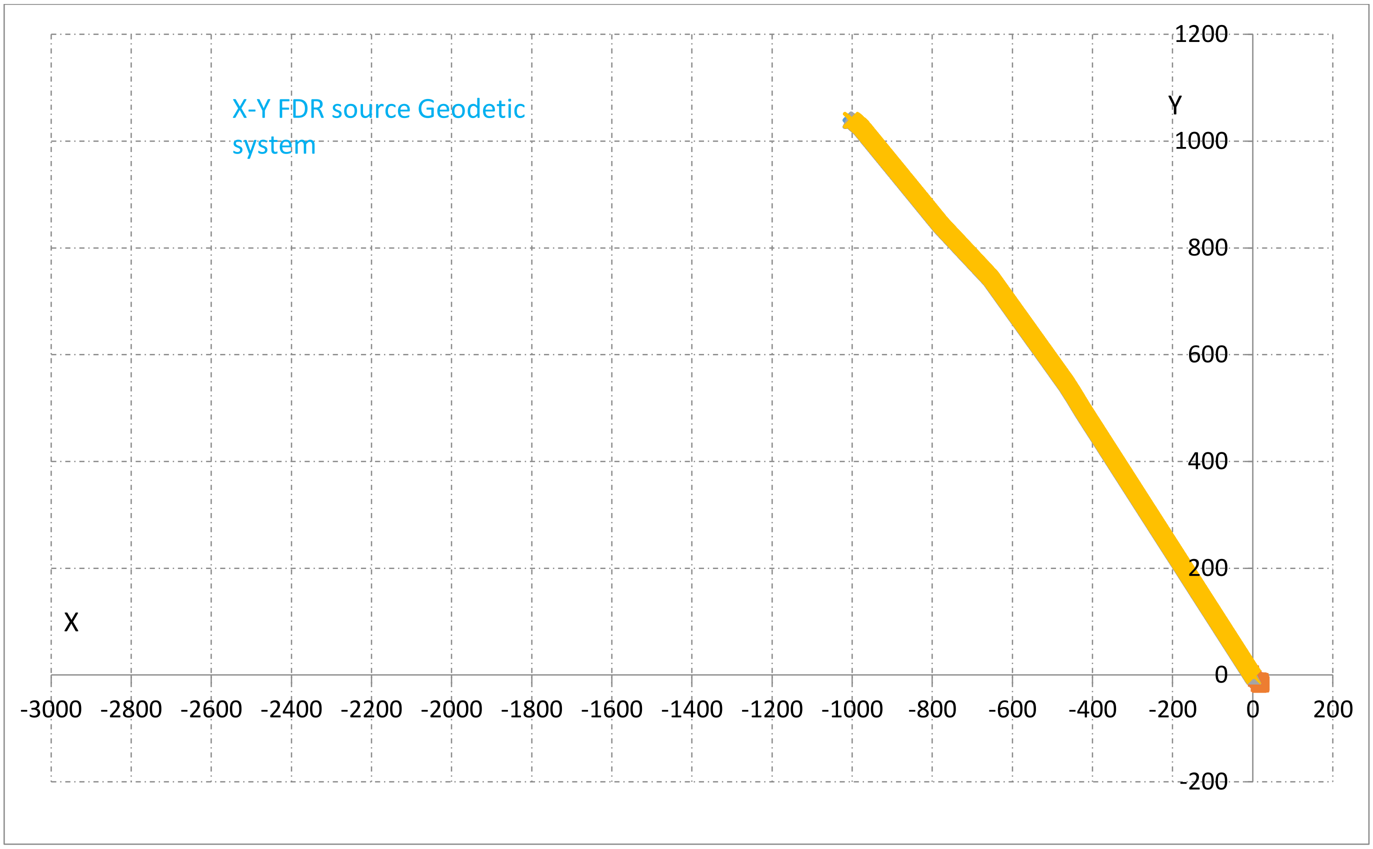


Lat-Long FDR file source plot

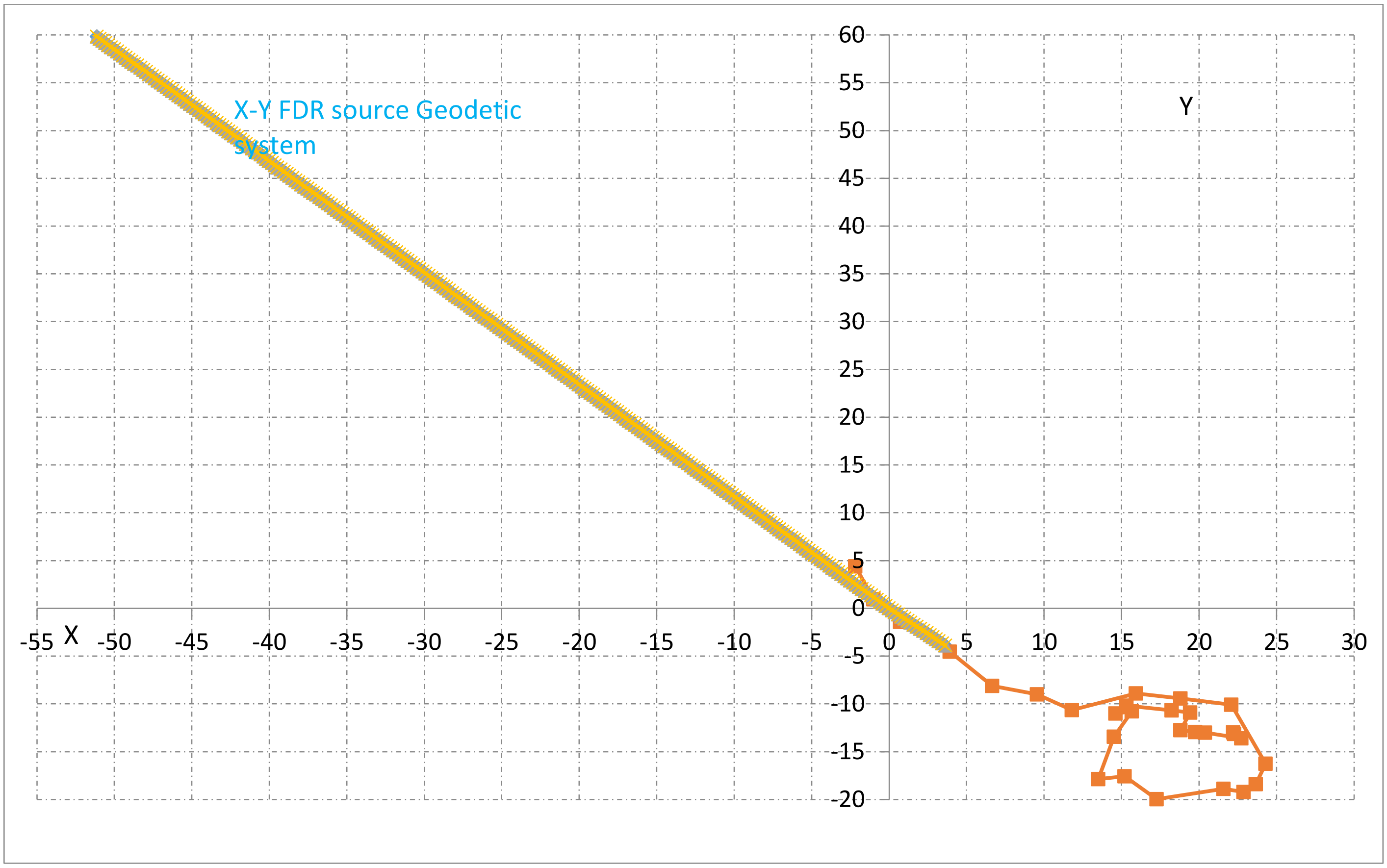
- Actual Lat-Long in degrees from FDR had been calculated.
- Results are shown graphically above

E. Comparison between radar data and FDR

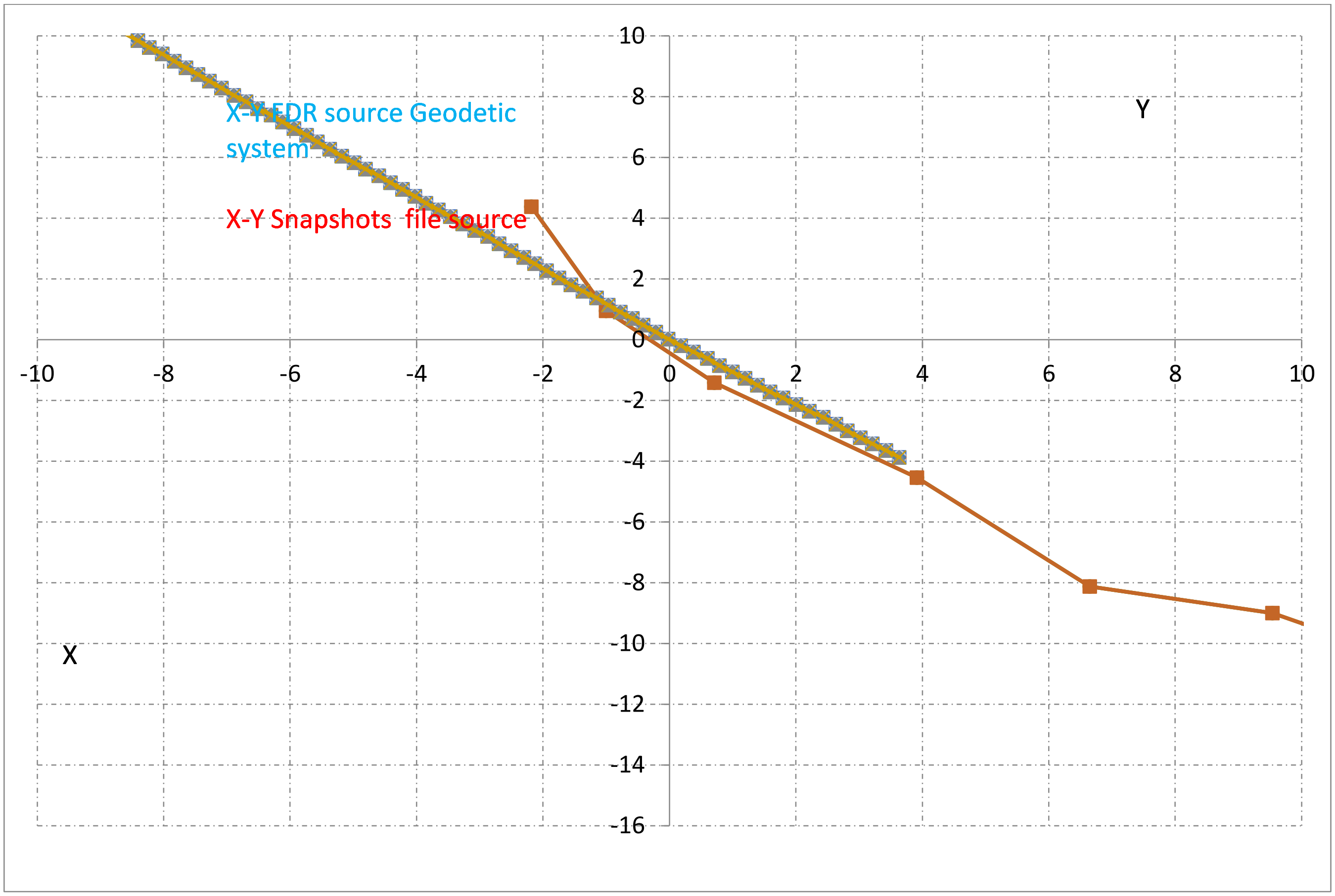
E.1 x-y plots



x-y comparison based on Geodetic sys between Greek radar data and FDR information (plot 1)

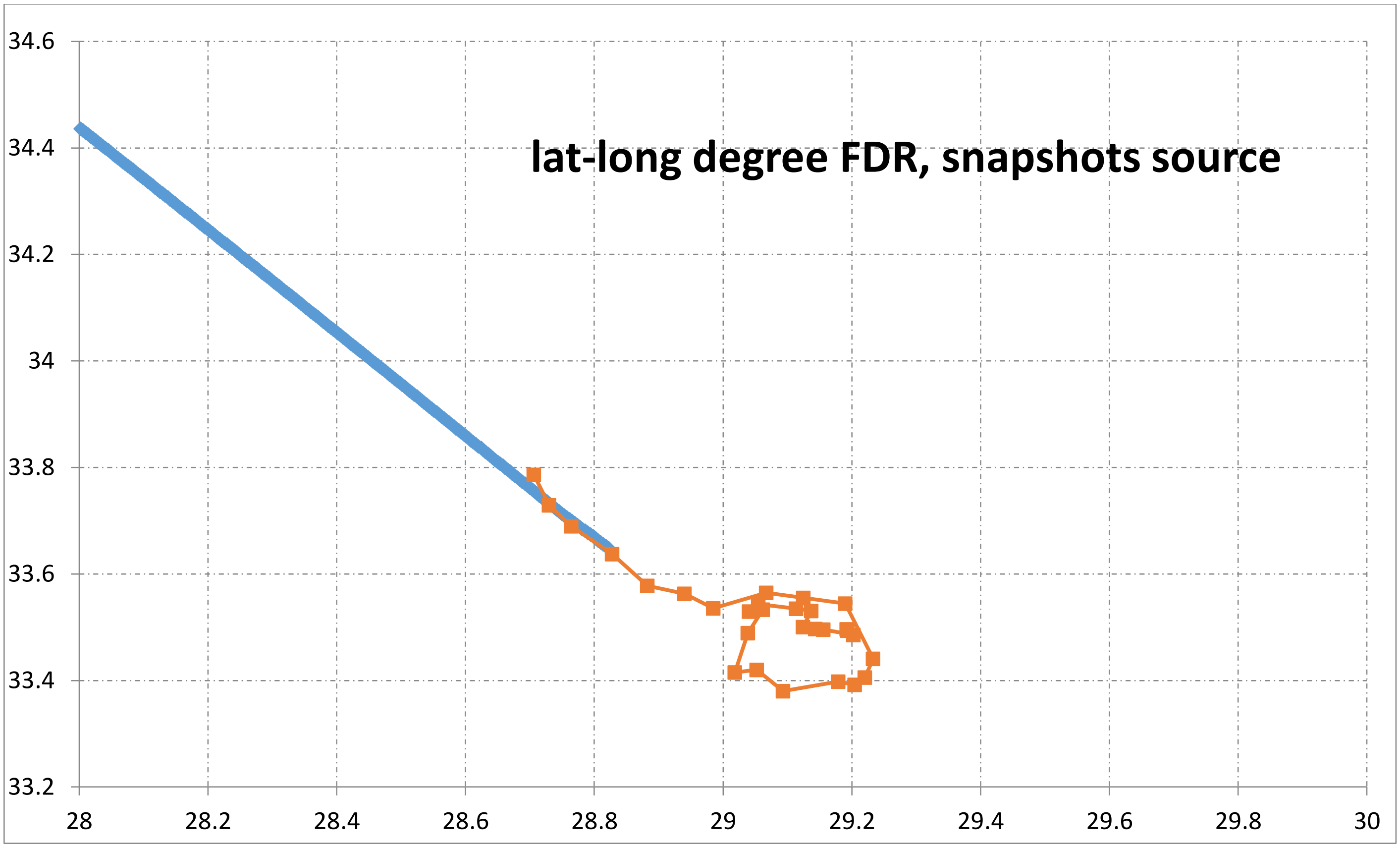


x-y comparison based on Geodetic sys between Greek radar data and FDR information (plot 2)

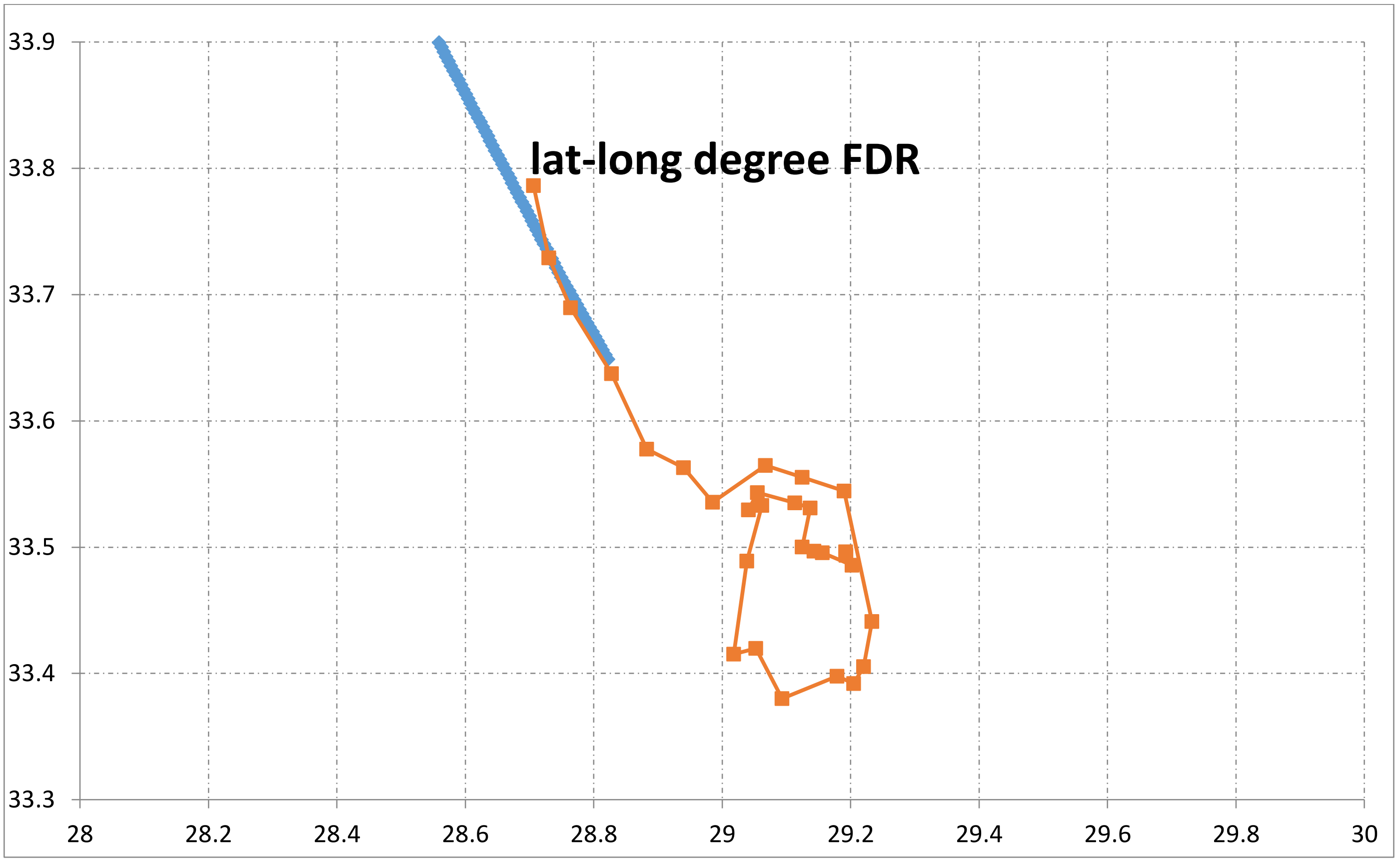


x-y comparison based on Geodetic sys between Greek radar data and FDR information (plot 3)

E.2 Lat-Long plots



Lat-long comparison between Greek radar data and FDR information (plot 1)



Lat-long comparison between Greek radar data and FDR information (plot 2)

Notes:

- UTC time from the FDR data file is used
- The time in the Greek radar snapshots are derived directly from the radar png files as local time.
- The snapshot Greek radar returns starts at time 0:28:48.191 UTC, ends at time 0:38:50 UTC

F. Results:

- The second and Fourth points in the Greek radar snapshots table shows very good match with the end points of the FDR data
- The second point in the snapshots table (radar time 0:29:1.255) almost matches with point in the FDR at time 0:28:57 (FDR time)
- The end time of the FDR is 0:29:45 based on the FDR UTC time, it almost matches with the 4th point of the snapshots file at time 0:29:57
- It is evident that the time base in the radar data, is very close to the time base in the FDR data

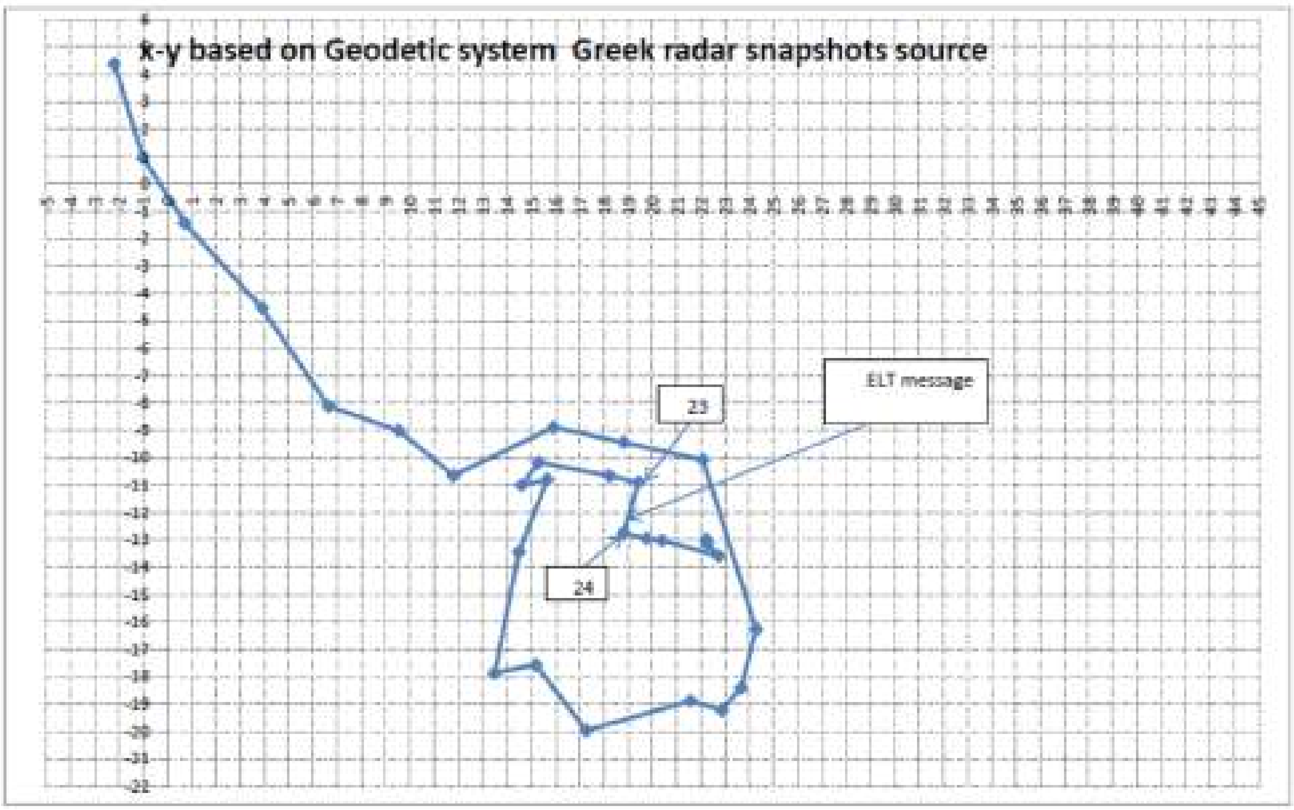
It's evident that the Greek radar information is consistent with the last FDR information

G. Locating ELT position on the aircraft path as defined by the radar information the moment the ELT sent the distress message

- ELT message was originated at 00:36:59 UTC, 666 seconds after first hissing sound, there were 6 snapshots Greek radar returns after that.
- ELT message was originated between radar point number 23 and point number 24. (Refer to following table).
- The radar return point which comes directly after the ELT message was at 00:37:24 UTC (25 seconds after ELT message) (point 24 in the following table).
- At this point (point 24) which is 25 seconds after ELT message origination, the aircraft started turning left from almost south direction to almost east direction). (Refer to next graph)
- Last radar point return was at 00:38:50 (111 seconds after ELT message. 1 minutes, 51 seconds after ELT message).

Ser. No	UTC	seconds from 00:00:00	∆ time	X target	Y target	Lat degree North	Long degree East
23	0:36:43.666	2203.666	20.782	19.43368386	-10.89168769	33.53111	29.13694
24	0:37:24.095	2244.095	40.429	18.8126035	-12.74308849	33.50028	29.12444
25	0:37:44.265	2264.265	20.17	19.76235362	-12.93945992	33.49694	29.14333
26	0:38:4.639	2284.639	20.374	20.39071129	-13.02032072	33.49556	29.15583
27	0:38:33.083	2313.083	28.444	22.7379402	-13.59361421	33.48583	29.2025
28	0:38:43.199	2323.199	10.116	22.2613708	-13.12923946	33.49361	29.19306
29	0:38:50.56	2330.56	7.361	22.21878785	-12.96283555	33.49639	29.19222

Last 7 snapshots Greek radar returns



Results:

- There were at least 6 radar return points from snapshots Greek radar data after the ELT message (covering 1 minutes, 51seconds after ELT message).
- It can be concluded that the aircraft was still in the air when the ELT message was originated, excluding the probability that the ELT message was originated because of hitting the water.
- Therefore, it can be concluded that the originated ELT message was because the aircraft was subjected to high G load (at least 2.0 G in axial direction).
- From the above plot, it seems that the aircraft was almost flying straight the time of the ELT message origination (between point 23 and point 24). However, the exact aircraft maneuver information between point 23 and point 24 (40.4 seconds interval) cannot be well defined, because of lack of information during this time interval. (The flight path above is based on the snapshots Greek radar data in a polygon chart format which approximately express actual aircraft flight path directions).
- The aircraft started turning left after 25 seconds of ELT message.

1.9 Communications

1.9.1 Communications made by Greek traffic control

- At 23:22:27 radar and communication contact established with MSR804 by ACC Sector AC4 over point PINDO at FL 370, the flight is cleared direct to point KUMBI the crew confirmed clearance.
- At 23:47:55 flight MSR804 was transferred for communication and control to AC5 on Frequency 133.325 MHZ, the crew confirmed clearance.
- At 23:48:13 Flight MSR804 established communication and radar contact with sector AC5.
- At 00:27:25 AC5 radar controller calls MSR804 and clears it to contact HECC ACC on Frequency 124.7 MHZ with no read back from the crew. The controller calls repeatedly with no response. The flight according to radar recorded data, at the time, was 14.8 nm North of point KUMBI.
- At 00:28:22 AC5 controller asked HECC ACC if they have established contact with the aircraft. Yet, there was no response from the aircraft.
- From 00:28:48 until 01.40.25 the AC5 controllers along with flights MSR780, IBE 3320, MC5387, THY7EY, MSR995, RAM 217 and UAE9753, call MSR804 on emergency frequency 121.5 MHZ, there was no response from the aircraft.
- At 00:29:57, according to video replay of radar data, target was lost from radar display of AC5.
- At 00:32:52 until 00:35:22 AC5 controller called MAMBO unit of the HELLENIC Tactical Air Force and notified that communication and radar contact of MSR804 were lost. They stated final position before it was lost from radar display. They were asking if there was a target indication on their radar but they received a negative answer.
- At 00:31:45 the controller notified HECC ACC for loss of radar contact and asked whether they have established radio communication or radar contact. The answer was negative. HECC ACC reported that they will call on emergency frequency 121.5 MHZ.
- At 00:34:08 the ACC supervisor notified NAOP about the loss of radar and communication with MSR804 and that radar contact was lost 10 nm south of KUMBI.
- At 00:34:42 the Air Ground Service was asked to contact the flight through its SELCAL (LQGP). The controller also asked if and when they established contact to instruct the flight to contact the sector on125.2 MHZ or HECC ACC.
- At 00:35:13 MAMBO reported that "if there was any flight at this location they would have noticed it".

- At 00:35:22 the AC5 controller asked MAMBO if they succeeded in establishing radar contact with MSR804 .They received a negative response .The controller expressed his worry by stating that neither he, nor HECC ACC and MAMBO have any indication or sign of the flight.
- At 00:35:44 ACC supervisor alerted JRCC and ADIC with detailed information.
- At 00:36:18 AC5 controller alerted ADIC, ADIC reports that it will alert NAOP as soon as possible.
- At 00:38:12 AC5 controller notified MAMBO unit of the Hellenic Tactical Air Force, providing all pertinent information on initiatives taken and on the way, including the SSR of the flight (7624-unless otherwise assigned),and that the flight plan was finished by the system. MAMBO report no radar indication on flight MSR804 which should normally have.
- At 00:40:09 the controller gave MAMBO the flight data.
- At 00:46:56 ADIC (Air Defense Information Center) asked ACC supervisor for any news and POB and that a C130 SAR aircraft will take-off from ELEFSINA Air Force Base for SAR mission.
- At 00:48:48 ACC supervisor notified NAOP that the aircraft is declared lost.
- At 00:56:17 AC5 controller notified Nicosia ACC and asked for support.
- At 01:00:15 ADIC notified controller that MAMBO radar reported that at 00:40 approximately MSR804 target was lost on radar display and that the flight was out of ATHINAI UIR at the time.
- At 01:04:05 AC5 planner notified ADIC that MAMBO reported that no target was seen in the area where the flight was missed. Normally, according to their radar range, they should have indication of the flight position.
- At 01:18:49 ATHINAI approach notified AC5 planner that SAR operations had been initiated and aircraft HRK 69A is airborne from LGEL.
- At 01:26:36 ACC supervisor notified PALLAS ATSEPS that they will begin video replay of flight MSR804.
- At 01:39:26 ACC supervisor notified ADIC that persons on board were 59 and 7 Crew members.
- At 04: 19:15 ACC supervisor report to MAMBO the co-ordinates given by HECA ACC for HRK59A SAR mission (33251, 8 N, 02942 E).

1.9.2 Egyptian Air Traffic Control communication

A. Download transcript for the communications between Cairo Area Control and Athens Area Control

Conversation	ATC Unit	Timing Hrs:min
Do you have contact with EgyptAir 804?	ATC Athens	00:30
Yes, flight plan track.	ATC Cairo	00:31
Confirm do you have contact MSR 804 on your radar	ATC Athens	00:31
Yes, flight plan track	ATC Cairo	00:32
Lost MSR 804 on your radar?	ATC Athens	00:34
Search & rescue on position missing plane	ATC Athens	01:40
Thank you	ATC Cairo	01:40

B. Download transcript for the communications between Cairo Area Traffic Control and an aircraft (MSR 780) that was flying at the area where the aircraft disappeared

(Translated from Arabic)

Conversation	ATC Unit	Timing Hrs:min
Flight MSR 780, would you please acknowledge when you see any abnormal thing in the route.	Controller	01:13
O.K.	Pilot MSR780	01:14
Would you like us to descend to a lower altitude	Pilot MSR780	01:18
MSR 780 Descend to FL 370	Controller	01:18
MSR 780 Descend to FL 310	Controller	01:20
I have seen a light, I could not identify it, maybe it is a ship light	Pilot MSR780	01:27
MSR 780, where did you see the light exactly	Controller	01:28
10 nm behind me, the light coordinates are: N 33 25 1.8, E 29 42 00	Pilot MSR780	01:28

1.10 Aerodrome Information

Charles De-Gaulle airport has four runways for take-off and landing as follows:

1. 08L/26R
2. 08R/26L
3. 09L/27R
4. 09R/27L

The following maps show the parking stands, runways and the aircraft path from parking gate to takeoff runway

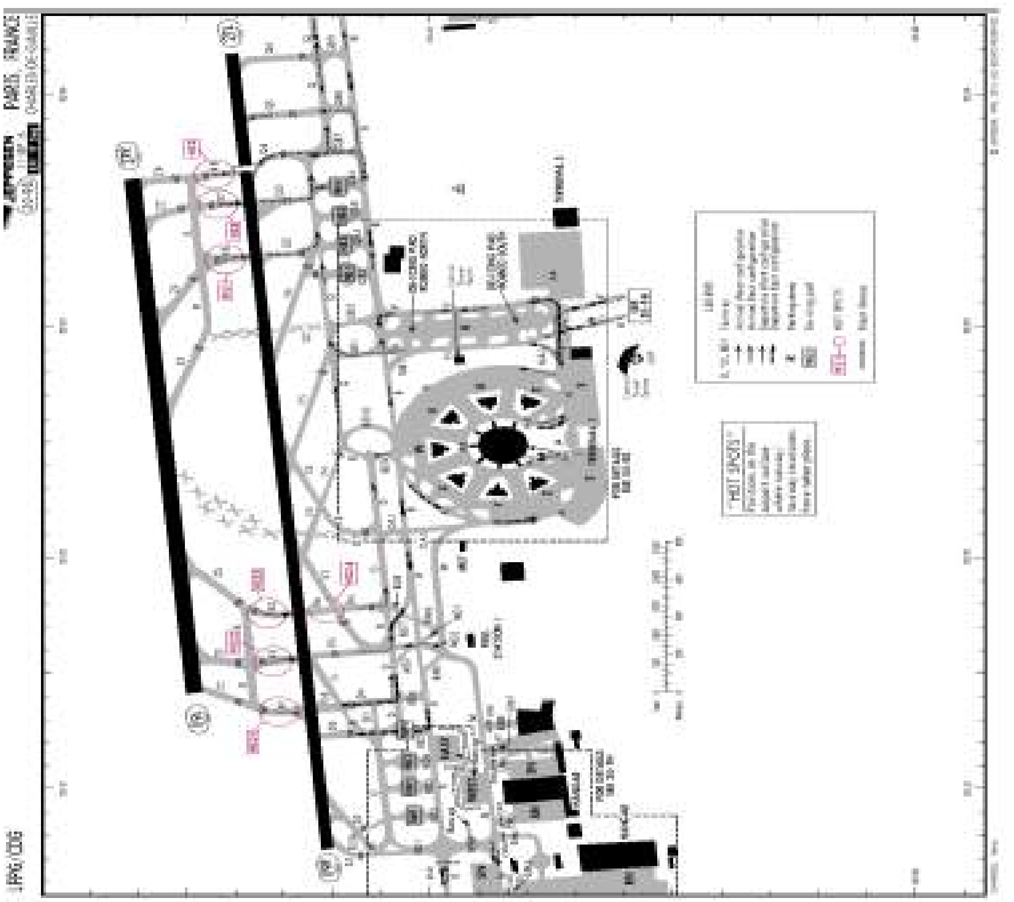


Figure1.10/1: Paris France Charles –De-Gaulle (Jeppesen)

Figure1.10/2: Aircraft Path from Parking Gate to Takeoff Runway

1.11 Flight Recorders

1.11.0 General

A. Recovery of the Flight Recorders:

The two "Crash Survivable Memory Units (CSMU'S)" were recovered from the bottom of the sea.

The first unit was recovered on 16/06/2016 from a depth of 3020 meter from sea water surface.

The second unit was recovered on 17/06/2016 from a depth of 2960 Meter from sea water surface.

- The two CSMU units were kept in fresh water immediately after recovery.
- The two units were moved same day to the Egyptian Aircraft Accidents Investigation Directorate, Ministry of Civil Aviation to perform the download and readout.
- Until the opening of the first unit, there was no conclusive evidence to show which unit belongs to the Flight Data Recorder FDR, and which unit belongs to the Cockpit Voice Recorder CVR.
- The work started on the two units at the Egyptian Aircraft Accidents Investigation Directorate FDR,CVR analysis center on 18/06/2016 with the participation of the investigation committee members, the accredit representatives and their advisors.
- Representatives from the following entities participated in the FDR, CVR work:
    - EAAID
    - BEA
    - NTSB
    - Honeywell

B. Egyptian AAI Laboratory Capabilities

The laboratory capabilities include the following:

- Bench units
- Interface cables
- Downloaders
- General tools
- Special tools

The Investigation committee technical team participants (EAAID, BEA, NTSB, and Honeywell) agreed that the Egyptian AAI laboratory had the capability to perform the normal read out for the flight recorders (FDR, CVR).

1.11.1 Flight Data Recorder (FDR)

1.11.1.0 General

- The Flight Data Recorder consists of chassis, Circular Crash Survival Memory Unit (CSMU) containing the memory unit on which the data is recorded.
- Mounted on CSMU source unit Under Water Locator Beacon (ULB).
- The CSMU unit has the same part number and different serial number.

Figure 1.11/1: Example of undamaged Flight Recorder

- Manufacturer : Honeywell
- Part Number : 980-4700-0042
- Serial number :12786

Figure 1.11/2: CSMU received in water

1.11.1.1 Procedures carried out on the FDR in Cairo

A. Examinations/ Checks

A.1 External examination

The CSMU was removed from the container of fresh water and examined. There were no visible markings on the CSMU indicating the part or serial number. The CSMU had damage indicative of significant impact forces including:

- Chips in the paint;
- Significant gouges in the external surface of the CSMU case;
- 3 of the 4 mounting brackets that secure the CSMU to the chassis broken off;
- Shearing of the flex cable between the CSMU and the chassis;
- Absence of the one of two Underwater Locator Beacon (ULB) mounting brackets and the ULB;
- Structural failure of the second ULB bracket.

A.2 Removal of the memory board

The CSMU was opened following the manufacture's procedures documented in "AID to investigators: procedure for solid state CVR and/or FDR data recovery", Honeywell reference document DWG NO: 022-0010 Rev C, and summarized below.

1. The four fasteners attaching the cover plate to the CSMU were observed to be tight and without structural damage. They were removed.
2. The cover plate and the 4 hold down latches were removed.
3. The insulation end plug was removed to expose the memory CCA, while preserving the remaining part of the flex cable.
4. The heat absorbing powder around the memory was observed to be wet, and agglomerated into pieces but did not obstruct the removal of the memory board.
5. The RTV covering the memory board was observed to be in good shape, without indications of thermal or structural damage.

The memory board was then stored in an ESD container and the working area was then cleaned. ESD protections were applied for the remainder of the work documented in this report.

The RTV was removed from the board according to the manufacturer's procedures. No visible evidence of water inside the RTV was found at this stage. An initial visual inspection was performed and there were no obvious signs of thermal or structural damage to the board. The determination was made that it would be safe to continue the data recovery process by drying the memory board.

A.3 Drying process

The Technical Research Center of the Armed Forces provided access to one modern climatic chamber to perform the drying process. Two investigators witnessed the complete drying process. The heating profile was the following:

- From ambient temperature to 60°C, increase of the temperature with a rate of 2 °C per minute
- Stabilize the temperature at 60°C during 8 hours. The climatic chamber provided a stabilization of the temperature at 60°, +/- 0.1 °C.
- Decrease of the temperature gradually back to ambient.

A.4 Electrical checks

The flex cable between the CSMU and the chassis is an intentional structural and thermal weakness designed into the SSFDR to help protect the memory of the CSMU from inertial and thermal damage. It is designed to be broken outside the CSMU in the event that the CSMU breaks free of the chassis during the accident sequence or burned away in the event that the recorder is subjected to a post-crash fire. As noted above, the CSMU separated from the chassis during this accident and severed the flex cable. When the flex cable is damaged in this way, there is a possibility that the copper traces in the damaged end of the flex cable could come in contact with each other creating short circuits and prevent the recorder from downloading properly and/or damage the stored data. There are two processes to prevent and test for this problem.

The first process is cutting away the end of the flex cable and polishing it to ensure the cutting process did not create shorts between the copper traces. The flex cable of the FDR was trimmed and polished.

The second process is a series of electrical impedance tests conducted on the pins of the factory installed connector used to attach an additional flex cable to the memory board for downloading in the event of an accident. The electrical check was performed using reference values provided by Honeywell. Additional tests of the connectivity between each pin and the ground pin were conducted to help ensure that there were no short circuits caused by crush or pinch type damage to portions of the flex cable which could not be inspected because they were still encapsulated by the CSMU insulation membrane. (Removal of the membrane to inspect the flex cable is a time consuming task that imposes a slight, but additional, risk to damaging the cable so it is not part of the initial inspection process). The measured values were all within the range of tolerance of the impedance references. No short-circuits were detected during the test. Some open circuits were detected. However, an open circuit is not indicative of a failure that would impose a risk to the data so the Technical Group determined that it was safe to attempt a download at this time.

A.5 First download attempt

– A Honeywell SSFDR golden chassis, P/N 980-4700-042, S/N 6604, was used in for this accident. This golden chassis and the tools used to perform the download were tested with the original chassis' CSMU.
– The accident FDR memory board was connected to the golden chassis using a replacement flex cable.
– A download was attempted using a Flight Data Systems Handheld Multi-Purpose Interface (HHMPI) device.
– The download was declared unsuccessful.

A.6 Localization of the failure

– Although the HHMPI tool was tested before the download and found to be fully functional, the Technical Group determined that a second attempt using a different downloading tool would not pose any additional risk to the data and may succeed.

- A Honeywell Hand Held Download Unit was then tested with the golden chassis and the golden CSMU and found fully functional. It was then used to attempt a second download of the accident FDR memory board. It provided an error message, without any explanation or additional information.
- In order to eliminate the possibility that the replacement flex cable was faulty, the flex cable was changed and additional download attempts were performed using the HHMPI and the Honeywell download device. They provided the same result as the initial attempts.
- An additional download with a golden CSMU was then successfully performed, validating the correct behavior of the downloading chain and confirming that the failure was the result of a fault with the accident FDR memory board.

A.7 Trouble shooting of the memory board

Because no short circuit was detected through the electrical tests and the download process behaved as if a 1x DFDR was detected (the default operation of the chassis when a problem with communications to the memory board occurs), the Technical Group focused first on the connection between the memory board and the golden chassis. Honeywell was also contacted through the NTSB representative to provide advice.

The Technical Group developed the following work plan:

- Visually check the flex cable under the insulation membrane for damage.
- Repeat the trimming and polishing of the flex cable.
- Ensure the pins of the on board connector are free of corrosion and contaminants.
- Rerun electrical tests associated with flex cable short circuits.
- If no short circuit is identified, try another download attempt.

A.7.1 Additional visual inspection

All of the insulation membrane and the silicon attaching it to the flex cable were removed. Inspection of the flex did not find any damage.

A.7.2 Re-trimming and re-polishing

The damaged flex cable was cut again. The edge was polished and went through microscopic examination. No short was detected on the cable.

A.7.3 Connector pins

All the pins of the connector were cleaned and examined with a magnifier to remove any traces of conformal coating, dust or anything that would impede a good electrical connection between the flex cable and the memory board.

A.7.4 Electrical tests

The electrical checks, dedicated to the flex cable, were performed. All the measured values were close to the Honeywell reference values except the measurement between pin 24 and pin 25 of the connector:

- The reference value was 277 k Ω.
- The measured value was 778 k Ω.

Because this value did not indicate a short circuit and a risk to the recorded data, a new download attempt was performed without any success.

A.7.5 Localization of the defect

Honeywell was advised of this small difference and assisted the Technical Group assessing the issues and reviewing the memory board schematic to identify a possible cause of the failed downloads. Pin 24 of the connector is a direct connection to pin 2 of the PAL chip. (The PAL is the chip on the memory board that manages the memory interface addressing from the SSFDR chassis). A microscopic examination of the PAL leads and solder joints was performed. The examination of the soldering points showed that more than 50% of the pins were fractured at or near the solder joints. Figure 1.11/3 shows the fractures on the pin 18–25 edge of the PAL.

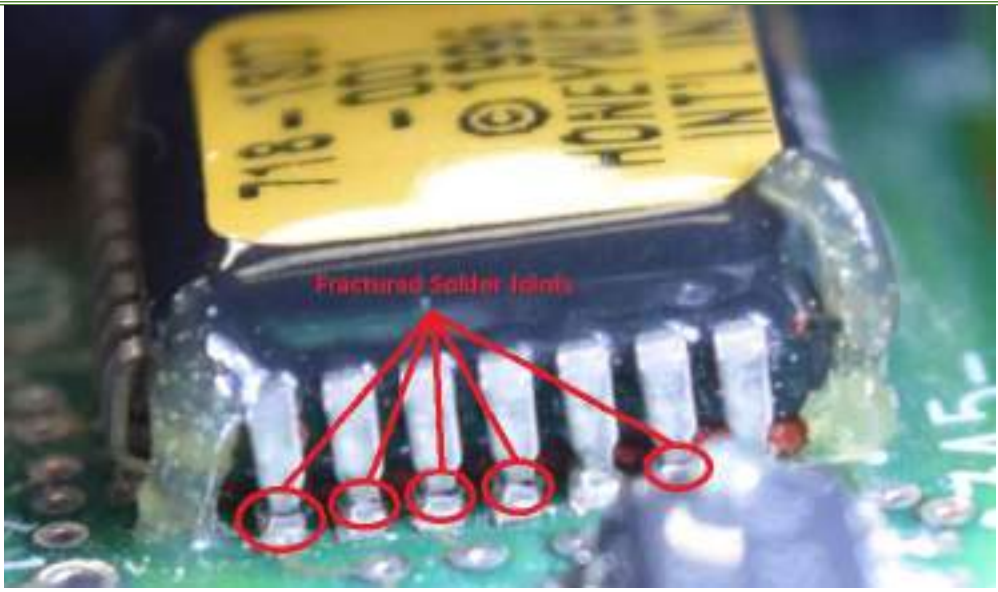


Figure 1.11/3: Solder Joint Fractures

B. Findings and Recommendation of the CVR/FDR technical group

B.1 Findings of the CVR/FDR technical group

- The CSMU housing had significant gouges and broken mounting points which are consistent with significant impact forces and/or accelerations.
- The examination of the memory board identified multiple failures in the solder joints of the PAL chip which could be indicative of inertial forces significant enough to shift components on the memory board.
- Inertial forces of that magnitude may cause damage to the memory board, the component solder joints, or the components themselves that would not be detectable without more extensive diagnostic capabilities.
- Continued attempts to diagnose, repair and download the FDR memory board require advanced tools, techniques and experience to prevent unnecessary risk to the data stored in the card.

Note:

- Recorder downloading facilities generally fall into four categories: basic, intermediate, advanced, and highly advanced.
  - Advanced category laboratories are those that have researched and developed specialized tools and techniques and assembled teams of experienced personal to recover data from severely damaged electronic devices.
  - Few investigatory organizations have this expertise and those that do only have it for specific devices. The NTSB and BEA are two of these organizations.

B.2 Recommendation

Due to the damage identified on the FDR memory board, which could be indicative of much more significant damage to the board which is very difficult to detect, and the time constraints of an accident investigation the FDR Technical Group recommends that:

i. The group ceases further attempts to diagnose and repair the board. Additional visual and photographic documentation may be made for reference but no other diagnostic work should be performed without specialized equipment operated by personnel with experience working with Honeywell recorder memory boards.

ii. The FDR memory boards to be accompanied with the Egyptian CVR/FDR technical group, packaged and transported to the BEA laboratory or Honeywell for further examination and data recovery attempts.

1.11.1.2 FDR Readout at BEA (FDR memory board)

A. Initial Test Plan

During the examination performed at the EAAID lab, the FDR Technical Group identified several broken solder joints on the PAL chip. Based on the initial results, the following test plan was agreed:

- X-Ray and microscopic examinations.
- Decision on PAL re-soldering.
- In case of PAL re-soldering:
  - Electrical checks to confirm the condition of the board before and after the proposed repairs.
  - Partial memory readout through the header connector in order to verify the internal data structure.
  - RPGSE readout (official readout equipment mean).

B. X-Ray and microscopic inspections

B.1 X-Ray inspection of the PAL

The PAL chip was radio graphed and the following observations were performed:

- The internal die could not be observed as it was made of an internal metallic plate hiding the die and because there was a component located on the opposite side of the board.
- All the internal bonding wires and all the contact pads were inspected and were found in good condition. No fracture was detected.
- All the solder joints were fractured, confirming the initial inspection performed in EAAID lab in Cairo.
- X-Ray examination was also performed at the vicinity of the PAL. It did not show any other damage to the board or to the surrounding components.

B.2 Microscopic inspection of the PAL chip

The microscopic inspection of the solder joints of the PAL chip was performed. The solder joints were confirmed fractured / broken.

B.3 Conclusions

All the solder joints of the PAL chip were fractured. Only the PAL chip was found damaged. The initial working plan agreed was to re-solder the PAL pins as an initial working plan.

C. PAL chip re-soldering

All the pins of the PAL chip were then soldered manually.

The electrical checks performed before and after the PAL re-soldering confirmed the repair and were found in accordance with the expected impedance values.

D. Memory checks

The data structure of the headers of every data block were found correct confirming that the address line signals (from A0 to A25) and the data busses (bus A and bus B) were functional. The results of the data check confirmed that a download could be performed.

E. RPGSE download

RPGSE is the official manufacturer dedicated tool dedicated to the readout of the recorders.

The complete readout chain was first checked using the BEA golden recorder (P/N: 980-4700-042-S/N: 11426).

The FDR memory board was then plugged on the golden chassis (P/N 980-4700-042 S/N: 08995) through the BEA customizable flex. Following the BEA and the manufacturer procedure, the data was downloaded using RPGSE and Playback 32 software.

F. FDR data validation

The downloaded file was transferred on a workstation dedicated to the FDR data analysis. The BEA in-house analysis software detected data frames of 256 words per second.

As agreed by the IIC, a first set of parameters were plotted to check the coding of some selected parameters.

A first overview of a selection of the parameters was then requested by the IIC and the listing of the decoded parameters was transferred, with the raw data file, to the Egyptian CVR/FDR laboratory in Cairo, through a dedicated FTS account.

1.11.1.3 Preliminary results

i. Parameters have been reviewed the period from frame number 83600 (20:06:21 UTC) to frame number 96265 (end of the recording). The duration time of the period is 3:31:05 hrs: min: sec.

ii. Review of the data shows that the last valid information is most probably at frame number 96242 (00:29:45UTC). The last 23 seconds of the recording can be considered as invalid data.

iii. Most relevant FDR parameters were examined, they showed normal behavior except for the following:

- Lavatory smoke was detected, followed by Master warning
- Avionic smoke was detected followed by Master caution
- The longitudinal, lateral and normal accelerations showed abnormal values at the last recorded valid 2 seconds (00:29:44 and 00:29:45).

1.11.1.4 FDR plots

Refer to exhibit A, FDR plots

1.11.2 Cockpit Voice Recorder (CVR)

1.11.2.0 General

- Manufacturer : Honeywell
- Part number : 980-6022-001
- Serial number 120-06094

Crash Survivable Memory Unit (CSMU)

- P/N: 980-6022-001
- S/N: 2200

Note:

CVR data plate of solid state CVR (SSCVR) has not been recovered.

1.11.2.1 Procedures carried out on the CVR in Cairo

A. Work Performed

A.1 External Examination

The CSMU was removed from the container of fresh water and examined. There were no visible markings on the CSMU indicating the part or serial number. The CSMU had damage indicative of significant impact forces The CSMU had damage indicative of significant impact forces including:

- Chips in the paint;
- Significant gouges in the external surface of the CSMU case;
- 2 of the 4 mounting brackets that secure the CSMU to the chassis broken off;
- Shearing of the flex cable between the CSMU and the chassis;
- Absence of the one of two Underwater Locator Beacon (ULB)
- Mounting brackets and the ULB;
- Structural failure of the second ULB bracket

As shown in the following figures.

Figure 1.11/4 : Missing decals, paint chips and gouges in the CSMU

Figure 1.11/5: Two of four mounting brackets missing

Figure 1.11/6 : Sheared flex cable

Figure 1.11/7:ULB bracket failure and the second bracket missing

Figure 1.11/8: Example of undamaged Honeywell 980-6022-XXX recorder

A.2 Removal of the memory boards

The CSMU was opened following the manufacture's procedures documented in "AID to investigators: procedure for solid state CVR and/or FDR data recovery", Honeywell reference document DWG NO: 022-0010 Rev C, and summarized below.

1. The four fasteners attaching the cover plate to the CSMU were observed to be tight and without structural damage. They were removed. One of the fasteners was corroded and was removed with the help of vice grip pliers.
2. The cover plate and the 4 hold down latches were removed.
3. The insulation end plug was removed to expose the memory CCA, while preserving the remaining part of the flex cable.
4. The heat absorbing powder around the memory was observed to be wet with a consistency of paste.
5. The memory boards were stuck inside the chassis.
6. Additional insulation around CSMU was removed as necessary to free the memory boards.
7. The RTV covering the memory boards was observed to be in good shape, without indications of thermal or structural damage.

The memory boards were then stored in an ESD container and the working area was then cleaned. ESD protections were applied for the remainder of the work documented in this report.

The RTV was removed from the boards according to the manufacturer's procedures. Droplets of water were found inside the RTV. An initial visual inspection was performed and there were no obvious signs of thermal or structural damage to the board. The determination was made that it would be safe to continue the data recovery process by drying the memory board.

A.3 Drying process

The Technical Research Center of the Armed Forces provided access to one modern climatic chamber to perform the drying process. Two investigators witnessed the complete drying process. The heating profile was the following:

- From ambient temperature to 60°C, increase of the temperature with a rate of 2 °C per minute
- Stabilize the temperature at 60°C during 8 hours. The climatic chamber

provided a stabilization of the temperature at 60°, +- 0.1 °C.

- Decrease of the temperature gradually back to ambient.

The climatic chamber temperature was monitored by 2 additional independent sensors. The heating profile was accomplished without any anomalies.

A.4 Electrical checks

The flex cable between the CSMU and the chassis is an intentional structural and thermal weakness designed into the SSCVR to help protect the memory of the CSMU from inertial and thermal damage. It is designed to be broken outside the CSMU in the event that the CSMU breaks free of the chassis during the accident sequence or burned away in the event that the recorder is subjected to a post-crash fire. As noted above, the CSMU separated from the chassis during this accident and severed the flex cable. When the flex cable is damaged in this way, there is a possibility that the copper traces in the damaged end of the flex cable could come in contact with each other creating short circuits and prevent the recorder from downloading properly and/or damage the stored data. There are two processes to prevent and test for this problem.

The first process is cutting away the end of the flex cable and polishing it to ensure the cutting process did not create shorts between the copper traces. The flex cable of the CVR was trimmed and polished.

The second process is a series of electrical impedance tests conducted on the boards. Because this recorder has 2 boards, the factory installed connector normally used to attach an additional flex cable to a single memory board for downloading in the event of an accident cannot be used and a specially created jumper board must be used.

A jumper board was provided by the BEA and used to re-connect the two memory boards. The electrical check was performed on the flex connector pins of the jumper board using reference values provided by Honeywell. These electrical checks highlighted a short circuit between pins 12 and 13 and an impedance between pins 1 and 25 (Ground and Vcc, respectively) that was too low. The boards were then disconnected from the jumper board and electrical checks were performed individually. The board with the flex cable attached (board 2) passed all the tests.

The board without the flex cable attached (board 1) showed the previously detected discrepancies. Honeywell was contacted for advice about these discrepancies.

A.5 First check proposed by the manufacturer

The manufacturer proposed a check of all the capacitors. No measurement was significantly lower than the others. Therefore no capacitor or section of the board could be identified as the possible location of the problem.

A.6 Localization of the short between pins 12 and 13

Honeywell provided the group with the schematic of the board. Pins 12 and 13 of the connector were connected to pins 40 and 41 of the U29 chip. It was also noted that pin 42 of U29 was connected to the Vcc signal. Because these three pins are all closely tied to both discrepancies detected with the impedance tests, special examination and cleaning was performed on this area of the board. The RTV was carefully removed from pins 39 to 48. Then this part of the board (header, up to a level including the chip U29) was immersed into an ultrasonic bath of ethyl alcohol to attempt to eliminate any salt that may have been causing the problems.

After 10 hours in bath, the board was removed and left at the ambient temperature for 2 hours to remove all the alcohol moisture.

The board was then examined with the electronic microscope. The effects of the bath were clearly visible on the pins of the chipset U29. A new electrical check was then performed:

- Pins 12 and 13 were still shorted.
- The impedance between ground and Vcc reached 3 k Ω, a value more consistent with the expected test results.

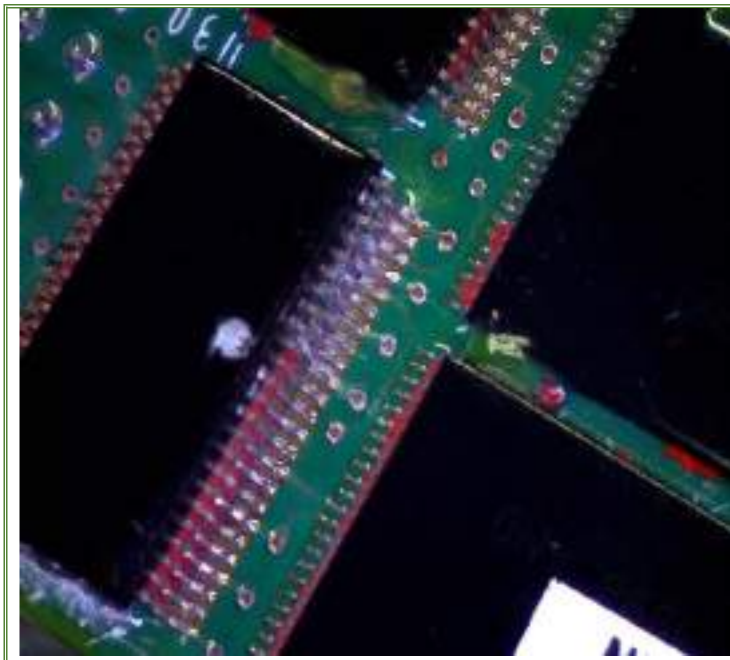


Figure 1.11/9: Chip U29 pins 39 to 48 before bath

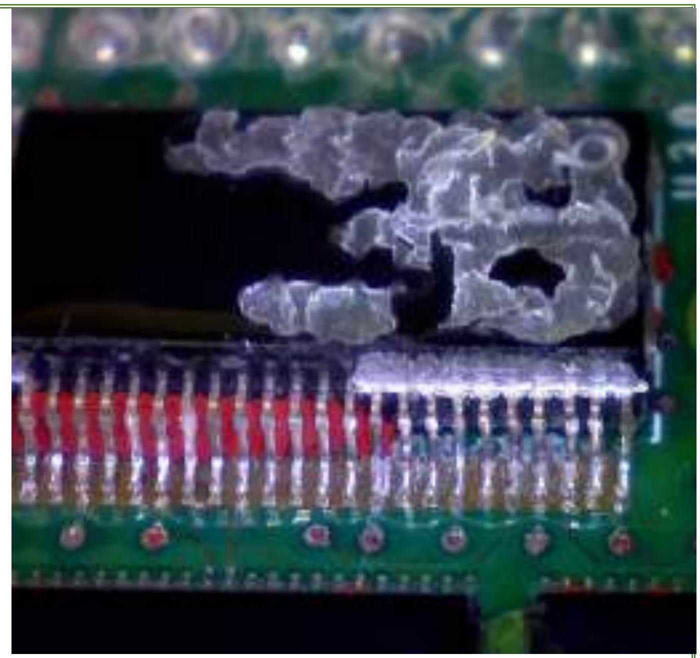


Figure 1.11/10: Chip U29 pins39 to 48 after bath

B. Findings and recommendation of the CVR/FDR Technical Group

B.1 Findings of CVR/FDR Technical Group

- The CSMU housing had significant gouges and broken mounting points which are consistent with significant impact forces and/or accelerations.
- The electrical examination of the main memory board (board 1) identified a short, the cause of which could not be determined at this time.
- The electrical examination of board 1 also identified a lower than normal impedance value between ground and Vcc which appears to have been cleared by the additional cleaning techniques applied to the board.
- Continued attempts to diagnose, repair and download the SSCVR memory boards require advanced tools, techniques and experience to prevent unnecessary risk to the data stored in the boards.

Note:

- Recorder downloading facilities generally fall into four categories: basic, intermediate, advanced, and highly advanced

– Advanced category laboratories are those that have researched and developed specialized tools and techniques and assembled teams of experienced personal to recover data from severely damaged electronic devices.

– Few investigatory organizations have this expertise and those that do only have it for specific devices. The NTSB and BEA are two of these organizations.

B.2 Recommendations

Due to the failure identified on the SSCVR memory board 1 and due to the limited amount of time to avoid potential degradation of the board, the CVR Technical Group recommends, to speed up the process, that:

1) The group ceases further attempts to diagnose and repair the board. Additional electrical, visual and photographic documentation may be made for reference but no additional diagnostic work should be performed without specialized equipment operated by personnel with experience working with Honeywell recorder memory boards.
2) The CVR memory boards be packaged and transported to the BEA laboratory or Honeywell for further examination and data recovery attempts.

1.11.2.2 CVR Readout at BEA

A. CVR Memory Board #2 (board with the flex cable)

A.1 Test plan

During the inspection performed in Cairo, the CVR Technical Group did not identify failures on the CVR board #2.

Based on the initial results and discussions, the following test plan was agreed:

– Electrical checks to confirm the condition of the board.
– Memory chips readout and file reconstruction.

A.1.1 Flex examination

Following the recommendation of the CVR Technical Group, the flex cable of the CVR board was polished with the LaboPol-5 polishing machine. The polished edge of the flex was inspected under magnification to check that no short circuit existed between the signal layers.

A.1.2 Electrical checks

The electrical check confirmed the examination performed by the CVR/FDR Technical Group at Cairo: no discrepancy was found on the board #2.

A.2 CVR board #2 readout

All the memory chips of the CVR board #2 were readout with the BEA memory reader through the header connector. Each memory chip was addressed and its content was downloaded. The data structures of the header of the blocks were checked and were consistent. The specific BEA reconstruction software was used to rebuild the DLU file containing the mixed band as if the file was downloaded from RPGSE. The resulting file was provided to the IIC.

The EAAID performed the file decompression in the CVR specific room and the IIC confirmed that the data related to the event was recorded and that the duration of the audio file was consistent.

B. CVR Memory Board #1 (board without the flex cable)

B.1 Initial test plan

Following the examinations of the CVR Technical Group performed in Cairo and the preliminary inspection performed at BEA, the initial plan was as follows:

- Dry the board.
- Replace the transceivers U29, U32 and the resistor R2.
- Perform electrical check before and after the replacement to confirm the repair.
- Readout and check the data structure of the content of the memory chips.
- Perform the complete download of the CVR using board #1 and board #2.
- Check the audio file by the IIC.

B.2 X-Ray and microscopic inspection

The x-ray inspection confirmed that U29 was cracked. The transceiver U30 was also checked and no failure was found:

- The R2 resistor was found broken.
- A fracture was found on the chip U32.
- All the passive components (resistors and capacitors) of the CVR board#1 were also checked.
- The following components showed surface scratches:
  - Resistor R1.
  - Capacitor C15, C16, C18, C25, C27, C31, C33.

B.3 CVR board#1 re-works

B.3.1 Drying process

The drying process applied to the CVR board lasted approximately 40 hours at 90°C.

B.3.2 Removal of U29 and U32

The following process was applied on U29 and U32 components

– The epoxy glue present on the components was removed with a temperature controlled iron.
– The pins were cleaned with a fiber glass pen.
– The components were removed with the WQB3000 unsoldering machine.
– Similar components were manually soldered on the board.

B.3.3 Replacement of passive components

The broken R2 resistor was removed as well as R1, C15, C16, C18, C25, C27, C31, and C33 as they showed surface scratches. They were all replaced by similar components.

B.4 CVR board #1 check

The CVR then passed the electrical check. The communication with the memory chips was tested: the data structure of a selected number of memory chips was performed with the BEA memory reader (same process than the one used for the FDR board). It allowed verifying most of the signal lines. The board was then plugged onto the Honeywell test bench to verify that the communication of with all the memory chips was functional. No data was downloaded during this process.

B.5 CVR readout

Both CVR boards were then connected to the BEA connection board and plugged through the BEA customizable flex to the proper golden chassis (P/N 980-6022-001,S/N CVR120-13393). The readout was then performed with RPGSE, following the BEA procedure based on the manufacturer procedure. The downloaded raw file was provided to the Egyptian team to check the result of the download on EAAID lab computer (decompression phase and listening session).

1.11.2.3 CVR transcript

Refer to exhibit B "CVR transcript"

1.12 Wreckage and Impact Information

1.12.1 Maritime Search of the aircraft wreckage

- Complete coordination had been established with the Navy Force Commanders, Armed forces Operation Center, Search and Rescue Center, in order to send the Egyptian navy vessels to secure the rescue and search area, and to search for the wreckage that might be floating on the Mediterranean Sea water surface for the event flight.
- The location for the aircraft impact probability area with the Mediterranean Sea was determined, based on the radar records covering the flight path area, and based on received signal originating from the (Emergency Locator Transmitter).
- A plan view was drawn for the wreckage area based on BEA experience, using the information about the places where the floating wreckage was found, and the location where the aircraft disappeared from the radar screen that was covering the flight, in addition to the signal that was received and originated from the Emergency Locator Transmitter (ELT).

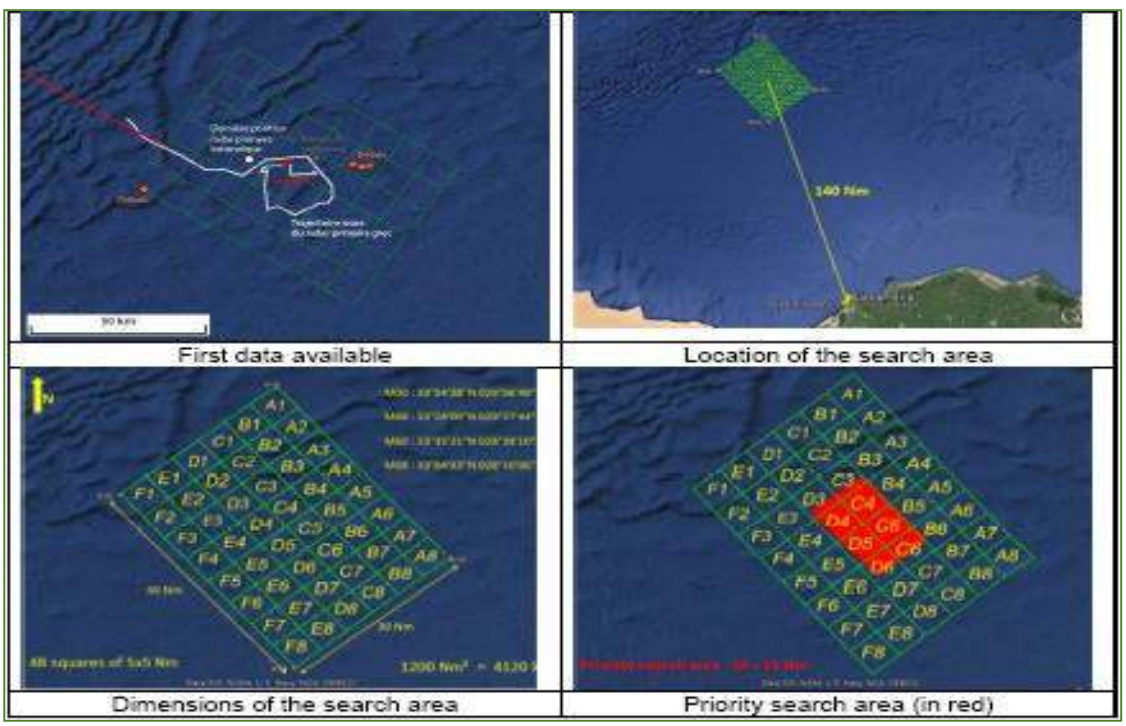


Figure 1.12/1: Wreckage Area Map

- The wreckage area was conclusively determined using the Hydrophone Scan within the equipment of ALSEAMAR Company, carried by the ship Laplace which participated in the search work the time between 31/05/2016 to 15/06/2016.
- On 10/06/2016, the vessel John Lethbridge that is leased by the Egyptian government to perform the search and recovery for the wreckage using the equipment of Deep Ocean Search DOS Company carried on board arrived to the search area.

Figure 1.12/2 : Deep Ocean Search Team at Alexandria port

- Some areas that were expected to find the wreckage into them were found, using Side Scan Sonar equipment at a frequency of low accuracy 30 KHZ, then using the frequency of high accuracy 100 KHZ to validate the information about wreckage location.
- On 13/06/2016 a signal was received from an Underwater Locator Beacon ULB for one of the Fight Recorders.

- Some theoretical computations had been performed, based on the scanned pictures of the "Side Scan Sonar", to confirm the location of the Underwater Locator Beacon ULB. The location was confirmed to be at 33° 28.170N 29° 15.349 E.

1.12.2 Recovery of the two Flight Recorders from the bottom of the sea

- On 15/06/2016 at time 01:00 Cairo local time, an ROV unit was lowered at the location where signal was originated at C5 square.
- To do that, the ship was moved to stop over the mentioned square to drop the ROV for the purpose of recovering one of the aircraft Flight Recorders. A part of the fuselage was found (AFT right side fuselage part) with part of the aircraft tail section.
- The above mentioned part was moved for the purpose of finding the Underwater Locator Beacon ULB. The ULB was not found, therefore the ROV was raised.
- At 23:15 Cairo Local Time, 15/06/2016, an unsuccessful trial was done by the ROV unit to recover the ULB unit.
- At 09:45, 16/6/2016, a memory unit for one of the aircraft Flight Recorders was located at a depth of 3020 Meter from the sea surface at the site C28 by use of the video facility that is presented on the ROV unit screen, immediately all communications with the ship has been inhibited for two hours. The head of the investigation committee has been contacted timely to inform him about that.

Figure 1.12/3: The memory unit belonging to one of the aircraft flight recorders at the depth of 3020 meter from the sea surface

- The CSMU memory unit for one of the aircraft flight recorders was recovered and transferred to Alexandria at 21:00, 16/06/2016.

Figure 1.12/4: The CSMU memory unit belonging to one of flight recorders after being recovered.

- At 23:50, 16/06/2016 the ROV was lowered reaching the bottom of the sea at 01:15 following day (17/06/2016). At 03:10, The CSMU memory unit belonging to the second flight recorder was located at a depth of 2960 meter from the sea surface.
- Procedures were made to inform the head of the investigation committee and all communications to and from all personnel onboard were inhibited.

Figure 1.12/5: The memory unit belonging to one of the aircraft recorders at the depth of 2960 meter from the sea surface

– The second CSMU memory unit for the aircraft recorders was recovered and transferred to Alexandria at 11:45, 17/06/2016.

Figure 1.12/6: The CSMU memory unit belonging to one of the aircraft recorders after being recovered

– After the completion of the recovery of the two memory boards, the stage for drawing a "Systematic Visual Search Map" for the wreckage at the bottom of the sea was started. The ROV was lowered for 8 times within 5 days the period from 17/06/2016 to 21/06/2016.

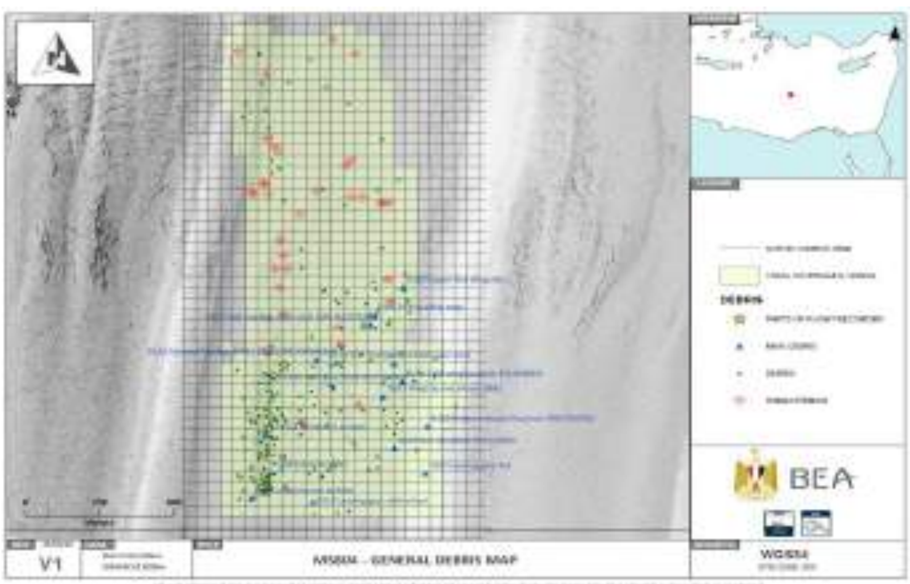


Figure 1.12/7: Systematic Visual Search Map

The Wreckage recovery priority rectangle was 1.2 km by 525m. Other aircraft parts existed outside this rectangle.

Starting from 21/06/2016, the ROV unit was lowered for the purpose of recovering the wreckage.

The wreckage was recovered through 7 rounds within 4 days. 21pieces of the aircraft wreckage were recovered.

Refer to Exhibit C

1.12.3 Recovered Debris inspection

All wreckage debris at custody area have been inspected by the investigation committee.

They were divided into two categories:

- CAT I: Particles (fragmented floating wreckage) that were kept inside 10 bags.
- CAT II: 21 big parts.

Figure 1.12/8: Wreckage Debris at Custody Area

The following procedures were followed:

A. Identification for each wreckage debris part and capturing photos from different views.

B. All wreckage debris parts (318) have been categorized as follows in the table.

Serial	Category	No of parts
1	Fuselage Parts	101
2	Aircraft Furnishing	80
3	Portable Parts	28
4	Personal Belongings	109
Total	318	

Remarks on parts:

While inspecting wreckage debris, some remarks were identified on thirteen parts as follows:

Serial	part	Identification No.	Category	Remarks	Part photo
1	Life Jacket	1/12	Portable parts	Used	
2	Black cloth seems to be like crew baggage	17/12	Personal belongings	Affected by heat	
3	A small piece of cargo floor panel with dimensions of 13 cm * 30 cm	3/11	Fuselage parts	Affected by load	

4	Cabin seat headrest	19/11	Aircraft furnishing	Affected by heat	
5	A set of head rest covers	20/11	Portable parts	Affected by heat	
6	Part of cabin seat	21/11	Aircraft Furnishing	Affected by heat	
7	A back pack with a portable hard disk and a piece of fiber stuck in it	7/13	Personal belongings	Affected by heat	

8	Two sides of two trolleys along with a part of galley composite material	1/4	Portable parts	Deformation on trays holders	
9	Trolley side	2/4	Portable parts	Deformation on trays holders	
10	Bag	2/17	personal belongings	Affected by heat	
11	A lower part of business class seat	6/9	aircraft furnishing	Affected by heat	

12	Part of lavatory/galley panel	8/5	aircraft furnishing	Slight heat effect	
13	Forward fuselage with static part	37	fuselage parts	Fuselage skin rolled out and curled outward/forward	

1.12.3.1 Matching two big wreckage parts with a same make and model aircraft

		
RHS FWD fuselage part with STBY static port	RHS FWD fuselage part with STBY static port	RHS FWD fuselage part with STBY static port

		
RHS FWD fuselage part with STBY static port	RHS FWD fuselage part with STBY static port	RHS FWD fuselage with static port

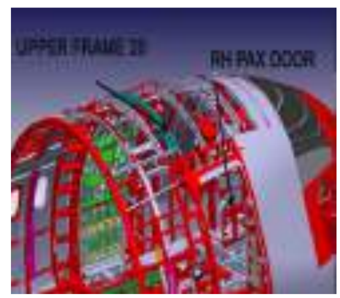
Figure 1.12/9: Matching two big wreckage parts with a same make and model aircraft

1.12.3.2 Pieces of special interest

Photos for five pieces were arranged beside each other, it includes the underwater, on deck, at the hanger and its position on aircraft.

- Piece 1

Description	Upper Central Segment of frame 20
No.	21
Diving no.	D2

			
Part shape underwater (Airbus)	Part shape recovered on deck (Airbus)	Part shape at hangar	Part position on the aircraft. (Airbus)

Location on wreckage Cartesian map	G20

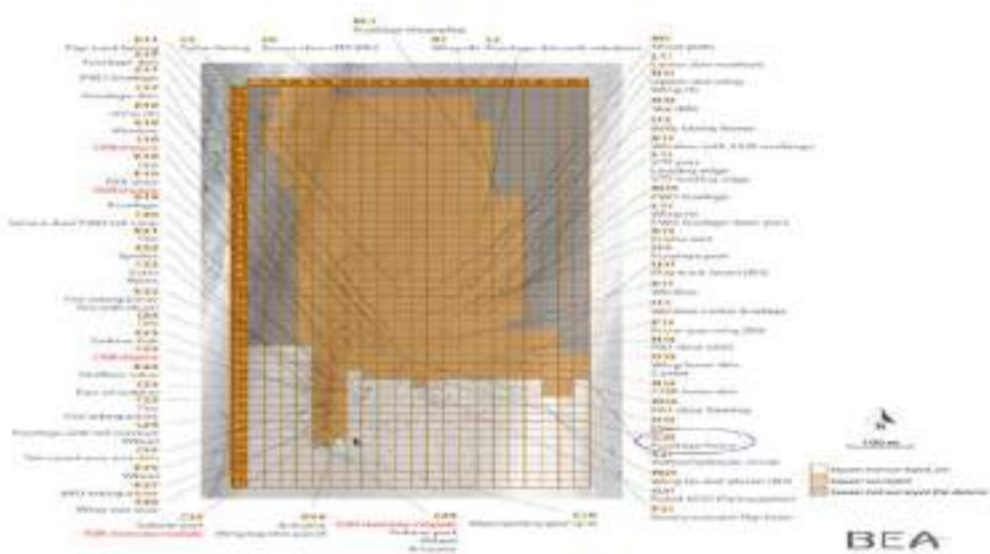
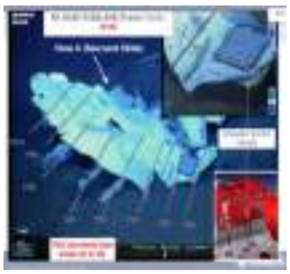
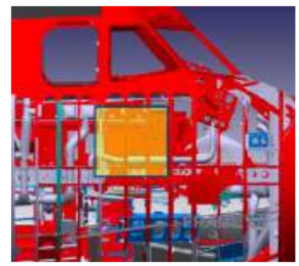


Figure 1.12/10: Upper Central Segment of frame 20

Part/ piece position on the aircraft	- Upper central part connecting the two aft edges of left and right passenger door.
description	A part of aircraft frame with the dimensions of 190 cm ×15 cm consisting of flange-web-flange
Remarks on piece/ Part	- The original crescent shape has deflected backward out of its original vertical plane. - A bend was found in the center and edge. - a change in the original metal color was identified on both edges

- Piece 2

Description	Forward fuselage part with stand by static port
No.	31
Diving no.	D4
Location on wreckage Cartesian map	L14

			
Part shape underwater (Airbus)	Part shape recovered on deck (Airbus)	Part shape at hangar	Part position on the aircraft. (Airbus)

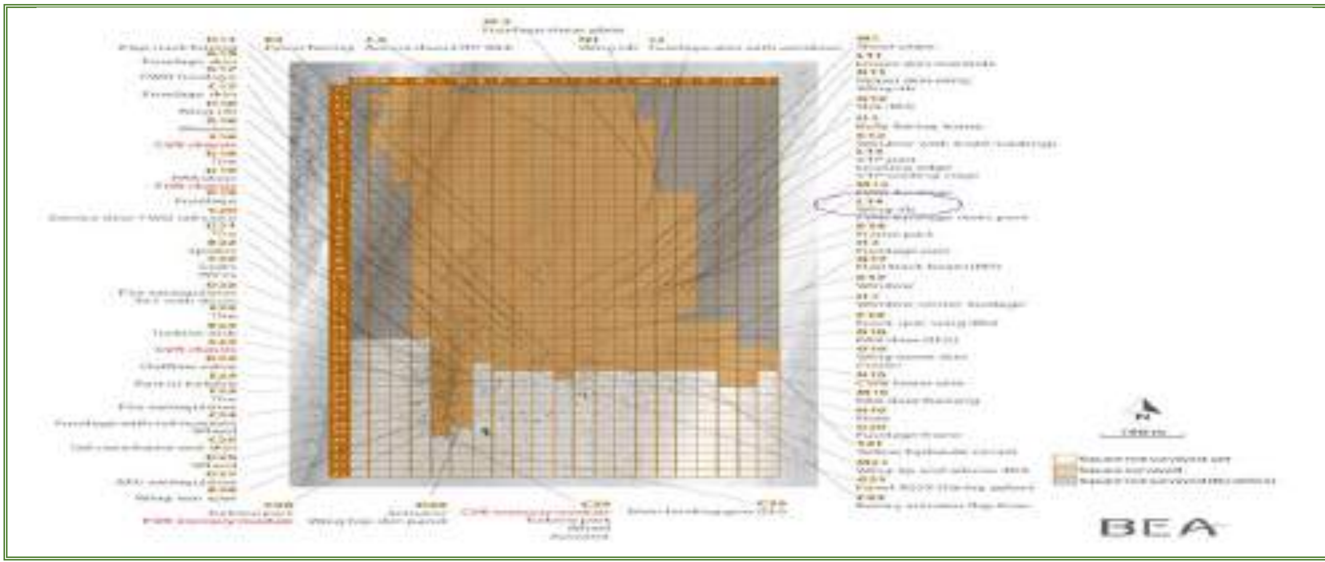


Figure 1.12/11: Forward fuselage part with stand by static port

Part/ piece position on the aircraft	The part is located on the outer part of the aircraft right side in the cockpit beside First officer seat from frame 3 to frame 8.
description	Fuselage metal part with the dimensions of 143 cm×106 cm consisting of skin, stringers, and frames. It includes the rear (support) of the outer frame of the sliding window, it includes part of the stringers cockpit floor panel as well, moreover, stringers of equipment compartment and part of the stand by static part of the air pressurization.
Remarks on piece/ Part	- Stringers /frames deformed outward in a backward direction. - Electric cables with their isolation layers seemed to be normal (No apparent heat effect) - A puncture was identified in the middle of the part. - All edges were torn off. Different and dark spots were noted in the internal lower part.

- Piece 3

Description	Forward fuselage with static port
No.	37
Diving no.	D2
Location on wreckage Cartesian map	G17

			
Part shape underwater (Airbus)	Part shape recovered on deck (Airbus)	Part shape at hangar	Part position on the aircraft (Airbus)

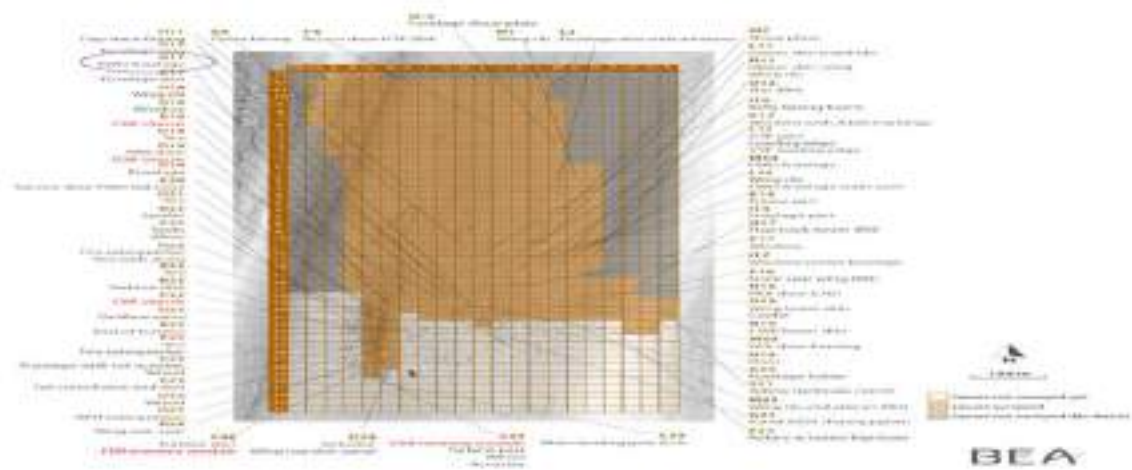


Figure 1.12/12: Forward fuselage with static port

Part/ piece position on the aircraft	right side of the aircraft from frame 23-frame 25
description	Metallic part with the dimensions 74 cm× 61 cm of the fuselage consisting of skin and stringers
Remarks on piece/ Part	- Outward deformation of the forward edge skin. - Front lower corner of part rolled outward with dark color on the internal side. - All edges are torn off except the back edge.

- Piece 4

Description	Food trolley
No	1/4
Diving no.	Recovered floating part
Location on wreckage map	None

	
Part shape at hangar	Part position on the aircraft Note: Photo to demonstrate trolleys color

Figure 1.12/13: Food trolley

Piece/ Part Location on the aircraft	Portable part which is uploaded on board in order to keep and serve meals for passengers and crew, catering is prepared at galley.
description	A part consisting of two sides of two trolleys and part of the galley composite wall twisted harshly all together with the dimensions 50cm×30cm, the sides of the trolleys are made of composite material covered with metallic layer. It has side tray tracks to accommodate food trays.
Remarks on piece/ Part	– Apart twisted harshly. It was folded inside out to the extent that it lost its structure. – Tray tracks were twisted and flattened. They lost the purpose they were made for by diminishing the side tray tracks.

- Piece 5

Description	RH forward passengers door
No	25
Diving no.	D1

		
Part shape underwater	Part shape at hangar	Inner side

Part position on the aircraft

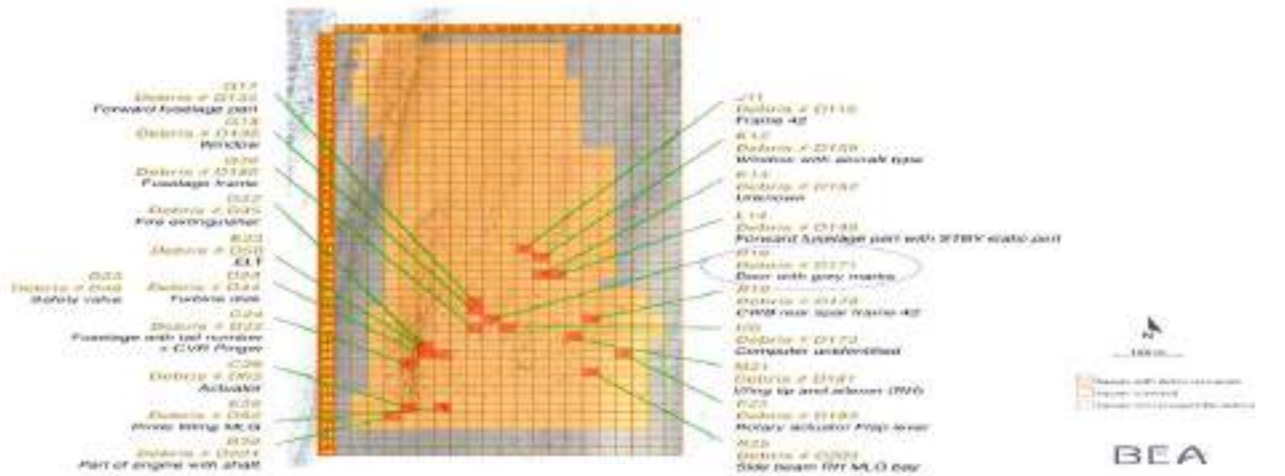


Figure 1.12/14: RH forward passengers’ door

piece/ Part Location on the aircraft	Door (1R)
description	Upper third part of the FWD RHS PAX door.
Remarks on piece/ Part	Almost two thirds of the FWD RHS PAX door lower part was torn away and missing. The piece shows buckling outwards in 2 locations. Inner side of the remaining part shows dark spots. With exit sign in red color.

1.13 Medical and Pathological Information

On 26th June, 2016, after mutual co-ordination between the Egyptian and the French side, the human remains started to be recovered from the wreckage site utilizing DOS system which was set upon John Lethbridge ship. Experts from Forensic Medicine Department of the Ministry of Justice, Egypt together with French experts from the French Forensic Medicine Department, in addition to Egyptian investigators were on board as follows:

- The action plan started with performing a survey on the wreckage site as identified upon the wreckage map using ROV device at the Mediterranean seabed.
- After dropping the device for 32 times through 18 days (which was supposed to end on 15 July 2016), the mission of John Lethbridge vessel was extended until 18 July 2016 to ensure that no human remains had been left behind.
- The human remains which had been recovered were kept at a specific refrigerator container to reserve them and was sent to the Forensic Medicine Department in Cairo.
- On 28 November 2016, the Head of the Technical Investigation Committee received the forensic reports concerning the human remains of the aircraft accident victims.
- The reports stated that traces of highly explosive materials were found on the victim's human remains.
- The Head of the Technical Investigation Committee presented the reports to the committee members.
- With reference to The Egyptian Civil Aviation Law, article 108 and Annex 13 to the Convention of International Civil Aviation Organization (ICAO), item 5-11, it is imperative to inform the General Prosecution in case it is suspected, that an act of unlawful interference was involved.

Exhibit D "Summary of Forensic Medicine Report Regarding the victims remains"

1.14 Fire

1.14.1 Debris Parts Inspection

Inspection of the wreckage parts that were recovered from seabed indicated that some of them were exposed to thermal effects as stated in item 1.12 " Wreckage and Impact Information " of this report as follow:

Serial	Part	Identification No.	Category	Remarks	Part photo
1	Black cloth seems to be like crew baggage	17/12	Personal Belongings	Affected by heat	
2	Cabin seat head rest	19/11	Aircraft Furnishing	Affected by heat	
3	A set of head rest covers	20/11	portable parts	Affected by heat	
4	Part of cabin seat	21/11	aircraft furnishing	Affected by heat	

5	A back pack with a portable hard disk and a piece of fiber stuck in it	7/13	personal belongings	Affected by heat	
6	Bag	2/17	personal belongings	Affected by heat	
7	A lower part of business class seat	6/9	aircraft furnishing	Affected by heat	
8	Part of lavatory/galley panel	8/5	aircraft furnishing	Slight heat effect	

1.14.2 Cockpit Voice Recorder (CVR)

Cockpit Voice Recorder (CVR) transcript included the word "Fire" and the request of a fire extinguisher as illustrated in the following Table:

No.	Time (UTC)	Speaker	Statement	Translated
1	00:25:30	First officer	Fire Fire	
2	00:25:31	Cabin Attendant (female)	Fire	
3	00:25:32	Pilot In Command	Fire	
4	00:25:35	Pilot In Command	الطفاية الطفاية بسرعة هات الطفاية بسرعة	Extinguisher, extinguisher quickly Bring the Fire extinguisher quickly
5	00:25:40	Pilot In Command	fire الطفاية بسرعة	Fire extinguisher quickly, fire

1.14.3 Flight Data Recorder (FDR)

The extracts from Flight Data Recorder (FDR) indicated the following warnings:

No.	Time (UTC)	Parameter
1	00:26:14	Lavatory Smoke
2	00:27:00	Avionics Smoke
3	00:29:35	Cargo Smoke

1.14.4 AIRMAN Messages

AIRMAN Messages indicated the following:

No.	Time (UTC)	Message
1	00:26:38	Smoke Lavatory Smoke
2	00:27:16	Avionics Smoke

1.14.5 Forensic Medical Report

It was stated in the forensic medical report that the visual inspection of human remains samples under test indicated the presence of fire traces on some human remains and some solid particles stuck in it.

1.14.6 Triple Committee Report

The Egyptian general prosecution formed a committee headed by a forensic evidence expert and included two experts, an aviation expert and a forensic medicine expert. This committee will be referred to as the triple committee in the following context (refer to item 1.18.3).

A. Thermal effect were apparent on some debris as follows:

1. Upper central part connecting the two aft edges of left and right forward passenger door (Frame 20).
2. The part is located on the outer part of the aircraft right side in the cockpit beside First officer seat from frame 3 to frame 8.
3. Right side of the aircraft from frame 23 to frame 25.
4. Outer part of right front passenger door with exit sign.
5. Small particles of catering trays found on right inner part of aircraft right front door.

B. The report stated that the minor fire traces is due to that fire continued until oxygen was consumed.

1.15 Survival Aspects

- No Survivors.

1.16 Test and Research

1.16.1 Inflight F/O oxygen mask microphone flow test

In flight test has been carried out by using similar aircraft type of the accident aircraft to check the F/O oxygen mask microphone flow sound and download it for comparison.

- Test Objective:

To compare test flight CVR recordings of oxygen flow sound and wave form in four cases with the hissing sound that was heard through the accident flight cockpit voice recorder CVR .

To compare ambient noise heard on cockpit speakers with the noise recorded in the CVR of the test flight.

Case No.1:

- The procedures:

Press the Test/Reset push button on the oxygen box door.

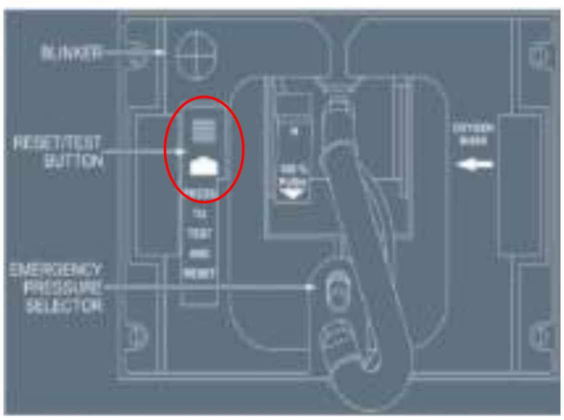


Figure 1.16/1: Test/Reset push button on the oxygen box door

Figure 1.16/2: Wave forms from test CVR recording (case no.1)

Figure 1.16/3: Wave forms from MSR804 CVR recording

The results:

1. Oxygen flow sound was heard.
2. On test CVR the oxygen flow sound was heard on channel 2 (F/O).

Case No.2:

The procedures:

1. Press the press to Test/reset push button on the Oxygen box door.
2. Set the knob on Emergency position (simultaneously).

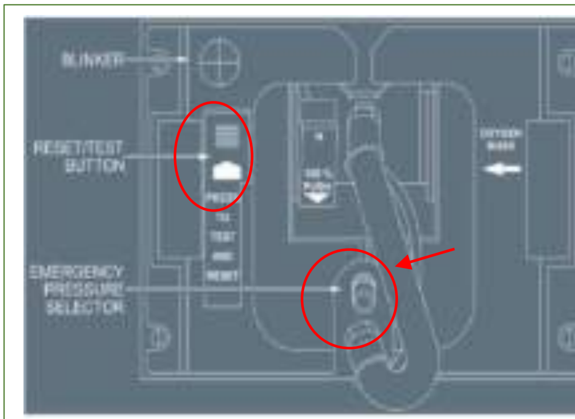


Figure 1.16/4: Test/Reset push button and Emergency knob on the oxygen box

 Figure 1.16/5: Wave forms from test CVR recording (case no.2)	 Figure 1.16/6: Wave forms from MSR804 CVR recording

The results:

1. Oxygen flow sound was heard
2. On test CVR the oxygen flow sound was heard on all channels

Case No.3:

The procedures:

1. Open oxygen box left door.
2. Set the knob on Emergency position.

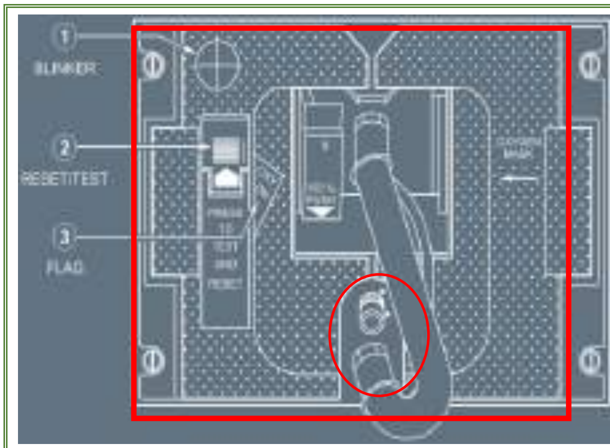


Figure 1.16/7: oxygen box left door and Emergency knob

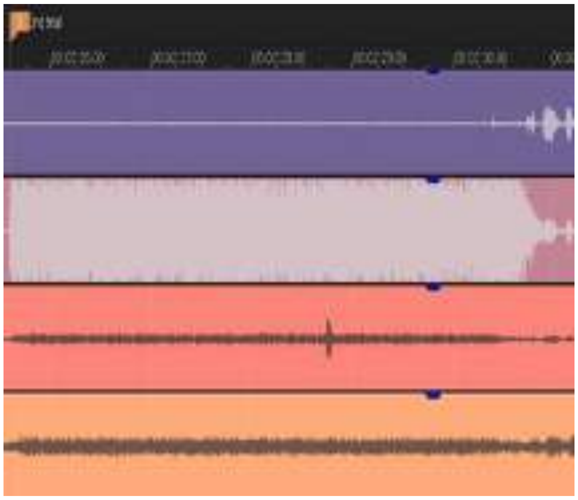


Figure 1.16/8: Wave forms from test CVR recording (case no.3)

Figure 1.16/9: Wave forms from MSR804 CVR recording

The results:

1. Oxygen flow sound was heard clearly on channel 2(F/O)
2. Oxygen flow sound was heard weak(low intensity) on channel 1,3,4 (Captain , third occupant and area mic)

Sound of MS 804 is similar to the sound of case 3 in all its four channels.

Case No.4:

The procedures:

1. Close oxygen box door, but not reset.
2. Press the knob on Emergency position.

Figure 1.16/10: Emergency knob

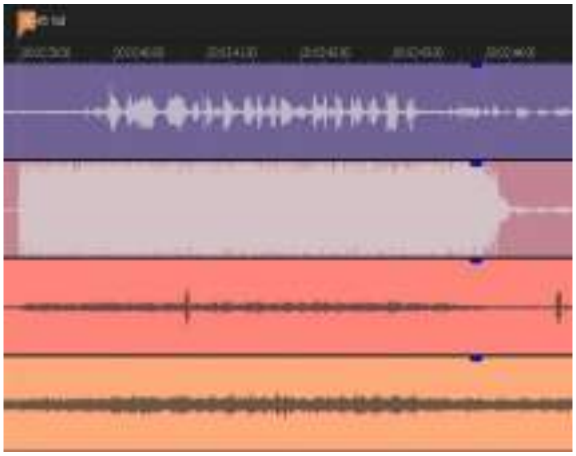


Figure 1.16/11: Wave forms from test CVR recording (case no.4)

Figure 1.16/12: Wave forms from MSR804 CVR recording

The results:

1. Oxygen flow sound was heard clearly on channel 2(F/O)

2. The oxygen flow sound was heard weak(low intensity) on channel 1,3,4 (Captain, third occupant and area mic)

Conclusions:

After comparing recorded 4 channels oxygen flow sound and wave form of every case of the 4 cases with the hissing sound in the 4 channels of MSR804, it was found that:

1. The sound of oxygen flow heard on the inflight test (three cases 2, 3, 4) is similar to the hissing sound of MSR804 CVR recording in which the knob was set to emergency position.
2. By comparing all the four channels for case no.3 with the hissing sound for the four channels in the MSR804 CVR recording found similarities in wave form and sound intensity.
3. Sound of MSR804 is similar to the sound of case no.3 (Open oxygen box door, the knob on Emergency position) in all its four channels.
4. Ambient noise recorded clearly in the CVR but was not heard on cockpit speakers.

1.17 Organizational and Management Information

1.17.1 The operator

EgyptAir company was established in 1932. It consists of group of companies that includes EgyptAir Airlines, EgyptAir Maintenance and Engineering besides other companies that supports airline operations. EgyptAir airlines provides commercial passenger and cargo transportation services.

At the time of accident EgyptAir Airbus A320 fleet included 13 aircraft.

1.17.2 EgyptAir Airlines Company

The organizational structure of the airlines include flight operation, maintenance, safety and quality, commercial and cabin crew. The flight operation includes crew planning, training, IOCC, technical research and chief pilots.

The company is headquartered in Cairo, Egypt. Cairo International Airport is the base for its operations.

The company joined the Star Alliance in July 2008, and its aircraft reach destinations in 195 countries around the world (Europe, Africa, the Middle East, Asia, United States).

1.17.2.1 Accreditations and Certificates

The company holds an air operations certificate (AOC) in compliance with all requirements of the Egyptian Civil Aviation Authority (ECAA).

The company holds accreditations for quality, safety, occupational health and environment as follows:

ISO 9001/2015 certificate for the quality management system.

ISO 14001/2015 certificate for the environmental management system.

ISO 45001/2015 certificate for the occupational health and safety management system.

- The company hold the (IOSA) certificate starting from 2004 till 2016.
- The company hold the (ISAGO) certificate starting from 2008 till 2016.

1.17.3 EgyptAir Maintenance and Engineering

EgyptAir Maintenance and Engineering Company provides technical services for EgyptAir Airlines and other customers according to maintenance programs approved by the manufacturer inside and outside Egypt. The company provides:

- Maintenance services before aircraft take-off (Pre Departure Check PDC) and after landing (after landing check ALC).
- Periodic inspections and overhauls of aircraft.
- Maintenance, repair and overhaul of aircraft parts and engines.

1.17.3.1 Accreditations and certificates

EgyptAir Maintenance and Engineering Company holds international accreditations for the maintenance of aircraft and their parts (including the model of the accident aircraft) from the following entities:

- Egyptian Civil Aviation Authority.
- European Aviation Safety Agency (EASA).
- Federal Aviation Administration (FAA).
- And more than 20 civil aviation authorities in other countries.

The company has been accredited by the aforementioned authorities and carries out its business in accordance with the requirements of the legislation relevant to each accreditation.

- The company passed the inspections of:
  - IATA Operational Safety Audits (IOSA).
  - International Organization for Standardization (ISO).
  - Occupational Health and Safety Audit and Certification (OHSAS).

1.18 Additional Information

1.18.1 The BEA Study

On 20th October 2023 the investigation committee received from the BEA a study concerning the oxygen fires in cockpit **(Exhibit E).**

1.18.2 Summary of Egyptian Public Prosecution memorandum

On 28/11/2023, the Egyptian Public Prosecution issued a memorandum regarding the case under investigation, the memorandum was summarized as follows:

- The Egyptian A320 aircraft, flight no. MSR804, departed from Charles de Gaulle Airport in France to Cairo Airport. It disappeared from radar screens of Greek air traffic control, and communication was lost 10 Nautical Miles after entering Egyptian Airspace, after crossing KUMBI fix, the boundary point between Greek and Egyptian FIR.
- Persons on board were 66 in total. They were 29 Egyptian, 14 French, 2 Iraqi, 1 British, 1 Belgian, 1 Kuwaiti, 1 Saudi, 1 Sudanese, 1 Chadian, 1 Portuguese, 1 Algerian, 1 Canadian, 1 Palestinian (holding Egyptian travel document), 1 French refugee residing in France (holding French travel document), 7 crew members and 3 company security personnel.
- The aircraft took off from Cairo Airport to Charles de Gaulle Airport in France and stayed on ground for an hour and ten minutes, where cleaning, fuel supply, and technical inspection were carried out by an EgyptAir for Maintenance and Engineering’s technician. Then the aircraft took off to Cairo.
- Security personnel from MCTX French Security Company secured the aircraft while being ground serviced at Charles de Gaulle Airport in accordance with the contract with EgyptAir.
- Forty-five minutes before arriving at destination, communication was lost between the aircraft and the Greek air traffic control and it disappeared from radar screens.
- The Egyptian air traffic controller on-duty was called up by Greek air traffic controller informing him that the communication with the aircraft had been lost approximately 20 miles before entering Egyptian Airspace, despite previously being seen to be flying at an altitude of 37,000 feet and at a speed of 500 knots.

- The Captain of, Flight No. 803, Cairo-Charles de Gaulle, reported that there was no technical defects, and he signed the technical log book, while the First officer of the flight confirmed the Captain statement.
- The Chairman of EgyptAir Maintenance and Engineering Company stated that the aircraft was purchased in 2003 and all maintenance procedures were carried out in accordance with the maintenance program issued by the aircraft manufacturer. The last technical procedure carried out in Cairo was the pre departure check before heading to Charles de Gaulle on May 18th, 2016. There were no technical notes or malfunctions during the aircraft last two flights before the accident flight.
- The chief forensic physician at the Forensic Medicine Authority reported that three teams of physicians and forensic experts were formed as follows:
  A team of field forensic physician to examine the recovered human remains and preserve them from damage. A team of forensic laboratory physician to get samples from the human remains, extract the DNA, and perform the necessary cross-matching of the samples drawn from the relatives of the aircraft passengers. A team of chemical laboratory experts specialized in examination and analysis to determine whether traces of explosive materials are found or not.
- On 22nd May 2016, 23 plastic bags containing pieces of human remains that were recovered by the rescue teams of the Egyptian Navy and were numbered with serial numbers from 169 to 191, were examined. They were transported to the Autopsy Department in Cairo and were examined with X-rays and the necessary samples were withdrawn for DNA analysis. The DNA analysis proved that it belongs to a twenty-three victims of the passengers. Results of withdrawn samples No. 174, 175, 183, 184, 187, and 190 revealed they contained traces of highly explosive materials. LC TRIPLE QUAD and GC/MS techniques were used to detect and prove those results.
- On 25th June 2016 Forensic experts from both French and Egyptian sides boarded the civilian search and recovery vessel, John Lethbridge, for the wreckage site in the Mediterranean Sea for human remains search, recovery, examination and analysis. Over the course of nine days, experts from both Egyptian and French sides recovered 105 human remains and some aircraft debris, the experts preserved them using appropriate scientific methods. Serial numbers were given, starting from Number 230 to Number 334, and the French team conducted the numbering

of the human remains and debris using the updated barcode system started from PM - 020 - 0001 to PM - 020 - 0133, in addition to the extraction of twenty debris consisting of solid metal parts.

- On 3rd of July 2016, both Egyptian and French teams returned to Alexandria port, human remains were transferred to the Forensic Medicine Authority in Cairo. On 4th of July 2016, two French experts (bomb expert and medical forensic expert), came to the Forensic department in Cairo, and they participated with the laboratory experts in the Chemical examination and analysis of samples of the recovered human remains and solid parts extracted from the seabed resulted in the presence of explosive TNT derivatives in seven pieces of solid plastic and metal parts. The human remains were also separated from the wires, metal and plastic parts that were stuck to them. The devices showed the presence of indicators of the presence of TNT explosive.
- Because of the importance of the accident and for more confirmation, it was agreed between the Egyptian and the French experts to continue the examination and the analysis using a more sensitive and advanced device to confirm the results on 14 July 2016, the Egyptian and the French experts went to the (Pharma Gene) laboratory contracted by the Forensic Medicine Authority .this lab.is equipped with The LC-999 device, which is specialized in conducting chemical analyses,. they had the following:
  - A collective sample extracted from the samples after being preserved.
  - A standard sample of explosive TNT.
  - A third negative sample of similar materials which does not contain any traces.
- By subjecting the samples extracted from the seabed to examination, the results showed the presence of traces of the explosive substances of DNT and TNT. Confirming the results of the analysis of the samples recovered by the Egyptian naval rescue teams.
- On 3rd of July 2016, a team of Egyptian forensic physicians went to the ship in Alexandria Port to complete the mission, 95 body parts were recovered with serial numbers from 335 to 429. No tests or analysis were conducted on those samples as positive results in the analysis for the first and second stages.
- The total human remains found presented sixty-four of the total sixty-six persons on board.
- All procedures related to DNA analysis were carried jointly with French experts at all stages.

- Some of investigation committee members traveled to France to process the flight recorders memory cards of the case under investigation.
- A copy of flight data recorder (FDR) extracts was delivered to the French accredited representative, and he was also enabled to listen to the content of the cockpit voice recorder (CVR). He received only a CVR written transcript.
- On 28 November 2016, the EAAID received from the Public Prosecution the Forensic Medicine Authority's report in which it was proven that the remains of the victims belonged to 64 passengers out of 66 of person onboard including crew. It was revealed by chemical examination of the samples drawn from human remains, metal, plastic, solid materials that were recovered from the aircraft wreckage site the existence of traces of highly explosive TNT, which is neither an aircraft component material nor included in its manufacture or operation. All necessary measures and precautions were taken by Egyptian and French forensic experts participating in the search and analysis to avoid samples contamination. It was clear that this substance was released at a high speed as a result of the blast wave that hit persons and fuselage, leading to aircraft falling and the death of all persons on board.

  After that report was received by the technical committee, a meeting was held to study its contents and concluded that there was a criminal suspicion of unlawful interference. In accordance with Egyptian law and Annex 13 of the International Civil Aviation Organization Convention, the technical committee prepared a technical report containing all carried out procedures and available information since the occurrence and until the forensic report was received and delivered a report to the Public Prosecution.
- The Forensic Medicine Department's report stated that by conducting chemical analysis on the parts of the debris and recovered human remains in the first and second stages, they found traces of the substances 2, 4, 6-trinitrotolene (TNT), 3-nitrophthalic acid, and 4, 6-dinitrotolene (DNT), the explosives, as well as traces of substances that can be considered as outcomes of the explosives. The conclusion was that explosive materials were stuck to the bodies of the persons and to the solid objects used in manufacture, which indicates that this materials were released at a high speed as a result of the explosive blast, and was flanged to passengers and aircraft fuselage which led to its fall and the death of all persons.

1.18.3 The triple committee report

The Egyptian general prosecution formed a committee headed by a forensic evidence expert and included two experts, an aviation expert and a forensic medicine expert. This committee will be referred to as the triple committee in the following context.

The triple committee issued a report concluded the following:

- After reviewing the wreckage (except those items that has been previously examined by forensic medicine department experts), it was found out that all wreckage parts show varied traces of crash damage , dent, deformation , mechanical loads , and heat effects .
- The previously mentioned parts are all from the section directly aft of aircraft cockpit. These effects indicates that this area was exposed to pressure wave from inside to outside the aircraft.
- Swabs were taken from the wreckage parts in the defected area, which located in the rear part of aircraft cockpit, no explosive material traces were found. This might be because those wreckage parts were remained in sea bed for some time.
- By studying and analyzing findings, it was agreed upon the following :

– There was a disruption at the rear part of aircraft cockpit. The area that includes galley and lavatory.

– There were indications of mechanical loads and heat effects which might be a result of explosive material on five parts of the wreckage as follows :

1- The upper part of frame No. (20) above passenger’s front entrance.
2- Outer part of the cockpit beside First officer seat from fuselage frame no. (3) To no. (8).
3- Right outer part of aircraft fuselage from frame no (23) to no (25)
4- Outer Part of the right forward door with the word “exit.”
5- Small parts of catering trolleys.

– The presence of a leak sound under pressure near mic no.3 located in the cockpit right back area, is likely due to oxygen pipeline crack near to forward galley area and frame no. 12.

– The leak sound stops after three minutes due to complete discharge of oxygen bottle.

- A fire might take place in the presence of a heat source, flammable material and oxygen, till it is consumed. This explains why there is no indication of huge fire traces.
- The presence of the Pilot alone in the cockpit after noticing the fire and requesting the first officer to locate the fire extinguisher and go out of the cockpit. Hearing the sound of his breathing indicated he was suffering a breathing difficulty.

- From the above , the possible scenario for the accident would be the following :

  Passing an explosive device that includes (TNT and DNT) according to the chemical analysis performed by forensic medicine department inside crew catering trolleys, in the galley behind the cockpit.

  The device was exploded after a specific time which resulted in a disruption in this area and the cracking of the oxygen pipe that passes near the area behind the cockpit (galley). This resulted in oxygen leakage and fire in the cockpit due to the presence of a heat source resulting from the explosion, flammable material and the oxygen.

- Fire stops when oxygen is depleted. Lack of oxygen in the cockpit, results in the presence of toxic carbon monoxide which unites with blood hemoglobin and forms carboxy hemoglobin which causes loss of consciousness and might lead to death.

1.19 Useful or Effective investigation Techniques

- None

2. Analysis

2.1 General

– Analysis is based on factual information included in section 1 "Factual information".
– In accordance with Annex-13 and Egyptian rules and regulations; the investigation committee assessed all the relevant data records of FDR, CVR, ATS communication, and other information collected, analysis was done accordingly.
– Analysis focus on the most significant and relevant parts that could be related to the accident.
– Analysis includes presentation of the sequence of events.
– Rational analysis is used to reach the causal and contributing factors.
– Analysis will lead to the issuance of the safety recommendations for the prevention of further accidents.

2.2 Flight Crew

2.2.1 Flight Crew training

The flight crew was current and qualified for the duties being performed; simultaneously the crew's medical certificates were current on the date of the accident. They were all eligible to flight.

The flight crew did not report to ATC, or to any other aircraft that they were having problems. There was no malfunction of navigation. They did not announce any difficulty in aircraft handling during any stage of the flight till the start of accident sequence.

2.2.2 Human Factors

– Cockpit behavior was normal including basic human factors elements such that:
  - Cooperation
  - Communication
  - Decision making
  - Alertness
  - Management of workload
  - Situation awareness
  - Vigilance

- The flight crew had a complete day rest before this flight. So fatigue, tiredness can be ruled out.
- The crew were very responsive towards the fire although the event took place very quickly, they did not have the time to declare emergency.

2.2.3 Information extracted from CVR relevant to flight crew behavior

- CVR recordings did not show symptoms of fatigue. They were quite vigilant, working as a team.
- The crew was very responsive towards the fire, by calling fire and asking for a fire extinguisher within seconds of the fire recognition.

Finding:

Flight crew was not a causal or a contributing factor in the accident.

2.3 Cabin Crew

- The cabin crew was current and qualified for the duties being performed; simultaneously the crew’s medical certificates were current on the date of the accident.
- The CVR showed the normal behavior of the cabin crew before the accident sequence.

Finding:

Cabin crew was not a causal or a contributing factor in the accident.

2.4 Maintenance personnel

The maintenance personnel who performed the checks and carried out the maintenance actions and signed the technical log book were properly trained and licensed. Thus meeting relevant rules and regulation standards.

Finding:

Maintenance personnel were not a causal or a contributing factor in the accident.

2.5 Aircraft Airworthiness

- The aircraft was delivered by Airbus (the manufacturer) to EgyptAir (the operator) on 3rd of November 2003 when it was first issued its first Certificate of Airworthiness (C of A) by ECAA.
- The C of A was renewed annually following an airworthiness review activity carried out by the ECAA.

- The aircraft last C of A certificate was issued on the 27th of October 2015 and was valid until the 2nd of November 2016.
- The aircraft had been maintained in compliance with maintenance programs approved by ECAA. The last approved maintenance program was revision (13) issued in March 2015.
- Technical Log Book entries were reviewed covering a period of 3 months (covering 439 flights) prior to the accident.
- Defects have been rectified and deferred defects were rectified within the relevant deferral period.
- Last crew oxygen maintenance actions included:

• The replacement of oxygen bottle:

- On 20th of March 2016, the Captain reported on TLB that the pressure of the oxygen bottle is decreasing. Crew oxygen bottle was replaced and leakage check carried out found no leak.
- The aircraft flew 268 flights until the accident, there was no issues regarding crew oxygen system pressure.
- By reviewing earlier flights, there was no TLB entry regarding flight crew oxygen bottle pressure decrease.

• First Officer Oxygen Box Replacement:

- During a scheduled weekly maintenance check on the 16th of May 2016 and due to test /reset push button stuck in, the box had been replaced and system operational check was carried out satisfactorily according to the relevant procedure in the A320 AMM.
- The aircraft flew 10 flights, 32hr: 46mn flight time prior to the accident without any oxygen system issues.

Finding:

The accident aircraft was certificated, maintained and dispatched in accordance with applicable regulations and rules.

The aircraft is not a causal or a contributing factor in the accident.

2.6 Aircraft systems

- During the accident flight until the start of the accident sequence, all aircraft systems were operating normally without any sign of anomalies.
- Several computers had failed during the time between 00:29:26 and 00:29:45 (end of recording of FDR) including the following computers:
  - SEC3 (Spoiler, Elevator Computer)
  - TCAS (Traffic Alert and Collision Avoidance System)
  - Rudder Pedal Force Sensor
  - SEC2 (Spoiler, Elevator Computer #2)
  - SDCU (Smoke Detection Control Unit)
  - FAC2 (Flight Augmentation Computer)
  - Weather Radar
  - FMGC 2 (Flight Management Guidance Computer)
  - EEC2 Channel B (Electronic Engine Computer # Channel B)
  - DMC 3 (Display Management Computer #3)
  - FCDC2 Flight Control Data Concentrator
  - EVMU (Engine Vibration Monitor Unit)
  - FDR (Digital Flight Data Recorder)
- The above mentioned 13 computer/unit were failed during a 19 seconds period.
- "Rudder Pedal Force Sensor" failed at 00:29:28. Rudder Pedal Input forces changed from a constant value of 0 reciprocating between 2047 to -1024 Newton at 00:29:28, this can be referred to "Rudder Pedal Force Sensor" failure.
- A/P 2 that was engaged after take-off had been disconnected at time 00:29:39.
- ENG 2 N1 Vibration value changed from 0 to 8 at 21:29:45. This can be referred to EVMU Engine Vibration Monitor Unit failure at 00:29:45.
- Cargo smoke detection is discussed in the fire section.

Note regarding units/computers failure:

A thorough study of these units/computers in relation to their location, common wiring, common circuit breakers, common terminal blocks, and connectors. All these units/computers were dispersed and no relation could be established by location, by main power circuit breakers, by wiring routes nor by terminal blocks. But it was found that the affected units/computers connectors are located at the lower right hand side area of 120VU panel and are adjacent to each other.

It is evident that these units/computers failures are consequences of other issues.

Finding:

Aircraft systems behavior were not a causal or a contributing factor in the accident.

2.7 Meteorological condition

No unusual weather phenomena were found, and the meteorological conditions had no impact on the occurrence of the accident.

Finding:

Meteorological conditions were not a causal or a contributing factor in the accident.

2.8 Communication

- All Communications conducted with the accident aircraft were normal from the take-off time until the aircraft entered the Greek FIR.
- The aircraft crossed FIRs of six countries from the time it left the French FIR until it entered the Greek FIR, which are the: German-Swiss-Italian-Croatian-Serbian and Albania respectively.
- The flight crew did not declare emergency.

Finding:

Communications were not a causal or a contributing factor in the accident.

2.9 Mass and Balance:

Validation of the load sheet information:

Reviewing the relevant computerized load sheet, mass and balance information was as follows:

Flight number: MSR804

Aircraft Registration: SU-GCC

Version: 16C/129Y (16 business class, 129 economy class)

Date: 18 May, 2016

Time: 22:25

Compartments weights: Total 1727 kg (629 kg (hold 1) + 691 kg (hold 3) + 407 kg (hold 4))

Passengers Number: 59

Passengers' weight: 4597 kg

Total Traffic weight: 6324 kg (4597 kg max weight + 1727 kg Compartments weights)

Operating Weight: 44879 kg

Zero Fuel Weight Actual: 51203 kg (Maximum 62500)

(44879 kg Operating Weight + 6324 kg Traffic load)

Take Off fuel weight: 11900 kg

Take Off weight Actual: 63103 kg (Maximum 77000 kg)

Trip Fuel: 9000 kg

Landing Weight: 54103 kg (Maximum 66000 kg)

Weight at the end of the recording was 55490 kg (FDR)

MAC % Zero Fuel Weight 30.42 % (FWD limit 19.32 %, Aft limit 40.33 %)

MAC % T.O weight 28.61 % (FWD limit 19.29 %, Aft 38.83)

All the data are reliable, all weights and CG locations are within limits.

Finding:

Mass and balance were not a causal or a contributing factor in the accident.

2.10 Flight recorders

2.10.1 FDR

- The data contains huge number of analog data and discrete data.
- Most of the relevant data had been plotted and thoroughly examined.
- The considered data was sorted mostly according to ATA 100 standard, whether being analog or discrete.
- Based on FDR recording, smoke was detected at several areas:
  - Lavatory smoke warning at time 00:26:14 and remained until the end of FDR recording.
  - Avionics smoke warning was triggered at time 00:27:00 (46 seconds later).

- Autopilot 2 was disconnected at time 00:29:39, with no manual control inputs recorded until the end of FDR recording.
- Several computers failed during the interval between 00:29:26 and 00:29:45 (refer to item 2.6)
- Relevant FDR data output is included in the sequence of events item no. 2.12.
- FDR recording ended at time 00:29:47 while the aircraft was cruising at FL370.
- Data recorded after time 00:29:45 are considered not valid.

Findings:

- Computer failures, as recorded by the FDR, do not indicate a condition that would prevent the aircraft from flying after the fire was initiated.
- The apparent absence of activity in the cockpit and the disconnection of the auto-pilot shortly before the end of FDR operation with no recorded manual control inputs, it was evident that the aircraft flight path was no longer controlled.
- Lavatory smoke warning preceded the Avionics smoke warning by 46 seconds.
- If the fire started in the cockpit then the "Avionics Smoke" message would have been triggered first.
- In the absence of on-board recordings after the FDR disconnection, it is not possible to describe the sequence of events until the impact with the water surface.

2.10.2 CVR

2.10.2.1 CVR Channels Content

CVR is 5 audio tracks from the 4 recorded channels, the total duration of recording is 02 h 05 m 26 s. CVR disconnected at 00:29:54.

- For CH.1(Captain side):

1. Sources of recording for channel 1 are

    a) Radio and interphone communication,

    b) Headset mic,

    c) Hand held mic, and

    d) When activated oxygen mask.

2. The whole recording duration were from all sources till the end of the recording 00:29:54
3. Total duration of recording is 00h 30m 30s.
4. Hissing sound started at 00:25:24.

- For CH.2(first officer):
  1. Sources of recording for channel 2 are :
     a) Radio and interphone communication,
     b) Headset mic,
     c) Hand held mic, and
     d) When activated oxygen mask.
  2. Total duration of recording is 00h 30m 30s.
  3. Hissing sound started at 00:25:24.
  4. CH.2 MICs disconnected at 00:25:48.

5. Radio communication was recorded till the end of recording at 00:29:54.

- For CH.3(Third occupant behind first officer seat):
  1. Sources of recording for channel 3 are:
     a) Radio and interphone communication,
     b) Headset mic,
     c) Hand held mic, and
     d) When activated oxygen mask.
     e) Cabin interphone.
     f) FSK (frequency shift keying).
  2. Total duration of recording is 00h 30m 30s.
  3. Hissing sound started at 00:25:24.
  4. CH.3 MICs and radio communication disconnected at 00:26:42.
  5. Only FSK signal was recorded till the end of recording 00:29:54.

- For CH.4 (Area Mic.):
    1. Sources of recording for channel 4 is cockpit area microphones.
    2. Total duration of recording is 02h 01m 3s.
    3. Hissing sound started at 00:25:24.
    4. CH.4 MIC disconnected at 00:29:00.
- CVR mix audio track:

  It contains CVR channels 1, 2 and 3 for duration of 02h 05m 26s.

2.10.2.2 CVR sequence of events starting from the hissing sound

CVR sequence of events (graphical and tabulated)

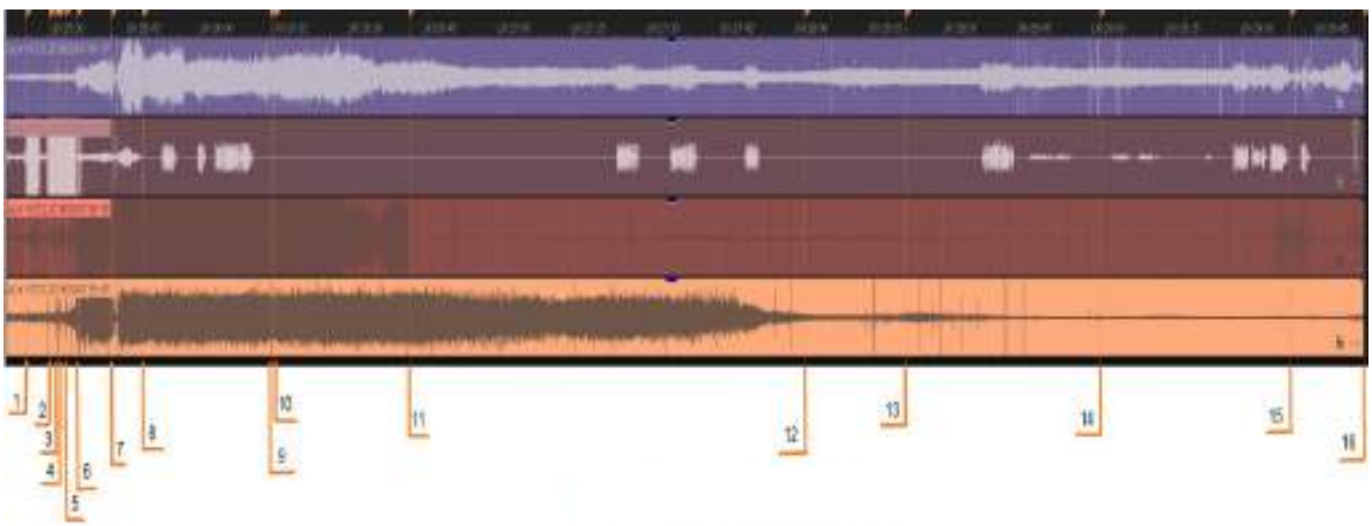


Figure 2.10/1: CVR Sequence of events

NO.	UTC Time	Event
1	00:25:24	1st Hissing Sound
2	00:25:27	Unidentified word
3	00:25:29	2nd Hissing Sound
4	00:25:30	F/O calling: “Fire Fire”
5	00:25:31	Female flight attendant calling: “ Fire”
6	00:25:32	PIC calling: “Fire”
7	00:25:35	PIC calling: “Extinguisher, Extinguisher quickly bring extinguisher quickly”
8	00:25:42	PIC calling: “close the door”
9	00:25:48	Ch.2 mic. disconnected

10	00:26:14	LAV SMOKE WARNING (low Triple chime) repeated every 30 sec
11	00:26:15	MASTER WARNING
12	00:26:42	Ch.3 (mic. + Radio) Disconnected
13	00:28:02	Weak breathing sound
14	00:28:21	Ask forgiveness of God
15	00:29:01	Ch.4 mic. Disconnected
16	00:29:39	Auto Pilot Disconnected (Cavalry Charge)
17	00:29:54	End of CVR Recording

- 1st Hissing starts from 00:25:24 to 00:25:27 (3 Sec.) then a momentary stop for 2 seconds, hissing starts again from 00:25:29 to 00:27:54 then it began to attenuate to the background noise level.
- The Hissing sound lasts to 00:25:32 with the same sound intensity then the audio sound intensity changes to a different sound intensity.
- CVR disconnected at 00:29:54 after (4min. and 30 Sec.) from 1st hissing start.
- Highest Frequency of the hissing sound was in CH.2, CH.3, CH.4, and CH.1 respectively.
- RMP of Pilot and First officer installed in the center pedestal CH.2 MICs disconnected at 00:25:48, although radio communication was recorded till end of CVR operation.
- RMP of 3rd occupant installed in the overhead for the 3rd seat and CH.3 (MICs and radio communication) disconnected at 00:26:42.
- Wiring of the captain Mic. is on the left side.
- Wiring of first officer and 3rd crew and Area Mic. is on the right side.

Findings:

- All communication and actions in cockpit didn’t reflect any abnormal condition before the event (1st Hissing sound).
- There is no sign in cockpit communication between pilot and first officer that reflect any oxygen leak detected in cockpit before the event.
- There is no audio evidence or intention from either of the pilots to use their oxygen masks nor smoke hood.

- Fire was announced by the flight crew and a female cabin crew. It is not possible to definitely decide if they meant fire or smoke.
- There is no audio evidence to confirm that a fire extinguisher was used in the cockpit.
- Conversation between pilots was recorded clear at CH.2 similar to CH.1, if the first officer oxygen mask mic was activated before the event, then the recorded sound would not be the same for the two channels.
- It would then be concluded that the First officer boomset microphone was a hot mic during the whole flight and oxygen mask mic was only activated at the event time.
- There was no mention from the cockpit occupants regarding burning odors in cockpit prior to "Fire, Fire" call out.
- The cockpit crew did not declare emergency.
- The cockpit crew did not discuss diversion.

2.10.2.3 Radio Communication in the last 2 hours

The following table shows last five times of radio communication between ATC and accident aircraft within last two flight hours. All were done by the first officer (voice identified), by correlation of FDR (VHF 1) parameter and Ch.4 (Area mic) of CVR.

Communication time	Reference to CVR timing
23:03:00	00:34:00
23:06:00	00:37:00
23:11:00	00:42:00
23:22:00	00:53:00
23:48:00	01:19:00

Note: time from FDR

Finding:

- It is concluded that first officer performed the last five ATC communications.

2.10.2.4 Sound intensity in various channels during the event

Time of Event	Critical Conversation	Speaker Identification	Sound Intensity			
			High	Med	Low	CH.4
00:25:27	Unidentified Word"….."		CH.2	CH.3	CH.1	√
00:25:30	Fire Fire	First officer	CH.1	CH.3	X	√
00:25:31	Fire	Flight Att.	CH.3	CH.1	X	√
00:25:32	Fire	Pilot	CH.1	CH.3	X	√
00:25:33	Oppaaa (surprise)	Pilot	CH.1	CH.3	X	√
00:25:35	"Extinguisher, Extinguisher quickly bring extinguisher quickly"	Pilot	CH.1	CH.2	X	√
00:25:40	extinguisher quickly fire	Pilot	CH.1	CH.2	CH.3	√
00:25:42	"close the door"	Pilot	CH.1	CH.2	X	√

- (X) Sign indicates that sound was not heard in respective channel while (√) indicates that the sound was heard.

Finding:

- CH2 and CH3 were recording high hissing sound which impaired pilots' voice to be clearly recognized in relation to their working stations.
- Sound intensity of pilot in CH1 suggests that he was occupying his seat. While the flight attendant was occupying the third occupant seat behind the first officer during the start of the event.

2.10.2.5 Inflight F/O oxygen mask microphone flow test

After comparing recorded four channels oxygen flow sound and wave form of each of the four cases with the hissing sound in the four channels of MSR804 it was found that:

1. The sound of oxygen flow was heard on the inflight test (three cases 2, 3, 4) is similar to the hissing sound of MSR804 CVR recording in which the knob was set to emergency position.
2. By comparing all the four channels of case no.3 with the hissing sound for the four channels in the MSR804 CVR recording found similarities in wave form and sound intensity.

3. Sound of MSR804 is similar to the sound of case no.3 (where the door is open and the knob on emergency) in all its four channels.
4. Ambient noise recorded clearly in the CVR but was not heard on cockpit speakers.

Findings:

- Test of the ambient noise was heard clearly on the CVR flight test while there was no sound out of cockpit speakers.
- The intensity and clarity of the hissing sound indicates that the MSR804 oxygen system was in its normal state.
- With the emergency knob set on emergency position and the left oxygen mask door is opened then the oxygen will flow and the microphone will be activated.
- The test results suggest normal system emergency flow of MSR804 rather than oxygen system leak.
- Normal system emergency flow explains why the MSR804 oxygen cylinder was not depleted in a short time.
- Most probably the emergency knob was set to the emergency position before the start of the event.

2.11 Wreckage

- The Wreckage recovery priority rectangle was 1.2 km by 525 meters. Other aircraft parts existed outside this rectangle.
- All the 318 pieces related to the aircraft wreckage were classified and identified.
- Eight pieces were affected by a fire and/or high temperature. Some of them are parts of passenger cabin.
- The wreckage cabin parts which indicated that they were exposed to thermal effects are; a set of head rest covers, black cloth which seems to be like crew baggage, cabin seat headrest, Part of cabin seat, A back pack with a hard disk and a piece of fiber stuck in it, a bag, a lower part of business class seat and part of lavatory / galley panel.

The 5 parts that were closely inspected revealed the following:

1. Food trolleys

- Two sides of two trolleys were twisted inside-out together with a part of galley composite wall stuck within. The trolley tray tracks were so worn out probably due to gas wash.

	
Part shape at hangar	Part position on the aircraft Note: Photo to demonstrate trolleys color

Figure 2.11/1: Food trolleys

2. Upper central segment of frame 20

   – The original crescent shape has deflected backward out of its original vertical plane.

   – A bend was found in the center and edge.

   – A change in the original metal color was identified on both edges.

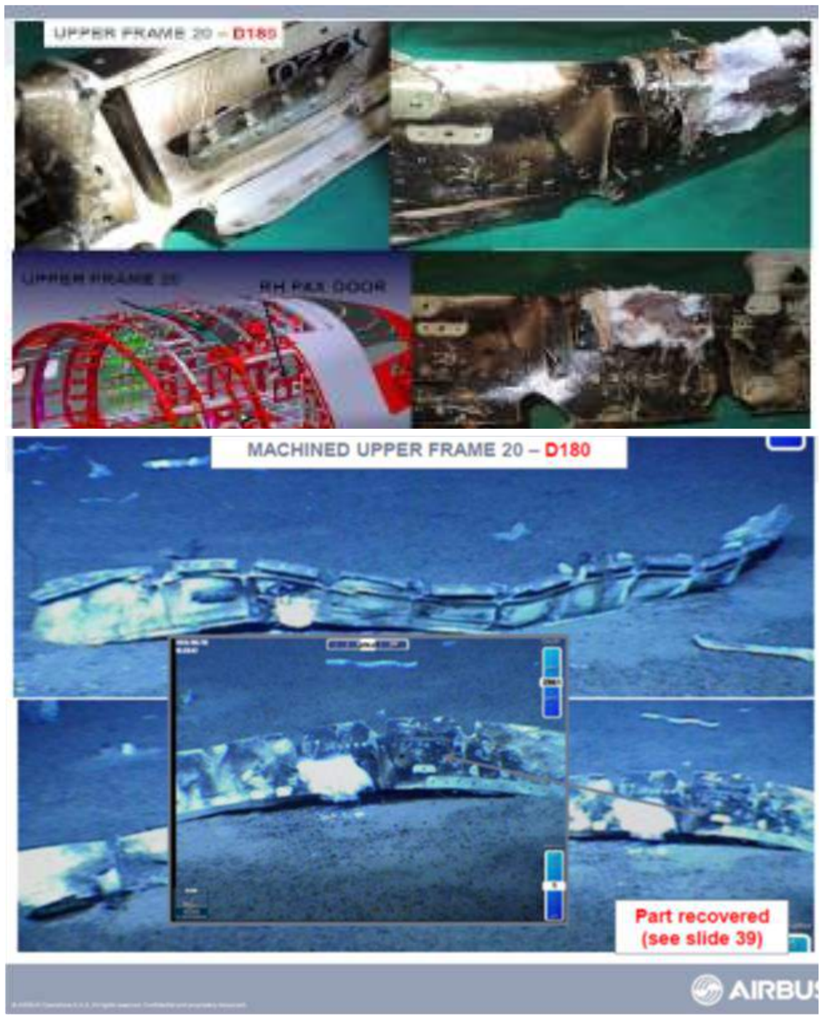


Figure 2.11/2 : Upper central segment of frame 20   Food trolleys

3. <u>Forward fuselage part with stand by static port</u>

- Stringers /frames deformed outward in a backward direction.
- Electric cables with their insulation seemed to be normal (no apparent heat effect).
- A puncture was identified in the middle of the part.
- All edges were torn off, and dark spots were noted in the internal lower part
- Skin rolled outward and stringers bent outward.

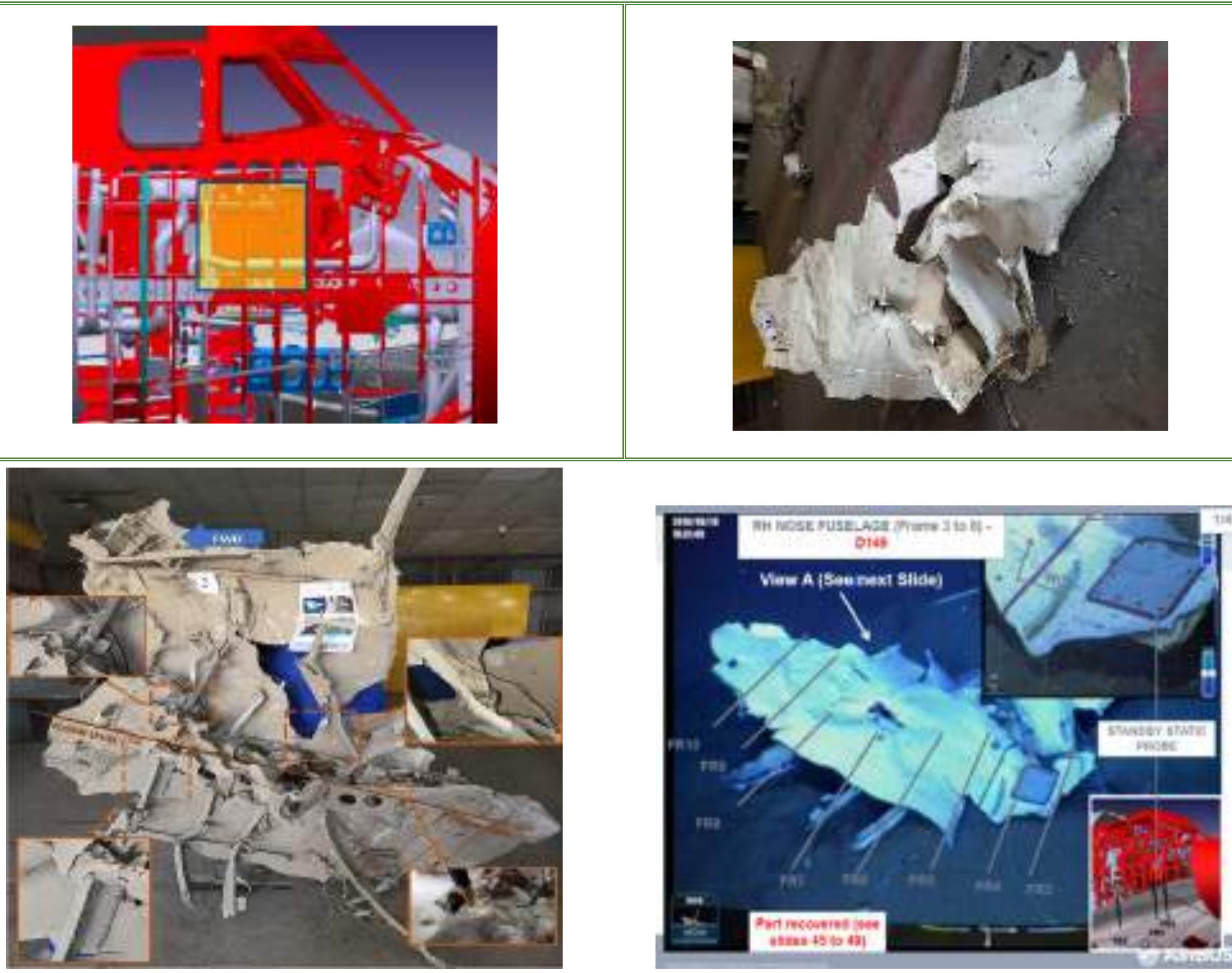


Figure 2.11/3 : Forward fuselage part with stand by static port

4. <u>Forward fuselage with static port (part No. 37)</u>

- Outward deformation of the forward edge skin.
- Front lower corner of part rolled outward with dark color on the internal side.
- All edges are torn off except the back edge.

Figure 2.11/4 : Forward fuselage with static port (part No. 37)

5. <u>FWD PAX RHS DOOR</u>

- Upper third part of the FWD RHS PAX door.
- Almost two thirds of the FWD RHS PAX door lower part was torn away and completely dethatched. The piece shows buckling outwards in 2 locations. Inner side of the remaining part shows dark spots.

<table>
<tr><td></td><td></td><td></td></tr>
<tr><td>Part shape underwater</td><td>Part shape at hangar</td><td>Inner side</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Part position on the aircraft</td></tr>
</table>

Figure 2.11/5 : FWD PAX RHS DOOR

Finding:

- The inspection of the 5 items collectively indicates that an area of over pressure between the 5 wreckage parts resulted in star-burst fractured fuselage of forward fuselage with static port and forward fuselage part with stand by static port, buckling outward of FWD PAX RHS DOOR with completely detached two thirds of the door, backward deflection of upper central segment of frame 20 and bending it in the center while crushing and twisting. Two sides of two trolleys together with a part of galley composite wall stuck within (This feature is known only to result of the venting of high pressure gases and rolling over the sharp fractured edge in a direction away from the venting gases).
- All the 5 parts are adjacent to each other and surround the area of the FWD galley at door 1R (FWD fuselage RHS). The mating skin plates showed peeling away, curled skins and torn rolled edges outward suggesting internal overpressure.
- In this area (FWD fuselage RHS), there are no aircraft systems that are likely to produce overpressure taking into account that the oxygen cylinder is on the left side.
- Referring to the oxygenated fire of the registered aircraft SU-GBP on 29th July 2011-though the GBP was on ground while the GCC was flying at 37000ft the time elapsed from the start of the oxygenated fire till the time where the fire punctured the aircraft fuselage was one minute and forty seconds, so in terms of fire propagation if that was the case in the SU-GCC there would have been cabin altitude warning triggered.

2.12 Sequence of events

2.12.1 General

Information gathered from all relevant sources including FDR (Flight Data Recorder), CVR (Cockpit Voice Recorder), ARINC Raw Data messages, ATC (Communication, Radar information) were used to create a chronological scenario to best explain sequence of events.

2.12.2 Detailed Sequence of events

Note:

- Communications of ATC with other flights as shown by CVR were omitted (not relevant).
- ARINC raw data messages are recorded in HH:MM format.

Time	Event
21:21:00	the Aircraft took off for its return flight to Cairo MSR804 (FDR)
21:21:10	Aircraft was airborne (FDR)
21:21:14	The L/G lever was selected up (FDR)
21:43:38	Aircraft reached top of climb (37000ft) (FDR)
23:22:27	Radar and communication contact established with MSR804 by ACC Sector AC4 over point PINDO at FL 370, the flight was cleared direct to point KUMBI the crew confirmed clearance. (Greek traffic control)
	Aircraft entered the Greek airspace HELLAS UIR at the point PINDO, at flight level FL370 (Greek ATC radar)
23:47:55	Flight MSR804 was transferred for communication and control to AC5 on Frequency 133.325 MHZ, the crew confirmed clearance. (Greek traffic control)
23:48:13	Flight MSR804 established communication and radar contact with sector AC5. (Greek traffic control)
	The crew exchanged his last ATC communication, with the Greek ATC. (Greek traffic control)
From 23:59:24 to 23:59:37	Personal conversation, irrelevant (CVR)
From 23:59:44 to 23:59:49	Personal conversation, irrelevant (CVR)
From 23:59:51 to 00:03:45	Personal conversation, irrelevant (CVR)
00:04:31	Cockpit doorbell sound (CVR)

00:04:35	Door opening sound (CVR)
From 00:04:38 to 00:04:45	Personal conversation, irrelevant (CVR)
00:04:45	Sound like table opening lock (CVR)
From 00:04:46 to 00:04:54	Personal conversation, irrelevant (CVR)
00:05:43	door closing sound (CVR)
00:16:43	Cockpit doorbell sound (CVR)
00:16:46	Door opening sound (CVR)
00:21:46	Door closing sound (CVR)
From 00:22:51 to 00:23:15	Personal conversation. The PIC asked for a blanket and a pillow. He was feeling cold (CVR)
00:23:18	Door closing sound (CVR)
00:23:40	Cockpit doorbell sound (CVR)
00:23:43	Door opening sound (CVR)
00:23:49	Door closing sound (CVR)
00:23:50	Unidentified word (CVR)
00:23:52	Yes (Female flight attendant) (CVR)
00:23:57	You are four, right? Have a seat (F/O) (CVR)
00:24:34	Can I sit? (Female cabin attendant) (CVR)
00:24:38	Observer seat opening sound (CVR)
00:25:24	1st Hissing sound (CVR)
00:25:29	Pop sound (CVR)
	2nd Hissing sound (CVR)
00:25:30	Fire Fire (F/O) (CVR)

00:25:31	Fire (The Female cabin attendant) (CVR)
00:25:32	Fire (PIC) (CVR)
00:25:33	Oppaaa (expressing surprise, PIC) (CVR)
00:25:35	Extinguisher, extinguisher quickly, bring the fire extinguisher quickly (PIC) (CVR)
00:25:40	Bring the extinguisher quickly, Fire (PIC) (CVR)
00:25:42	Close the door (PIC) (CVR)
00:25:58	Rudder trim position started reciprocating between 1 and 0 until the end of the recording (FDR)
00:26:14	Lavatory smoke started, continued to the end of the recording (FDR)
00:26:15	Master warning (FDR)
	"Master warning Captain FWC1 " started, continued to the end of the recording (FDR)
	Master warning F/O FWC1 started, continued to the end of the recording (FDR)
	Master warning Captain FWC2 started, continued to the end of the recording (FDR)
	Master warning F/O FWC2 started, continued to the end of the recording (FDR)
00:26:23	stabilizer moved from almost constant value of -1 to 0 until the end of the recording (FDR)
00:26:48	CRC aural warning (CVR)
00:26	Lavatory Smoke (ARINC Raw Data)
	ANTI ICE R. WINDOW (ARINC Raw Data)
	R. SLIDING WINDOW SENSOR (ARINC Raw Data)
00:27:00	Avionic smoke started, continued to the end of the recording (FDR)
00:27:01	"Master Caution Captain FWC2 " started, continued to the end of the recording (FDR)

00:27:02	"Master Caution Captain FWC1 " started, continued to the end of the recording (FDR)
	"Master Caution F/O FWC1 " started, continued to the end of the recording (FDR)
	"Master Caution F/O FWC2 " started, continued to the end of the recording (FDR)
00:27:18	CRC aural warning (CVR)
00:27:23	EgyptAir 804 contact Cairo 124.7 bye bye (Athena) (CVR)
00:27:25	AC5 radar controller calls MSR804 and clears it to contact HECC ACC on Frequency 124.7 MHZ with no read back from the crew. The controller calls repeatedly with no response. The flight according to radar recorded data, at the time , was 14.8 nm north of point KUMBI.(Greek traffic control)
00:27:34	EgyptAir 804 contact Cairo 124.7 (Athena) (CVR)
00:27:50	EgyptAir 804 (Athena) (CVR)
00:27	AVIONICS SMOKE (ARINC Raw Data)
00:28	AC5 planner asked Cairo area control if they could communicate with the aircraft. Whereas, no communication was established with the aircraft.(ATC)
00:28:02	Breathing Sound (CVR)
00:28:16	Undefined (Sound of an object falling) (CVR)
00:28:21	Ask for forgiveness of God (CVR)
00:28:22	AC5 controller asked HECC ACC if they have established contact with the aircraft. Yet, there was no response from the aircraft. (Greek traffic control)
00:28:38	Breathing Sound (CVR)
	EgyptAir EgyptAir 804 contact Cairo 124.7(Athena) (CVR)
00:28:42	Breathing Sound (CVR)
00:28:47	EgyptAir 804 contact Cairo 1247 (Athena) (CVR)

00:28:48	until 01:40:25 the AC5 controllers along with flights MSR780, IBE 3320, MC5387, THY7EY, MSR995, RAM 217 and UAE9753, call MSR804 on emergency frequency 121.5 MHZ, there was no response from the aircraft. From 00:28:48 to 01:40:25) (Greek traffic control)
00:28:52	EgyptAir 804, 1247 (Athena) (CVR)
00:28:59	Roll angle started increasing from -0.7 degrees (left turn) (FDR)
00:28	R. FIXED WINDOW SENSOR (ARINC Raw Data)
00:29:00	Radar traffic controller of the Greek traffic control AC4 started calling the aircraft to instruct them to communicate with Cairo area control without any response. (Greek traffic control)
00:29:03	EgyptAir 804 Cairo 1247 (Athena) (CVR)
00:29:09	EgyptAir 804................. EgyptAir 780 (Athena) (CVR)
00:29:10	Roll angle reached a maximum value of -6 degrees (left turn) (FDR)
00:29:13	Go ahead (Athena) (CVR)
00:29:22	Roll angle dropped to its initial value -0.7 degrees (left turn) remained almost fixed to the end of recording (FDR)
00:29:23	Calling "name of the F/O" (Another Aircraft)(CVR)
00:29:26	SEC3 Failed. It kept changing its status through the whole interval between 00:29:26 and 00:29:42 (FDR)
	TCAS failed until the end of the recording (FDR)
00:29:28	Rudder Pedal Force Sensor failure (FDR)
	Rudder Pedal Input forces changed from a constant value of 0 reciprocating between +2047 to -1024 Newton (FDR)
	TCAS (Traffic Alert and Collision Avoidance System) failure (FDR)
00:29:33	FCDC 2 detected failure between 00:29:37and 00:29:42 (FDR)
00:29:34	SEC2 (Spoiler, Elevator computer 2) failure (FDR)
00:29:35	SDCU (Smoke Detection Control Unit) failure (FDR)

	Smoke FWD upper cargo 2 detected smoke (FDR)
	Smoke AFT lower cargo 2 detected smoke (FDR)
	Smoke FWD lower cargo 2 detected smoke (FDR)
	Smoke AFT upper cargo 2 detected smoke (FDR)
	Wind shear detection 2 started reciprocating between ON and OFF until the end of the recording
00:29:36	A/P 1 (that was disengaged), started reciprocating between ON and OFF until the end of the recording (FDR)
	FAC2 (Flight Augmentation Computer 2) failure (FDR)
	Weather radar failure (FDR)
	A/P 2 (that was engaged), started reciprocating between OFF and ON (FDR)
00:29:37	FMGC 2 (Flight Management Guidance Computer 2) failure (between 00:29:37 and 00:29:42) (Airbus)
	EEC2 Channel B (Electronic Engine Computer # Channel B failure) (between 00:29:37 and 00:29:42) (Airbus)
	DMC 3 Display Management Computer #3 failure (between At 00:29:37 and At 00:29:42) (Airbus)
	FCDC2 Flight Control Data Concentrator failure (between 00:29:37 and 00:29:42) (Airbus)
00:29:39	The A/P 2 is recorded as disconnected. (FDR) The CRC linked to the lavatory smoke warning stopped and the cavalry charge associated with the A/P disconnection sounded in the cockpit until the end of the recording.(CVR)
	Sound of A/P disconnect (Cavalry charge) (CVR)
00:29:44	Undefined (Sound of an object falling) (CVR)
	lateral acceleration changed suddenly from almost a constant value of

	-0.008 to 0.828 (FDR)
	longitudinal acceleration changed suddenly from almost a constant value of -0.043 to 0.828 (FDR)
	Normal acceleration changed suddenly from almost a constant value of 0.997 to -2.134 (FDR)
00:29:45	vertical speed reached 144 ft/min (FDR)
	lateral acceleration changed from 0.828 to 0.812 (FDR)
	longitudinal acceleration changed from 0.828 to 0.801 (FDR)
	Normal acceleration changed from -2.134 to -2.2 (FDR)
	the Blue hydraulic pressure dropped from 2994 psi to 2560 psi (FDR)
	EVMU (Engine Vibration Monitor Unit) failure (Airbus)
	ENG 2 Vibration N1 value changed from 0 to 8 (FDR)
	Data recovered from Flight Radar 24 flight tracking indicate that the aircraft stopped transferring data (BEA)
00:29:47	FDR Digital Flight Data Recorder failure
00:29:57	The aircraft disappeared from the Greek ATC screen(Greek traffic control)
	According to video replay of radar data, target was lost from radar display of AC5. (Greek traffic control)
	According to the radar information from the Greek air traffic unit AC5, it was shown that the aircraft was lost at a distance of 7.1 nm south of the point KUMBI. (Greek traffic control)
00:29	AUTO FLT FCU 2 FAULT (ARINC Raw Data)
	F/CTL SEC 3 FAULT (ARINC Raw Data)
00:30:00	Do you have contact with EgyptAir 804? (Greek traffic control)
00:30:08	The aircraft disappeared from the Egyptian ATC(ATC Cairo)
00:30:08	Aircraft disappeared from the radar screen of Cairo area control. (ATC Cairo)

00:31:00	Yes, flight plan track. (ATC Cairo)
	Confirm do you have contact MSR 804 on your radar (Greek traffic control)
00:31:04	Aircraft started turning left flying almost east (snapshots Greek radar data)
00:31:45	The controller notified HECC ACC for loss of radar contact and asked whether they have established radio communication or radar contact. The answer was negative. HECC ACC reported that they will call on emergency frequency 121.5 MHZ. (Greek traffic control)
00:32:00	Yes, flight plan track (ATC Cairo)
	Greek air traffic control unit AC5 contacted the unit MAMBO that belongs to the Greek Air Force to inform them about the loss of the aircraft. (Greek traffic control)
0:32:04	Aircraft started turning right flying almost south east (snapshots Greek radar data)
0:32:52	Until 0:35:22 AC5 controller called MAMBO unit of the HELLENIC Tactical Air Force and notified that communication and radar contact of MSR804 were lost. They stated final position before it was lost from radar display. They were asking if there was a target indication on their radar but they received a negative answer. from 00:32:52 to 00:35:22(Greek traffic control)
0:32:44.7	Aircraft started turning right flying almost south west (snapshots Greek radar data)
0:33:22.8	Aircraft started turning right flying almost west (snapshots Greek radar data)
00:34:00	Lost MSR 804 on your radar? (ATC) (Greek traffic control)
00:34:08	The ACC supervisor notified NAOP about the loss of radar and communication with MSR804 and that radar contact was lost 10 nm south of KUMBI. (Greek traffic control)
00:34:42	The Air Ground Service was asked to contact the flight through its SELCAL (LQGP). The controller also asked if and when they established contact to

	instruct the flight to contact the sector on125.2 MHZ or HECC ACC. (Greek traffic control)
00:35:13	The Air Ground Service was asked to contact the flight through its SELCAL (LQGP). The controller also asked if and when they established contact to instruct the flight to contact the sector on125.2 MHZ or HECC ACC. (Greek traffic control)
00:34:41	Aircraft started turning right flying almost north (snapshots Greek radar data)
00:35:22	The AC5 controller asked MAMBO if they succeeded in establishing radar contact with MSR804 .They received a negative response .The controller expressed his worry by stating that neither he, nor HECC ACC and MAMBO have any indication or sign of the flight. (Greek traffic control)
00:35:44	ACC supervisor alerted JRCC and ADIC with detailed information. . (Greek traffic control)
00:36:18	AC5 controller alerted ADIC, ADIC reports that it will alert NAOP as soon as possible. (Greek traffic control)
00:36:3.2	Aircraft started turning right flying almost east (snapshots Greek radar data)
00:36:59	signal from the ELT of the aircraft was emitted
00:38:12	AC5 controller notified MAMBO unit of the Hellenic Tactical Air Force, providing all pertinent information on initiatives taken and on the way, including the SSR of the flight (7624-unless otherwise assigned),and that the flight plan was finished by the system. MAMBO report no radar indication on flight MSR804 which should normally have. (Greek traffic control)
00:38:33.1	Aircraft started turning left flying almost North West (snapshots Greek radar data)
00:38:50	last snapshot radar returns(snapshots Greek radar data)
00:40:09	The controller gave MAMBO the flight data. (Greek traffic control)

00:46:56	ADIC (Air Defense Information Center) asked ACC supervisor for any news and POB and that a C130 SAR aircraft will take-off from ELEFSINA Air Force Base for SAR mission. (Greek traffic control)
00:48:48	ACC supervisor notified NAOP that the aircraft is declared lost. (Greek traffic control)
00:56:17	AC5 controller notified Nicosia ACC and asked for support. (Greek traffic control)
01:00:15	ADIC notified controller that MAMBO radar reported that at 00:40 approximately MSR804 target was lost on radar display and that the flight was out of Athena UIR at the time. (Greek traffic control)
01:04:05	Planner notified ADIC that MAMBO reported that no target was seen in the area where the flight was missed. Normally, according to their radar range, they should have indication of the flight position. (Greek traffic control)
01:08:49	At 1:18:49 ATHINAI approach notified AC5 planner that SAR operations had been initiated and aircraft HRK 69A is airborne from LGEL. (Greek traffic control)
01:13:00	Flight MSR 780, would you please acknowledge when you see any abnormal thing in the route. (ATC Cairo)
	The area control unit in Cairo contacted the aircrafts flying in the area where the aircraft was lost, without obtaining any information about the accident aircraft. (ATC Cairo)
01:14:00	O.K. (Pilot MSR780) (ATC Cairo)
01:18:00	Would you like us to descend to a lower altitude (Pilot MSR780) (ATC Cairo)
	MSR 780 Descend to FL 370 (ATC Cairo)
01:20:00	MSR 780 Descend to FL 310 (ATC Cairo)
01:26:36	ACC supervisor notified PALLAS ATSEPS that they will begin video replay of flight MSR804. (Greek traffic control)

01:27:00	I have seen a light, I could not identify it, maybe it is a ship light (Pilot MSR780) (ATC Cairo)
01:28:00	MSR 780, where did you see the light exactly (ATC Cairo)
	10 nm behind me, the light coordinates are: N 33 25 1.8, E 29 42 00 (Pilot MSR780) (ATC Cairo)
01:39:26	ACC supervisor notified ADIC that persons on board were 59 and 7 Crew members. (Greek traffic control)
01:40:00	The area control unit in Cairo contacted the Search and Rescue Center, to inform them about the loss of the aircraft. At the same time, the Greek Search and Rescue aircrafts reached the site where the aircraft was lost. (ATC Cairo) (Greek traffic control)
	Search & rescue on position missing plane (Greek traffic control)
	Thank you (ATC Cairo)
04:19:15	ACC supervisor report to MAMBO the co-ordinates given by HECA ACC for HRK59A SAR mission (33251, 8 N, 02942 E). (Greek traffic control)

2.12.3 Sequence of events findings

- The aircraft was flying normally at 37000ft pressure altitude. 0.78 Mach until 00:25:24 UTC
  - Aircraft performance was normal
  - Cockpit behavior was normal including cooperation, communication, alertness, authority gradient. CVR information did not show symptoms of fatigue. They were quite vigilante, working as a team.
  - One of the female cabin crew was doing the cockpit service. She was in the cockpit sitting on the 1st observer seat the time the fatal events started.
- At 00:25:30, 00:25:31and at 00:25:32, the F/O, the female cabin attendant and the PIC announced fire.
- The time 00:25:35 and 00:25:40, the PIC asked for the fire extinguisher quickly twice, and then asked to close the door (sound of door opening might not be heard in CVR because of the hissing sound noise). It is not easy to determine who remained inside or went outside the cockpit after asking for the door closure. The CVR does not support the hypothesis that the fire extinguisher was used in the cockpit.
- At 00:26:14 Lavatory smoke started, continued to the end of the recording as shown by the FDR, master warning came on after one second supporting this information. This lavatory smoke warning was supported by ARINC Raw Data.
- At 00:27:00 Avionic smoke started, continued to the end of the recording as shown by FDR. ARINC Raw Data supported the avionics smoke detection.
- The fire announced by the cockpit crew, the lavatory smoke detection (44 seconds later) and the avionics smoke detection (90 seconds later), suggest that the fire (or smoke) might have originated just outside the cockpit in a location that can affect both lavatory and avionics compartment in sequence.
- From 00:27:25 to 00:28:00 several communication attempts were made by Athena but no communication was established with the aircraft.

- The breathing sound at 00:28:02, the asking for forgiveness of God at 00:28:21, the second breathing sound at 00:28:38 and the third breathing sound at 00:28:42 heard in the CVR, suggests that there was still one crew member at least in the cockpit.
- Several computers had failed during the time between 00:29:26 and 00:29:45 including the following computers:
    - SEC3 (Spoiler, Elevator computer 3)
    - TCAS (Traffic Alert and Collision Avoidance System)
    - Rudder Pedal Force Sensor
    - SEC2 (Spoiler, Elevator computer 2)
    - SDCU (Smoke Detection Control Unit)
    - FAC2(Flight Augmentation Computer 2)
    - Weather radar
    - FMGC 2 (Flight Management Guidance Computer)
    - EEC2 Channel B (Electronic Engine Computer 2 Channel B)
    - DMC 3 (Display Management Computer 3)
    - FCDC2 (Flight Control Data Concentrator 2)
    - EVMU (Engine Vibration Monitor Unit)
    - FDR (Flight Data Recorder)

      All of these units /computers were dispersed and no relation can be established by location, main power circuit breakers, wiring routes and terminal blocks.

      It’s found that the affected computers connectors at lower right hand side area of 120VU panel are adjacent to each other.
    - "Rudder Pedal Force Sensor" failed at 00:29:28. Rudder pedal input forces changed from a constant value of 0 reciprocating between 2047 to -1024 Newton at 00:29:28, this can be referred to "Rudder Pedal Force Sensor" failure.
- The SDCU (Smoke Detection Control Unit) failed at 00:29:35. Therefore it is likely the following smoke detection warnings could be related to the SDCU failure:
    - FWD upper cargo 2

  - AFT lower cargo 2
  - FWD lower cargo 2
  - AFT upper cargo 2

- A/P 2 was disengaged at 00:29:39. There was no detection of manual control input after A/P disengagement .It is believed that the crew- who remained in the cockpit -were unable to perform flying duties and no one was flying the aircraft at this time.
- The three accelerations (lateral, longitudinal, normal) had changed significantly at last two seconds of recording (00:29:44 and 00:29:45).
- The aircraft disappeared from the Greek ATC screen at 00:29:57.
- A signal from the ELT of the aircraft was emitted at 00:36:59. With reference to ELT specifications, the signal is emitted when the aircraft accelerations (between +2.0 to +2.6G in the longitudinal direction).The aircraft was still traced by the snapshots Greek radar.
- Aircraft was still traced by snapshot radar return at 00:38:50. This means that the aircraft had flown for at least 13 minutes and 26 seconds after the 1st hissing sound, 09 minutes and 05 seconds from the end of valid FDR recording.
- Although the crew was very responsive towards the fire, by calling fire and asking for a fire extinguisher within seconds of the fire recognition. It was evident that events took place very quickly.

2.13 Aircraft Performance

2.13.1 Aircraft Performance before the major events

Aircraft Performance parameters did not show anomalies before the major events.

The main performance parameters were as follow: (Based on FDR information).

- Pressure altitude was 37000ft.
- Vertical speed was almost zero (aircraft was flying straight and level).
- Airspeed was almost 254 knot.
- Mach number was ranging almost between 0.780 and 0.784.
- Lateral acceleration was almost zero.

- Longitudinal acceleration during the level flight was almost zero (Aircraft was not accelerating or decelerating).
- Normal acceleration was almost one.
- LH local Angle of Attack showed a fixed value of 5 degrees.
- RH local Angle of Attack showed a fixed value of 5 degrees up till 24:29:42.
- Heading was almost constant at 142 degree at the last portion of the recording.
- The Pitch was almost 1.8 degrees almost at the end portion of the recording.
- Roll was to the left (between -0.4 to -0.7 degrees), then starting from 00:28:59 changing reaching a max value of -6 degrees at 00:29:10 then dropped to its initial value of -0.7 at 00:29:22.
- Weight recorded at the end of the recording was 55490 kg.
- The wind speed was shown to be 95 knots at the end recording.
- Last True wind direction recorded is 286 degrees.
- (Aircraft heading was about 142 degree)
- Relative angle= 36 degree.
- Tail Wind = Vwind * cos (36) = 95 knots * cos (36) = 76.87 kts TW
- Cross wind (right to left) = Vwind * sin (36) = 95 kts * sin (36) = 55.84 kts from right to left.
- Drift angle varied between 6, 7 degrees (right) throughout the end portion of the recording.

Figure 2.13/1 : wind direction analysis illustration

- Windshear: No windshear detected (Windshear detection 1).
- No wind shear detected until 00:29:35 UTC (Windshear detection 2).
- TAT was slightly increasing going south. Last TAT was -26 degree Celsius.

2.13.2 Aircraft Performance after the major events

2.13.2.1 Regarding the Load factors changes

Lateral acceleration changes:

UTC	Lateral acceleration
00:29:42	-0.008 (Left)
00:29:43	-0.008 (Left)
00:29:44	0.828 (Right)
00:29:45	0.812 (Right)

Longitudinal acceleration changes:

UTC	Longitudinal acceleration
00:29:42	-0.043 (Accelerate)
00:29:43	-0.043 (Accelerate)
00:29:44	0.828 (Decelerate)
00:29:45	0.801 (Decelerate)

Normal acceleration changes:

UTC	Normal acceleration
00:29:42	0.977 (Up)
00:29:43	0.997 (Up)
00:29:44	-2.134 (Down)
00:29:45	-2.2 (Down)

It can be noticed that all the accelerations (Lateral, longitudinal, normal) had changed dramatically and abnormally at the last two seconds of the reliable recording (00:29:44, 00:29:45 UTC).

Two hypothesis will be discussed next:

1. The data is not reliable
2. The data is reliable

To assist in this analysis, a brief description about the means of recording these parameters is presented.

Hypothesis 1 (The data is not reliable):

Parameters might not be reliable for the possible causes:

1. Power supply Interruptions (SPI)

   Acceleration values from linear accelerometer are acquired by both SDACs and directly transmitted to the FDIMU. Airbus has identified that Short Power supply Interruptions (SPI) during flight could break down the Linear Accelerometer voltage for a very short period of time. If sampled by the SDAC, this erroneous acceleration value could be converted to a negative figure, significant enough to exceed the trigger limits of the FDIMU. This accelerometer sensitiveness to SPI is as per accelerometer.

   The acceleration values shown through the valid time of the FDR are not consistent with the SPI condition.

2. Failure of the Linear Accelerometers (LA)

   FDR does not show that LA has failed.

3. SDAC (System Data Acquisition Concentrator)

   The SDAC is not among the computer units listed as failed.

4. FDIU SDAC INPUT PORT:

   The two parameters "FDIU SDAC1 INPUT PORT FAILED", "FDIU SDAC2 INPUT PORT FAILED" in the FDR were examined. No detected failure up to the end of the valid data.

5. FDIU

   The FDIU is not among the computers units listed as failed.

   The FDIU was functioning until end of FDR recording.

6. FDR

   Last reliable FDR time is at 24:29:45 UTC. The FDR failed at 24:29:47 UTC

   (3 seconds after the dramatic sudden changes in the acceleration)

Finding:

The hypothesis that “The data is not reliable” could be considered as very remote.

Hypothesis 2 (The data is reliable):

FDR data is valid up to 00:29:45 seconds. The sudden changes in the acceleration values occurred at 00:29:44, 00:29:45. This indicates that these changed occurred within the valid data recorded by the FDR.

The altitude, attitude (on the three axes) and speed parameters shall be affected by the changes in the accelerations. However, the time interval recorded for the acceleration sudden changes is very short (2 second), and the speed and attitudes changes are deducted by integrating these acceleration. Therefore, the changes in the other parameters might not be noticed through this very short period of time.

Finding:

The sudden changes in the accelerations are considered valid.

The hypothesis that “The data is reliable” should be ruled in.

There is still a high probability that these changes might be as a result of explosion.

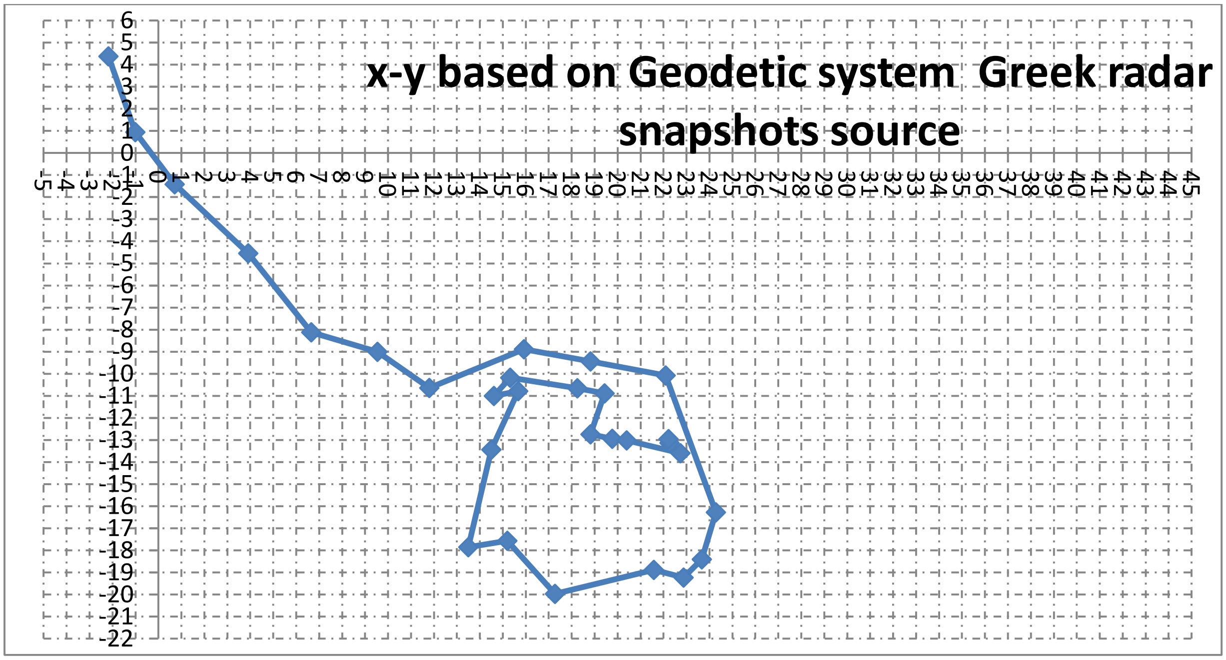
<u>2.13.2.2 Regarding the heading</u>

- Heading was almost constant at 142 degree at the last portion of the recording, changed slightly to 139 degree 40 seconds before the end of the recording (FDR information)
- At almost 00:31:00 aircraft started turning left flying from south east direction to almost east (Radar information)
- At almost 00:32:01 aircraft started turning right flying from almost east to almost south east (Radar information)
- At almost 00:32:44 aircraft started turning right flying from almost south east to almost south west (Radar information)
- At almost 00:33:22 aircraft started turning right flying from almost south west to almost west (Radar information)
- At almost 00:34:44 aircraft started turning right flying from almost west to almost north (Radar information)

- At almost 00:36:03 aircraft started turning right flying from almost north to almost east (Radar information)
- At almost 00:38:33 aircraft started turning right flying from almost east to almost north west (Radar information)
  (last snapshot return was 00:38:50)

Finding:
The aircraft changed its direction several times. The aircraft has entered in a complete circle.

A/P was disengaged with no manual control inputs



Aircraft flight path based on Greek radar snapshots source

2.13.2.3 Regarding wind shear

- Windshear detected after 00:29:35 UTC (Windshear detection 2)
- No windshear detected (Windshear detection 1)

Finding:

Windshear detected by windshear detection 2 can be ignored. Windshear detection 1 did not show wind shear.

2.14 Forward Galley/ Trolleys and electrical wiring connectors

Trolleys (containing passengers and crew meals) are housed in the FWD galley, back to back with 120VU panel.

Finding:

Since Trolleys are back to back where the connectors supplying the failed computers are adjacent to each other and concentrated in the lower right side area of the 120VU panel, then if an uncontained damage occurs to a trolley unit it would affect the wiring / connectors.

2.15 FDR/ARINC Raw Data / Avionics Compartment / Lavatory

Since "smoke lavatory smoke" was followed by "Avionics smoke" then the highest probability is that the affected lavatory is the forward lavatory just outside the cockpit.

Smoke detectors are used to detect the visible and invisible combustion particles.

This is confirmed by the FDR as it indicates that lavatory smoke occurred at 00:26:14 FDR, while avionics smoke was triggered at 00:27:00 FDR (46 seconds later).

ARINC raw data messages supported the previous FDR sequence, as "Smoke. Lavatory Smoke" (at 00:26) then "Avionics Smoke" (at 00:27).

The largest quantity of air for ventilation of the lavatories and galleys comes from the cabin. Extraction causes the air to flow from the cabin into the lavatories and galleys. The air flows into the lavatories through grilles in the door, and into the galleys through grilles and filters which are installed in the galley walls and the ceiling. A small quantity of air for ventilation of the lavatories flows from individual air outlets. The extraction fan removes air from the lavatories and the galleys through a duct which is installed above the cabin ceiling. The air flows through filters into the duct. The air is then removed overboard through the outflow valve. The extraction fan operates continuously during flight and also on the ground when electrical power is available to the aircraft.

Whereas; The CRTs located on the pilot's panel are cooled with air blown through a sealed inlet/outlet on the panel, the pedestal instruments are cooled with air blown through the instruments on the upper panel and around the instruments on the lower panel. The air then goes into the avionics compartment through vents in the cockpit floor and the overhead circuit breaker and system control panels are cooled with cockpit air. This air is drawn around the back of the panels and into the avionics ventilation system.

It has to be highlighted that according to the CVR, none of the cockpit occupants (pilot, First officer and the flight attendant) mentioned any burning odor.

Findings:

- ARINC raw data messages supported the FDR sequence that Lavatory smoke warning preceded Avionics smoke warning.
- The following messages were recorded by ARINC raw data:
  Anti-ice right window, right sliding window sensor, and right fixed window sensor. Messages could be either due to respective sensor failure or a heat source. If the fire started in the cockpit then the "Avionics Smoke" message would have been triggered first.

2.16 Fire/ Smoke Analysis

- Eight pieces of debris were exposed to fire and high temperatures.
- Recordings of aircraft cockpit conversations showed that the word “fire” was heard and repeated by the pilot, first officer, and flight attendant.
- The AIRMAN messages also included evidence of the appearance of smoke in both the lavatory and the Avionics compartment.
- The Forensic Medicine Authority’s report confirmed the presence of burn marks on some of the human remains that were subjected to examination and some of the small solid parts stuck in them.
- The triple committee report indicated the presence of mechanical loads and thermal effects on five parts of the wreckage.

2.16.1 The Fire Triangle

The triangle illustrates the three elements a fire needs to ignite: heat, fuel/combustible material, and an oxidizing agent (usually oxygen). A fire naturally occurs when the elements are present and combined in the right mixture. A fire can be prevented or extinguished by removing any one of the elements in the fire triangle.

The elements of the fire triangle are:

a- Oxygen: which constitutes 21% of the air in the atmosphere. If there is an oxygen leak, the O2 percentage increases which would intensify and/or speed up the fire but oxygen is not inherently flammable. It's an oxidizing agent, which means that it helps other materials burn but it does not burn itself. Oxygen supports the chemical processes that occur during fire. When fuel burns, it reacts with oxygen from the surrounding air, releasing heat and generating combustion products (gases, smoke, embers, etc.). This process is known as oxidation.

However, crew oxygen leak may occur. The only effect of such leak would be to intensify and accelerate the fire if it exists. An oxygen leak on its own will not start a fire. (The BEA fire in cockpit study presented 3 examples of identical aircraft type/family to that of the accident's, flying at almost identical altitudes where excessive oxygen leak occurred in cockpit and none of which resulted in fire).

b- Combustible material/fuel: although materials used in aircraft are fire retardant but they eventually burn. A combustible material is a material that catches fire such as plastics, composite materials, carpet, drapery, upholstery...etc.

c- Ignition source / heat source:

The source of ignition capable of producing heat energy high enough to start and sustain a fire has to be externally introduced to the aircraft such as:

i. Glowing cigarette pushed intentionally all the way down the oxygen mask box (so it can reach and penetrate the oxygen hose).
ii. An ignition / heat source deliberately introduced into the lavatory of the aircraft.
iii. An ignition / heat source deliberately introduced into the galley of the aircraft.

2.16.2 Cockpit / Cabin

- Fire detection by humans (Pilot and First officer) preceded smoke detection by systems (lavatory smoke detection and avionics smoke detection).
- Cockpit by design, does not have inherently ignition/heat sources, and more specifically the crew oxygen system as the certification stipulates that the system must be intrinsically safe. In particular, the system's design must be such that a single failure of one of its components

does not lead to an uncontrolled fire in the aircraft and that in all cases, such a fire is extremely improbable. (Unless superimposed non-aircraft element capable of producing heat energy high enough to start and sustain a fire has been deliberately introduced).

- Cabin by design, does not have inherently ignition/heat sources (unless superimposed non-aircraft element capable of producing heat energy high enough to start and sustain a fire has been deliberately introduced).

– **Galleys**

However, galley inserts include ovens (used to heat passengers and crew meals) represent heat source, yet they are designed, and certified to be installed and operated on the aircraft safely (unless superimposed non-aircraft heat sensitive material is deliberately introduced into the oven capable of producing heat energy high enough to start and sustain a fire).

Two ovens are installed in the forward galley; each with 2 operating modes / temperatures; 100 degree Celsius for normal meal heating and 150 degree Celsius for grill mode.

– **Lavatories**

The lavatory by design, does not have inherently ignition/heat sources (unless superimposed non-aircraft element capable of producing heat energy high enough to start and sustain a fire has been deliberately introduced).

2.16.3 Fire Extinguishing Capabilities

In the unmanned zones of the aircraft such as engines, APU and cargo compartments the fire extinguishing system depends on remotely operated fire extinguishers.

On the other hand, the manned zones of the aircraft (such as cockpit, cabin and its galleys and lavatories) depend on man-held manually operated fire extinguishers.

2.16.3.1 The cockpit fire extinguisher

The cockpit of subject aircraft equipped with one portable Halon fire extinguisher. It is installed aft and to the right of the first officer on the right side console.

The BEA fire study in cockpit focused on the effectiveness of the Halon fire extinguisher on putting out an oxygenated fire and concluded that during the tests, a fire fuelled by oxygen could not be extinguished using Halon extinguishers. This result is consistent with the chemical mechanism by which Halon gas acts on a fire. The Halon acted on the oxygen, but the leak continued to supply oxygen to the fire. The Halon extinguisher was unable to extinguish the fire.

Additionally, during the tests, the presence of an unpleasant odor and acidic, irritating emanations was noted.

Using a Halon fire extinguisher on an oxygen fire produced opaque smoke that rapidly invaded the environment. Visibility became almost zero. The pyrolysis of the Halon created acid gases in quantities that were harmful to persons in the vicinity of where the fire was being put out.

It has to be highlighted that according to the CVR, no indication of using fire extinguisher inside the cockpit.

2.16.3.2 The cabin fire extinguisher

The cabin had 3 Halon fire extinguishers; one at the outer wall of lavatory A (FWD lavatory) at door 1L, and 2 at the outer wall of aft right hand lavatory at door 2R.

It has to be highlighted that there is no indication that any of them had been used inside the cockpit.

Findings:

- It has been proven that there were thermal effects that affected the aircraft parts, components, and contents, as well as the human remains of the victims that were on board.
- The lack of significant effects of the fire can be explained by that the fire begins, continues, and ends when the amount of oxygen available in the atmosphere surrounding the flammable parts runs out.
- Crew in the aircraft cockpit were affected by the depletion of oxygen, which can make them unable to act properly or unconscious.
- Oxygen leak on its own cannot start a fire wherever it occurs unless a source of ignition / heat is present that is capable of producing heat energy high enough to start and sustain a fire.
- The possibility that a glowing cigarette will start a fire in the oxygen box is remote and from the tests carried out the only condition that resulted in a fire was when the cigarette was introduced to the oxygen enriched box with a pole.
- Aircraft, by design in compliance to regulation and certification requirements, has no systemic sources of ignition / heat.
- Cabin parts that were recovered indicated that the cabin was affected by fire.

2.17 Oxygen Fire

2.17.1 Flight crew Oxygen system

Reviewing the aircraft technical log book have yielded the following maintenance activities carried out on the oxygen system:

1. On 17 February 2016 (414 flights prior to accident).

   It was reported in the TLB as engineering entry that "fourth seat crew oxygen mask is INOP. This was deferred in DDL (page 0010691) and cleared on the same day.
2. On 20 March 2016 (268 flights prior to accident).

– The Captain reported on TLB that the pressure of the oxygen bottle is decreasing. Crew Oxygen bottle was replaced and leakage check carried out found no leak.
– The aircraft flew 268 flights until the accident, there was no issues regarding crew oxygen system pressure.

– It was noted that by reviewing earlier flights to this one, there was no TLB entry regarding flight crew oxygen bottle pressure decrease.

3. On 21 March 2016 (263 flights prior to accident)

– Captain reported in TLB that "Oxygen mask cover is broken Capt. Side" and was corrected before further flight as "Capt. Oxygen mask cover repaired"
– This indicates that the flight crew flew with the crew oxygen mask covers in closed position and reported anomalies regarding them.

4. On 16 May 2016 (10 flights, 32hr : 46mn flight time prior to accident)

– First Officer Oxygen Box Replacement.
– This was carried out during a scheduled weekly check of the oxygen system where the maintenance engineer during the crew oxygen test found that the press to test / reset button stuck. According to NRC no. 004934 (in compliance with trouble shooting manual TSM 53-10-00-810-805-A) the oxygen mask stowage box had to be replaced.
– The aircraft flew 10 flights, 32hr : 46mn flight time prior to accident after the replacement without compliant regarding the crew oxygen system.

Finding:

No anomalies regarding the crew oxygen system.

2.17.2 Oxygen Fire Study (Ref. BEA)

2.17.2.1 Introduction

A fire is defined as the combustion of a fuel by oxygen and occurs when oxygen, fuel and heat combine to create a self-sustaining chemical reaction.

The chemical reaction is an oxidation of hydrocarbons. When wood, paper, oil or gas burn, for example, it is the hydrocarbons making up the materials that oxidize during combustion.

The oxidation reaction has to be initiated by the addition of heat. Since oxidation releases heat, the reaction is self-sustaining over time.

The pressure and concentration of oxygen affect the flammability of a material. The greater the quantity of oxygen present, the easier it is for the material to ignite, the faster and more extensive the combustion and the higher the temperatures.

The presence of the oxygen distribution system has a twofold impact: the air may become enriched with oxygen in the vicinity of the supply system; the presence of oxygen makes the elements more flammable and the start of a fire more likely.

A fire that damages the oxygen systems, if it causes a hose to rupture, becomes an oxygen- enriched fire that is difficult to control.

The cockpit oxygen system is therefore particularly critical and must be resistant to various ignition mechanisms (both internal to the system and external) to prevent it contributing to a fire in the cockpit.

2.17.2.2 Tests carried out on Oxygen system

Full-scale tests were carried out to study:

- Certain ignition mechanisms likely to affect the cockpit oxygen system, the spread of an oxygen-fed fire,
- The means to extinguish an oxygen-fed fire available in the cockpit.

Starting a fire affecting the oxygen system

The following ignition mechanisms were studied:

A. Impact of an external heat source

The certification requires the oxygen system to be designed and installed in such a way that the impact of an external ignition source is minimized. External ignition mechanisms are defined as elements outside the oxygen system, i.e. elements originally outside the mask storage boxes.

Two potential external sources of heat were selected and tested:

– A lithium battery from an electronic device (smartphones, tablets and electronic cigarettes)

BEA Findings:

In the conditions used for testing the lithium batteries in electronic equipment, the thermal runaway of a battery resulted in the sudden release of dense white smoke with a sharp and rapid rise in its temperature, without any significant transfer of heat to the surrounding environment. The incandescent particles ejected did not have sufficient thermal energy to ignite the materials. The only outbreak of fire observed was caused by the adhesive tape affixed to an electronic cigarette igniting.

– Handling a glowing cigarette

In the tests carried out, the handling of a cigarette in the immediate vicinity of an oxygen mask storage box, even if the box had been enriched with oxygen, did not lead to any variation in the combustion of the cigarette and did not cause a fire. The introduction of hot ashes into the storage box did not start a fire.

When glowing cigarette was brought into contact with the hose of an oxygen mask the cigarette went out after about ten seconds and the braided outer protection of the hose and its core were not damaged or altered.

Placing a cigarette in a mask storage box that had been enriched with oxygen accelerated its burning rate and produced a more intense flame. When the cigarette came into contact with an oxygen supply hose, the fire attacked the hose, pierced the internal silicone tube and created an oxygen leak under pressure. The leak intensified the fire, allowing it to spread rapidly.

B. Internal ignition mechanisms

B.1 A heat source causing ignition inside the device

BEA Findings:

The creation of a spark in one of the mask's oxygen supply hoses produced instant ignition. The ignition did not have a detonating effect. It led to the hose being punctured after 20 to 40sec. In some cases, the puncture was accompanied by a fire that spread rapidly to the surrounding materials when the flow of oxygen was maintained.

B.2 Metal particle impacts in the oxygen system

BEA Findings:

A total of 76 tests were carried out. No particle impact ignition or increases in temperature were observed during the tests.

Note: Due to the architecture of the test bench, some particles may have been trapped in the filter and not set in motion at each pressurization (three to five successive pressurizations per "part/particle" pair). The chances of particles colliding with a part were therefore lower than the number of tests.

B.3 Ignition due to electrostatic discharge

BEA Findings:

The measurements carried out on the oxygen system of a commercial air transport aircraft seemed to indicate that the accumulated electrostatic charges were too low to create sparks capable of igniting elements of the system itself or organic or synthetic debris present in the storage box.

B.4 Ignition of substances in oxygen - enriched environment

BEA Findings:

Since combustion is an oxidation reaction that releases heat, and greases are hydrocarbons that react with oxygen in the air to form peroxides, it is possible for greases to undergo spontaneous combustion in the presence of oxygen.

Normally, this oxidation does not produce enough heat to lead to combustion, except in special conditions such as:

- Large exchange surfaces between grease and oxygen,
- Poor air circulation (conducive to heat build-up),
- Adiabatic compression following rapid injection of pressurized oxygen into a non-pressurized system. However, a pressure of 5 bar seems too low to ensure a sufficient production of energy.

Oils in these candidate classes are found to have the following auto-ignition temperatures in Table X1.2:

CTFE 374 °C to 427 + °C

PFPE 410 °C to 427 + °C

PE 235 °C to 266 °C

Fluorosilicone 232 °C to 249 °C

HC 190 °C to 199 °C

Silicone 216 °C to 241 °C

The risk represented by the presence of grease in an oxygen-rich environment is commonly accepted and taken into account in procedures. However, the conditions under which spontaneous combustion occurs are poorly documented in the aeronautical field. The only test carried out highlighted the fact that the ignition of grease in an oxygen-enriched environment is not systematic.

Finding:

BEA study did not determine the ignition source.

2.18 Emergency Locator Transmitter (ELT)

- Last valid FDR recording was at 00:29:45
- A signal from the ELT of the aircraft was emitted at 00:36:59 (7 minutes and 14 seconds after last valid FDR recording)
- Last snapshot Greek radar return was at 00:38:50 (01 minute and 51 seconds after the signal emitted from the ELT).
- The above information suggests that when the ELT signal was transmitted, the aircraft was still in the air, and the reason for the signal transmission is that the longitudinal acceleration reached between +2.0G to +2.6G.

Finding:

The axial loads exceeded 2.0 G in aircraft. Above information cannot definitely identify the source and nature of the force resulting in G load exceeding limit.

2.19 Forensic Medicine Analysis

The Forensic Medicine Authority submitted a report to the investigation committee on 28/11/2016.

2.19.1 Stages of retrieving human remains

The recovery of human remains took place in three stages:

- The first stage: started on 21/5/2016 on Egyptian naval vessels. 23 samples were recovered, they are from sample No. 169 to sample No. 191.
- The second phase: started on 25/6/2016 on the leased JLB ship. 105 samples were recovered, they are from sample No. 230 to sample No. 334.
- The third stage: started on 3/7/2016 on the leased JLB ship. 95 samples were recovered, they were from sample No. 335 to sample No. 429.

2.19.2 Results of the examination of the remains of the victims

- Examination of the recovered body parts proved that they were human body parts, and it was proven using DNA technology for the purpose of showing the genetic fingerprint and matching it with the victim's families that they belonged to 64 passengers out of 66 passengers, who were the total number of passengers and crew on the aircraft.

- Chemical examination of samples taken from the body parts, metal and plastic materials stuck in them, and solid materials recovered from the site of the aircraft wreckage proved the presence of traces of TNT, which is a highly explosive substance. It is not a natural material of the aircraft body and is not included in the manufacturing of the aircraft or in the uses necessary to operate the aircraft.
- Ten samples from nine victims were proven positive in the first phase, 13 samples from 11 victims were proven positive in the second phase, and in the two phases there were 23 positive samples for 18 victims. No tests or analysis were conducted on the samples recovered in the third phase due to the repeated positivity of the tests in the first and second phases. It was possible that positive results would appear in addition to the previous results if tests were conducted on them.
- The explosive material was stuck to the bodies of passengers and solid objects used in the manufacturing of the aircraft, which indicates that this material was released at a high speed by the explosive wave accompanying the explosion, and it penetrated the passengers and the body of the aircraft, leading to the aircraft falling and the death of all of its passengers.
- It was found that there were burning traces on some human remains and some solid samples, as well as the presence of dents in the solid samples and small fragments.

2.19.3 Passengers with positive samples

Serial No.	Number of positive samples
1	1
2	1
3	1
4	1
5	1
6	3
7	2
8	2
9	1
10	1
11	1
12	2
13	1
14	1
15	1
16	1
17	1
18	1

2.19.4 Distribution of positive samples on aircraft seats

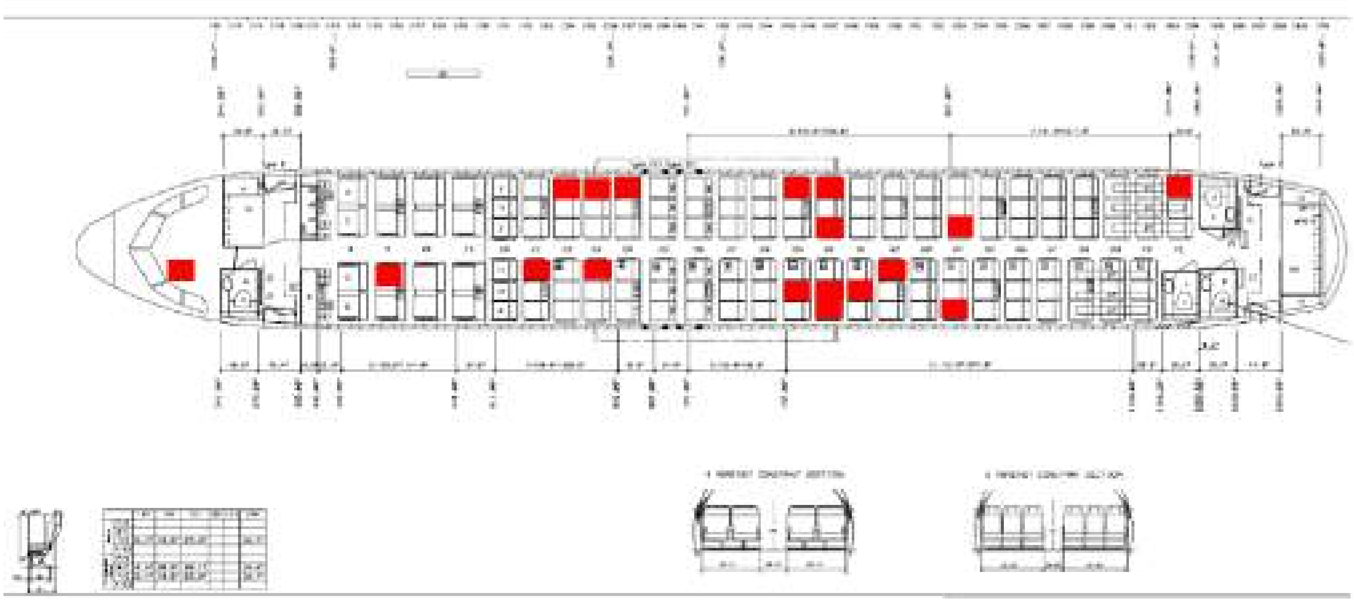


Figure 2.19/1: Distribution of positive samples on aircraft seats

Note:

Passenger distribution plotted in the above illustration is according to passengers manifest and since the flight had vacant seating capacity it cannot be confirmed the actual location of each passenger.

Forensic medicine results concluded the cause of the accident as:

The death of persons was attributed to injuries associated with the explosion and the plane crash as a result of the explosion with TNT compound.

2.20 Prosecution Memorandum

The Egyptian Prosecution’s memorandum submitted to the investigation committee on 28/11/2023. The prosecution Memorandum recognized the report of the Forensic Medicine Authority, that proved by conducting chemical tests and analysis on the parts of the wreckage and recovered human remains that traces of the explosive substances 2, 4, 6-trinitrotolene (TNT), 3-nitrophthalic acid, and 4, 6-dinitrotolene (DNT explosive) were found. In addition to material traces that can be considered from the detonation products, the explosive compounds were stuck into the bodies of the passengers and to the solid objects used in the manufacture of the plane, which indicates that this material was released at a high speed as a result of the explosive wave associated with the explosion, and it sprayed on the passengers and the body of the plane and led to its collapse and the death of all persons on board.

2.21 Triple committee Analysis

The prosecution formed a committee headed by a forensic evidence expert and included two experts, an aviation expert and a forensic medicine expert. This committee will be referred to as the triple committee in the following context.

The triple committee issued a report which included the following:

- Some parts of the wreckage found shows signs of varying severity of damage, dents, and declining, and some of them showed traces of mechanical stress and thermal effects, which could have occurred as a result of the explosion of explosive materials. These parts are from the direct rear part of the aircraft's cockpit, which contains the food preparation area in the upper part (the galleys) and a water closet (lavatory). These traces indicate that this area was exposed to a pressure wave from the inside to the outside. They were found to be free of any traces of explosive materials. This can be explained due to the presence of those parts in seawater for some time before they were recovered.
- The presence of a leaking sound under pressure near the location of the mic number (3) installed on the back of the cockpit on the rear right side, is likely to be the result of a broken oxygen pipe passing near the food preparation area (the galley) located behind the cockpit of the aircraft next to the fuselage frame number 12.
- A fire can take place after oxygen leaks with the existing contents if there is a heat source. The fire continues until the oxygen runs out, which explains the absence of significant fire traces.
- The presence of the pilot alone in the cockpit after noticing the fire and directing the First officer to take the fire extinguisher and exit the cockpit, and that the pilot had difficulty breathing action.
- The triple committee concluded : Passing an explosive package containing two explosive substances (TNT and DNT), according to chemical analyzes of the Forensic Medicine Authority, into the crew's meal carts, which are placed in the food preparation area "the galley" directly in the back area of the cockpit of the aircraft, and detonating it after a certain

elapsed time, leading to a deficiency in that area and breaking of the oxygen line pipe, passing near that area behind the galley area, resulting in a leak in the oxygen cylinder in the cockpit and starting fire as a result of the availability of (oxygen - the contents of the place - a suitable heat source from the site of the explosion). The fire ends when the oxygen cylinder runs out, which leads to the absence of oxygen in the cockpit, resulting in the formation of toxic carbon monoxide gas, which combines with blood hemoglobin to form a carboxyhemoglobin compound, which causes lethargy and loss of consciousness that may lead to death.

3.Conclusions

3.1 Findings

3.1.1 Aircraft Airworthiness

The accident aircraft was airworthy as it was certified, maintained, equipped and dispatched in accordance with applicable regulations and industry practices. There was no evidence of any pre-existing power plant, system, or structural failure. Aircraft airworthiness can be ruled out as a root cause or a contributing factor of the accident.

3.1.2 Flight Crew

- The flight crew was currently qualified for the duties being performed; simultaneously the crew's medical certificates were current on the date of the accident. They were all eligible to fly.
- The flight crew did not report to ATC about any problem during flight.
- They did not show any malfunction with navigation; and did not announce any difficulty in handling of aircraft during any stage of the flight till the start of accident sequence.
- The flight crew had a complete day rest before this flight; CVR information did not show symptoms of fatigue. They were quite vigilant, working as a team.

  Above information indicates that:
- There were no human factors anomalies.
- The crew were very responsive towards the fire although the event took place very quickly, they did not have the time to declare emergency.
- Flight crew behavior is neither a root cause nor a contributing factor in the accident.

3.1.3 Cabin Crew

– The cabin crew was currently qualified for the duties being performed; simultaneously the crew's medical certificates were current on the date of the accident.

  Above information indicates that:

– Cabin crew is neither a root cause nor a contributing factor in the accident.

3.1.4 Maintenance personnel

- The maintenance personnel were properly trained and licensed, meeting relevant rules and regulation standards.

  Above information indicates that:
- Maintenance personnel are not a root cause nor a contributing factor in the accident.

3.1.5 Aircraft systems

- Until the events leading to the accident, the aircraft systems were operating/performing normally without any sign of anomalies.
- Several computers/unit had failed during the time interval between 00:29:26 and 00:29:45 (end of valid recording of FDR).
- Based on the computers/unit failure study that was made in an attempt to find out if there is some common link between all these units that can contribute to all of these failures, it was shown that all of these computers/units were dispersed and no relation can be established by location, main power circuit breakers, wiring routes or terminal blocks. However, it was found that the affected computers/unit connectors at lower right side area of 120VU panel are adjacent to each other.

  Above information indicates that:
- Aircraft systems is neither a root cause nor a contributing factor in the accident.
- Computers/unit failures are consequences of another root causes that is linked to a common location of unit connectors at lower right side area of 120VU panel.

3.1.6 Aircraft Performance

- All performance parameters before the major events leading to the accident were reliable, no anomalies.
- Aircraft performance after the major events
  - The three accelerations (Lateral, longitudinal, normal) had changed dramatically and abnormally at the last two seconds of the reliable recording (00:29:44, 00:29:45).
  - Several changes in aircraft headings were noticed (by the end of the recording and after the end of the recording) as shown by the FDR and radar information. The aircraft showed

almost a complete circle after the end of recording. At this timing, the A/P was disengaged and with no manual control inputs.

Above information indicates that:

- Aircraft performance is neither a root cause nor a contributing factor in the accident.
- The sudden changes in acceleration G's suggest that the aircraft had been subjected to very large forces.

3.1.7 Mass and balance

- No anomalies regarding mass and balance. All the data related to mass and balance is reliable, all weights and CG locations were within limits.

3.1.8 Oxygen system

With reference to TLB review and maintenance records it was found out that:

- On 16 May 2016 (10 flights prior to accident), First Officer Oxygen Box was replaced.
- The aircraft flew 10 flights, 32hr: 46mn flight time after the replacement without complaint regarding the crew oxygen system.
- (262 flights prior to accident), Captain reported in TLB that "Oxygen mask cover is broken, Capt. Side". Capt. Oxygen mask cover repaired.
- On 20 of March 2016, the Captain reported on TLB that the pressure of the oxygen bottle is decreasing. Crew oxygen bottle was replaced and leakage check carried out found no leak.
- The aircraft flew 268 flights until the accident, there was no issues regarding crew oxygen system pressure.
- It was noted that by reviewing earlier flights to this one, there was no TLB entry regarding flight crew oxygen bottle pressure decrease.
- On 17 February 2016 (414 flights prior to accident), it was reported in the TLB as engineering entry that "fourth seat crew oxygen mask is INOP". This was deferred and cleared on the same day.

The above information indicates that:

- Crew oxygen system was properly maintained, in accordance with manufacturer's documents, the approved maintenance program and applicable rules and regulations hence it was airworthy.

3.1.9 FDR

- FDR data was valid up to 00:29:45.
- FDR data was used in the analysis of most of the report topics.
- The apparent absence of activity in the cockpit and the disconnection of the auto-pilot shortly before the end of CVR/FDR operation have led to a situation in which the aircraft flight path was no more controlled. In the absence of on-board recordings after the FDR disconnection, the only source available to determine the aircraft path until the impact with the water surface is the radar sources.

3.1.10 CVR

- Based on CVR recording, fire was announced by the flight crew and a female cabin crew.
- 1st Hissing started from 00:25:24 to 00:25:27 (3 seconds) then a momentary stop for 2 seconds, followed by a pop sound at 00:25:29 then hissing started again from 00:25:29 to 00:27:54, then it began to attenuate to the background noise level. The Hissing sound continued to 00:25:32 with the same sound intensity then the audio sound intensity changed to a different sound intensity.
- CVR disconnected at: 00:29:54 after (4min. and 30 Sec) from 1st hissing start.
- Highest frequency of the hissing sound was in CH.2, CH.3, CH.4, and CH.1 respectively.
- CH.2 MICs disconnected at 00:25:48, although radio communication was recorded till end of CVR operation at 00:29:54, because the location of RMP (Radio Management Panel) of Pilot and First officer installed in the center pedestal (away from cockpit right hand side).
- RMP of 3rd occupant installed in the overhead panel for the 3rd seat and CH.3 (MICs and Radio Communication) disconnected at 00:26:42.

- All communication and actions in cockpit did not reflect any abnormal condition before the event (1st Hissing sound).
- There is no sign in cockpit communication between pilot and first officer that reflect any oxygen leak detected in cockpit before the event.
- There is no audio evidence or intention from either of the pilots to use their oxygen masks.
- There is no audio evidence to confirm that a fire extinguisher was used in the cockpit.
- Conversation between pilots was recorded clear at CH.2 similar to CH.1, if the first officer oxygen mask mic was activated before the event, then the recorded sound would not be the same for the two channels.

The above information indicates that:

- The First officer boom set microphone was a hot mic during the whole flight and oxygen mask mic was only activated at the event time.
- The fire announced by the cockpit crew, followed by the lavatory smoke detection then the avionics smoke detection.
- The intensity and clarity of the hissing sound indicates that the oxygen system was in its normal state and there was no leak inside the system, if the emergency knob was set on emergency position then the oxygen microphone will be activated when the left oxygen mask door is opened.
- Normal system emergency flow explains why the oxygen cylinder was not depleted in a short time.
- Based on inflight F/O oxygen mask microphone flow test related findings:
    - Test ambient noise is heard clearly on CVR while there was no sound on cockpit speakers.
    - Most probably the emergency knob was set to the emergency position.

3.1.11 FDR/ ARINC raw data / Avionics Compartment / Lavatory

- It is evident that the lavatory smoke warning was generated before the avionics smoke warning as indicated by the FDR and supported by ARINC raw data indicating that fire started outside the cockpit.
- According to the CVR, none of the cockpit occupants (pilot, first officer and the flight attendant) commented that they smelt burning odor before the accident sequence starts.
- Most likely the smoke reached the avionics compartment through failure of the galley composite wall that gave way to smoke to enter the cockpit and hence the avionics compartment. If the fire started in the cockpit then the "AVIONICS SMOKE" message would have been triggered first.

The above information concludes that:

- Smoke/fire started outside the cockpit. If the fire started in the cockpit then the "AVIONICS SMOKE" message would have been triggered first.

3.1.12 ELT (Emergency Locator Transmitter)

- Last valid FDR recording was at 00:29:45
- A signal from the ELT of the aircraft was emitted At 00:36:59 (7 minutes and 14 seconds after last valid FDR recording)
- Last snapshot Greek radar return was at 00:38:50 (01 minute and 51 seconds after the signal emitted from the ELT).
- The above information indicate that when the ELT signal was transmitted, the aircraft was still in the air (as traced by the snapshot Greek radar), so the reason for the signal transmission is that the longitudinal acceleration exceeded 2.0 G.

The above information indicates that:

- The aircraft was subjected to a very high G (more than 2.0 in the axial direction) while in the air due to an induced very high force affecting the aircraft G's (at 00:36:59).

3.1.13 Wreckage examination

- Eight pieces were affected by a fire or high temperature. Five parts from passengers' cabin and three from personal belongings.
- The wreckage parts which indicated that they were exposed to thermal effects; A set of head rest covers, Black cloth which seems to be like crew baggage, Cabin chair head rest, part of cabin seat, a back pack with a hard disk and a piece of fiber stuck in it, a bag, a lower part of business class seat and part of lavatory/galley panel.
- Part No.31 "forward fuselage part with standby static port", revealed the presence of electrical wires with their plastic insulation intact.
- The Forensic Medicine Authority's report confirmed the presence of burn marks on some of the human remains that were subjected to examination and some of the small solid parts stuck in them.
- It has been proven that there were thermal effects that affected the aircraft's parts, components, and contents, as well as the human remains of the victims that were on board.
- The lack of significant effects of the fire can be explained by that the fire begins, continues and ends when the amount of oxygen available in the atmosphere surrounding the flammable parts runs out.
- The inspection of the 5 items collectively indicates that an area of over pressure between the 5 wreckage parts resulted in star-burst fractured of forward fuselage with static port and forward fuselage part with stand by static port, buckling outward of FWD PAX RHS DOOR with completely detached two thirds of the door, backward deflection of upper central segment of frame 20 and bending it in the center while crushing and twisting two sides of two trolleys together with a part of galley composite wall stuck within (This feature is known as a result of the venting of high pressure gases and rolling over the sharp fractured edge in a direction away from the venting gases).
- All the 5 parts are adjacent to each other and surround the area of the FWD galley at door 1R (FWD fuselage RHS). The mating skin plates showed peeling away, curled skins due to internal overpressure, torn rolled edges outward.
- In this area (FWD fuselage RHS), there are no aircraft systems that are likely to produce overpressure taking into account that the oxygen cylinder is on the left side.

3.1.14 Fire/Smoke

- There was no call from cabin to inform cockpit crew of any developing situation outside the cockpit. It could be interpreted as: it was so sudden and strong that the cabin crew did not have the chance to communicate it to the cockpit.
- There was no evidence that the cockpit crew used their respective oxygen masks nor the smoke hood, rather he asked for a fire extinguisher without CVR evidence that it was used in the cockpit. It might have been used outside the cockpit.
- Based on CVR the cockpit crew did not discuss diversion. Most probably because they were pre occupied with the situation.
- Based on FDR, blower and extract were not selected to OVRD (to clear the cockpit from smoke).
- Some of the cabin wreckage parts indicate that they were exposed to thermal effects indicating that the fire extended throughout the cabin.
- The only effect of oxygen leak would be to intensify and accelerate the fire if it exists. An oxygen leak on its own will not start a fire unless a source of ignition / heat is present that is capable of producing heat energy high enough to start and sustain a fire.
- Aircraft, by design in compliance to regulation and certification requirements, has no systemic sources of ignition / heat in cockpit, cabin nor lavatories that are capable of producing heat energy high enough to start and sustain a fire except for the ovens that are installed in the galleys.
- The source of ignition / capable of producing heat energy high enough to start and sustain a fire has to be externally introduced to the aircraft.
- Based on the BEA study regarding the cockpit fire extinguisher it was indicated that, a fire fuelled by an oxygen leak could not be extinguished using Halon extinguishers. This result is consistent with the chemical mechanism by which Halon gas acts on a fire. The Halon acted on the oxygen, but the leak continued to supply oxygen to the fire. The Halon extinguisher was unable to extinguish the fire. Additionally, during the tests, the presence of an unpleasant odor and acidic, irritating emanations was noted. Using a Halon fire extinguisher on an oxygen fire produces opaque smoke that rapidly invades the environment. Visibility become almost zero. The pyrolysis of the Halon created acid gases in quantities is harmful to people in the vicinity of where the fire is being put out.
- BEA study shows that Halon fire extinguishers are not suitable to extinguish oxygenated fires. Halon fire extinguishers produce harmful products.

3.1.15 The forensic medicine report

- The following conclusion is based on the Forensic Medicine Authority report submitted to the accident investigation committee on 28/11/2016:

  Forensic medicine results concluded that the cause of the accident and the death of persons were attributed to injuries associated with the explosion of TNT material.

3.1.16 The triple committee report

- The following conclusions are based on the outcomes of the triple committee report :

  An explosive package containing two explosive substances (TNT and DNT), was placed into the crew meal carts, which are placed in "the galley" directly located in the back area of the cockpit to be detonated after a certain elapsed time, affecting the oxygen pipe line, passing in the area behind the galley. This resulted in a leak in the oxygen and started a fire as a result of the availability of (oxygen, the contents of the place and a suitable heat source from the site of the explosion). The fire ends when the oxygen cylinder runs out, which leads to the absence of oxygen in the cockpit. This leads to the formation of toxic carbon monoxide gas, which combines with blood hemoglobin to form a carboxyhemoglobin compound, causing lethargy and loss of consciousness that may lead to death.

3.1.17 Proposed Scenarios

Based on the factual information and considering the analysis section, the investigation committee considered three scenarios.

3.1.17.1 Scenario No.1

Fire/Smoke started in the cockpit at the F/O side and enriched by oxygen leak.

- This scenario could be consistent with the hissing sound heard in the CVR at 00:25:24. However if there was a leak in the oxygen system, then the oxygen cylinder would have been depleted in a shorter time, which is not compatible with hissing sound time period heard in the CVR recording.
- Since this scenario assumes that the fire/smoke was originated in the cockpit and enriched by oxygen leak, then it was expected that the fire extinguishers should have been used. However there is no evidence in the CVR that a fire extinguisher was used inside the cockpit to fight the fire.

  Hence this evidence makes this scenario inconsistent with CVR contents.
- The "lavatory smoke" warning was recorded in the FDR at 00:26:14 (50 seconds after the first hissing sound) preceding the "avionics smoke" warning which was recorded at 00:27:00 (96 seconds after the 1st hissing sound).

  Since the air saturated with smoke in the cockpit is extracted into the avionics ventilation system thus suggesting to trigger "Avionics smoke" warning prior to "lavatory smoke", which is not the case.

  This scenario is inconsistent with smoke warnings.
- This scenario assumes that the fire started and continued at the right hand side of the cockpit, However and based on the wreckage examination/analysis:

  a) It has been proven that there were thermal effects that affected the aircraft's cabin parts, components and contents, as well as the human remains of the victims that were on board in the cabin.

  b) Wire insulations in part no.31 (which are most sensitive to heat effects) were intact. Leading to the conclusion that the temperature was not high enough to affect wire insulation. This highly suggest that the fire did not originate in the cockpit.

  These evidences make this scenario inconsistent with wreckage examination results.

- Based on the examination report dated 28/11/2016 of the remains of the victims, the forensic results concluded that the cause of accident and the death of persons was attributed to injuries associated with an explosion of highly explosive materials and the aircraft crash as a result of the explosion with TNT material and the presence of burn marks on some of the human remains that were subjected to examination and some of the small solid parts stuck in them was confirmed.

  In addition, and based on the triple committee report, the presence of thermal effects on the wreckage were indicated.

  This scenario is inconsistent with the forensic Medicine Authority studies/results and the triple committee report.
- This scenario did not identify the source of ignition.

<u>Based on the above information, scenario No.1 can be ruled out.</u>

3.1.17.2 Scenario No.2

Fire/ smoke started outside the cockpit due to explosive materials located at the galley just aft of the rear section of the cockpit.

- This scenario is inconsistent with the hissing sound heard in the CVR at 00:25:24.
- This scenario is consistent with the fact that "lavatory smoke" warning was recorded in the FDR at 00:26:14.
- Since the anti-hijack camera is designed to be activated for 5 minutes starting from entry request, and the timing between the entry of the cabin crew member and the call “fire” was detected after less than two minutes (1min: 47sec). Hence it can be concluded that the fire statement was based on viewing through the anti-hijack camera.
- After the cabin crew member entered the cockpit, the first officer asked her to confirm the cabin crew number onboard by asking "you are four... Right??" So probably the first officer was looking back while he was speaking with her when he saw the fire or smoke on the anti-highjack camera LCD located above the third occupant’s seat.

  Above information strongly suggest that the fire was originated in the area outside the cockpit and within the range of the anti-high jacking camera.
- Based on the wreckage examination/analysis, it has been proven that there were thermal effects that affected the aircraft’s parts, components and contents, as well as the human remains of the victims that were on board.

  These evidences make this scenario consistent with wreckage examination results.
- Reference to ELT, the ELT transmitted a signal at 00:36:59. The aircraft was still traced by radar returns meaning that the aircraft was still in the air. This indicates that the aircraft was subjected to very high G loads (at least 2.0 in the axial direction).

  This scenario is consistent with the ELT information with the assumption that there was another explosion after the first explosion.
- Based on the examination report dated 28/11/2016 of the remains of the victims, the forensic results concluded that the cause of accident and the death of persons was attributed to injuries associated with an explosion of highly explosive materials and the aircraft crash as a result of the explosion with TNT material and the presence of burn marks on some of the human remains

that were subjected to examination and some of the small solid parts stuck in them was confirmed.

In addition, and based on the triple committee report, the presence of thermal effects on the wreckage were indicated.

This scenario is consistent with the forensic Medicine Authority studies/results and the triple committee report.

- This scenario clearly identifies the source of ignition.

Based on the above information and because of inconsistency with the hissing sound, scenario No.2 can be ruled out.

3.1.17.3 Scenario No.3

Fire and smoke due to explosive materials located at the galley just aft of the rear section of the cockpit, the high energy and pressure generated from the explosion propagated affecting the right hand side oxygen system.

Fire/ smoke started outside the cockpit and eventually fire and smoke propagated to the cockpit from the right hand side. The explosion and the oxygen flow enriched fire were the causes of the accident.

- This scenario clearly identifies the source of ignition.
- The heat energy generated by the explosion set fire to the aircraft components including forward galley and surroundings.
- Explosion in the galley area behind the cockpit propagated to the cockpit affecting the right hand side oxygen system and might have opened the first officer left oxygen box door while the oxygen mask emergency knob set to emergency position leading to oxygen flow, resulting in the hissing sound.
- Based on FDR and CVR correlation, the cockpit crew announced fire 44 seconds prior to lavatory smoke warning and 90 seconds prior to avionics smoke warning indicating that the fire originated outside the cockpit before triggering the smoke warnings. This evidence makes this scenario consistent with FDR and CVR correlation.
- In order for the smoke to be dense enough to trigger the lavatory smoke warning while the lavatory door is closed (was closed to allow the cabin crew to access the cockpit), the smoke outside the door must go through the door grills to get to the smoke sensor, therefore taking into account the time and the density needed, then the triggering event should have occurred before the activation of the lavatory smoke warning.
- Based on the CVR and sequence of events, the cockpit door was closed at the beginning of the hissing sound then it was opened supported by captain’s order to close it. This suggests that the female cabin crew fled the cockpit. There was no evidence of any firefighting activities inside the cockpit. This supports that fire was originated outside the cockpit.

- There was no call from cabin to inform cockpit crew of any developing situation outside the cockpit, indicating that the fire/smoke was sudden and strong that the cabin crew didn't have a chance to communicate it to the cockpit.
- Some of the cabin wreckage parts were exposed to thermal effects suggesting fire originated outside the cockpit.
- The 5 wreckage parts that are adjacent to each other and surround the area of the FWD galley at door 1R (FWD fuselage RHS); condition suggest internal overpressure.
- Based on the wreckage examination/analysis, it has been proven that there were thermal effects that affected the aircraft’s parts, components and contents, as well as the human remains of the victims that were on board. These evidences make this scenario consistent with wreckage examination results.
- Trolleys are housed in the forward galley back to back with 120VU panel. The trolleys are back to back where the connectors supplying the failed computers are adjacent to each other and concentrated in the lower right hand side area of the 120 VU panel. This evidence makes this scenario consistent with the location of the connectors of failed computers.
- ARINC Raw Data messages support that the heat source propagated from the galley and affected the cockpit right side, as Lavatory smoke warning preceded Avionics smoke warning. This evidence makes this scenario consistent with ARINC Raw Data messages.
- Based on FDR and ELT analysis, there might have been another explosion:
  - The FDR indicated very high sudden acceleration G's at the last two seconds of the valid FDR recording (00:29:44, 00:29:45).
  - The ELT transmitted a signal at 00:36:59. The aircraft was still traced by radar returns meaning that the aircraft was still in the air. This indicates that the aircraft was subjected to very high G loads (at least 2.0 in the axial direction)

  This scenario is consistent with FDR and ELT information with the assumption that there was another explosion after the first one.
- Based on the examination report dated 28/11/2016 of the remains of the victims, the forensic results concluded that the cause of accident and the death of persons was attributed to injuries

associated with an explosion of highly explosive materials and the aircraft crash as a result of the explosion with TNT material and the presence of burn marks on some of the human remains that were subjected to examination and some of the small solid parts stuck in them was confirmed.

In addition, and based on the triple committee report, the presence of thermal effects on the wreckage were indicated.

This scenario is consistent with the forensic Medicine Authority studies/results and the triple committee report.

Based on the above information, scenario No.3 should be ruled in and the investigation committee adopt this scenario.

3.2 Probable cause/ Contributing factors

3.2.1 Probable cause

The aircraft flight path was uncontrollable as the aircraft and the flight crew were severely affected by fire and smoke. This resulted from the effects of the explosive materials located at the forward galley just behind the rear section of the cockpit. The aircraft crashed into the sea.

3.2.2 Contributing factors

- The fire/smoke event took place very quickly and flight crew were disabled.
- Several aircraft systems failure.
- Explosion resulted in oxygen flow in the cockpit, which enriched the fire/ smoke.

4. Safety Recommendations

EGAI2016-01-SR1: Regarding use of the anti-hijacking Camera

The anti-hijacking Camera is installed for the purpose of following up what is going on outside the cockpit:

Whereas:

- If the anti-hijack camera recording was retained it would have been feasible to link the recording with the FDR and CVR outcomes.
- By considering item 5-12 of Annex 13 regarding securing the relevant records and using them only for the purpose of investigation

The investigation committee recommends the following:

The need to assess/study the appropriateness of retaining last minutes of the anti-hijacking Camera(s) (positioned outside the cockpit) video recordings into a protected suitable media/memory (e.g. CVR), so these recordings could be retrieved when needed for accidents/incidents investigations.

EGAI2016-01-SR2: Regarding Propagation of a fire fed by oxygen

The BEA studied many cases of fire/smoke that were enriched by oxygen leaks with safety recommendations.

Whereas:

Oxygen leak might enrich cockpit fire/smoke.

Consequently the investigation committee recommends the following:

The need to assess/study the appropriateness of cockpit fire/smoke procedures incorporating recognition of an oxygen enriched fire, and the need for the immediate cutting off the oxygen supply in this case.

EGAI2016-01-SR3: Regarding effectively of the Halon fire extinguishers for fighting fires fuelled by oxygen leaks

Based on BEA study, many cases of oxygen fire/smoke were encountered where the Halon fire extinguishers were not effective in dealing fires:

Whereas:

- Using a Halon fire extinguisher on an oxygen fire produced opaque smoke that rapidly invaded the environment. Visibility became almost zero. The pyrolysis of the Halon created acid gases in quantities that were harmful to people in the vicinity of where the fire was being put out.
- In the four events that occurred on the ground regarding oxygen fire, the fire required the intervention of the firefighting services. In two of the events, the crew members tried to extinguish the fire with the means at their disposal, but found that it was difficult to gain access to the cockpit (black smoke) and that the Halon was ineffective.
- Halon fire extinguishers are therefore not suitable for treating fires fuelled by oxygen.

Consequently the investigation committee recommends the following:

The need to research on other types of fire extinguishers (other than Halon) that are suitable for treating fires fuelled by oxygen.

EGAI2016-01-SR4: Regarding oxygen mask emergency knob design

Flight crew oxygen mask emergency knob may cause confusion to the user due to its indication on the oxygen mask, the fact that the word “EMERGENCY” is written away from the indicated dot position.

Consequently the investigation committee recommends the following:

That the designer/manufacturer to study the appropriateness of writing the designation next to the desired knob position for "EMERGENCY" use.

Exhibits

Exhibits Index

Exhibit A

Flight Data Recorder

Parameters Plots

Content

A. Time definition

B. Reference Excel Files

B. Airbus Abbreviations

C. Most relevant parameters recorded at the FDR in a sorted condition:

1. Plot Time parameter
2. Performance parameters
   - ALTITUDE ELAB.
   - VERTICAL SPEED
   - ALTITUDE RATE
   - COMPUTED AIRSPEED
   - MACH NUMBER (ADC)
   - LATERAL ACCELERATION
   - BODY LATERAL ACCELERATION
   - LONGITUDINAL ACCELERATION
   - NORMAL ACCELERATION
   - LH LOCAL ANGLE OF ATTACK
   - RH LOCAL ANGLE OF ATTACK
   - HEADING (true or mag. value)
   - PITCH ATTITUDE
   - ROLL ATTITUDE
   - A/C GROSS WEIGHT
   - RH LOCAL ANGLE OF ATTACK
   - GROUND SPEED
   - WIND SPEED
   - TRUE WIND DIRECTION
   - DRIFT ANGLE
   - WINDSHEAR DETECTION 1
   - WINDSHEAR DETECTION 2
   - TOTAL AIR TEMPERATURE (TAT)
   - SELECTED ALTITUDE (MANUAL)
3. Auto pilot
   - A/P1 ENGAGED
   - A/P2 ENGAGED

4. Electrical
   - AC1 BUS ON
   - AC2 BUS ON
   - AC ESSENTIEL BUS ON
   - EMER GEN LINE CONTACTOR
   - APU GEN LINE CONTACTOR
5. Flight Controls
   - SIDE STICK POSITION PITCH CAPT.
   - SIDE STICK POSITION ROLL CAPT.
   - CAPT. SIDESTICK INOPERATIVE
   - SIDE STICK POS. PITCH F/O
   - SIDE STICK POSITION ROLL F/O
   - AILERON LEFT POSITION
   - AILERON RIGHT POSITION
   - RH AILERON GREEN AVAILABLE
   - Spoiler RH 2 Position
   - SPOILER LH.3 POSITION
   - SPOILER RH.3 POSITION
   - SPOILER LH.4 POSITION
   - SPOILER RH.4 POSITION
   - SPOILER LH.5 POSITION
   - SPOILER RH.5 POSITION
   - SPEED BRAKE COMMAND
   - LH ELEVATOR POSITION
   - RH ELEVATOR POSITION
   - STABILIZER POSITION
   - STABILIZER JAM
   - RUDDER POSITION
   - RUDDER PEDAL INPUT FORCES
   - RUDDER TRIM POSITION
   - SLATS SURFACE ANGLE
   - FLAP SURFACE ANGLE
6. Fuel
   - LEFT INNER TANK FUEL QUANTITY
   - LEFT OUTER TANK FUEL QUANTITY

- RIGHT INNER TANK FUEL QUANTITY
- RIGHT OUTER TANK FUEL QUANTITY
- HP FUEL VALVE CLOSED ENG1
- HP FUEL VALVE CLOSED ENG2
- FUEL FIRE VALVE NOT FULLY CLOSED ENG.1
- FUEL FIRE VALVE NOT FULLY CLOSED ENG.2

7. Hydraulic
   - GREEN HYDRAULIC PRESSURE
   - YELLOW HYDRAULIC PRESSURE
   - BLUE HYDRAULIC PRESSURE
   - HYD. LOW PRESS GREEN
   - HYD. LOW PRESS YELLOW
   - HYD. LOW PRESS BLUE
8. Warning, Failures

   Warning

   - APU FIRE
   - ENGINE.1 FIRE
   - ENGINE.2 FIRE
   - AVIONIC SMOKE WARNING
   - CARGO SMOKE WARNING
   - Smoke BULK AVN smoke
   - Smoke CAB VIDEO smoke
   - Smoke CAB GSM smoke
   - LAVATORIES SMOKE WARNING
   - VMO/MMO OVERSPEED
   - STALL WARNING
   - MASTER WARNING CAPTAIN (FWC1 only)
   - FIRST-OFFICER MASTER WARNING ON (FWC1 only)
   - CAPTAIN MASTER WARNING ON (FWC2 only)
   - FIRST-OFFICER MASTER WARNING ON (FWC2 only)
   - CAPTAIN MASTER CAUTION ON (FWC1 only)
   - FIRST-OFFICER MASTER CAUTION ON (FWC1 only)
   - CAPTAIN MASTER CAUTION ON (FWC2 only)
   - FIRST-OFFICER MASTER CAUTION ON (FWC2 only)

- RED WARNING
- RED WARNING spare
- SMOKE FWD UPPER CARGO 2
- SMOKE FWD UPPER CARGO 1
- SMOKE AFT LOWER CARGO 2
- SMOKE AFT LOWER CARGO 1
- SMOKE FWD LOWER CARGO 2
- SMOKE FWD LOWER CARGO 1
- SMOKE AFT UPPER CARGO 1
- SMOKE AFT UPPER CARGO 2
- EXCESS CABIN ALTITUDE
- PRESSURE ALTITUDE WARNING (ALTITUDE BARO DISCREPANCY)
- PRESSURE ALTITUDE WARNING (ALTITUDE STD DISCREPANCY)

Failure modes

- DFDR FAIL
- DFDR PLAYBACK RECEIVER FAIL
- DFDR TRANSMITTER FAIL
- FDIU BSCU1 INPUT PORT FAILED
- FDIU BSCU2 INPUT PORT FAILED
- FDIU CFDIU INPUT PORT FAILED
- FDIU CLOCK INPUT PORT FAILED
- FDIU DMC1 INPUT PORT FAILED
- FDIU DMC2 INPUT PORT FAILED
- FDIU FAIL
- FDIU FCDC1 INPUT PORT FAILED
- FDIU FCDC2 INPUT PORT FAILED
- FDIU FWC1 INPUT PORT FAILED
- FDIU FWC2 INPUT PORT FAILED
- FDIU SDAC1 INPUT PORT FAILED
- FDIU SDAC2 INPUT PORT FAILED
- QAR FAIL
- FDR STATUS SIGNAL

8.a Failed computers

9. Landing Gears
   - LDG SQUAT SWITCH LH
   - LDG SQUAT SWITCH RH
   - LDG SQUAT SWITCH NOSE
   - BRAKE PEDAL POSITION LH
   - BRAKE PEDAL POSITION RH
   - GEAR SELECTOR UP
   - GEAR SELECTOR DOWN
   - LH GEAR NOT UP LOCKED
   - LH GEAR DOWN LOCKED
   - RH GEAR NOT UP LOCKED
   - RH GEAR DOWN LOCKED
   - NOSE GEAR NOT UP LOCKED
   - NOSE GEAR DOWN LOCKED
   - GEAR SELECTED DOWN
10. Engines
   - THRUST LEVER ANGLE ENG1
   - THRUST LEVER ANGLE ENG2
   - ENG1 THR LEVER ABV IDLE
   - ENG2 THR LEVER ABV IDLE
   - EPR ACTUAL ENG.1
   - EPR ACTUAL ENG.2
   - EPR COMMAND ENG.1
   - EPR COMMAND ENG.2
   - N1 ACTUAL ENG1
   - N1 ACTUAL ENG2
   - N2 ACTUAL ENG.1
   - N2 ACTUAL ENG.2
   - ENG.1 N2 OVER LIMIT
   - ENG.2 N2 OVER LIMIT
   - EGT ENG.1
   - EGT ENG.2
   - ENG.1 EGT OVER LIMIT
   - FUEL FLOW ENG.1 ELAB

- FUEL FLOW ENG.2
- OIL PRESSURE ENG.1 (FROM SDAC)
- OIL LOW PRESSURE ENG.1
- OIL LOW PRESSURE ENG.2
- OIL TEMPERATURE ENG.1 (FROM SDAC)
- OIL TEMPERATURE ENG.2 (FROM SDAC)
- OIL QUANTITY ENG.1
- OIL QUANTITY ENG.2
- N1 VIBRATION ENG.1
- N1 VIBRATION ENG.2
- N2 VIBRATION ENG.1
- N2 VIBRATION ENG.2
- ENG.2 VIBRATION N1 ADV
- ENG.1 N1 OVER LIMIT
- ENG.1 N2 OVER LIMIT
- ENG.2 N1 OVER LIMIT
- ENG.2 N2 OVER LIMIT
- ENG.1 BLEED FAULT
- ENG.1 LOW TEMP
- PS3 ENG 2
- SEVERITY ICE DETECTED ENG.1
- REVERSER DEPLOYED ENG.1
- REVERSER DEPLOYED ENG.2
- REVERSER UNLOCK ENG.1
- REVERSER UNLOCK ENG.2

A. Time definition

- First data frame used for plotting is 84267 (21:10:10 GMT)
- An arbitrary index x was used for easier plotting such as:
  - X=1, at frame number 84267, at time 21:10:10
  - X= frame number – 84246 seconds
- Last valid data frame 96242 (00:29:45 GMT), X= 11976
- Last data frame 96265
- The valid data time is 12642 seconds (3 hours: 30 minutes: 42 seconds)
- The total data time is 12665 seconds (3 hours: 31 minutes: 05 seconds)
- The last 23 seconds data are truly invalid.
- Accordingly:

	Frame number	Plot time x	UTC Time
Start data for plotting	84247	1	20:10:10
End of valid time	96242	11976	00:29:45
End of invalid time	96265	invalid	invalid

B. Reference Excel Files

- Ref 1: all_1 +plots n trimmed.xls
- Ref 2: all_2 +plots n trimmed.xls
- Ref 3: all_3 +plots n trimmed.xls

C. Airbus Abbreviations

Name	Alternate Name
A	Amber
A	Alternate
A/C	Aircraft
A/D	Analog/Digital
A/DC	Analog-to-Digital Converter
A/R	Audio Reproducer
A/SKID	Anti-Skid
A/THR	Auto Thrust
A/XFMR	Autotransformer
ABCU	Alternate Braking Control Unit
AC	Alternating Current
ACARS	Aircraft Communication Addressing and Reporting System
ACC	Active Clearance Control
ACCEL	Acceleration/Accelerate
ACCLRM	Accelerometer
ACCU	ACCUMULATOR
ACMM	Abbreviated Component Maintenance Manual
ACMS	Aircraft Condition Monitoring System
ACP	Area Call Panel
ACP	Audio Control Panel
ACQN	Acquisition
ACSC	Air Conditioning System Controller
ACT	Active
ACTR	Actuator
ADC	Air Data Computer
ADF	Automatic Direction Finder
ADIRS	Air Data/Inertial Reference System
ADIRU	Air Data/Inertial Reference Unit
ADM	Air Data Module
ADR	Air Data Reference
ADS	Air Data System
ADV	Advisory
AEVC	Avionics Equipment Ventilation Computer
AF	Audio Frequency
AFS	Automatic Flight System
AGB	Accessory Gearbox
AGC	Automatic Gain Control
AGL	Above Ground Level
AGW	Actual Gross Weight
AIL	Aileron
AIM	Aircraft Integrated Maintenance
AIP	Attendant Indication Panel
ALI	Airworthiness Limitation Item
ALIGN	Alignment
ALT	Altitude
ALTM	Altimeter
ALTN	Alternate, Alternative
AM	Amplitude Modulation
AMM	Aircraft Maintenance Manual
AMS	Aerospace Material Specification
AMU	Audio Management Unit
ANI	Analog Input
ANN	Annunciator
ANN LT	Annunciator Light
ANO	Analog Output
ANT	Antenna
AOA	Angle-of-Attack
AOC	Airline Operational Control
AP	Autopilot
AP/FD	Autopilot/Flight Director
APPR	Approach
APPU	Asymmetry Position Pick Off Unit
APU	Auxiliary Power Unit
ARINC	Aeronautical Radio Incorporated
ARPT	Airport

ASCII	American Standard Code for Information Interchange
ASI	Airspeed Indicator
ASIC	Application Specific Integrated Circuits
ASM	Aircraft Schematics Manual
ASP	Audio Selector Panel
ASSY	Assembly
ATA	Air Transport Association of America
ATC	Air Traffic Control
ATE	Automatic Test Equipment
ATLAS	Abbreviated Test Language for All Systems
ATS	Auto Throttle System
ATSU	Air Traffic Service Unit
ATT	Attitude
ATTND	Attendant
AUTO	Automatic
AUX	Auxiliary
AVAIL	Available
AVNCS	Avionics
AWM	Aircraft Wiring Manual
AWY	Airway
AZ	Azimuth
B	Blue
BARO	Barometric
BAT	Battery
BCD	Binary Coded Decimal
BCL	Battery Charge Limiter
BFO	Beat Frequency Oscillator
BGM	Boarding Music
BITE	Built-in Test Equipment
BMC	Bleed Monitoring Computer
BNR	Binary
BOT	Begin of Tape
BP	Bottom Plug
BRG	Bearing
BRK	Brake

BRKR	Breaker
BRKT	Bracket
BRT	Bright, Brightness
BSCU	Braking/Steering Control Unit
BTC	Bus Tie Contactor
BTMU	Brake Temperature Monitoring Unit
BTN	Button
BTR	Bus Tie Relay
BU	Battery Unit
BUS	Busbar
BYDU	Back-Up Yaw Damper Unit
C	Close
C	Celsius, Centigrade
C/B	Circuit Breaker
C/L	Check List
CAB	Cabin
CKT	Circuit
CL	Center Line
CLB	Climb
CLG	Centerline Landing Gear
CLOG	Clogging
CLR	Clear
CMC	Central Maintenance Computer
CMD	Command
CMM	Component Maintenance Manual
CMR	Certification Maintenance Requirements
CNTOR	Contactor
CO	Company
COM	Communication
COMPT	Compartment
COMPTR	Comparator
COND	Conditioned, Conditioning
CONFIG	Configuration
CONT	Controller
CONV	Converter
COOL	Cooling, Cooler
COS	Cosine

CPC	Cabin Pressure Controller
CPLR	Coupler
CPMS	Cabin and Passenger Management System
CPMU	Cabin Passenger Management Unit
CPRSR	Compressor
CPU	Central Processing Unit
CRC	Continuous Repetitive Chime
CRG	Cargo
CRS	Course
CRT	Cathode Ray Tube
CRZ	Cruise
CSD	Constant Speed Drive
CSM/G	Constant Speed Motor/Generator
CSTR	Constraint
CSU	Command Sensor Unit
CT	Current Transformer
CTL	Central
CTL	Control
CTR	Center
CU	Control Unit
CUDU	Current Unbalance Detection Unit
CUR	Current
CVR	Cockpit Voice Recorder
CVT	Center Vent Tube
CW	Clockwise
D/D	Engine Out Drift Down Point
D/O	Description and Operation
DA	Drift Angle
DAC	Digital to Analog Converter
DAR	Digital ACMS Recorder
DC	Direct Current
DDRMI	Digital Distance and Radio Magnetic Indicator
DEC	Declination
DECEL	Decelerate
DECR	Decrease
DEF	Definition

DELTA P	Differential Pressure
DES	Descent
DEST	Destination
DET	Detection, Detector
DEU	Decoder/Encoder Unit
DEV	Deviation
DFDR	Digital Flight Data Recorder
DFDRS	Digital Flight Data Recording System
DGI	Digital Input
DGO	Digital Output
DH	Decision Height
DIA	Diameter
DIFF	Differential
DIM	Dimming, Dimension
DIR	Direction, Direct, Director
DISC	Disconnect, Disconnected
DIST	Distance
DMA	Direct Memory Access
DMC	Display Management Computer
DME	Distance Measuring Equipment
DMU	Data Management Unit
DN	Down
DNLK	Downlock
DPDT	Double Pole/Double Throw
DPI	Differential Pressure Indicator
DR	Dead Reckoning
DRVR	Driver
DSCRT	Discrete
DSDL	Dedicated Serial Data Link
DSI	Discrete Input
ETP	Equal Time Point
EVAC	Evacuation
EWD	Engine/Warning Display
EXC	Excitation, Excite
EXCESS	Excessive
EXT	Exterior, External
F	Fahrenheit

F-PLN	Flight Plan
F/O	First Officer
FAC	Flight Augmentation Computer
FADEC	Full Authority Digital Engine Control
FAIL	Failed, Failure
FAP	Forward Attendant Panel
FC	Fully Closed
FCDC	Flight Control Data Concentrator
FCMS	Fuel Control Monitoring System
FCOM	Flight Crew Operating Manual
FCPC	Flight Control Primary Computer
FCSC	Flight Control Secondary Computer
FCTN	Function
FCU	Flight Control Unit
FCV	Flow Control Valve
FMU	Fuel Metering Unit
FMV	Fuel Metering Valve
FO	Fully Open
FOB	Fuel On Board
FOD	Foreign Object Damage
FPA	Flight Path Angle
FPEEPMS	Floor Proximity Emergency Escape Path Marking System
FPPU	Feedback Position Pick-off Unit
FPV	Flight Path Vector
FQ	Fuel Quantity
FQI	Fuel Quantity Indicating/Indication/Indicator
FR	Frame
FREQ	Frequency
FRU	Frequency Reference Unit
FRV	Fuel Return Valve
FSB	Fasten Seat Belts
FW	Failure Warning
FWC	Flight Warning Computer
FWD	Forward
FWS	Flight Warning System

G	Green
G/S	Glide Slope
GA	Go-Around
GALY	Galley
GAPCU	Ground Auxiliary Power Control Unit
GCR	Generator Control Relay
GCU	Generator Control Unit
GEN	Generator
GLC	Generator Line Contactor
GLR	Generator Line Relay
GMT	Greenwich Mean Time
GND	Ground
GPCU	Ground Power Control Unit
GPS	Global Positioning System
GPU	Ground Power Unit
GPWC	Ground Proximity Warning Computer
GPWS	Ground Proximity Warning System
GRP	Geographic Reference Point
GRU	Ground Refrigeration Unit
GS	Ground Speed
GSE	Ground Support Equipment
GW	Gross Weight
H	Hot (Electrical Point)
HCU	Hydraulic Control Unit
HDG	Heading
HEGS	Hydraulic Electrical Generating System
HF	High Frequency
HI	High
HLAC	High Level Alternating Current Voltage
HLDC	High Level Direct Current Voltage
HMU	Hydro Mechanical Unit
HP	High Pressure
HPC	High Pressure Compressor

HPT	High Pressure Turbine
HPTACC	High Pressure Turbine Active Clearance Control
HS	High Speed
HSI	Horizontal Situation Indicator
HSMU	Hydraulic System Monitoring Unit
HUDC	Head Up Display Computer
HYD	Hydraulic
I/O	Input/Output
I/P	Intercept Profile
I/P	Input
IAE	International Aero Engines
IAS	Indicated Airspeed
IBR	Integral Bladed Rotor
ID	Inside Diameter
IDENT	Identification, Identifier, Identify
IDG	Integrated Drive Generator
IDGS	Integrated Drive Generator System
IGB	Inlet Gear Box
IGN	Ignition
IGV	Inlet Guide Vane
ILS	Instrument Landing System (LOC and G/S)
IMM	Immediate
INB	Inbound
INBD	Inboard
INCR	Increment
IND	Indicator
INFO	Information
INHIB	Inhibition, Inhibit, Inhibited
INIT	Initialization
INOP	Inoperative
INR	Inner
INT	Interrupt
INTCP	Intercept
INTFC	Interface
INTL	Internal

INTRG	Interrogate, Interrogator
INV	Inverter
IP	Intermediate Pressure
IPC	Illustrated Parts Catalog
IPPU	Instrumentation Position Pick-off Unit
IR	Inertial Reference
IRS	Inertial Reference System
ISA	International Standard Atmosphere
ISO	International Standardization Organisation
ISOL	Isolation
IVS	Inertial Vertical Speed
JAM	Jammed, Jamming
JAR	Joint Airworthiness Requirements
L	Left
L	Length
L/G	Landing Gear
LA	Linear Accelerometer
LAT	Lateral
LAT	Latitude
LAV	Lavatory
LBP	Left Bottom Plug
LRU	Line Replaceable Unit
LS	Loudspeaker
LSB	Least Significant Bit
LSI	Large Scale Integration
LT	Light
LTP	Left Top Plug
LV	Low Voltage
LVDT	Linear Variable Differential Transducer
LVL	Level
LW	Landing Weight
LWR	Lower
MAC	Mean Aerodynamic Chord
MAG	Magnetic
MAINT	Maintenance

MAN	Manual
MAX	Maximum
MCDU	Multipurpose Control & Display Unit
MCL	Maximum Climb
MCT	Maximum Continuous Thrust
MCU	Modular Concept Unit
MDA	Minimum Descent Altitude
MDDU	Multipurpose Disk Drive Unit
MECH	Mechanic, Mechanical, Mechanism
MED	Medium
MES	Main Engine Start
MI	Magnetic Indicator
MIC	Microphone
MICBAC	Micro-System Bus Access Channel
MID	Middle
MIN	Minimum
MISC	Miscellaneous
MKR	Marker (radio) Beacon
MLA	Maneuver Load Alleviation
MLG	Main Landing Gear
MLI	Magnetic Level Indicator
MLS	Microwave Landing System
MLW	Maximum Design Landing Weight
MMEL	Master Minimum Equipment List
MMO	Maximum Operating Mach
MMR	Multi Mode Receiver
MODLTR	Modulator
MON	Monitor, Monitoring, Monitored
MORA	Minimum Off Route Altitude
MOT	Motor, Motorized
MPD	Maintenance Planning Document
MRBR	Maintenance Review Board Report
MRW	Maximum Ramp Weight
MSA	Minimum Safe Altitude

MSB	Most Significant Bit
MSG	Message
MSL	Mean Sea Level
MSU	Mode Selector Unit (IRS)
MSW	Microswitch
MTBF	Mean Time Between Failure
MTBUR	Mean Time Between Unscheduled Removals
MTG	Mounting
MTO	Maximum Take-Off
MTOGW	Maximum Takeoff Gross Weight
MTOW	Maximum Design Takeoff Weight
MU	Management Unit
MUX	Multiplex, Multiplexer
MVT	Movement
MZFW	Maximum Design Zero Fuel Weight
N	Normal, North
N/A	Not Applicable
N/P	Next Page
N/W	Nose Wheel
N/WS	Nose Wheel Steering
NAC	Nacelle
NAS	Navy and Army Standard
NAV	Navigation
NAVAID	Navigation Aid
NBPT	No Break Power Transfer
NC	Normally Closed
NCD	No Computed Data
ND	Navigation Display
NDB	Non-Directional Beacon
NEG	Negative
NLG	Nose Landing Gear
NMI	Non Maskable Interrupt
No	Number
NO	Normally Open
NO	Normal Operation in SSM
NORM	Normal
NS	No Smoking

NUM	Numerical
NVM	Non-Volatile Memory
N1	Low Pressure Rotor Speed
OVBD	Overboard
OVHD	Overhead
OVHT	Overheat
OVLD	Overload
OVRD	Override
OVSP	Overspeed
OXY	Oxygen
P/B	Pushbutton
P/BSW	Pushbutton Switch
PA	Passenger Address
PATS	Passenger Air-to-Ground Telephone System
PAX	Passenger
PC	Pack Controller
PCB	Printed Circuit Board
PCM	Pulse Code Modulation
PCU	Passenger Control Unit
PCU	Power Control Unit
PD	Pitch Diameter
PED	Pedestal
PERF	Performance
PES	Passenger Entertainment (System)
PF	Power Factor
PFD	Primary Flight Display
PH	Phase
PHC	Probe Heat Computer
PIU	Passenger Information Unit
PMA	Permanent Magnet Alternator
PMG	Permanent Magnet Generator
PN	Part Number
PNL	Panel
POB	Pressure-Off Brake
POR	Point of Regulation
POS	Position
POT	Potentiometer
PPH	Pounds per hour

PPM	Parts per million
PPOS	Present Position
PR	Power Ready Relay
PRAM	Prerecorded Announcement and Music
PREAMP	Preamplifier
PRED	Prediction
PRESEL	Preselector/Preselection
PRESS	Pressure, Pressurization, Pressurize
PREV	Previous
PWR	Power
P&W	Pratt & Whitney
Q	Pitch Rate
QAD	Quick-Attach-Detach
QAR	Quick Access Recorder
QAT	Quadruple ARINC Transmitter
QEC	Quick Engine Change
QFE	Field Elevation Atmospheric Pressure
QFU	Runway Heading
QNE	Sea Level Standard Atmosphere Pressure
QNH	Sea Level Atmospheric Pressure
QTY	Quantity
R	Red
R	Right
R/I	Radio/Inertial
RA	Radio Altimeter, Radio Altitude
RAC	Rotor Active Clearance
RACC	Rotor Active Clearance Control
RACSB	Rotor Active Clearance Start Bleed
RAD	Radio
RAM	Random Access Memory
RAT	Ram Air Turbine
RBP	Right Bottom Plug
RC	Repetitive Chime
RCC	Remote Charge Converter

RCCB	Remote Control Circuit Breaker
RCDR	Recorder
RCL	Recall
RCPT	Receptacle
RCPTN	Reception
RCVR	Receiver
RECIRC	Recirculate, Recirculation
RECT	Rectifier
RED	Reduction
REF	Reference
REFUEL	Refueling
REG	Regulator
REL	Release
RES	Resistance
RET	Return
REV	Reverse
REV	Revise, Revision
RF	Radio Frequency
RFS	Regardless of Feature Size
RLA	Reverser Lever Angle
RLS	Remote Light Sensor
RLY	Relay
RMP	Radio Management Panel
RNG	Range
ROM	Read Only Memory
RPLNT	Repellent
RPM	Revolution per Minute
RQRD	Required
RST	Reset
RSV	Reserve
RSVR	Reservoir
RTE	Route
RTN	Return
RTP	Right Top Plug
RTS	Return to Seat
RUD	Rudder
RVDT	Rotary Variable Differential Transducer
RVR	Runway Visual Range

RWY	Runway
S	South
S/C	Step Climb
S/D	Step Descent
SAF	Safety
SAT	Static Air Temperature
SB	Service Bulletin
SC	Single Chime
SD	System Display
SDAC	System Data Acquisition Concentrator
SDCU	Smoke Detection Control Unit
SDN	System Description Note
SEB	Seat Electronic Box
SEC	Secondary
SEL	Select, Selected, Selector, Selection
SELCAL	Selective Calling System
SFCC	Slat Flap Control Computer
SH ABS	Shock Absorber
SHED	Shedding
SHT	Short
SIC	System Isolation Contactor
SID	Standard Instrument Departure
SIG	Signal
SLT	Slat
SMK	Smoke
SN	Serial Number
SOL	Solenoid
SOV	Shut-Off Valve
SPD	Speed
SPLY	Supply
SPMC	Service Process Material Control
SPOP	Service Process Operation Procedure
SQ	Squelch
SRU	Shop Replaceable Unit
SSB	Single Side Band
SSEC	Static Source Error Correction

SSM	Sign Status Matrix
SSTU	Side Stick Transducer Unit
STA	Station
STAB	Stabilizer
STAR	Standard Terminal Arrival Route
STAT	Static
STBY	Standby
STD	Standard
STGR	Stringer
STS	Status
SVA	Stator Vane Actuator
SVCE	Service
SW	Switch
SWTG	Switching
SYNTHR	Synthetizer
SYS	System
T	True, Turn
T/C	Top of Climb
T/D	Top of Descent
T/R	Thrust Reverser
T-P	Turn Point
TACT	Tactical
TAS	True Airspeed
TAT	Total Air Temperature
TBC	To Be Confirmed
TBD	To be Determined
TCA	Turbine Cooling Air
TCAS	Traffic Alert and Collision Avoidance System
T2CAS	Traffic and Terrain Collision Avoidance System
TCC	Turbine Case Cooling
TDS	Technical Data Sheet
TE	Trailing Edge
TEC	Turbine Exhaust Case
TEMP	Temperature
TFU	Technical Follow-Up
TGT	Target
THR	Thrust

THRM	Thermal
THS	Trimmable Horizontal Stabilizer
TIT	Turbine Inlet Temperature
TK	Tank
TKE	Track Angle Error
TLA	Throttle Lever Angle
TLU	Travel Limitation Unit
TMR	Timer
TO	Takeoff
TOGW	Takeoff Gross Weight
TOT	Total
TPIC	Tire Pressure Indicating Computer
TPIS	Tire Pressure Indicating System
TR	Transformer Rectifier
TRA	Throttle Resolver Angle
TRANS	Transition
TRDV	Thrust Reverser Directional Valve
TRF	Turbine Rear Frame
VC	Ventilation Controller
VCO	Voltage Controlled Oscillator
VCU	Video Control Unit
VDC	Voltage Direct Current
VDEV	Vertical Deviation
VDR	VHF Data Radio
VEL	Velocity
VENT	Ventilation
VERT	Vertical
VFE	Maximum Flat Extended Speed
VFTO	Final Takeoff Speed
VHF	Very High Frequency
VHV	Very High Voltage
VIB	Vibration
VLE	Maximum Landing Gear Extended Speed
VLO	Maximum Landing Gear Operating Speed
VLS	Lower Selectable Speed
VM	Voltmeter
VMAX	Maximum Allowable Airspeed

VMO	Maximum Operating Speed
VOR	VHF Omnidirectional Range
VOR.D	VOR-DME
VR	Rotation Speed
VRMS	Volt Root Mean Square
X FEED	Crossfeed
X-TALK	Cross-Talk
XCVR	Transceiver
XDCR	Transducer
XFMR	Transformer
XFR	Transfer
XMSN	Transmission
XMTR	Transmitter
XPDR	Transponder
Y	Yellow
Z	Zone
ZFCG	Zero Fuel Center of Gravity
ZFW	Zero Fuel Weight
3D	Three Dimensional (Lat, Long, Alt)
4D	Four Dimensional (Lat, Long, Alt, Time)

C. Most relevant parameters recorded at the FDR in a sorted condition:

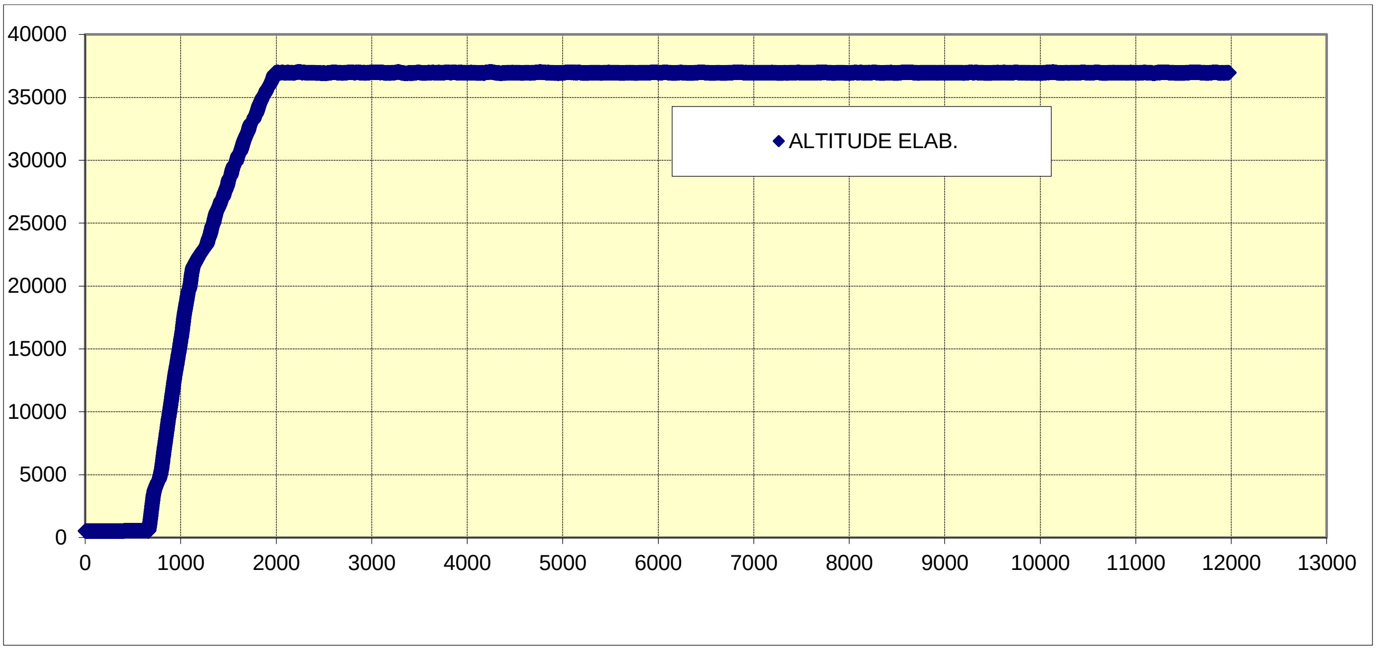
Note:

- FDR downloaded data had been processed and plotted using Excel facilities
- FDR data included Analog and Discrete data
- Discrete data were expressed using the two status logic 1 and logic 0
- Several parameters were received from more than one source, consequently plotted more than one time showing the information source.
- As an example, several warning parameters were plotted receiving data from FWC1 and FWC2, e.g. Lavatory smoke, Master warning, Avionic smoke, Master Caution.
- The parameter label refers to the information source as the unique source, e.g.
    - MASTER WARNING CAPTAIN (FWC1 only)
    - FIRST-OFFICER MASTER WARNING ON (FWC1 only)

    etc…

2. Performance parameters

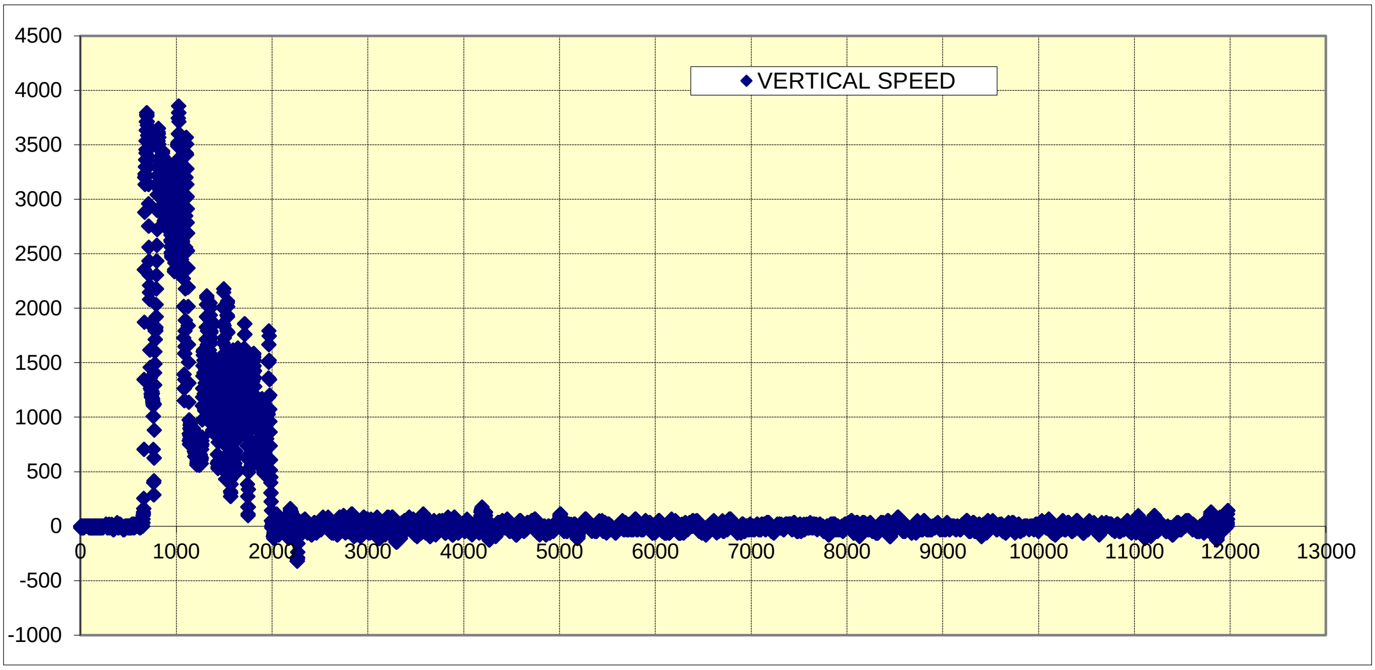
– ALTITUDE ELAB.

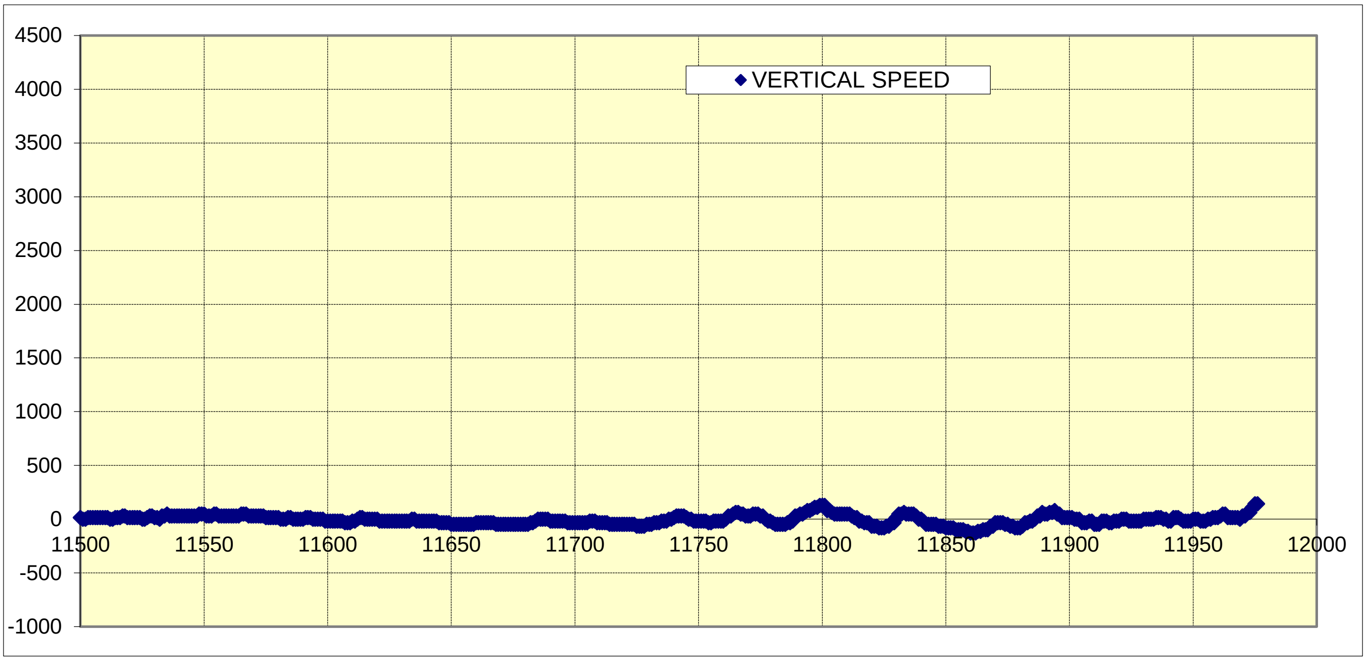


Aircraft reached top of climb (37000 ft) at almost 21:43:38 UTC (2009 seconds on the plot)

Cruise altitude was 37000 ft to the end of recording

- VERTICAL SPEED

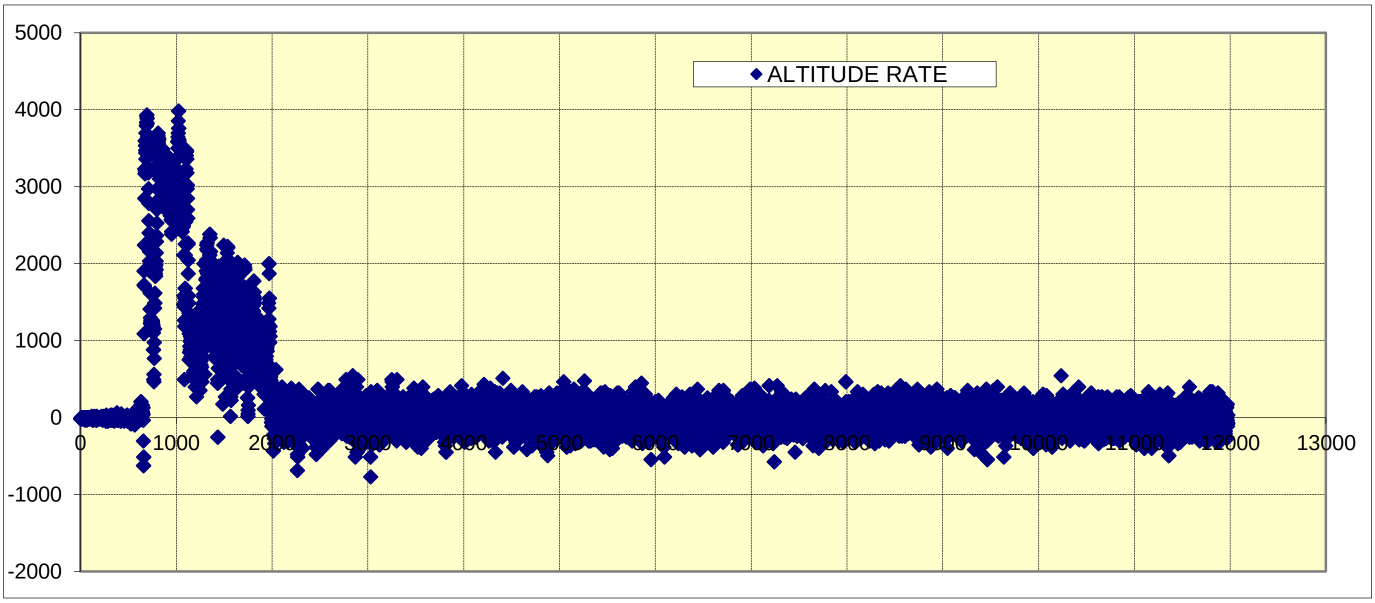


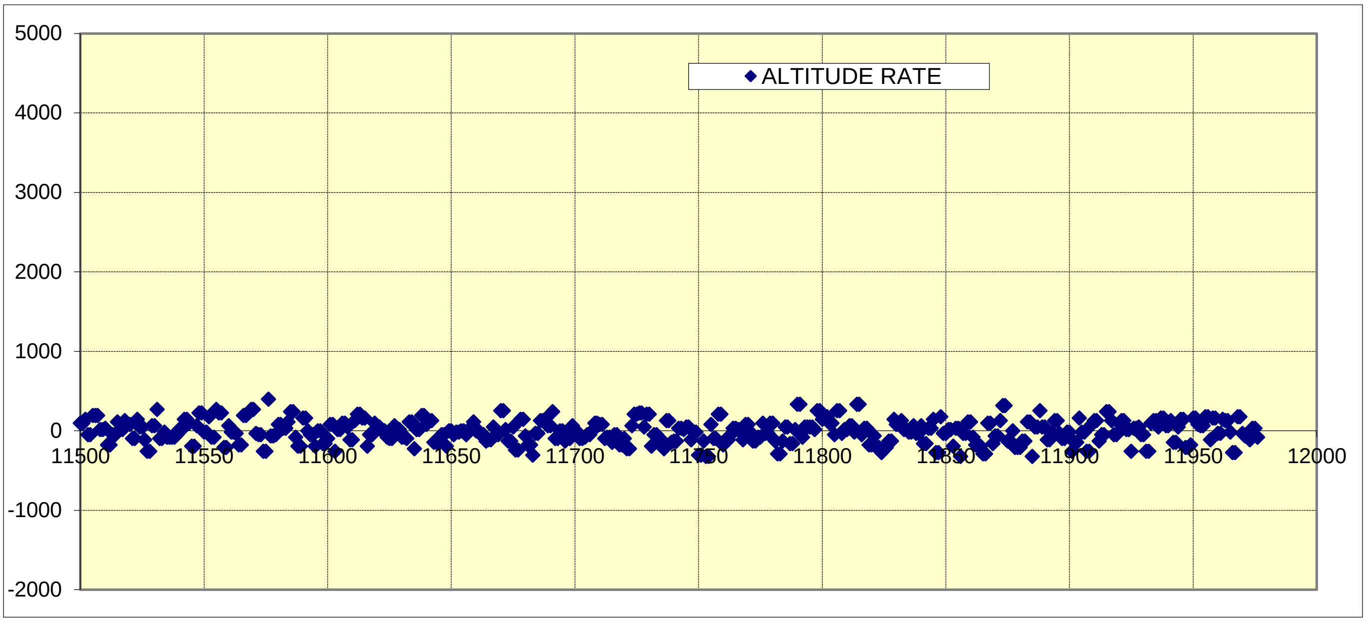


Vertical speed shown at the end portion of the recording

Last vertical speed was about 144 ft/min

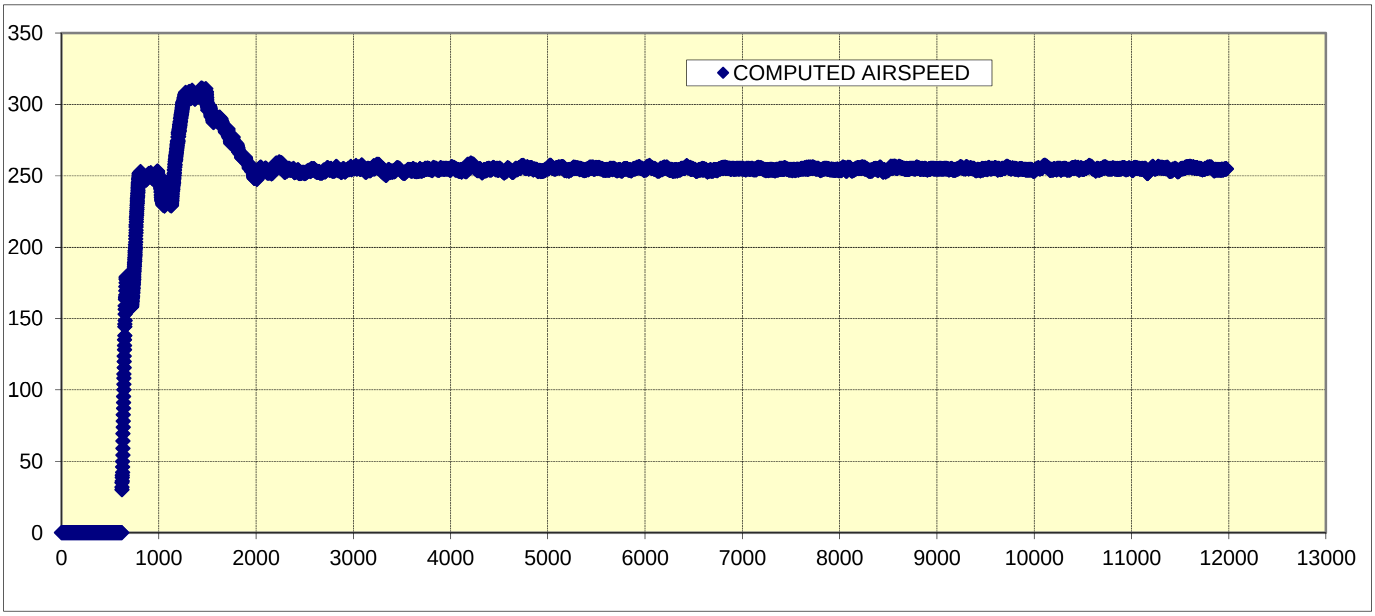
- Altitude Rate

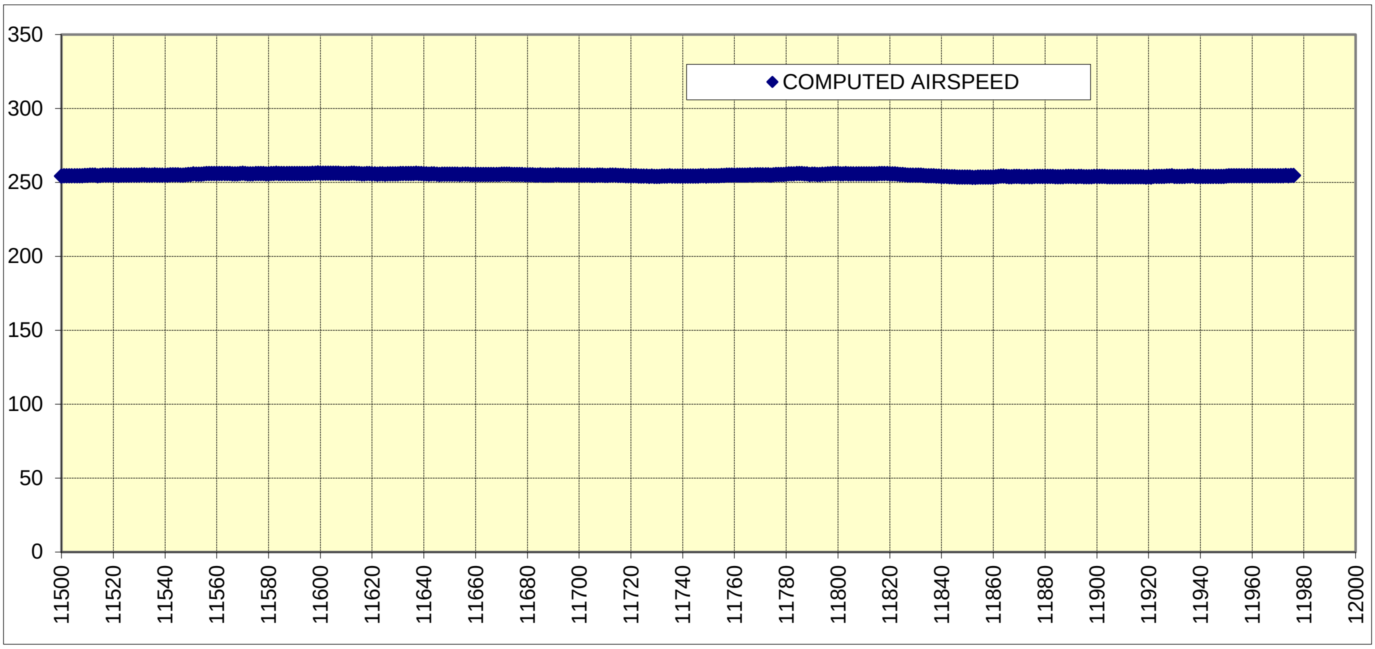




Altitude Rate shown at the end portion of the recording

– COMPUTED AIRSPEED

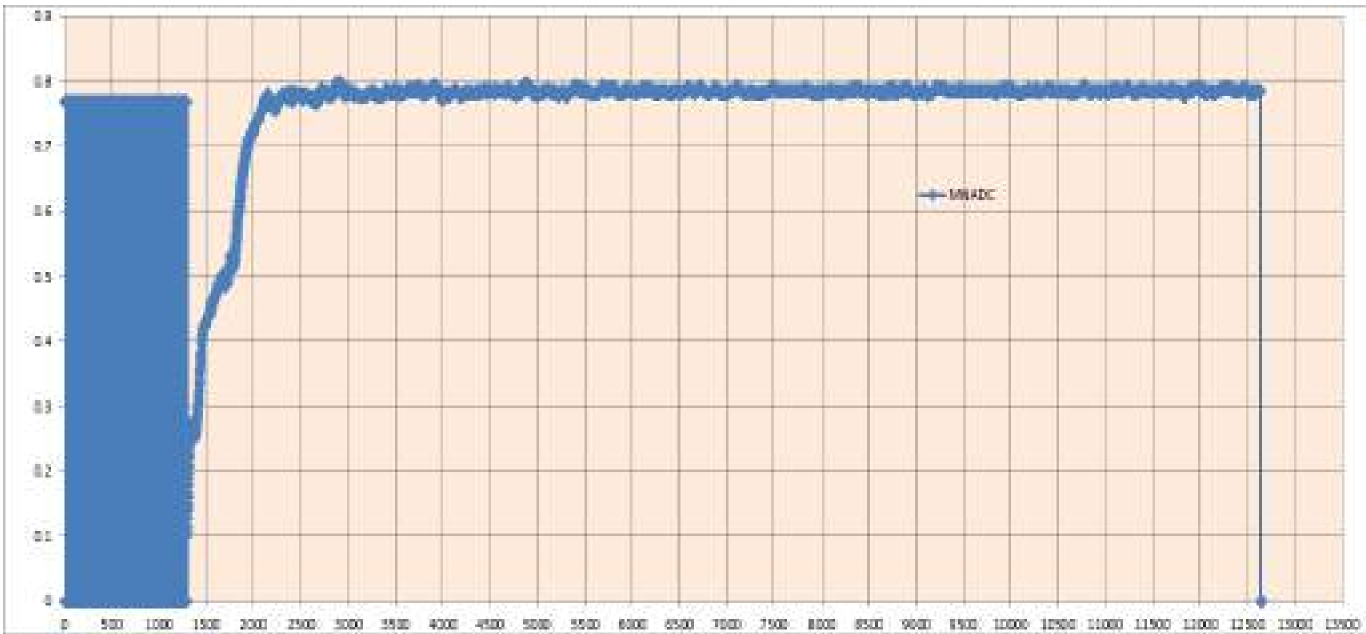




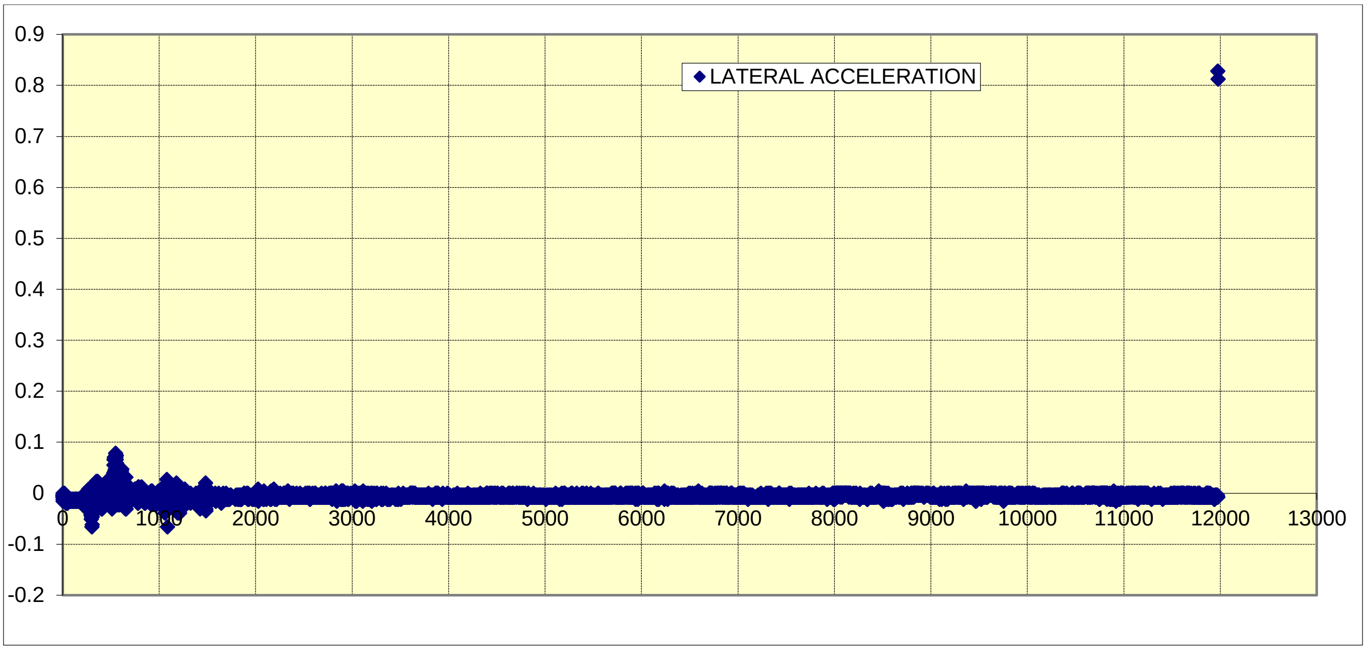
Computed Airspeed at the last portion of the recording

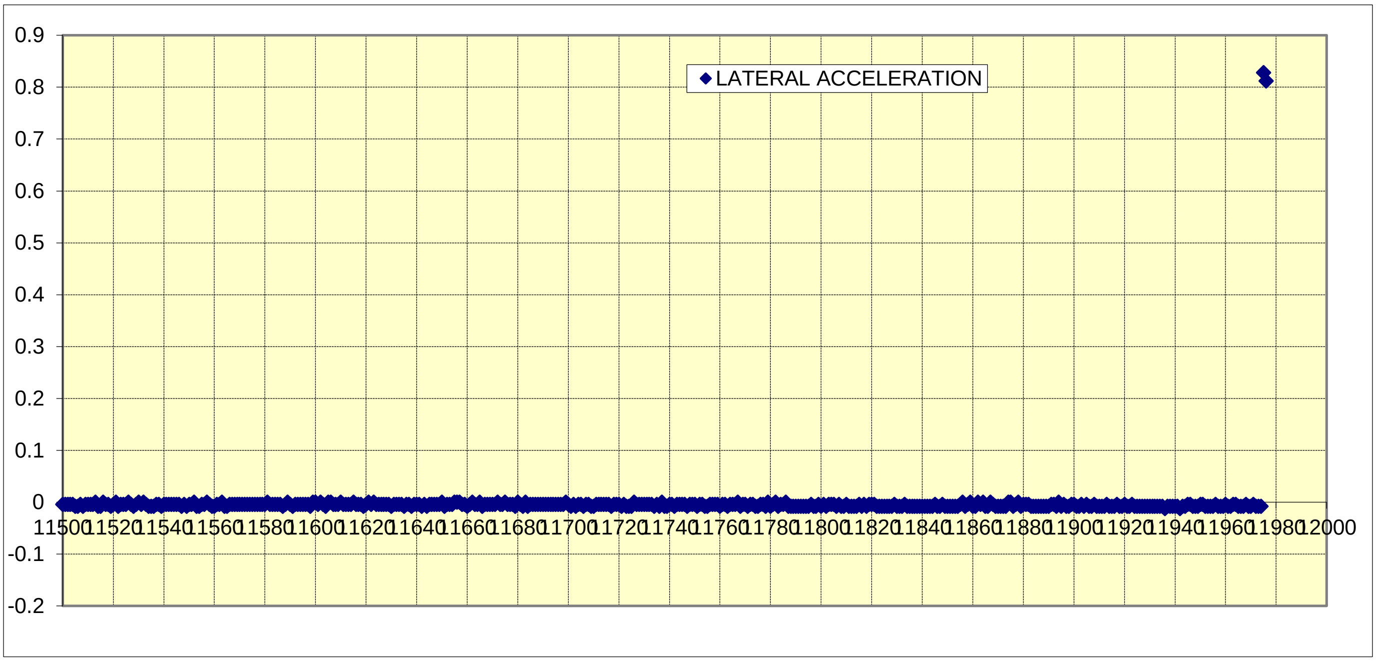
Airspeed was almost 254 knot

- MACH NUMBER (ADC)



– LATERAL ACCELERATION

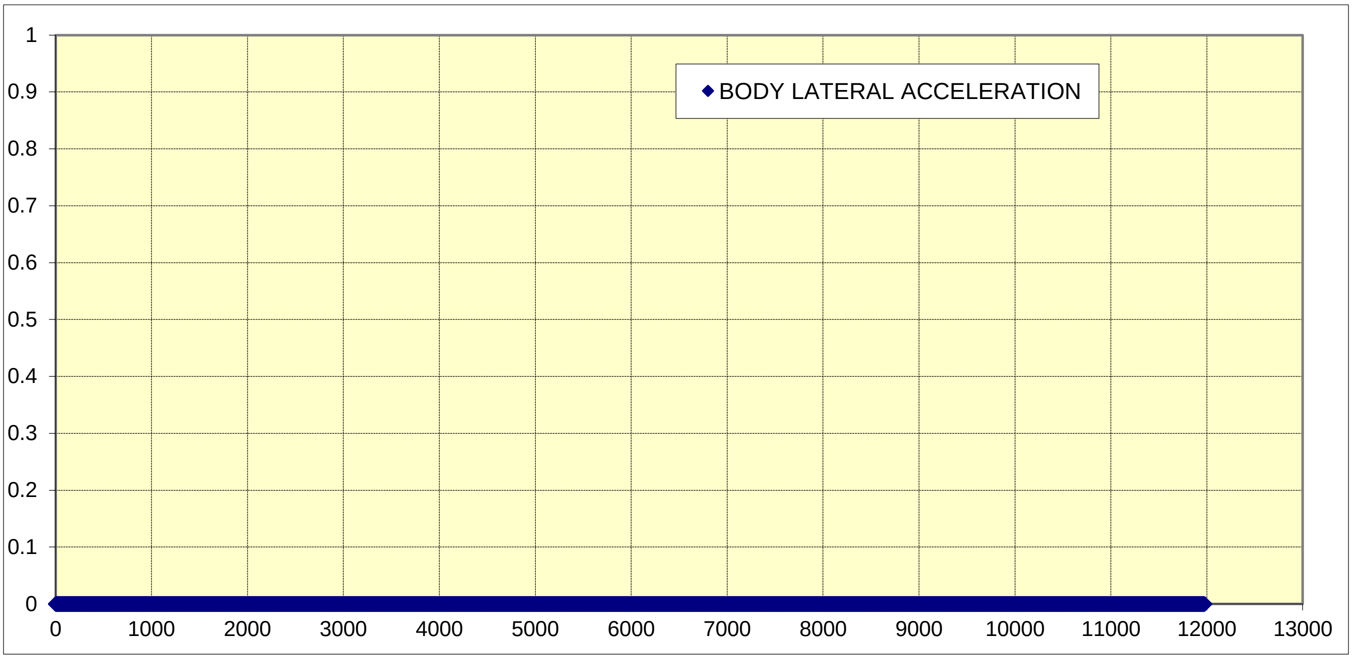




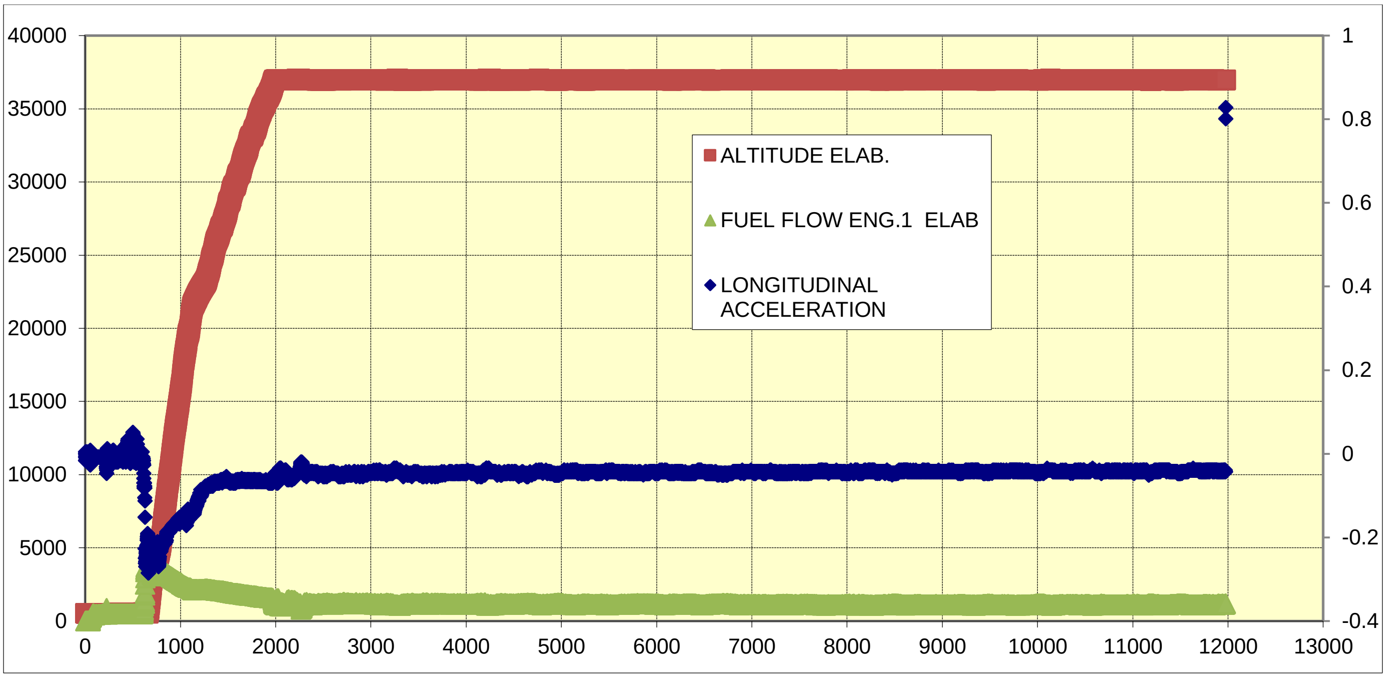
- Lateral Acceleration, closer view at the end of the recording

UTC	Lateral acceleration	Plot time
24:29:42	-0.008	11973
24:29:43	-0.008	11974
24:29:44	0.828	11975
24:29:45	0.812	11976

- Body lateral acceleration

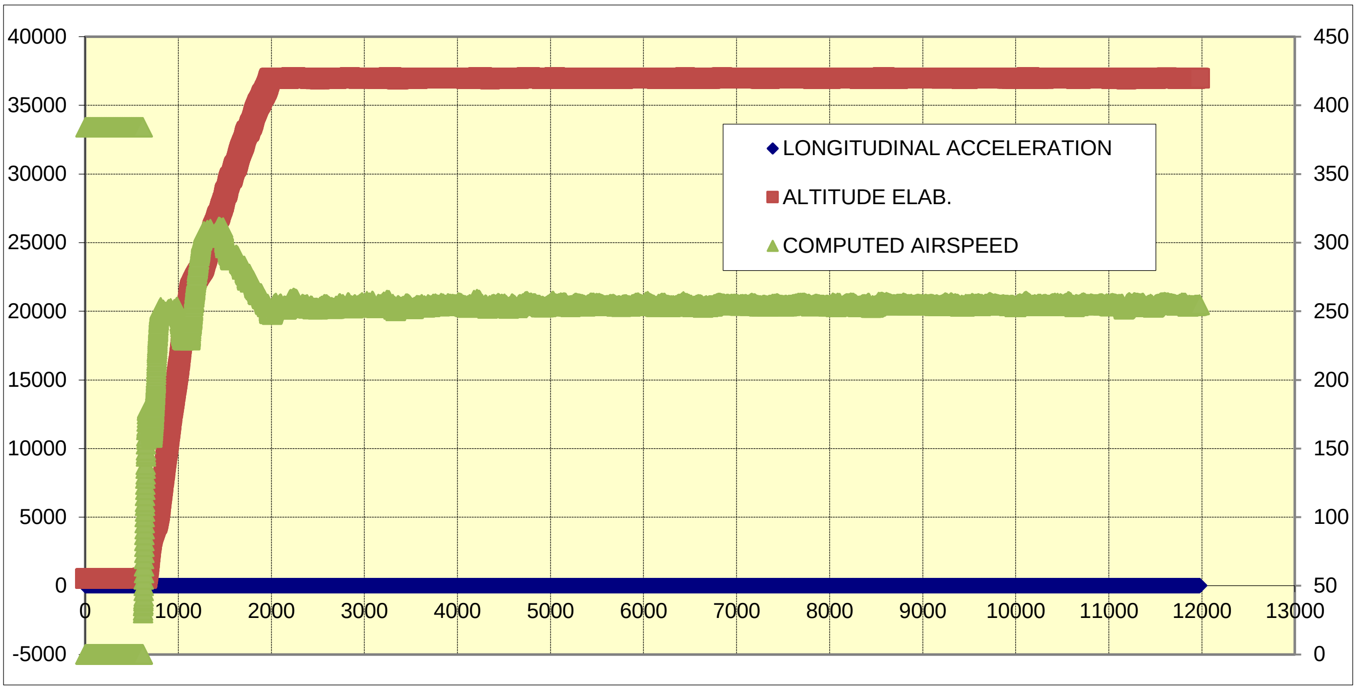


- LONGITUDINAL ACCELERATION



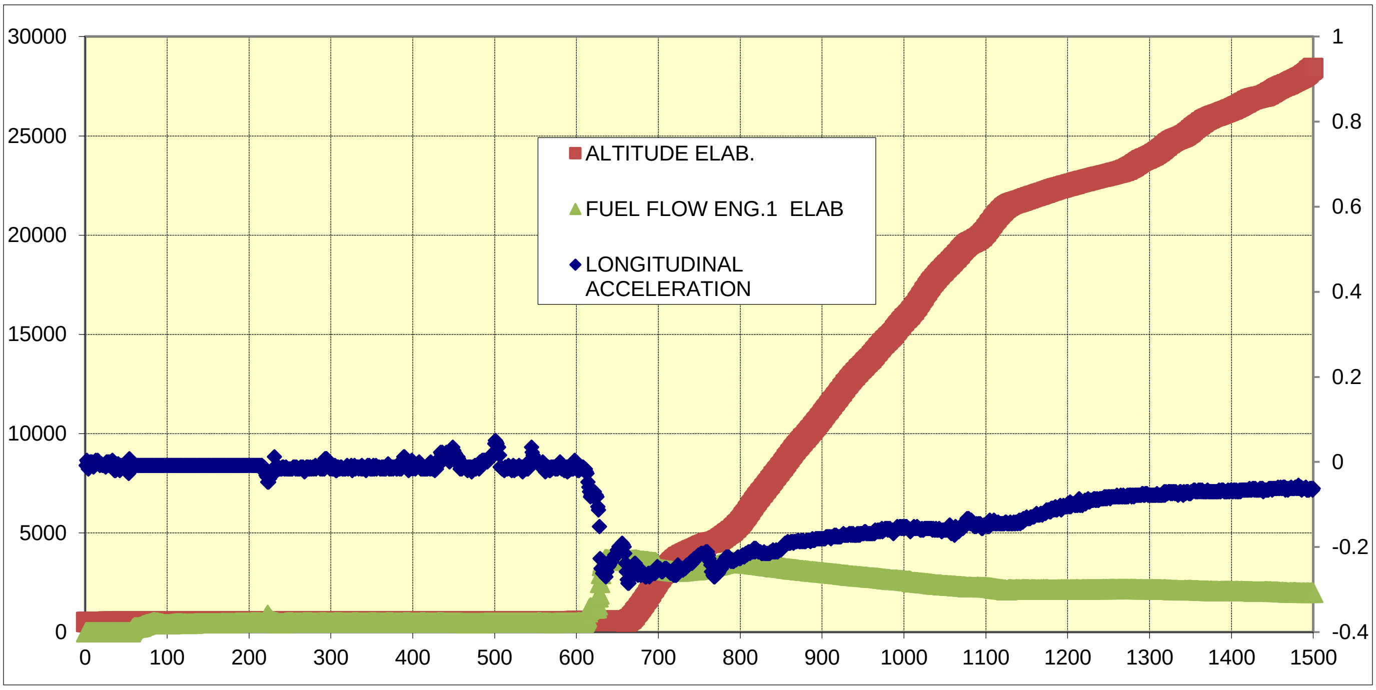
Combined plot:

- Longitudinal acceleration
- Pressure altitude
- Engine 1 fuel flow



Combined plot:

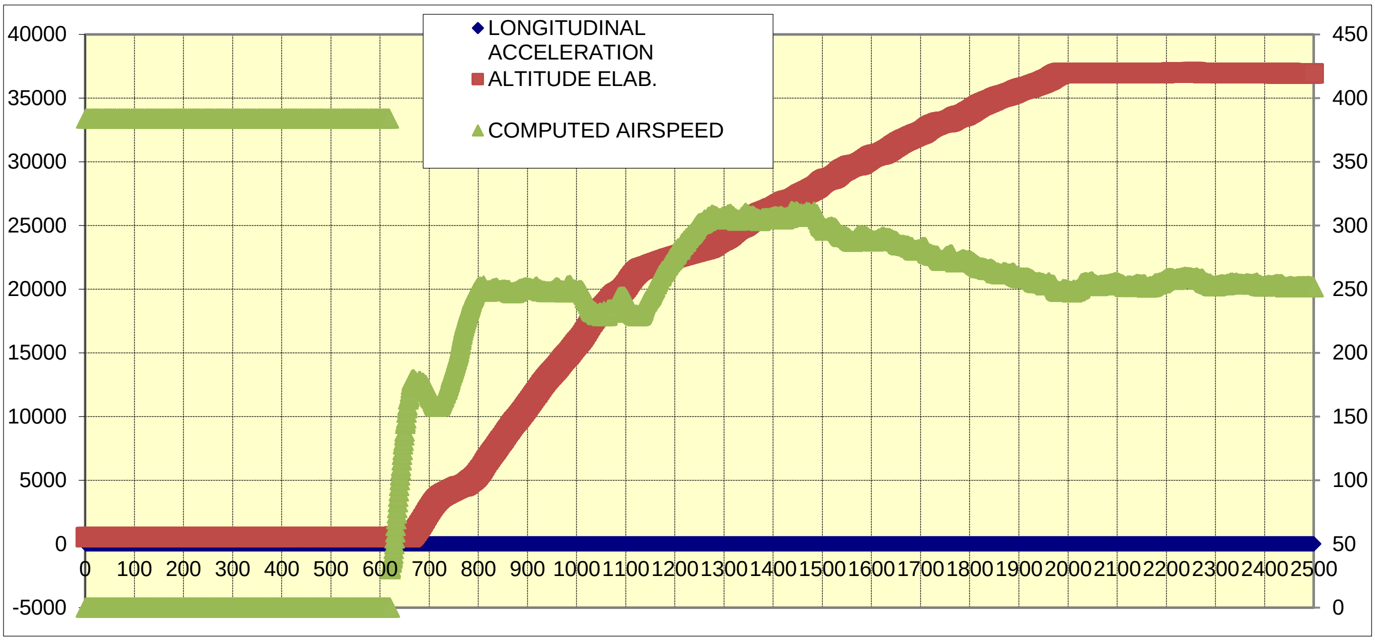
- Longitudinal acceleration
- Pressure altitude
- Computed Airspeed



Combined plot:

- Longitudinal acceleration
- Pressure altitude
- Engine 1 fuel flow

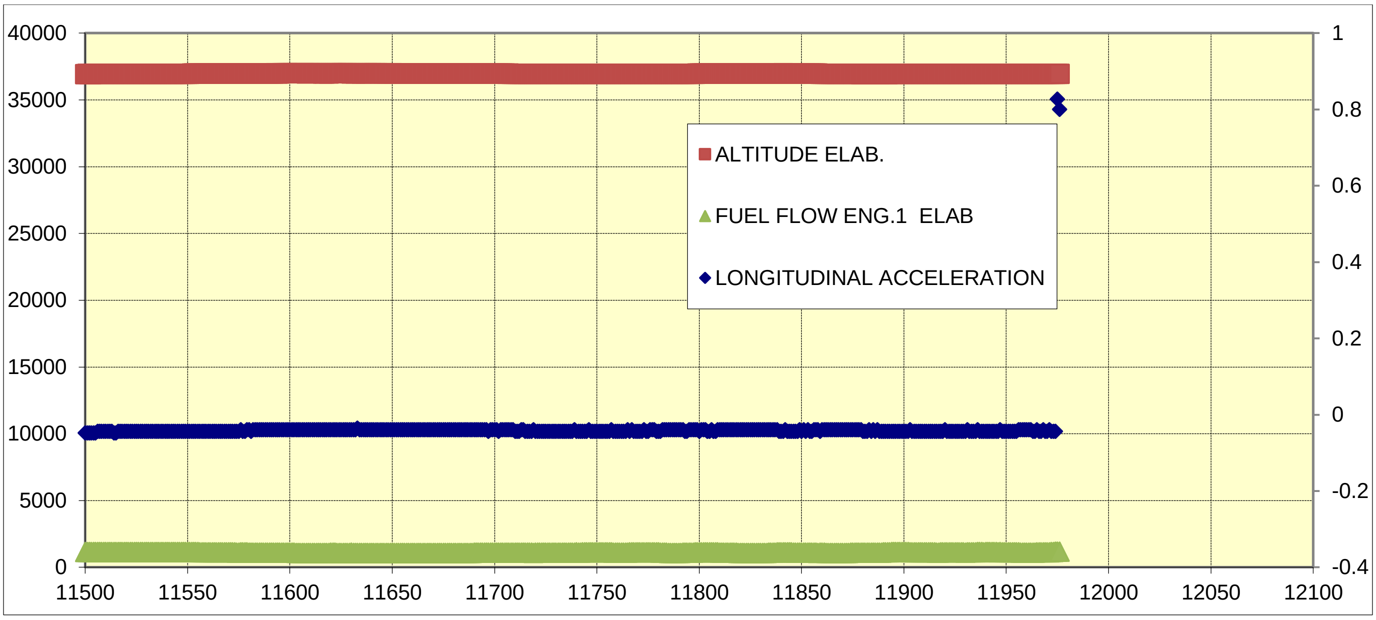
(first portion of the flight)



Combined plot:

- Longitudinal acceleration
- Pressure altitude
- Computed Airspeed

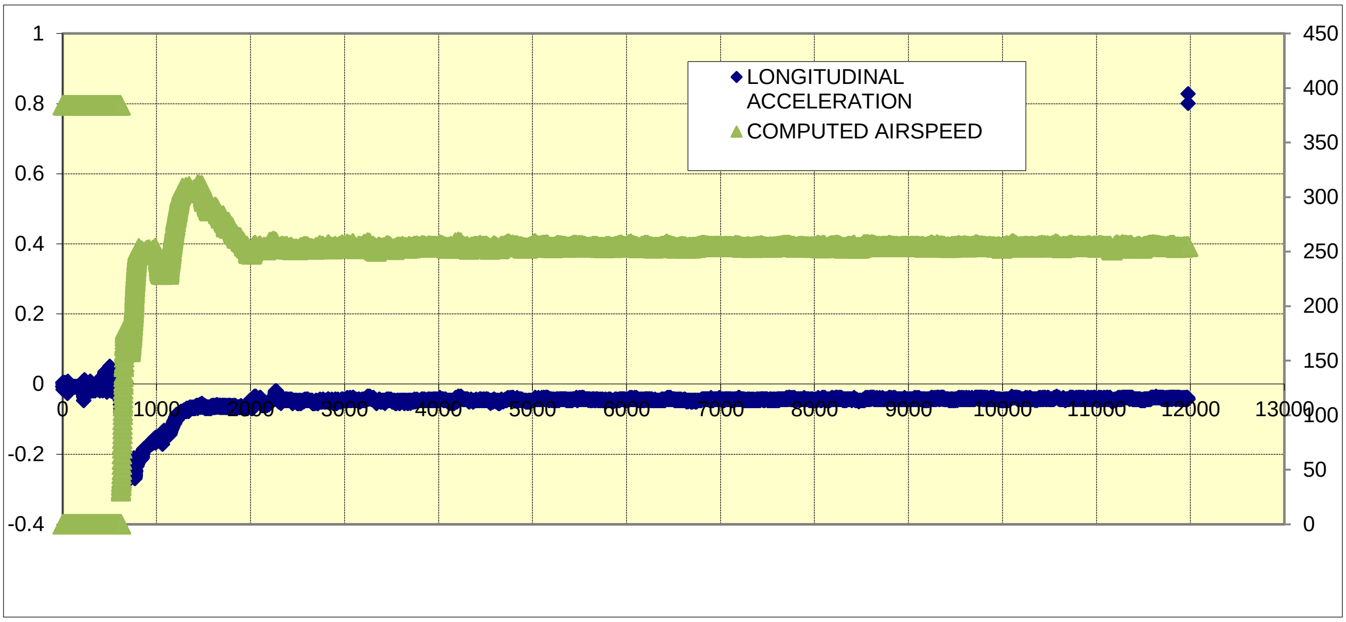
(first portion of the flight)



Combined plot:

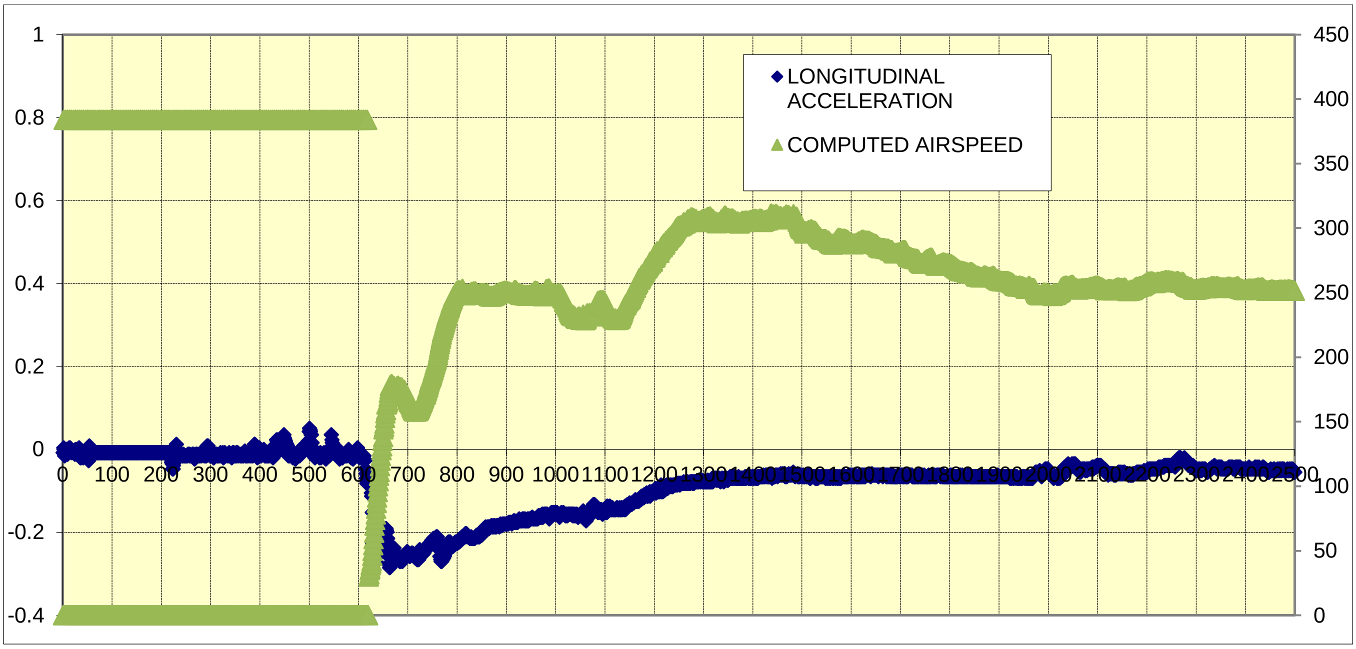
- Longitudinal acceleration plus
- Pressure altitude
- Engine 1 fuel flow

(last portion of the flight)



Combined plot:

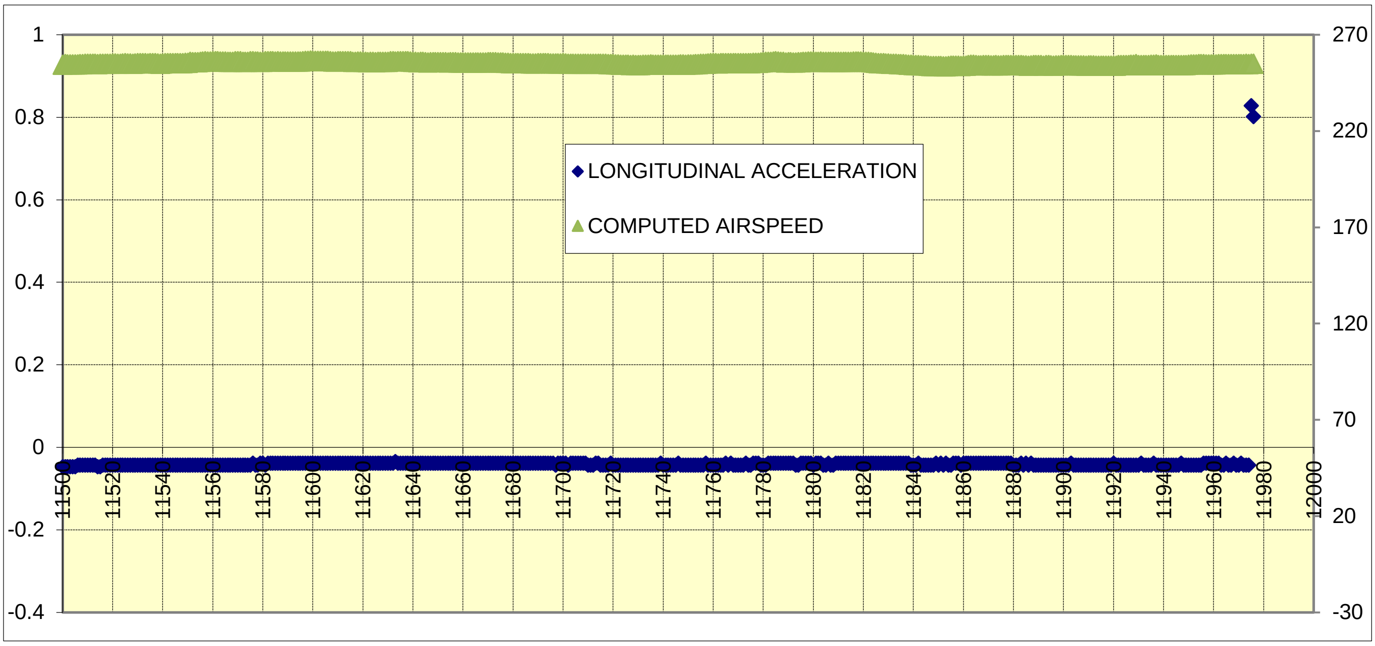
- Longitudinal acceleration plus
- Computed Airspeed



Combined plot:

- Longitudinal acceleration
- Computed Airspeed

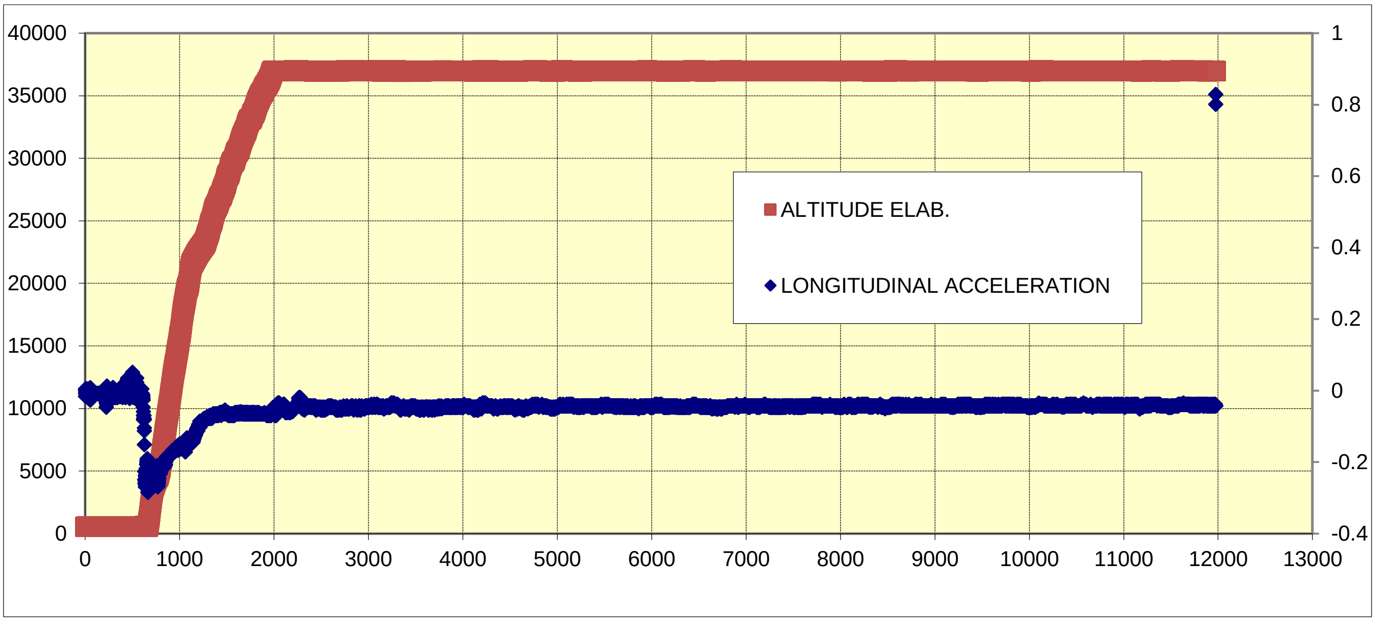
(First portion of the recording)



Combined plot:

- Longitudinal acceleration plus
- Computed Airspeed

(Last portion of the recording)



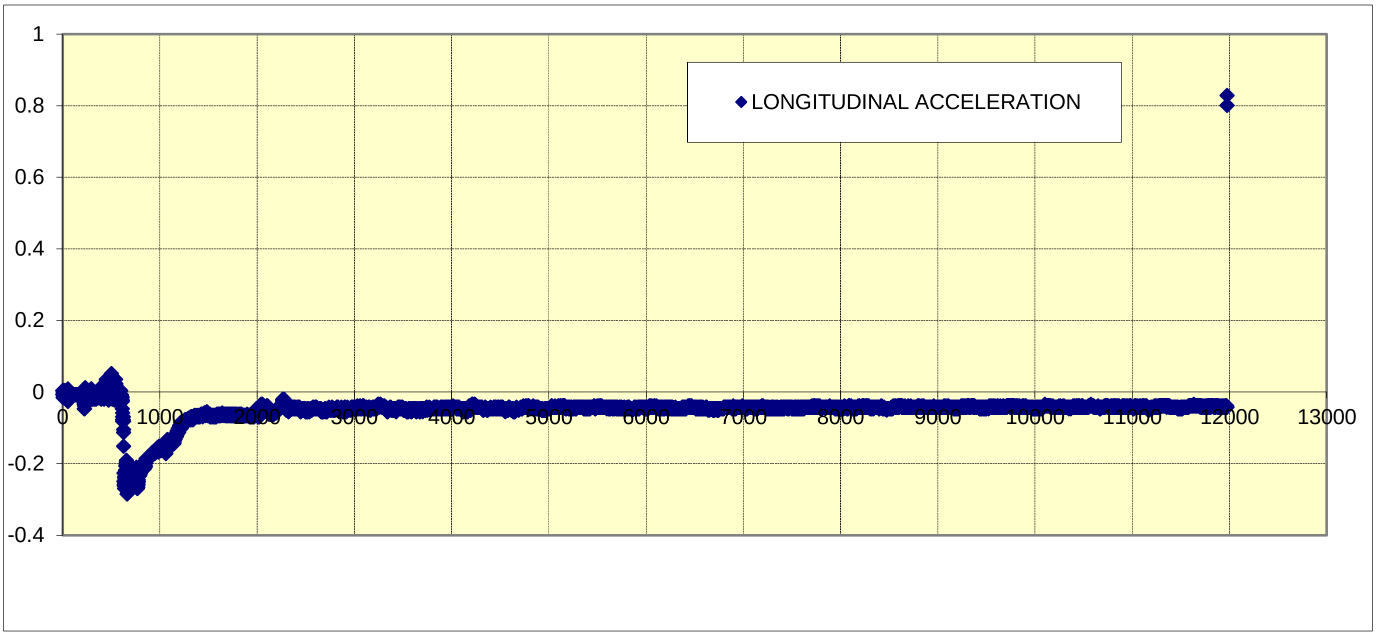
Combined plot:

- Pressure Altitude
- Longitudinal Acceleration

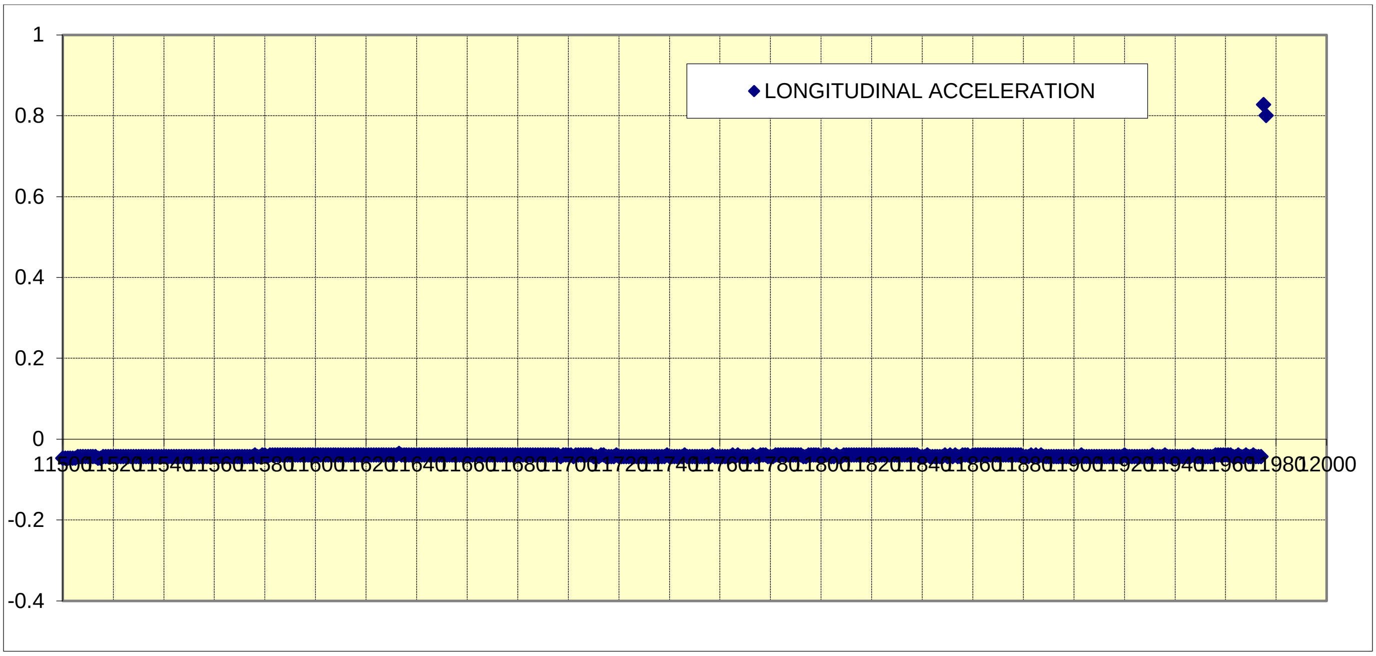
(First portion of the recording)

ARAB REPUBLIC OF EGYPT
MINISTRY OF CIVIL AVIATION
EGYPTIAN AIRCRAFT ACCIDENT
INVESTIGATION DIRECTORATE

جمهورية مصر العربية
وزارة الطيران المدنى
الادارة المركزية لحوادث الطيران



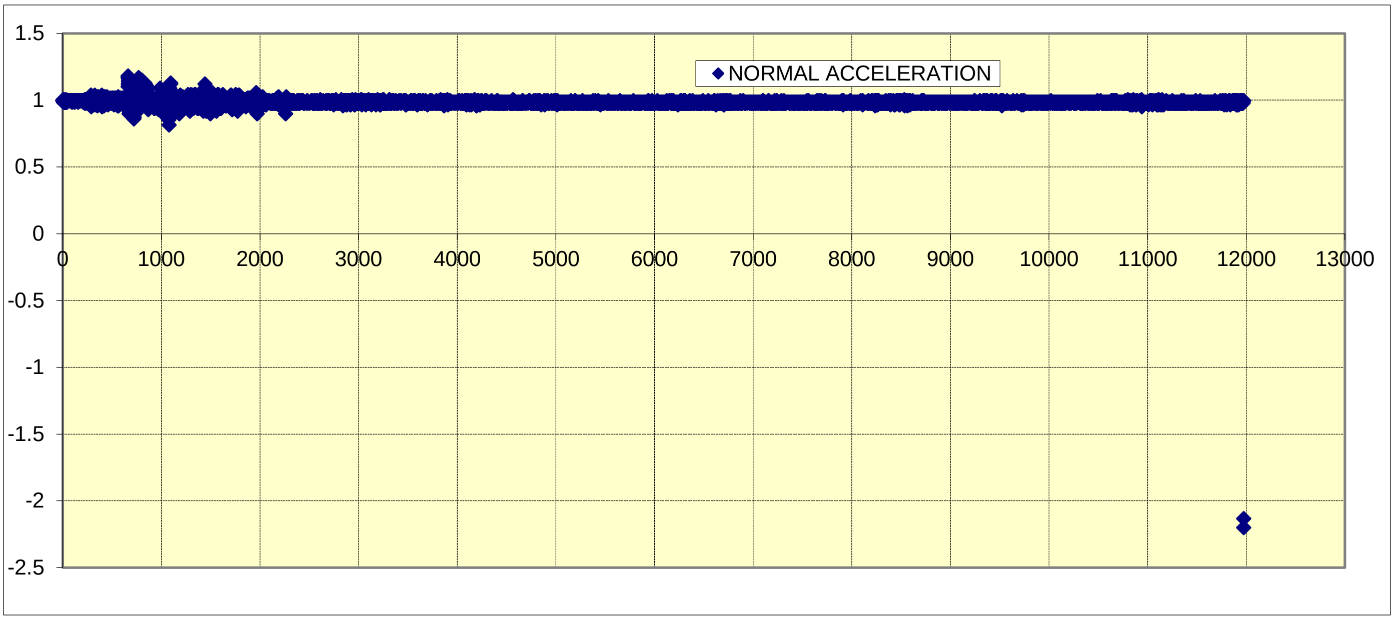
Longitudinal acceleration

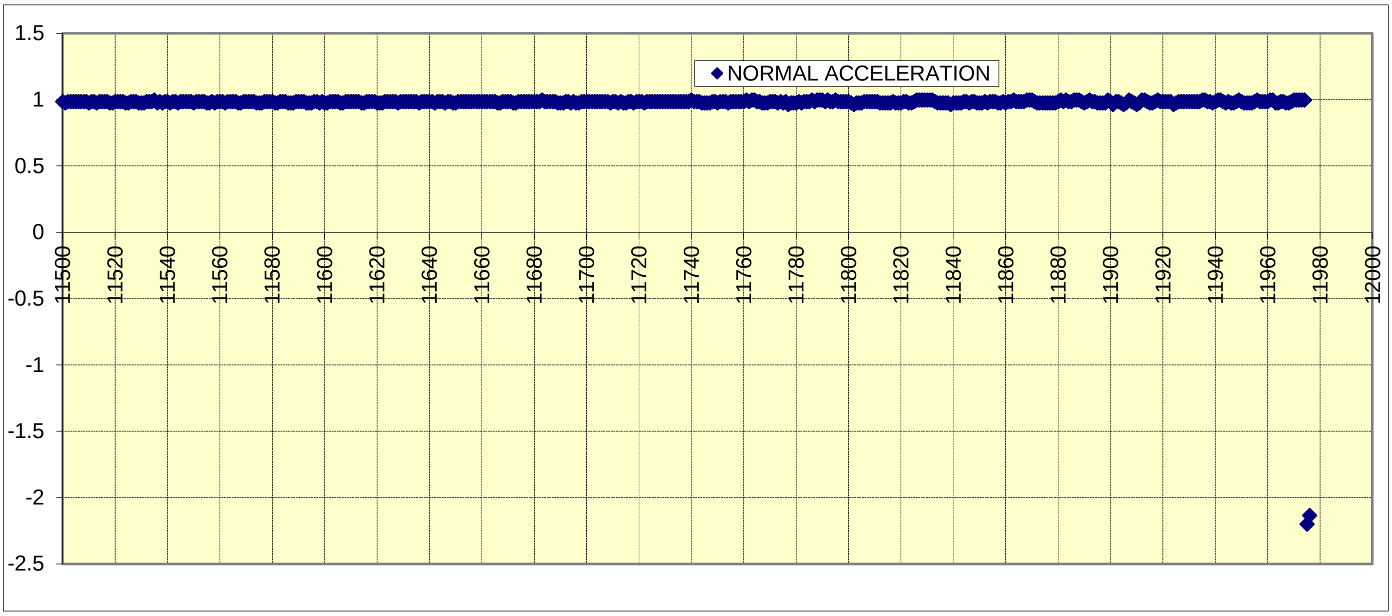


(last portion of the flight)

UTC	Longitudinal acceleration	Plot time
24:29:42	-0.043	11973
24:29:43	-0.043	11974
24:29:44	0.828	11975
24:29:45	0.801	11976

– NORMAL ACCELERATION

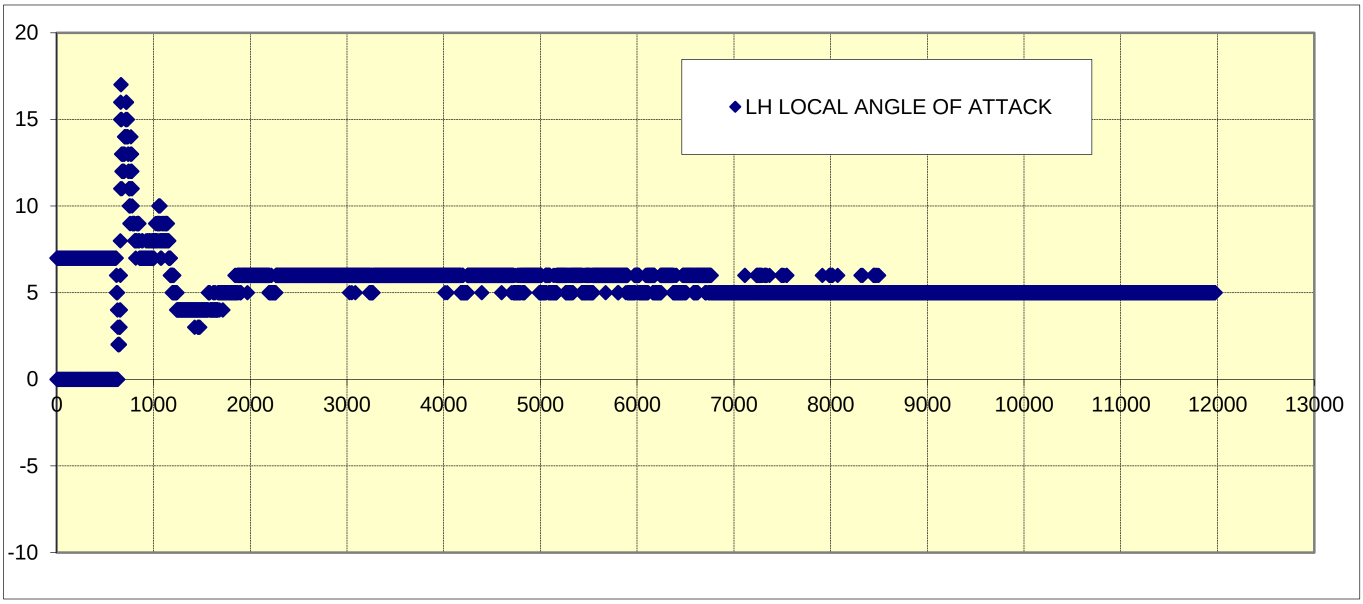




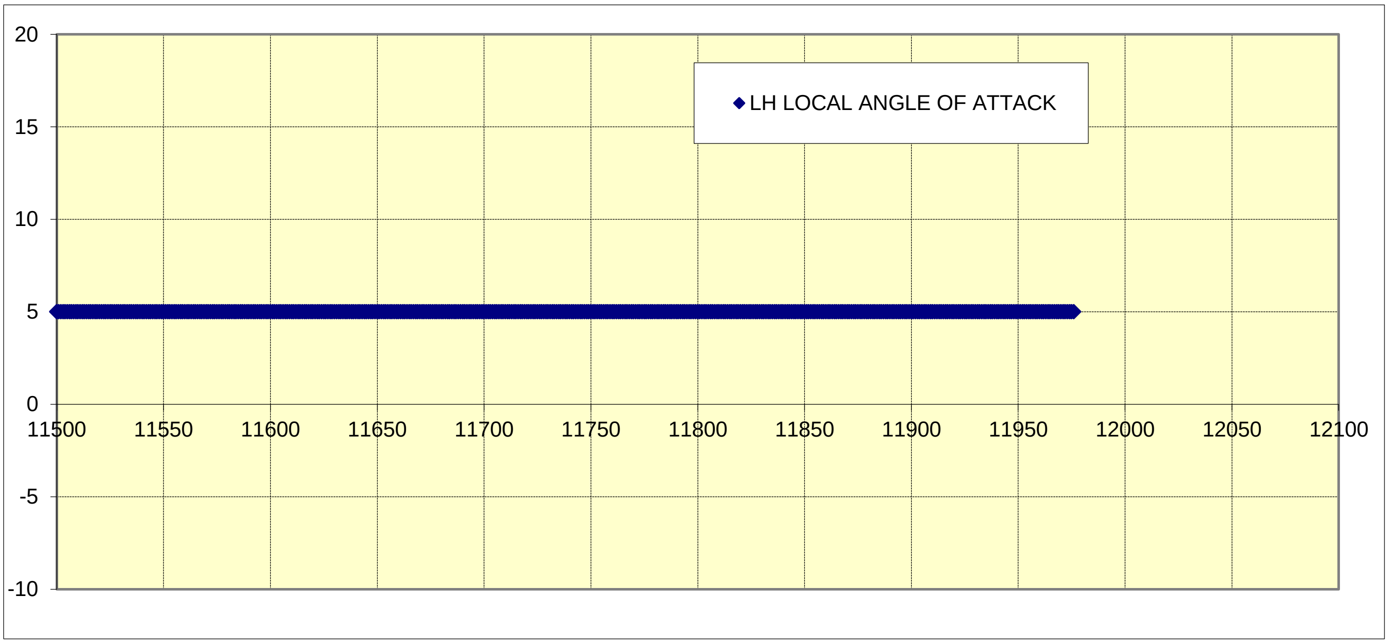
Normal Acceleration, closer view at the end of the flight

UTC	normal acceleration	Plot time
24:29:42	0.977	11973
24:29:43	0.997	11974
24:29:44	-2.134	11975
24:29:45	-2.2	11976

– LH LOCAL ANGLE OF ATTACK



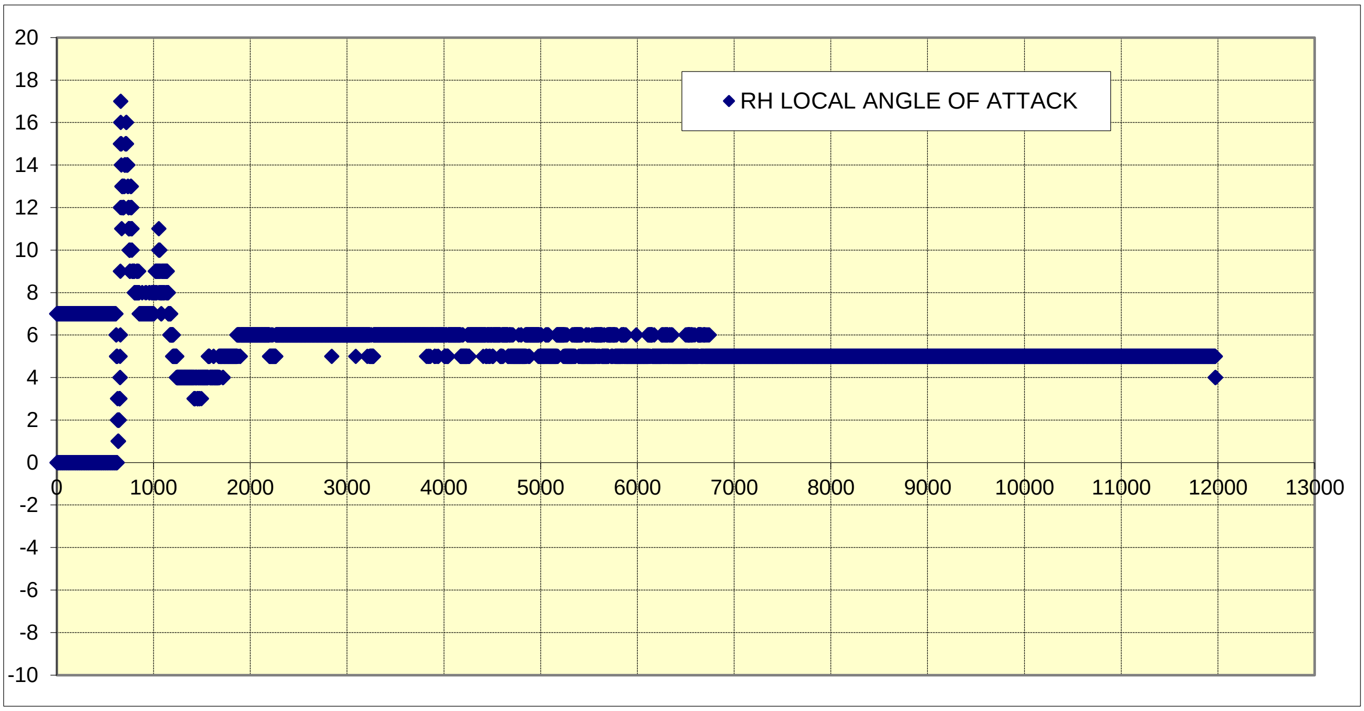
LH local Angle of Attack was varying between 6 degrees and 5 degrees

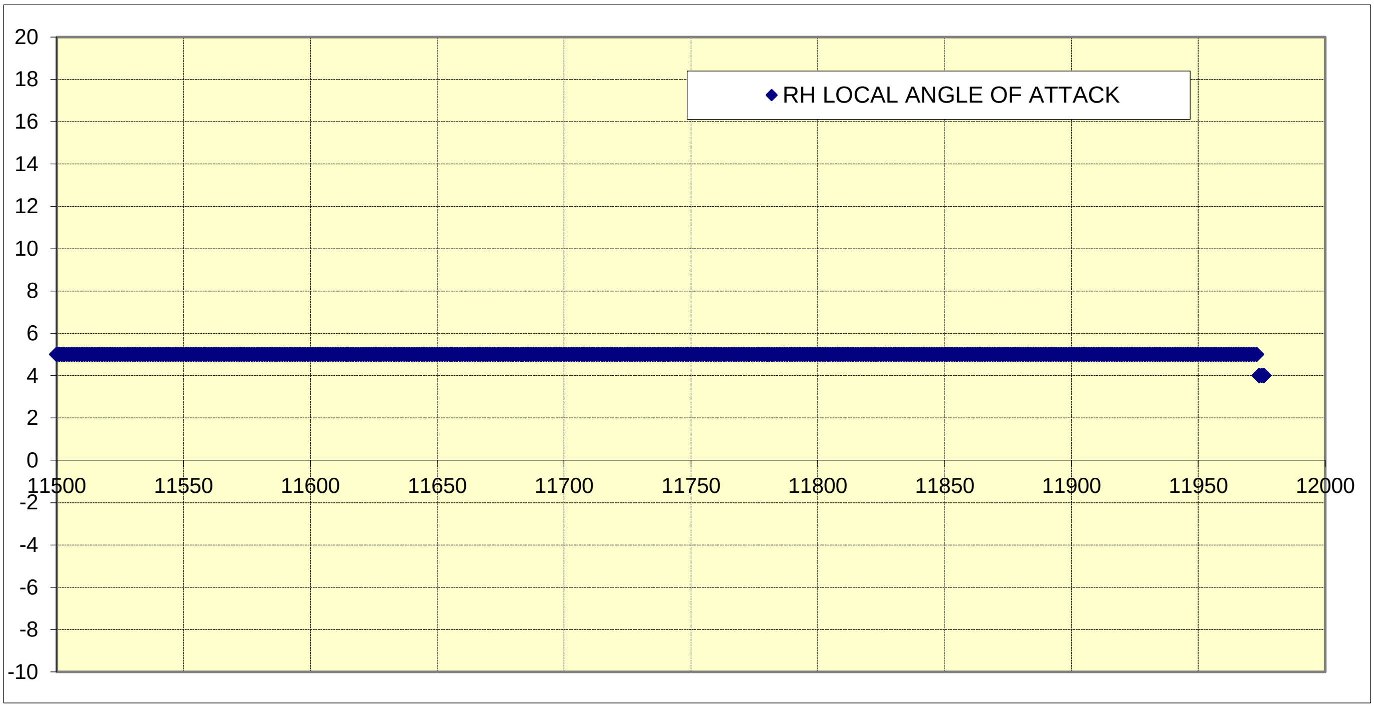


– LH local Angle of Attack, closer view at the end of the flight

LH local Angle of Attack showed a fixed value of 5 degrees for almost the last 3500 seconds of the recording

– RH LOCAL ANGLE OF ATTACK

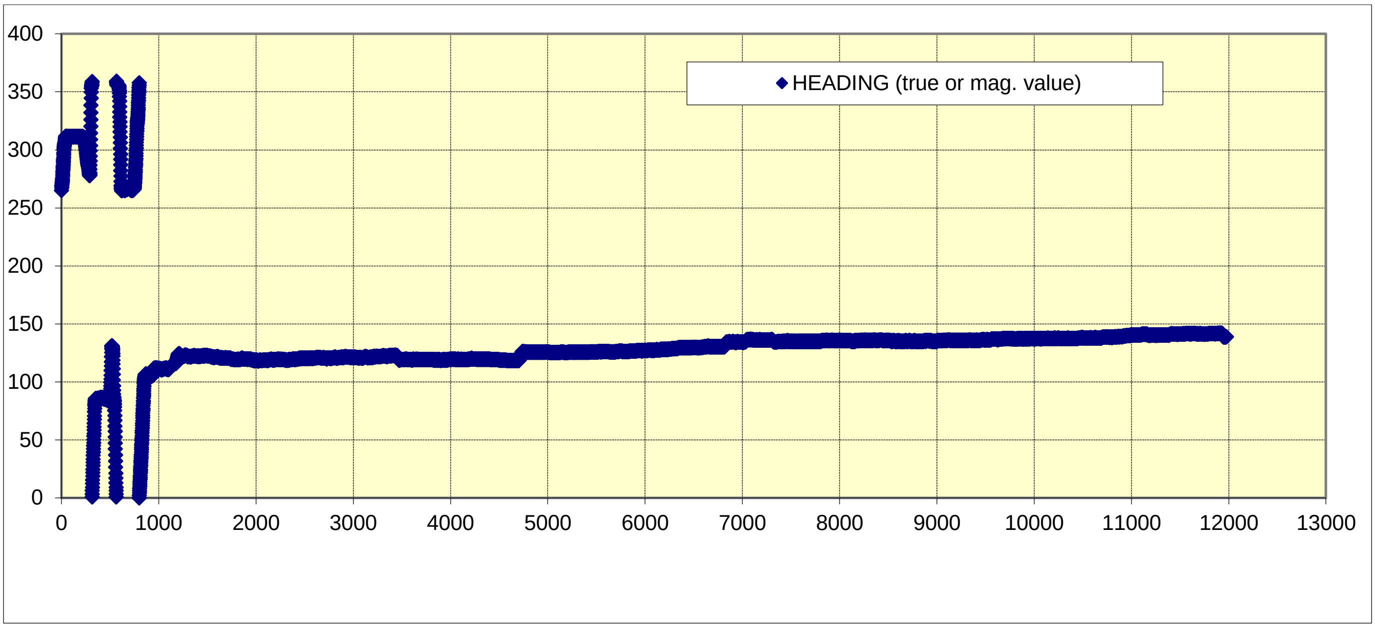


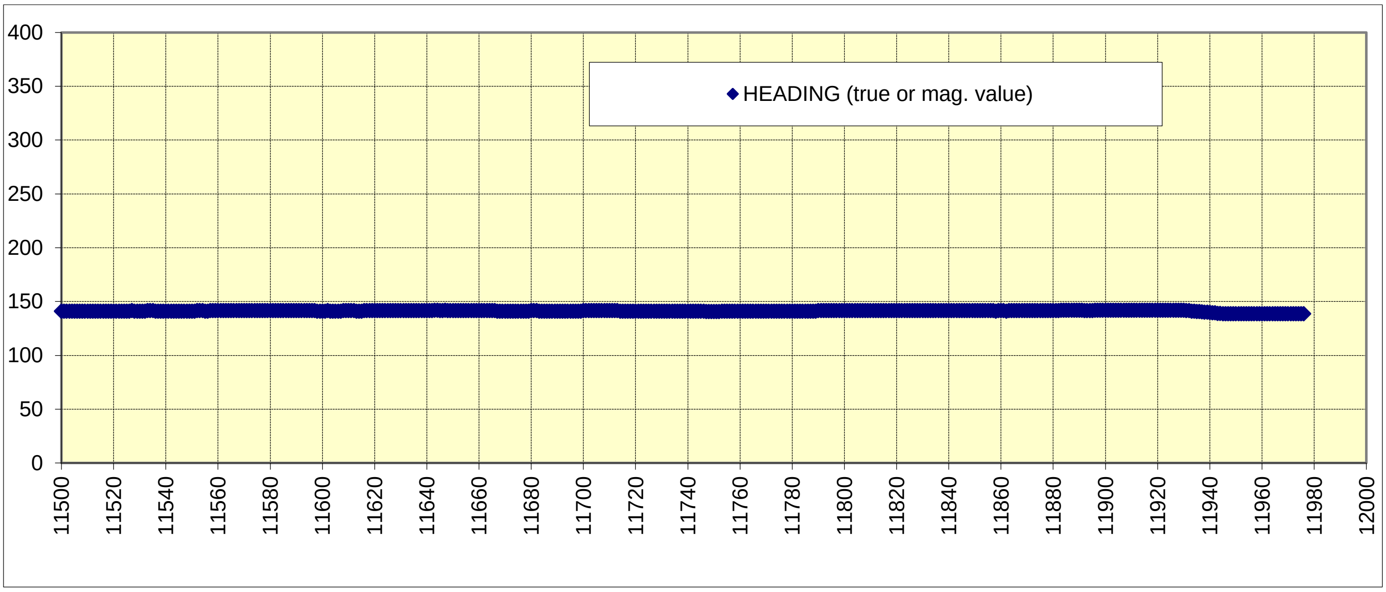


RH local angle of attack shown at the end portion of the recording

At almost 00:29:42 UTC (11973 seconds on the plot) RH angle of attack changed from a constant value of 5 degrees to -4 degrees till the end of the recording 00:29:45 UTC (11976 seconds on the plot)

- HEADING (true or mag. value)

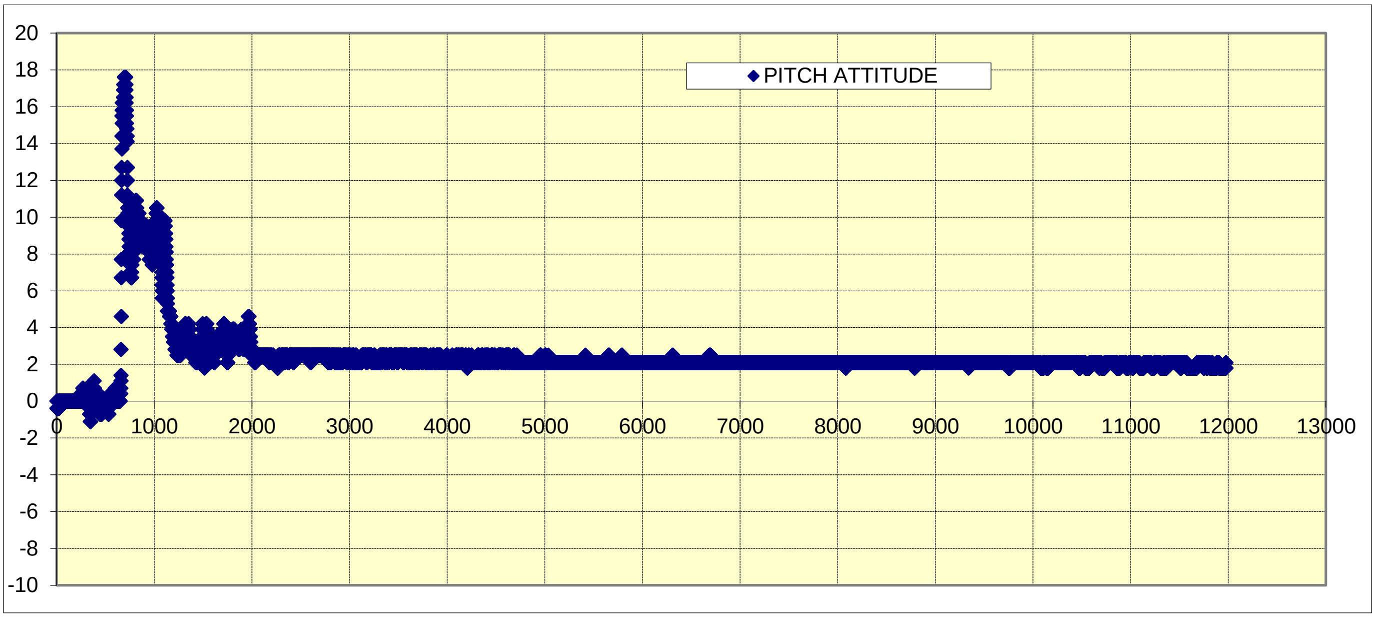


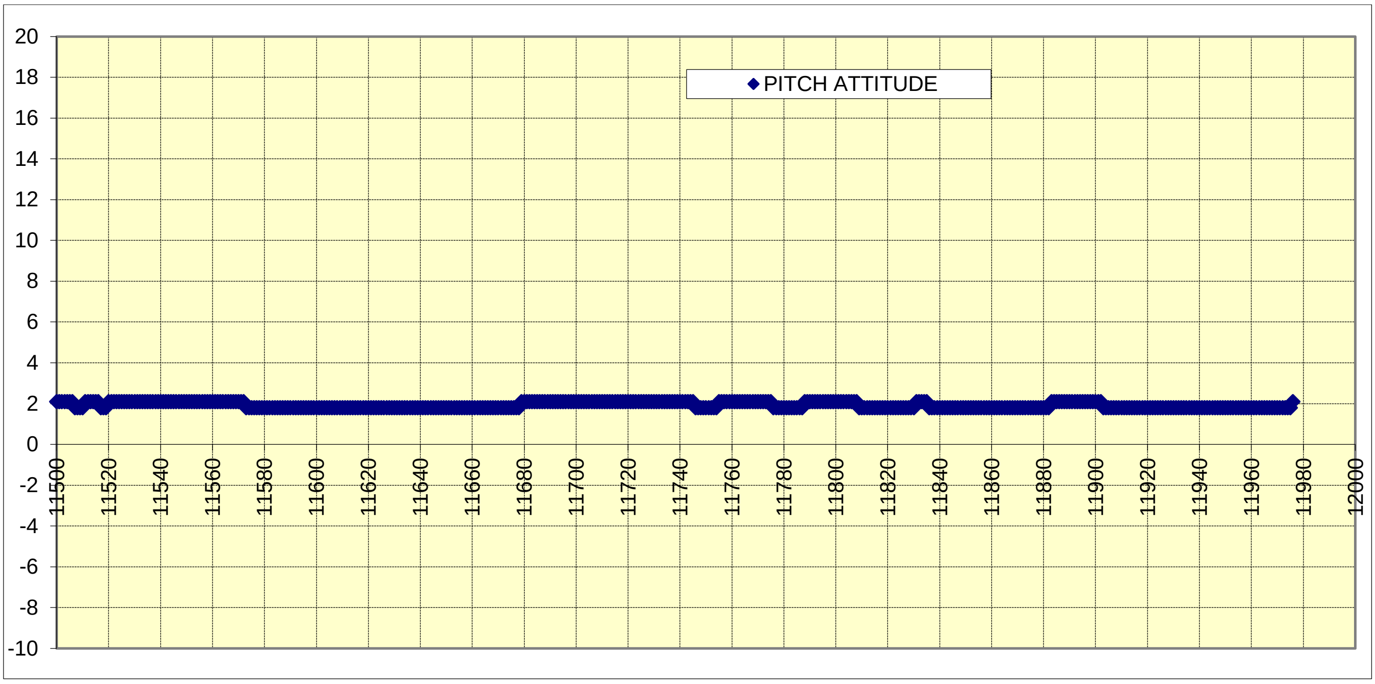


Heading shown at the last portion of the recording

Heading was almost constant at 142 degree at the last portion of the recording, changed slightly to 139 degree 40 seconds before the end of the recording

- PITCH ATTITUDE

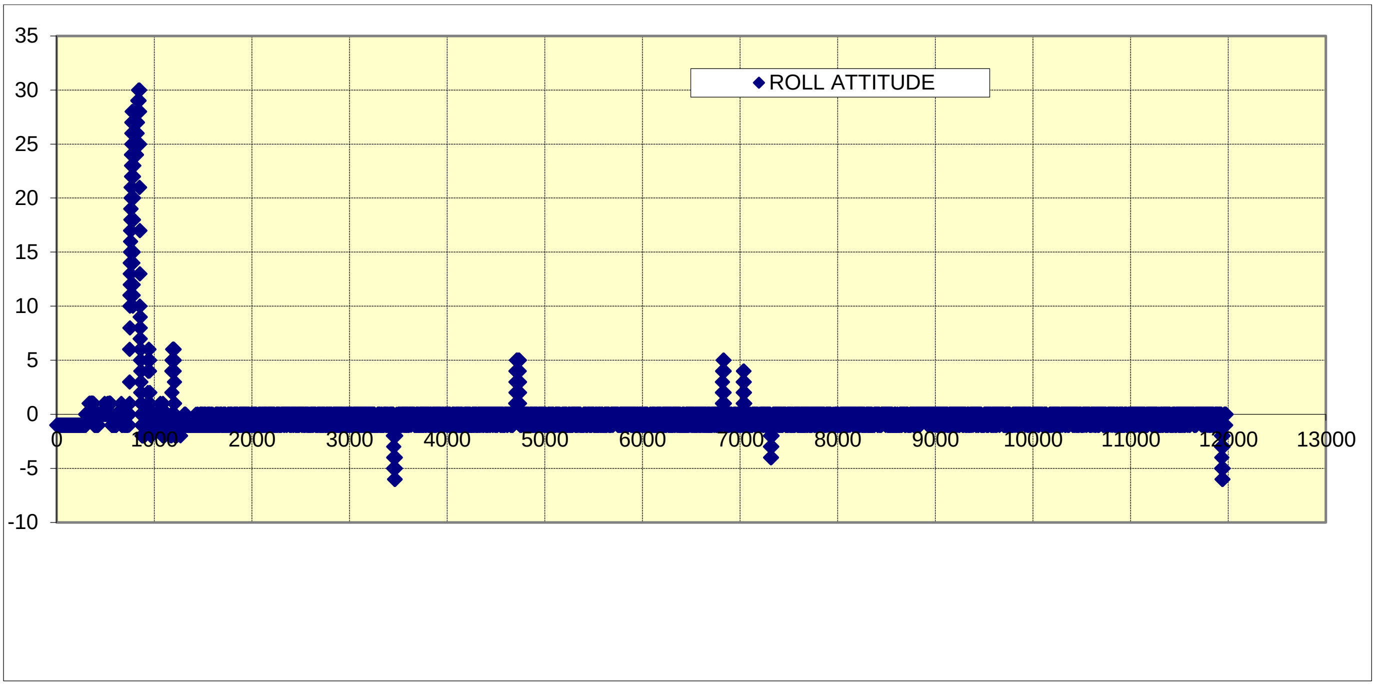


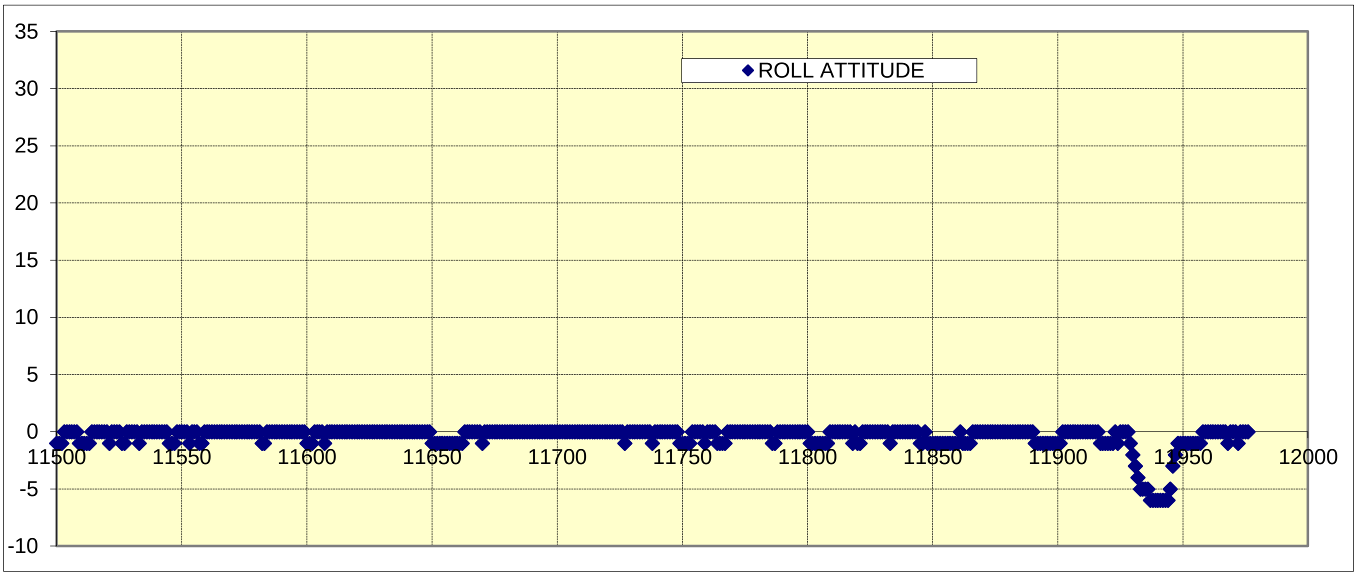


Pitch shown at the end portion of the recording

The Pitch was almost 1.8 degrees at the end portion of the recording with exception of the last second it changed slightly to 2.1 degree (at 00:29:45 UTC)

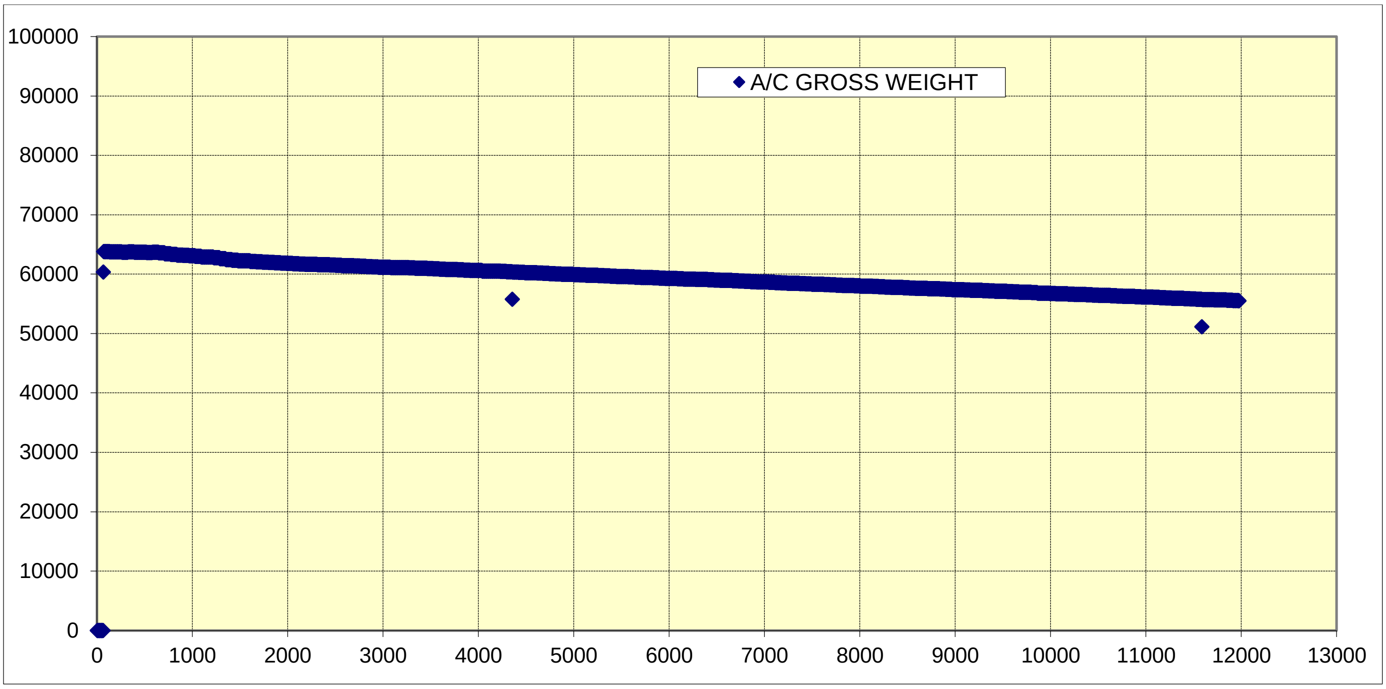
- ROLL ATTITUDE





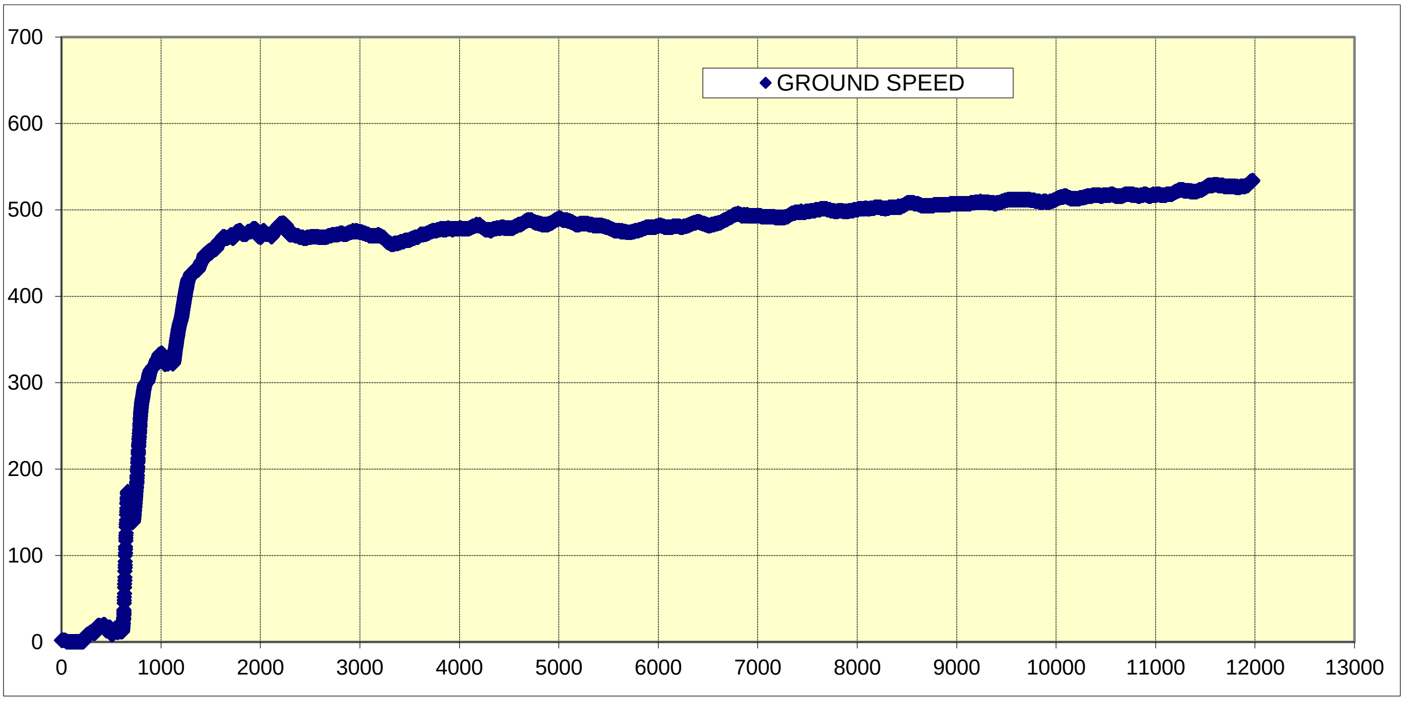
Roll was showing values between -0.4 to -0.7 degrees, then starting from 00:28:59 UTC changing reaching a max value of -6 degrees at 00:29:10 UTC then dropped to its initial value of -0.7 at 00:29:22 UTC

- A/C GROSS WEIGHT

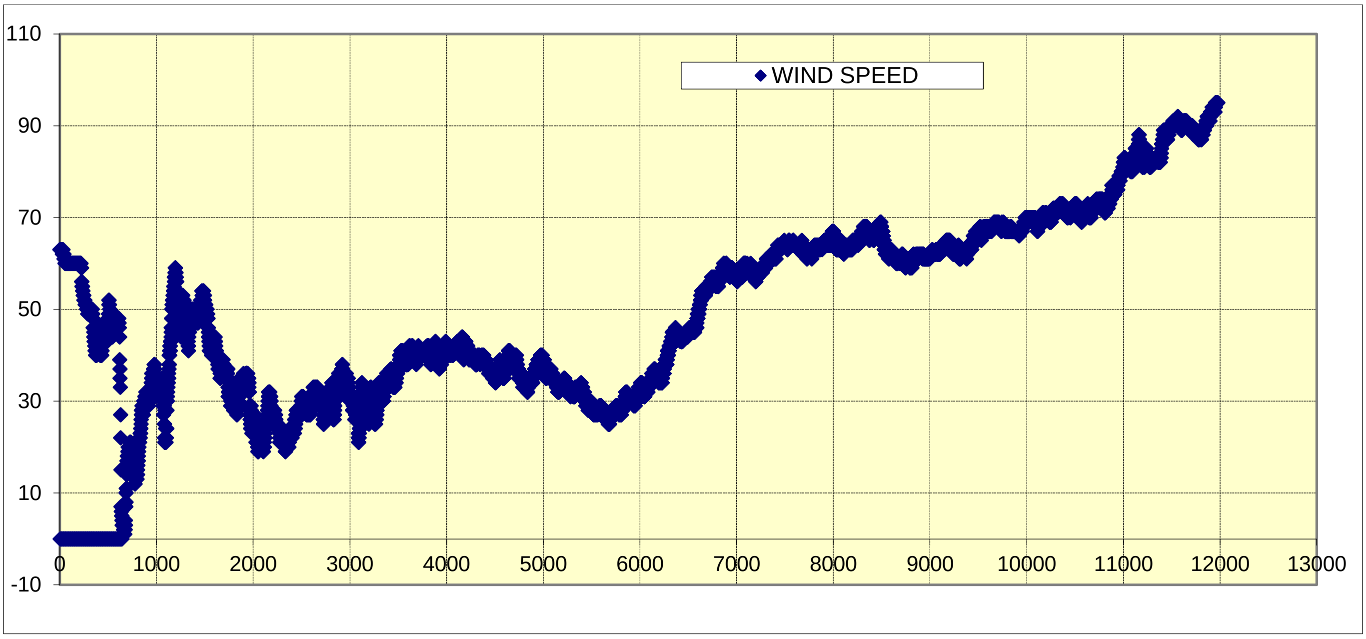


Recorded weight at the end of the recording was 55490 kg

- GROUND SPEED

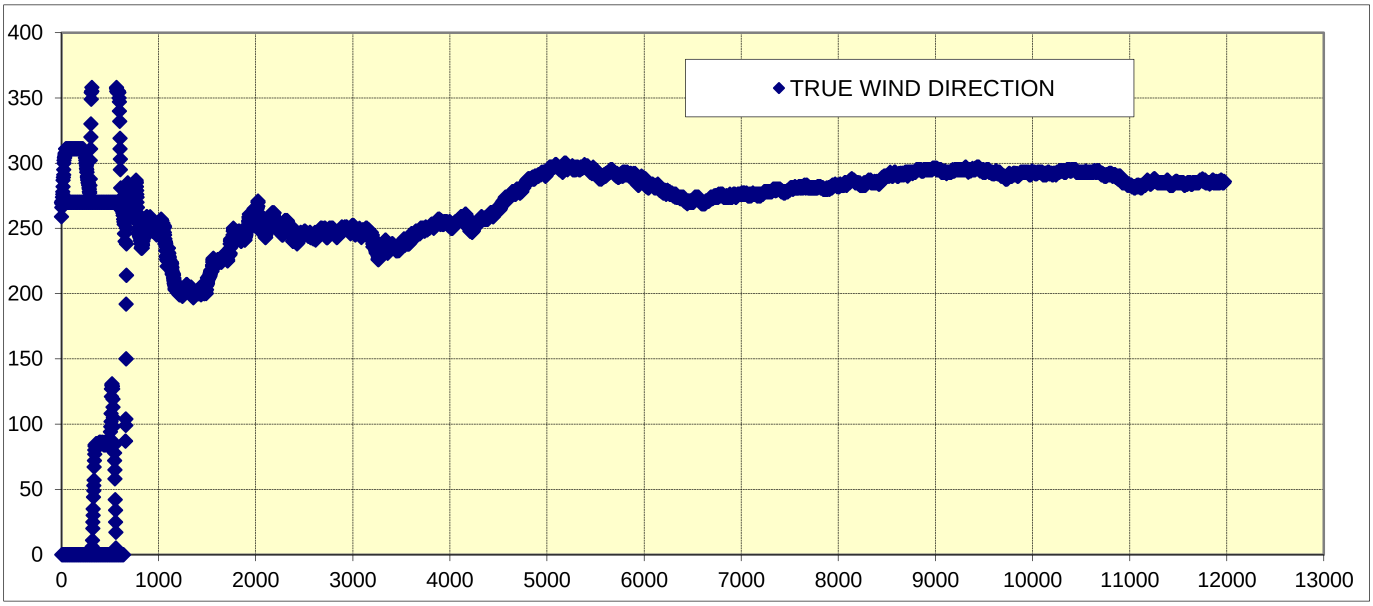


- WIND SPEED



The wind speed was shown to be 95 knots at the end recording

- TRUE WIND DIRECTION



Last True wind direction recorded is 286 degrees

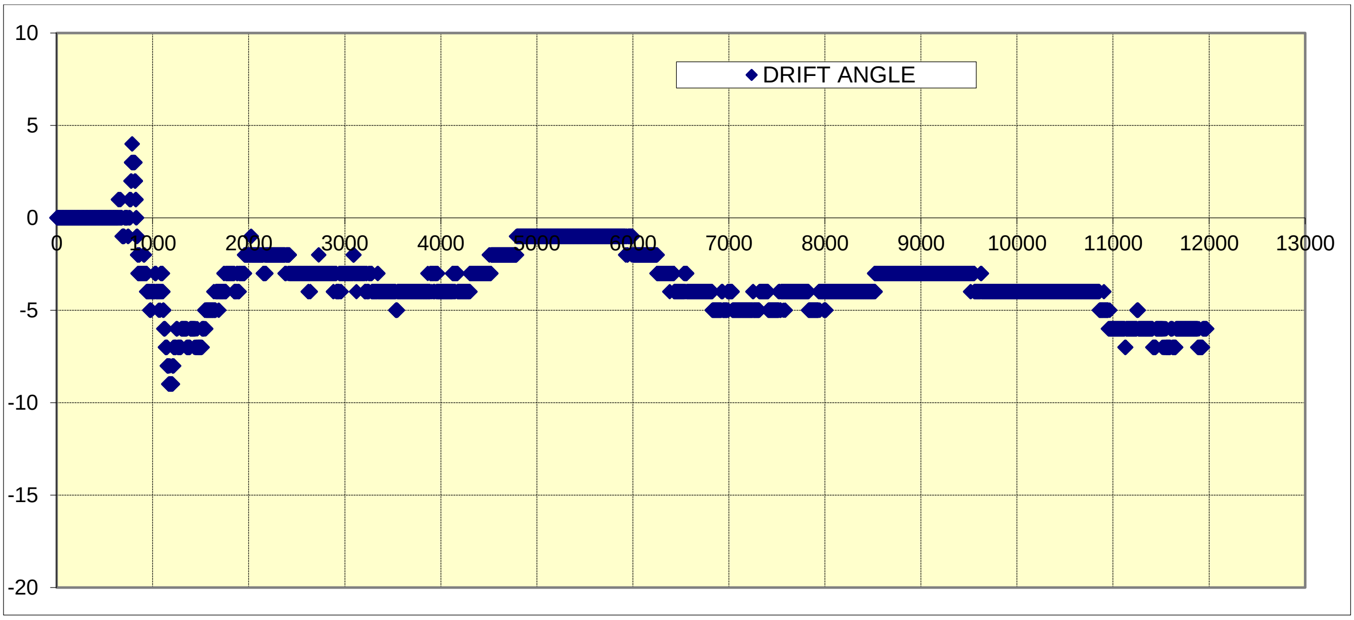
(A/C heading was about 142 degree)

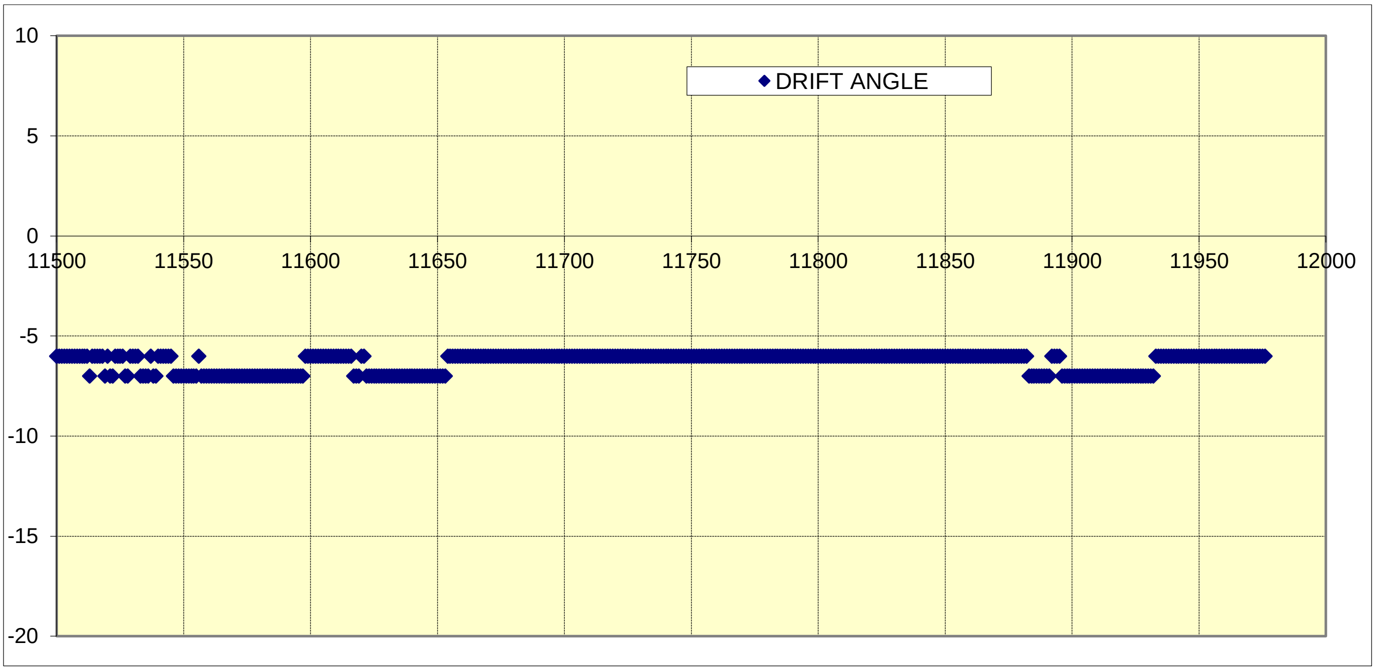
Relative angle= 36 degree

Tail Wind = V_{wind} * cos (36)

Cross wind (right to left) = V_{wind} * sin (36)

- DRIFT ANGLE



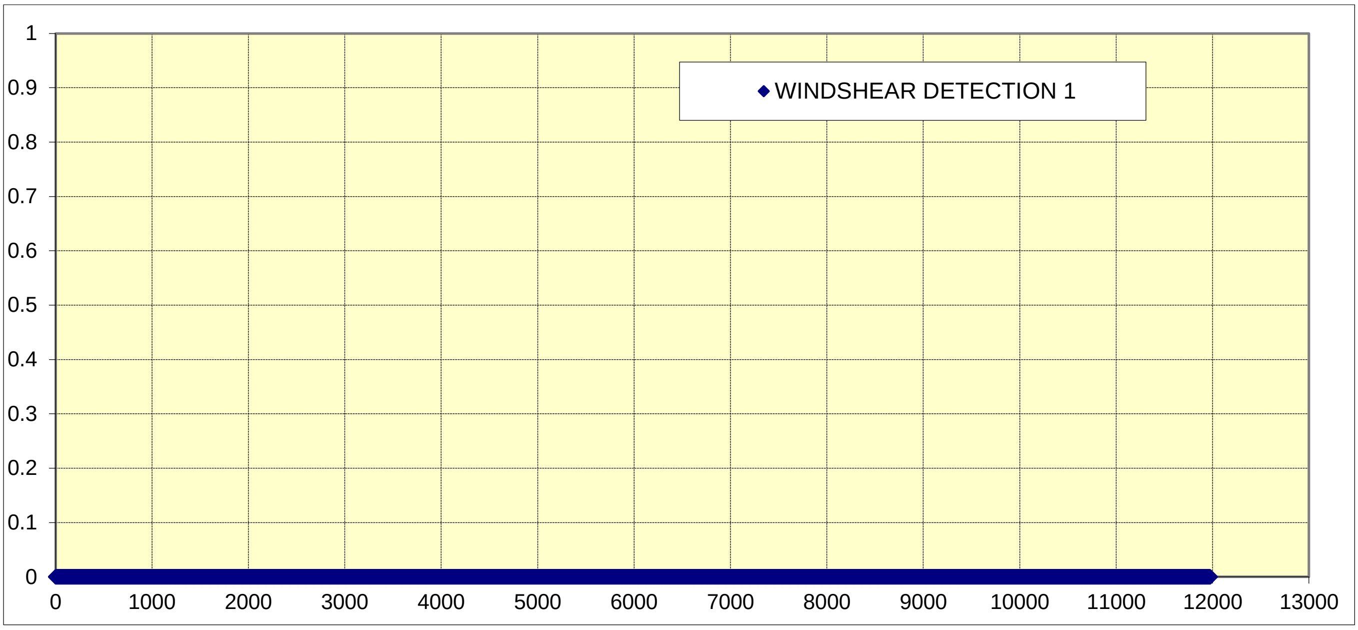


Drift angle shown at the end portion of the recording

Drift angle varied between -6, -7 degrees throughout the end portion of the recording

- WINDSHEAR DETECTION 1

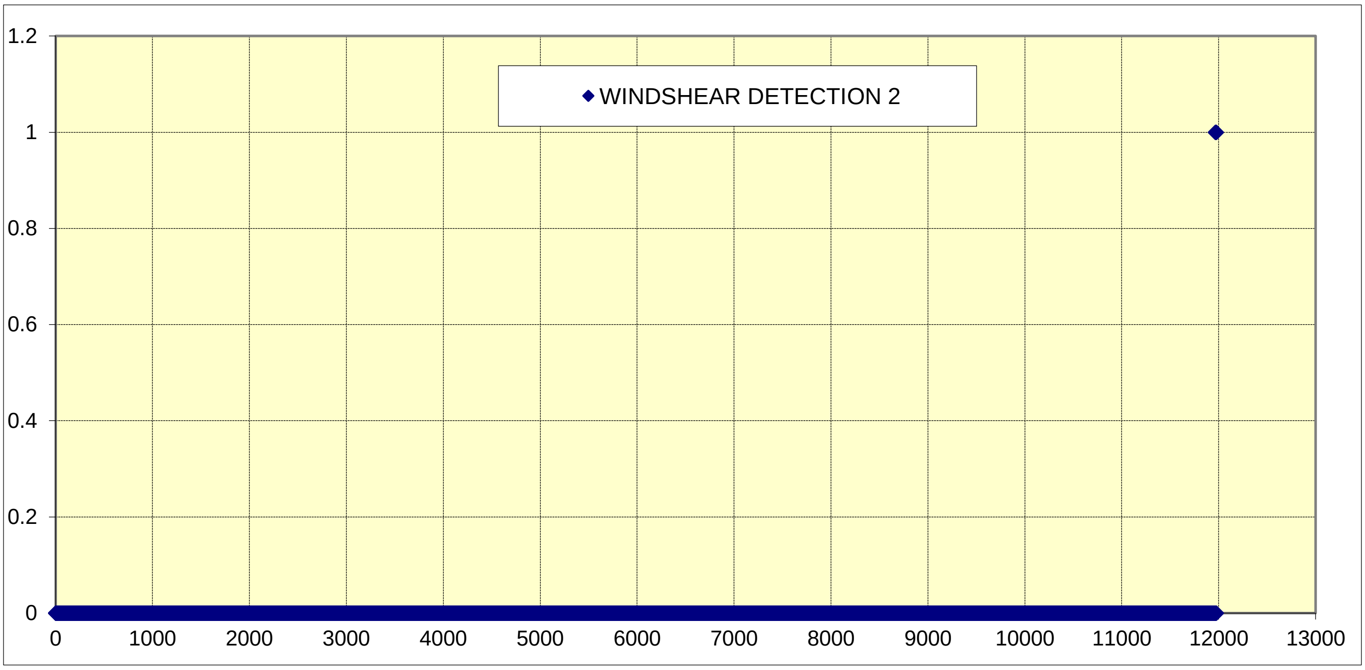
(0 no windshear)

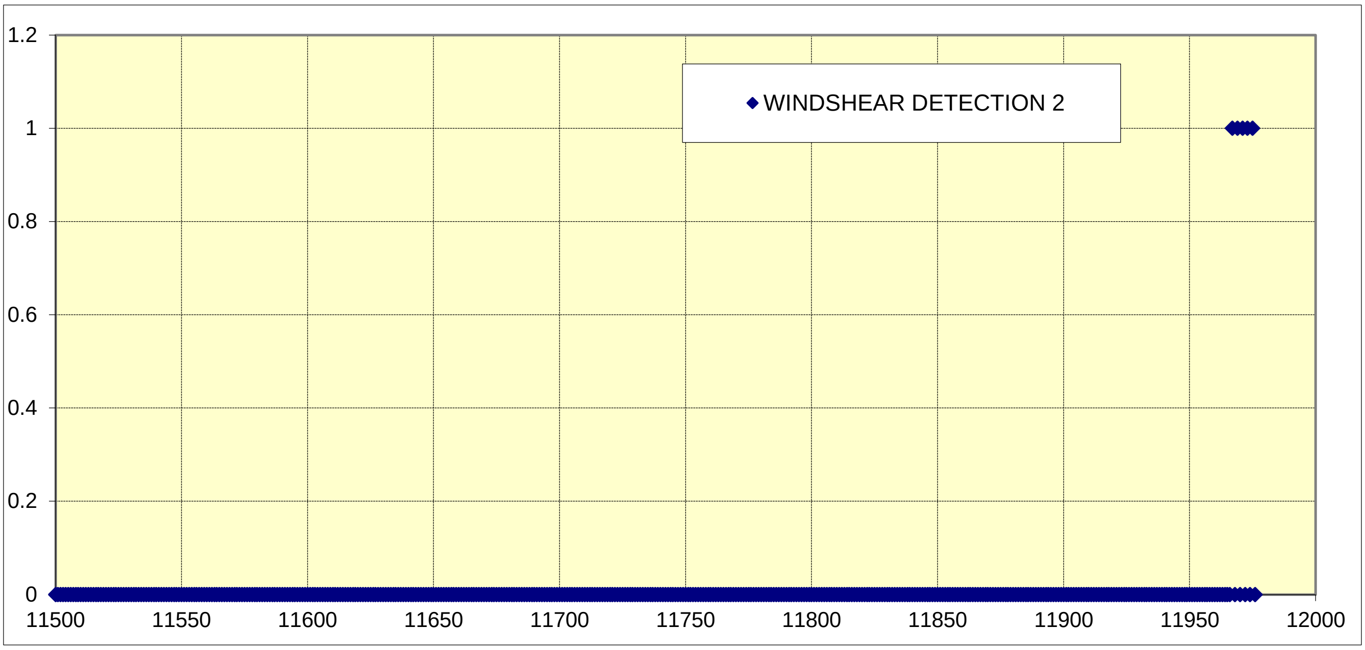


No windshear detected (Windshear detection 1)

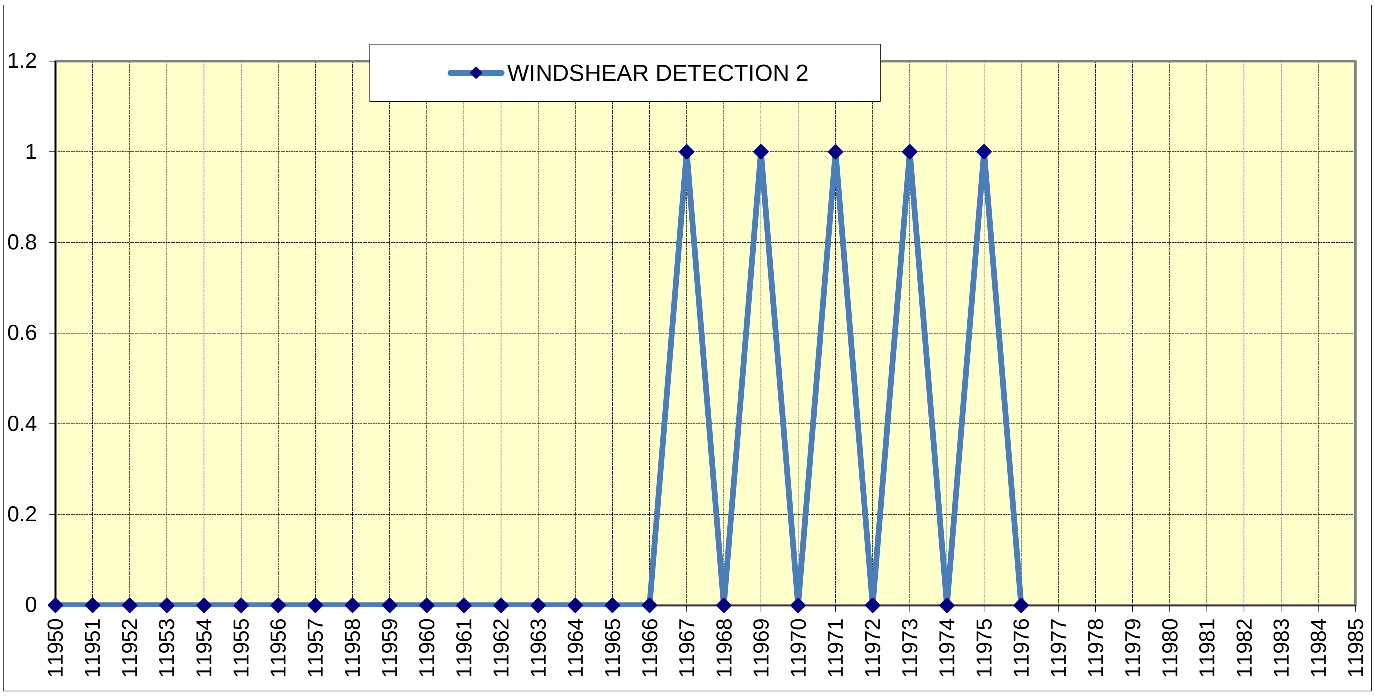
– WINDSHEAR DETECTION 2

(0 no windshear)





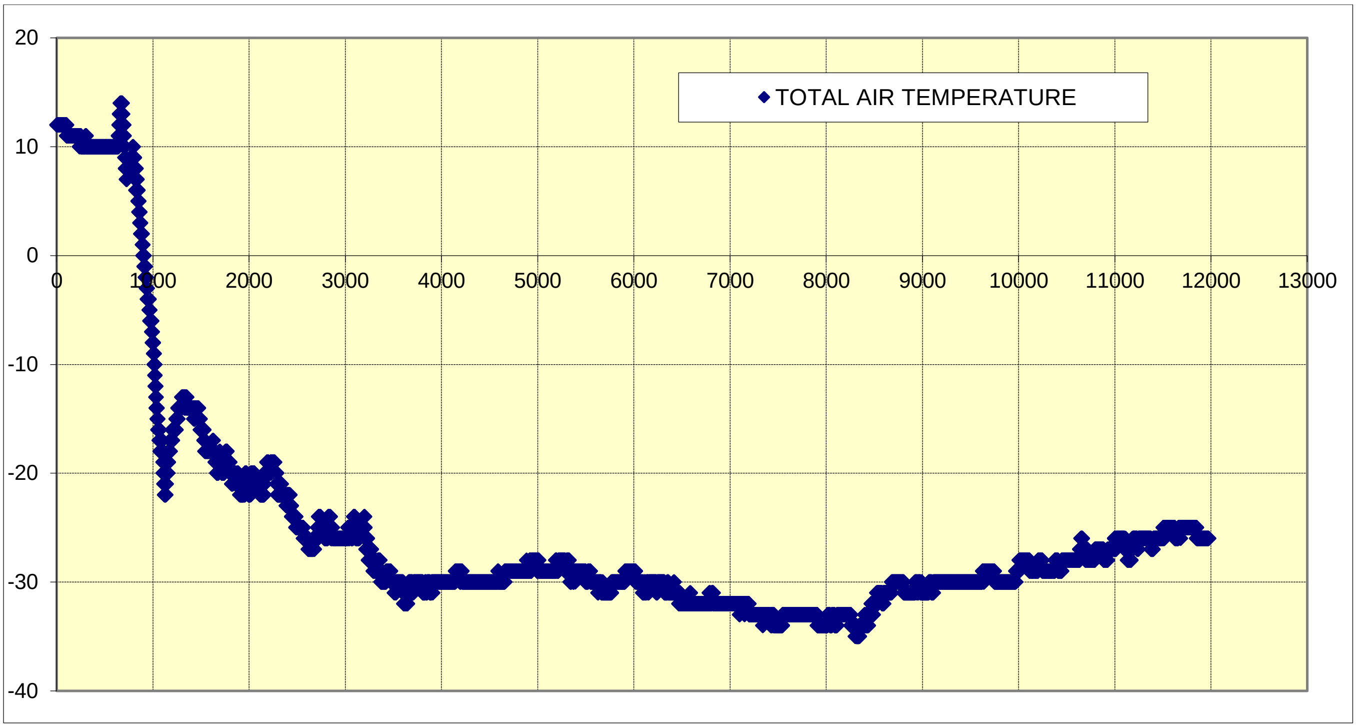
Windshear Detection 2 shown at the end portion of the recording



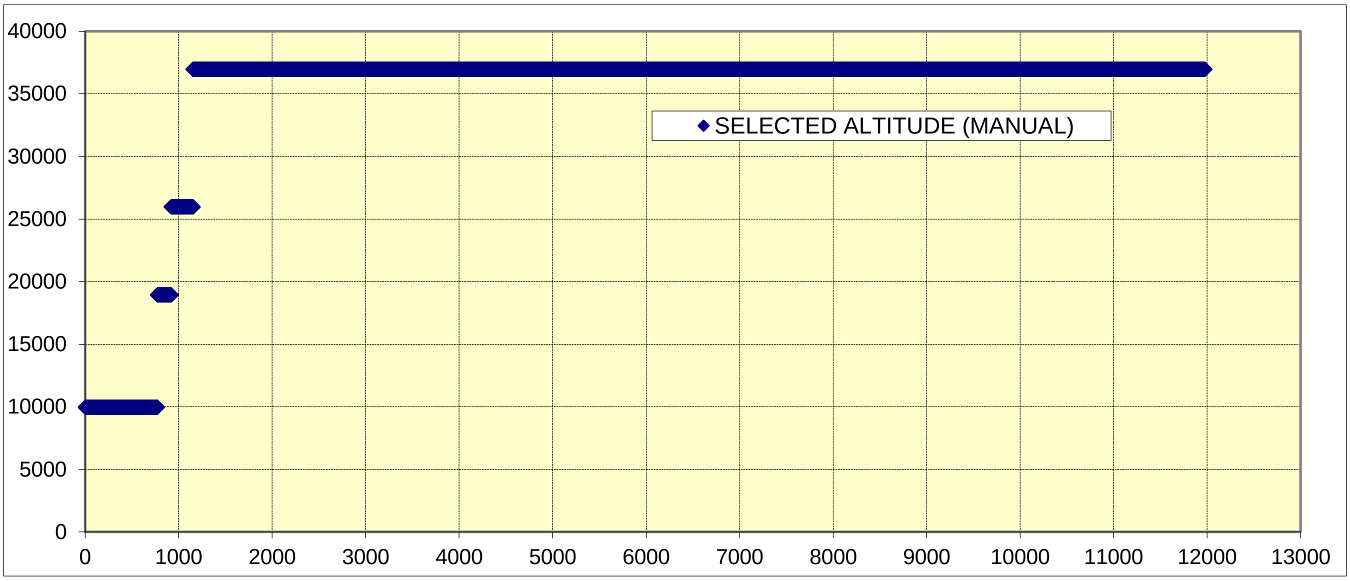
Windshear detection 2 shown at the end of the recording

No windshear detected until 00:29:35 UTC (11966 seconds on the plot) then started reciprocating between ON and OFF until the end of the recording at 00:29:45 UTC (11976 seconds on the plot) (about 10 seconds)

- TOTAL AIR TEMPERATURE (TAT)



- SELECTED ALTITUDE (MANUAL)

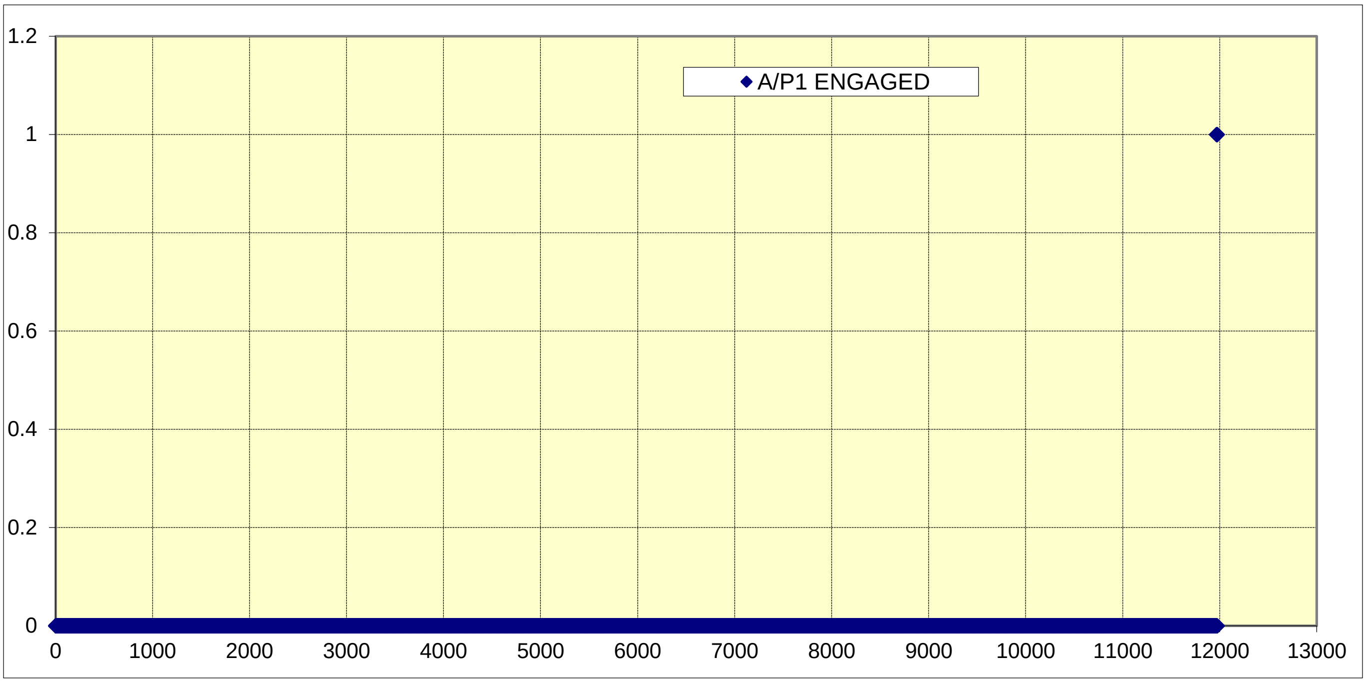


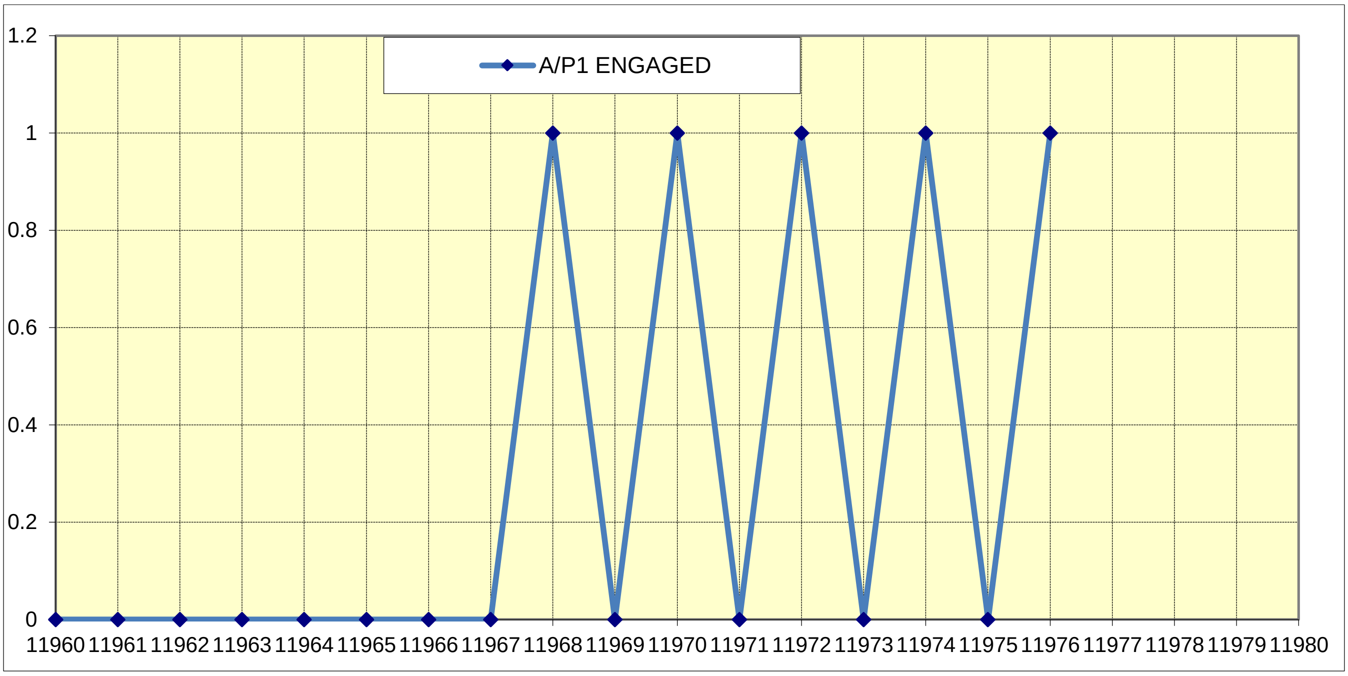
Selected altitude was 37000 ft

3. Auto pilot

– A/P1 ENGAGED

(Logic 1 engaged, Logic 0 disengaged)



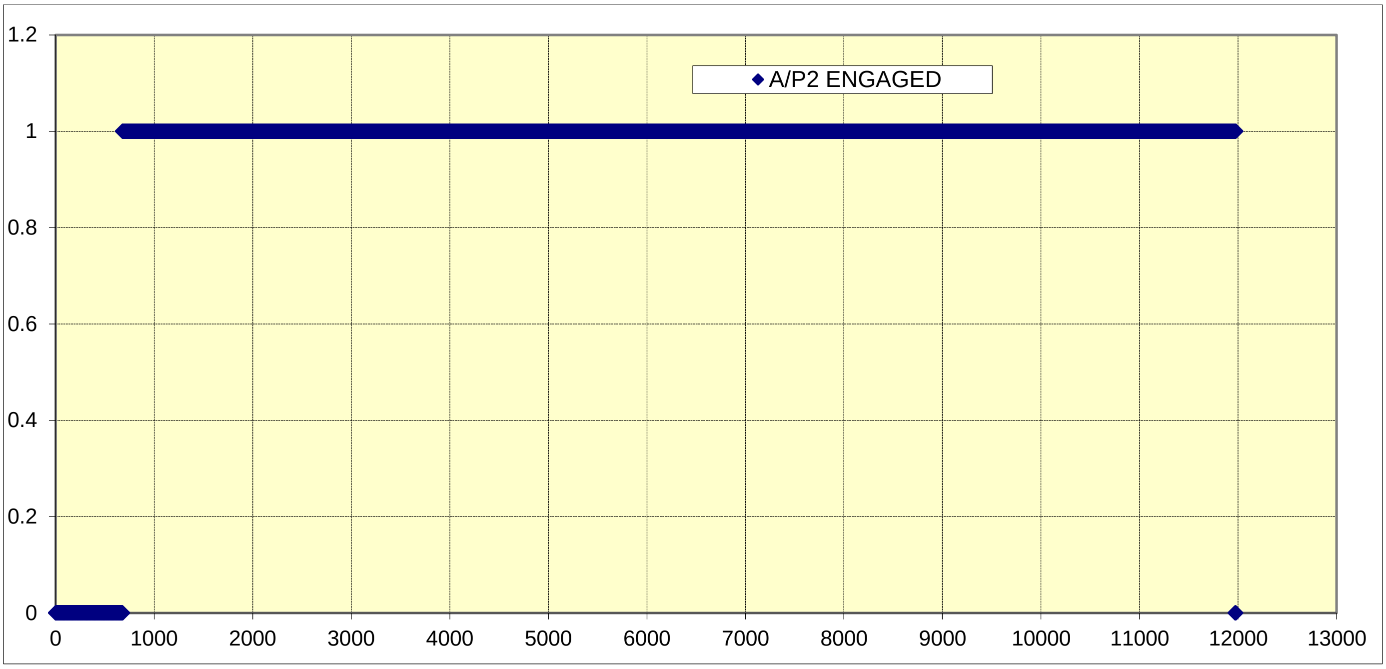


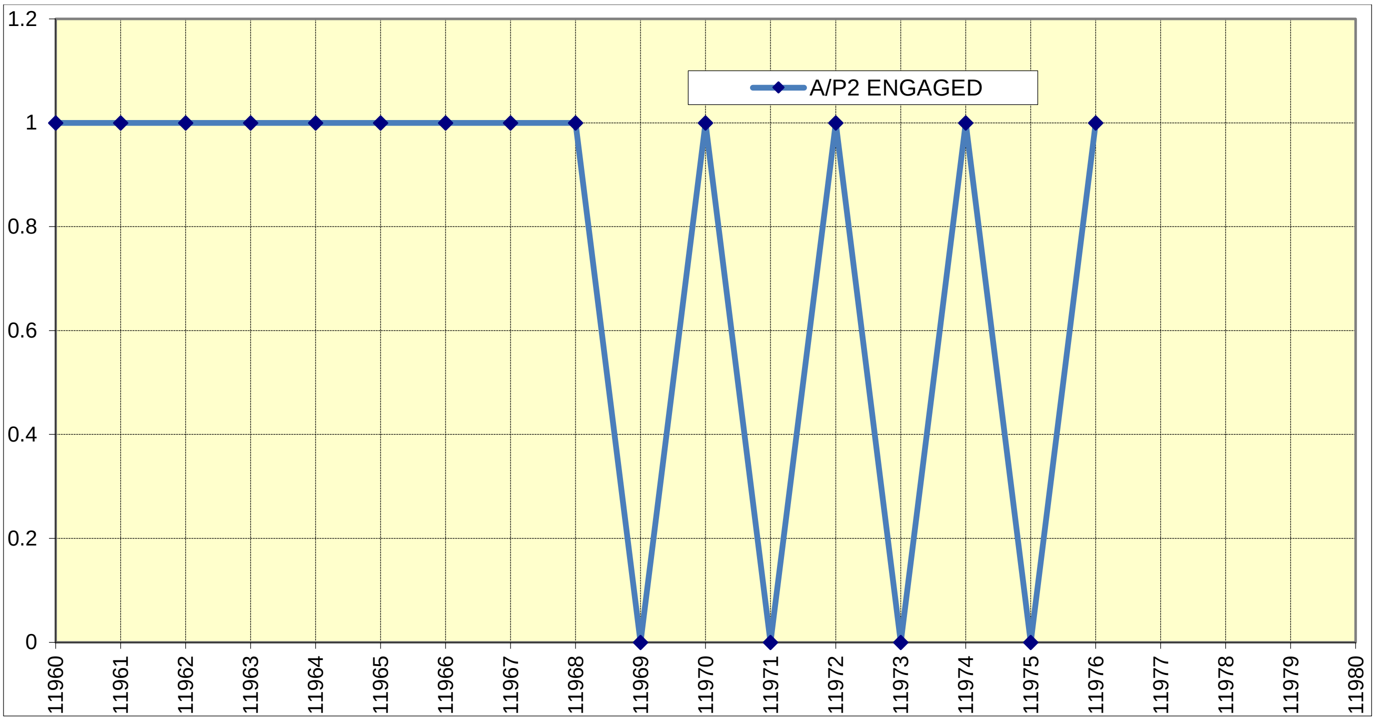
A/P 1 engaged shown near the end of recording

A/P 1 was not engaged throughout the whole recording time until 00:29: 36 UTC (11967 seconds on the plot), then it started reciprocating between ON and OFF until the end of the recording at 00:29:45 (11976 seconds on the plot) (about 9 seconds)

- A/P2 ENGAGED

(Logic 1 engaged, Logic 0 disengaged)





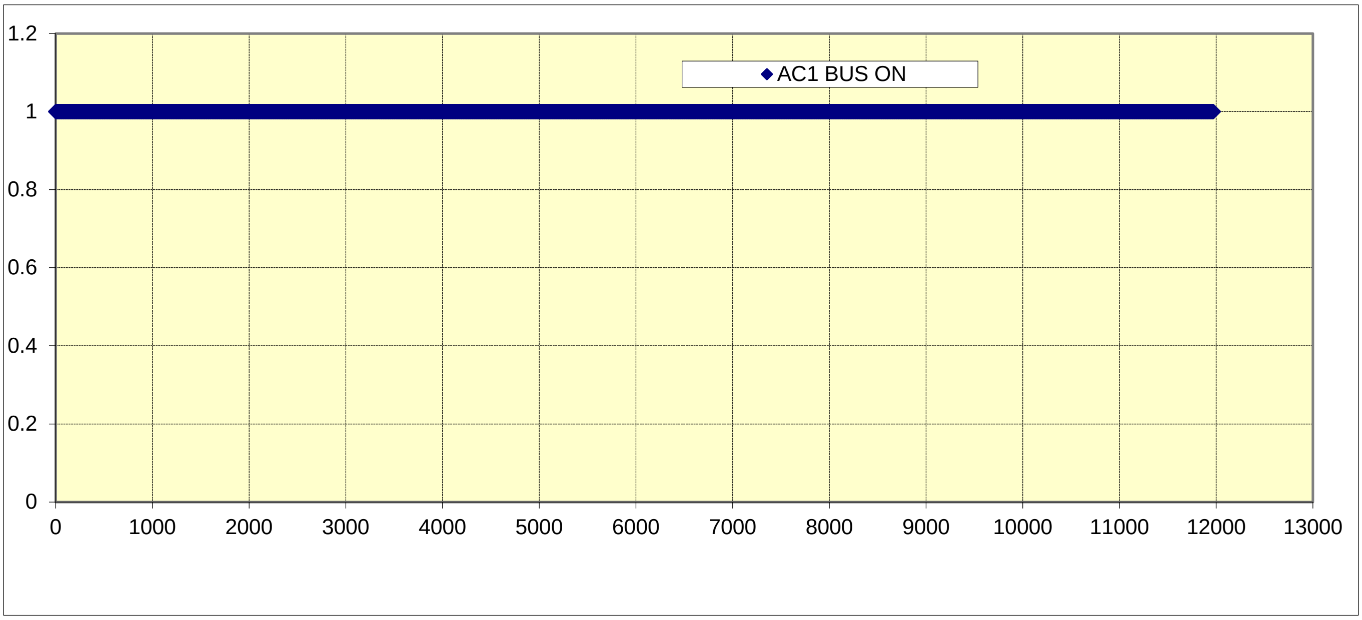
A/P 2 engaged shown near the end of recording

A/P 2 was engaged almost throughout the whole recording time until 00:29: 37 UTC (11968 seconds on the plot), then it started reciprocating between ON and OFF until the end of the recording at 00:29:45 (11976 seconds on the plot) (about 8 seconds)

4. Electrical

– AC1 BUS ON

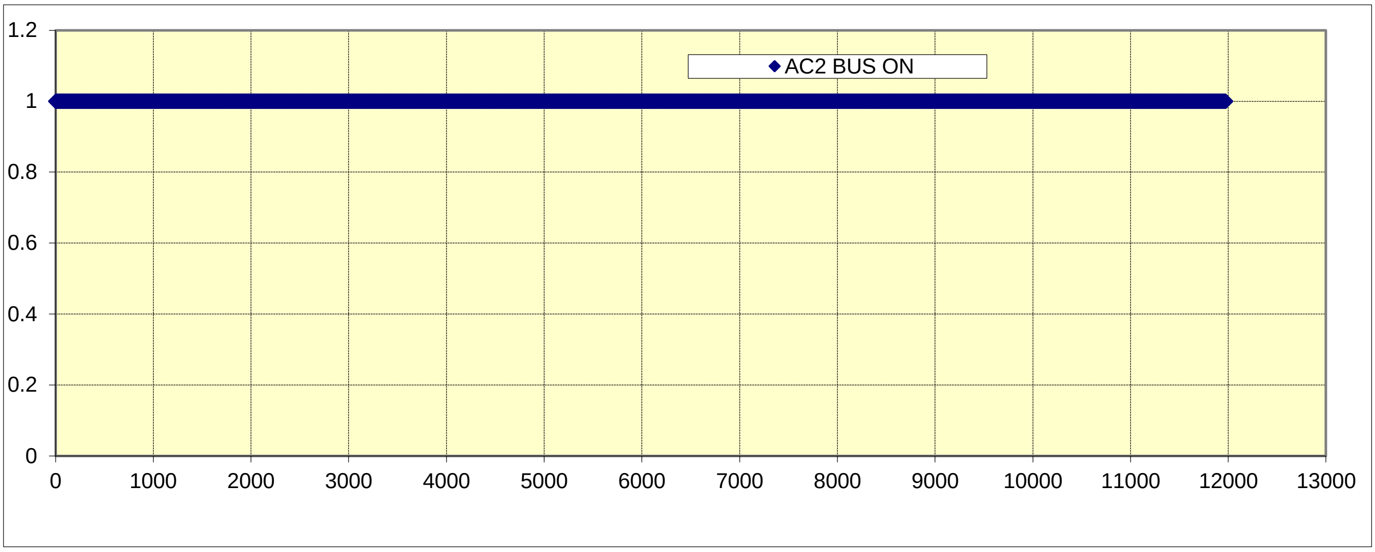
(1 powered)



AC1 BUS was powered throughout the whole recording

– AC2 BUS ON

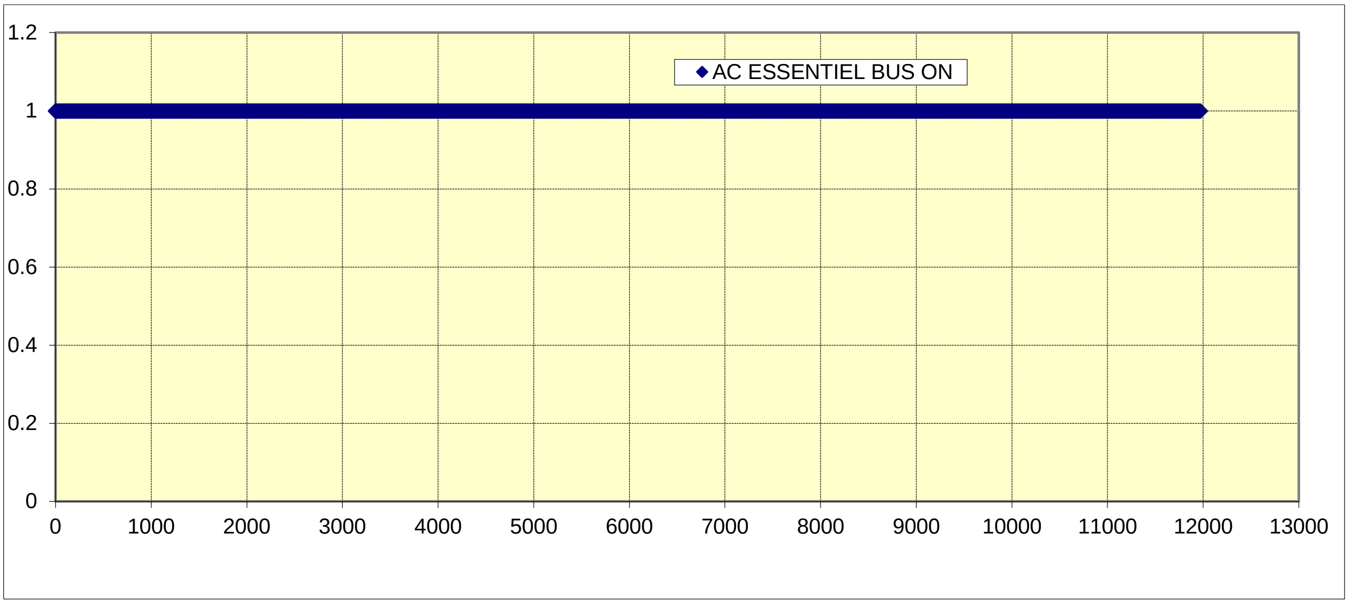
(1 powered)



AC2 BUS was powered throughout the whole recording

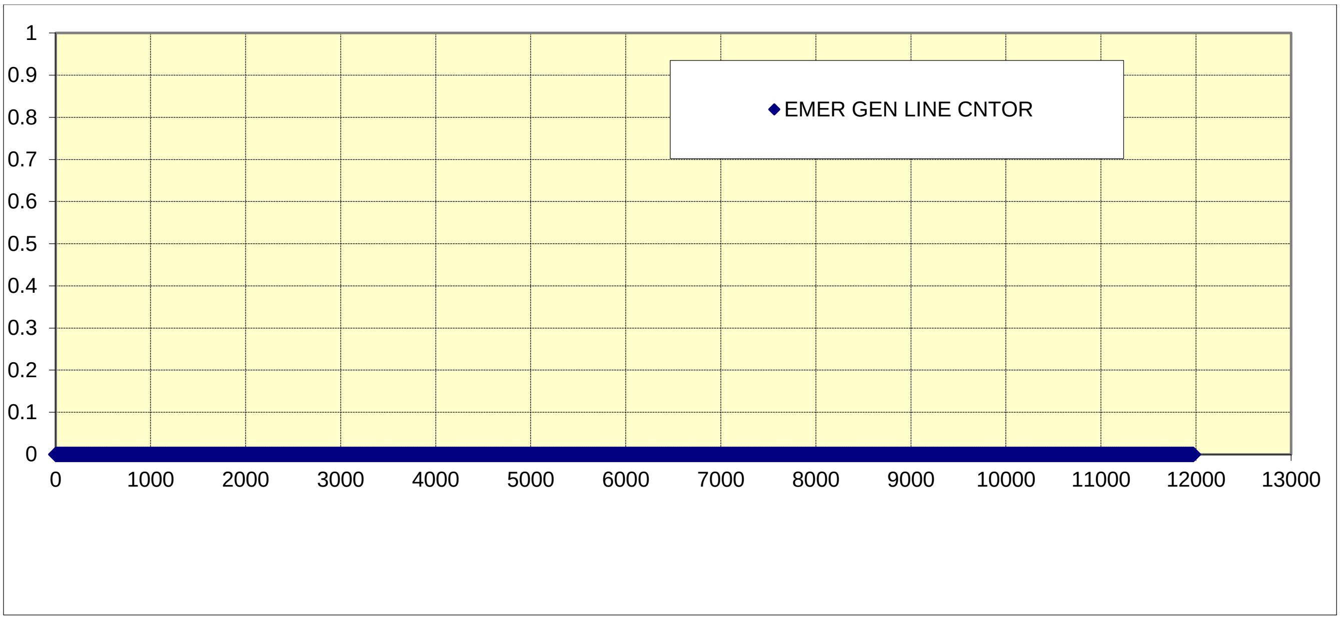
- AC ESSENTIEL BUS ON

  (1 powered)



AC essential BUS was powered throughout the whole recording

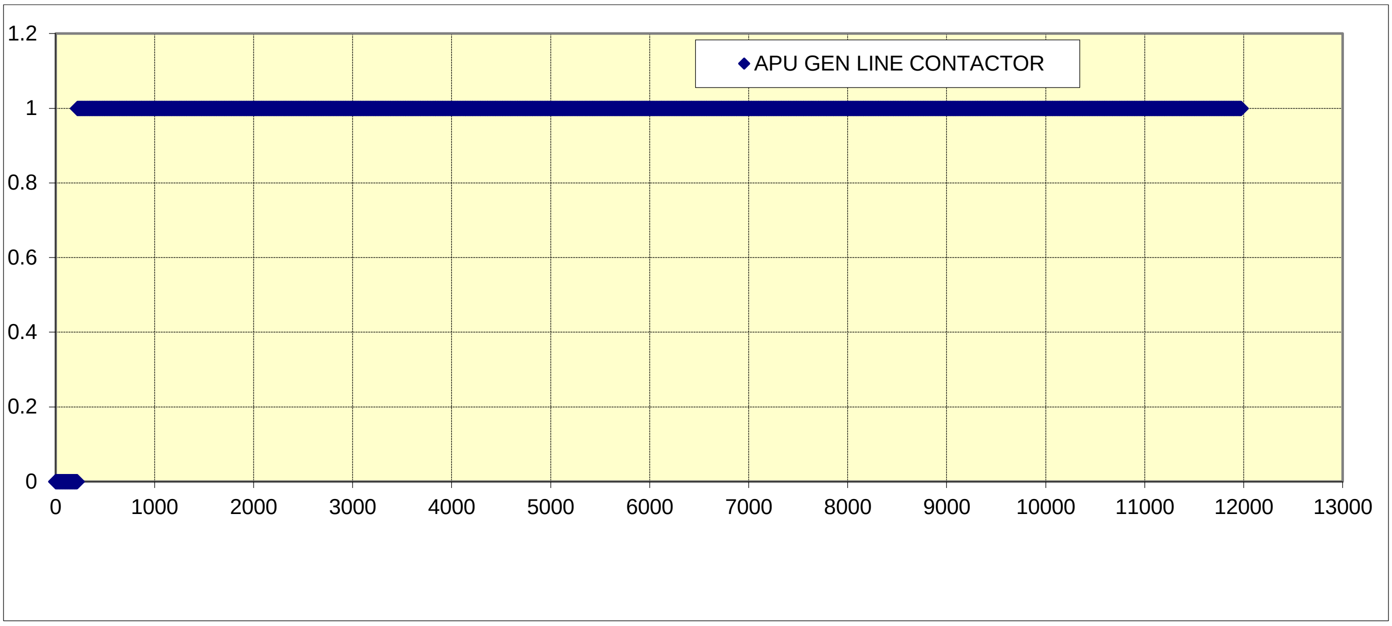
- EMER GEN LINE CONTACTOR



Emer Gen Line Contactor was off throughout the whole recording

- APU GEN LINE CONTACTOR

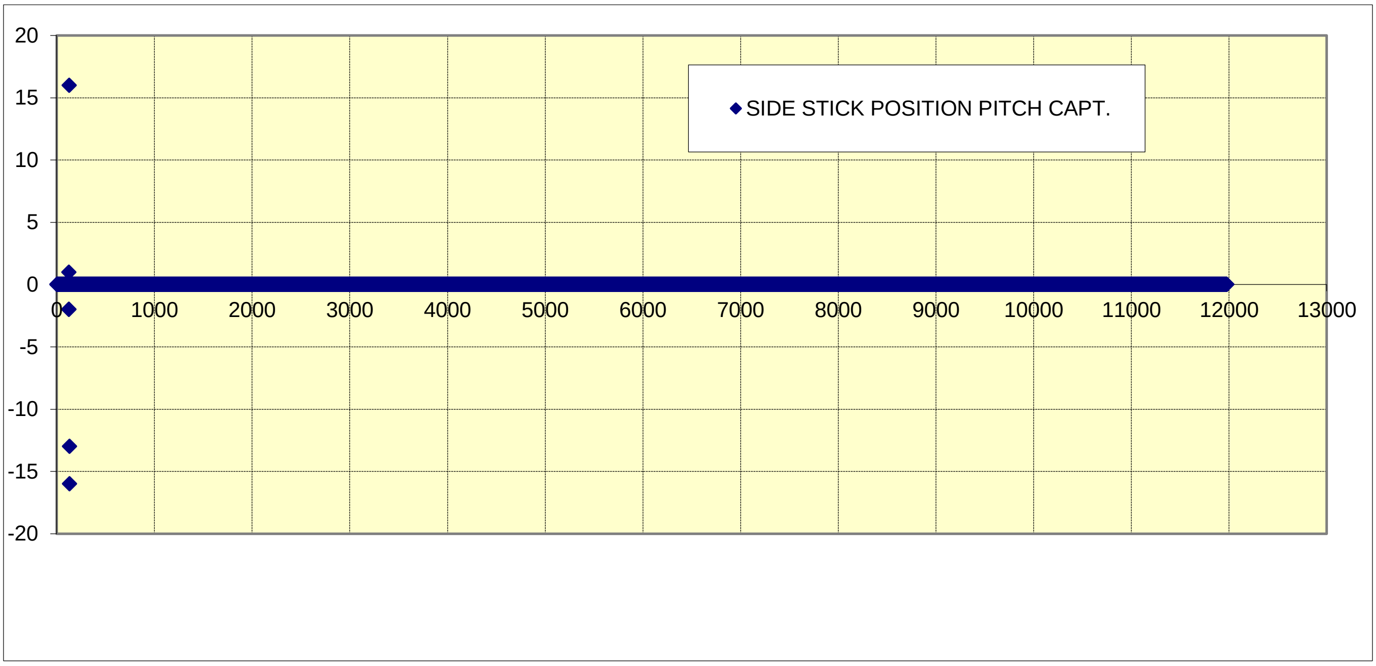
(0 closed)



APU Gen line contactor was off throughout the whole recording

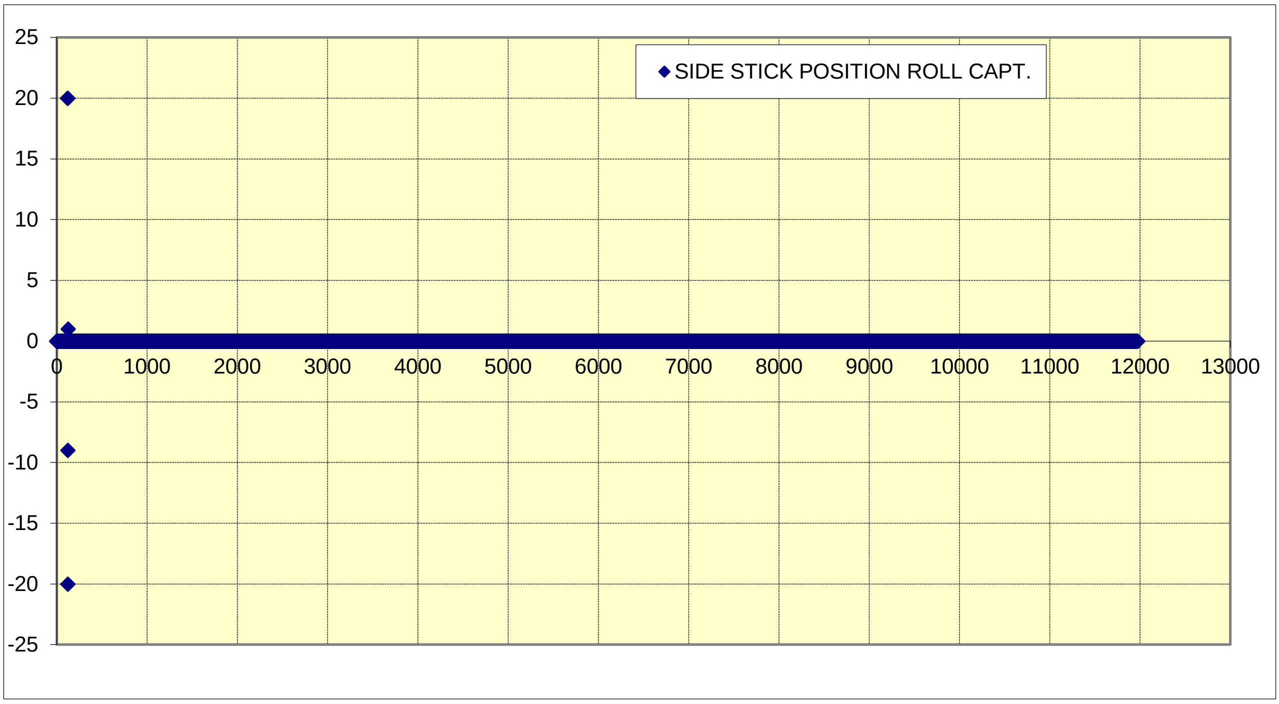
5. Flight Controls

- SIDESTICK position pitch Capt



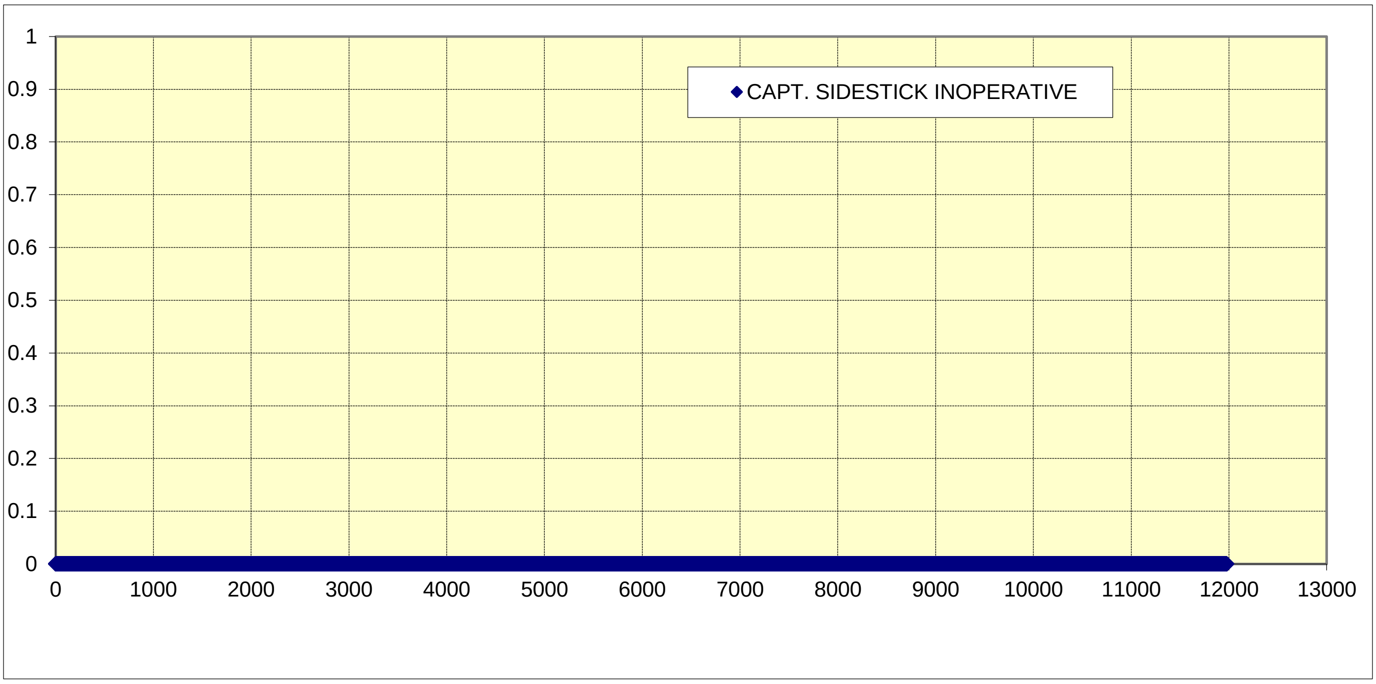
No pitch movement on the captain side stick during cruise throughout the recording

- SIDESTICK position roll Capt



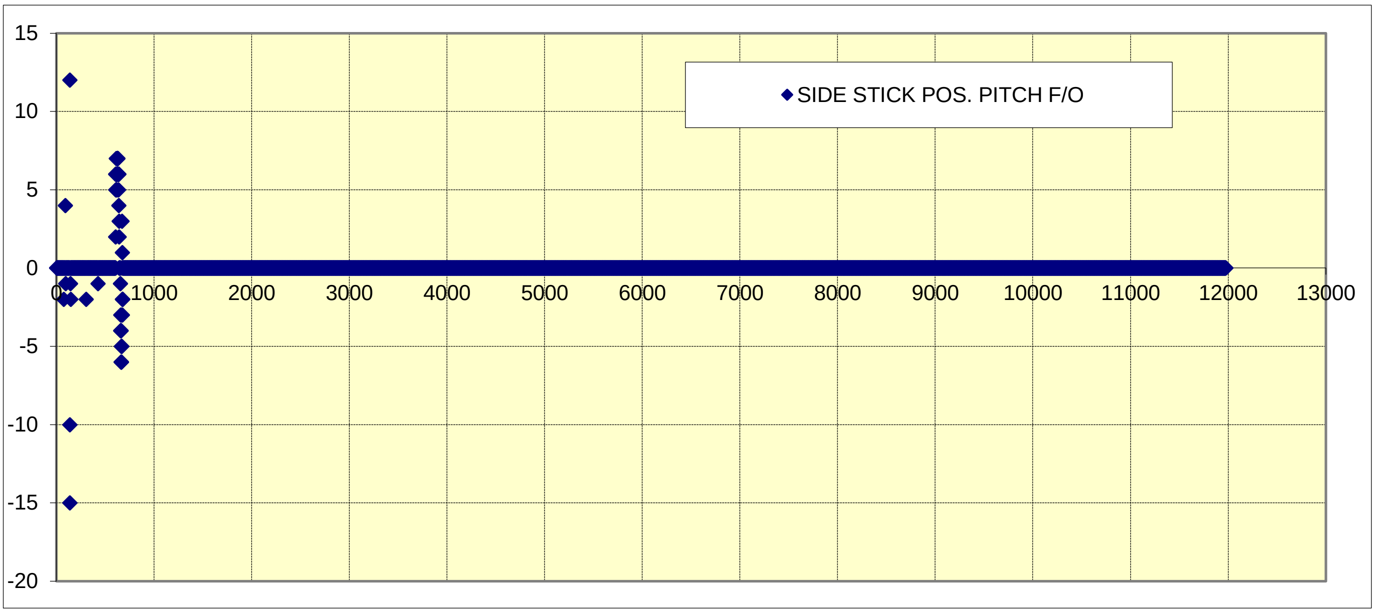
No roll movement on the captain side stick during cruise throughout the recording

- CAPT. SIDESTICK INOPERATIVE

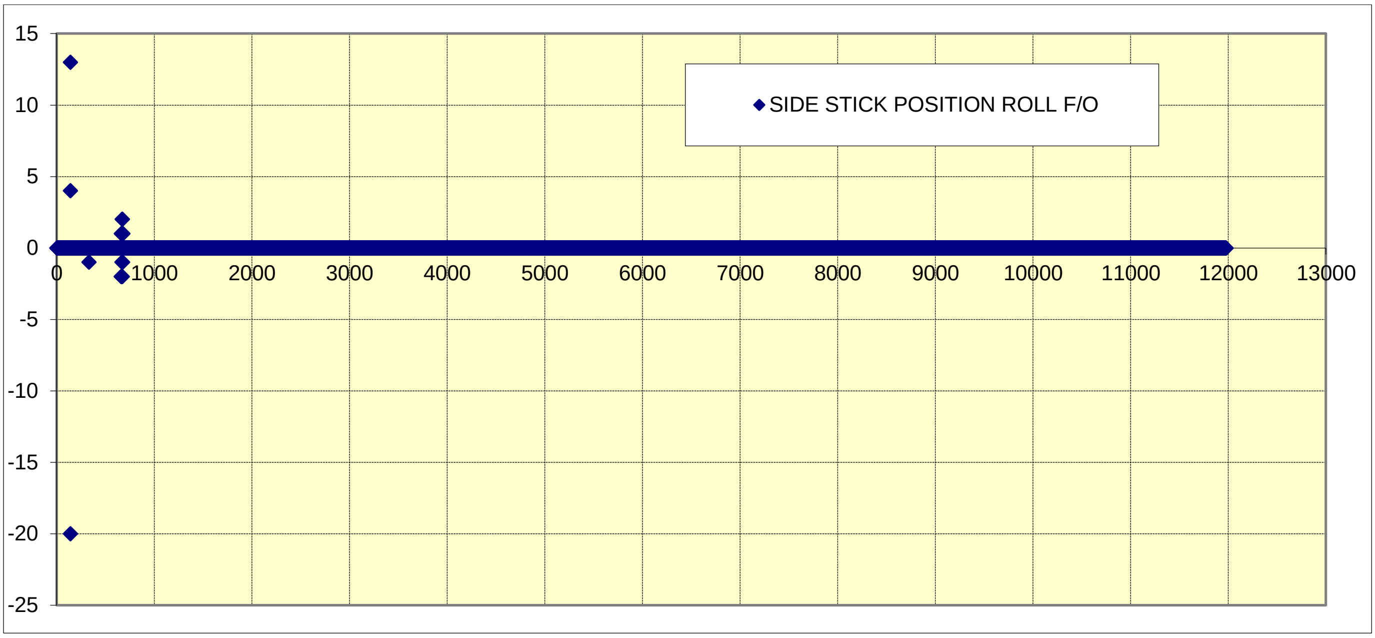


No evidence of CAPT. SIDESTICK INOPERATIVE condition

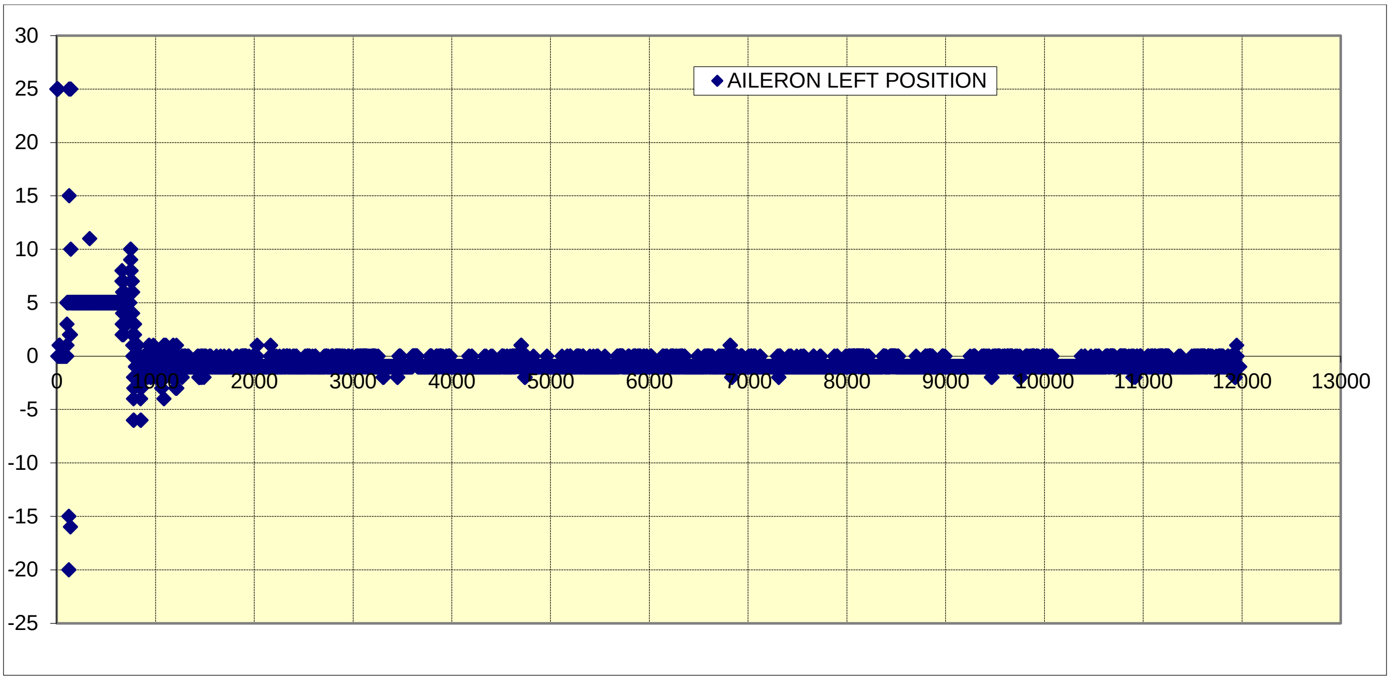
- SIDE STICK POS. PITCH F/O

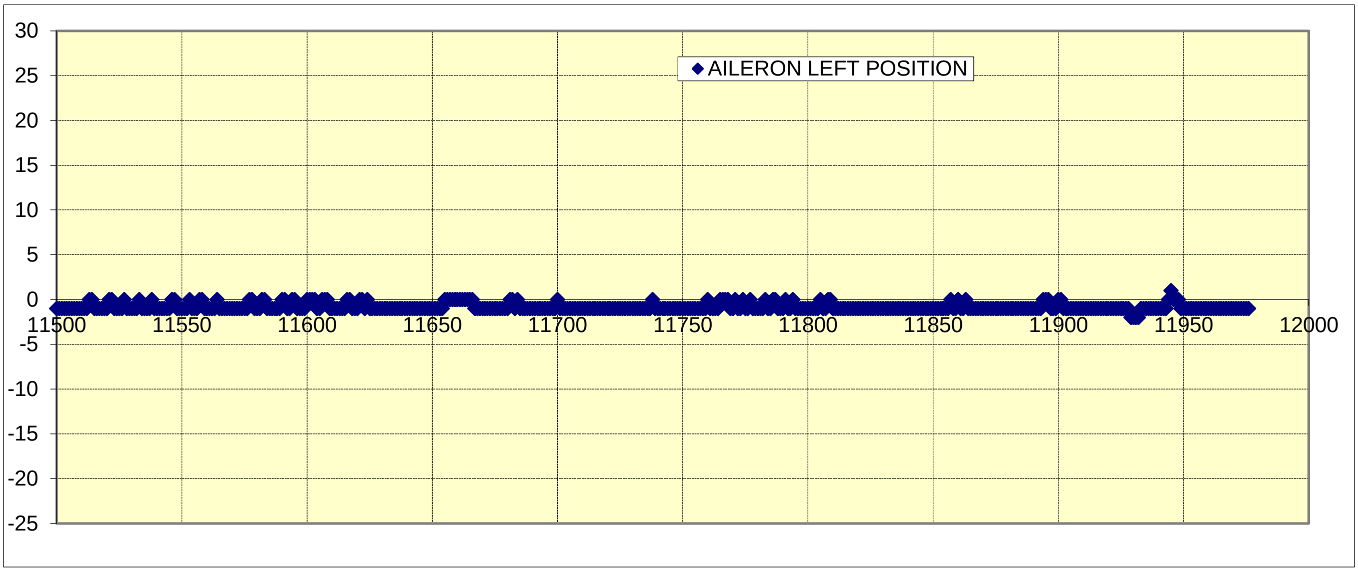


- SIDE STICK POSITION ROLL F/O



- AILERON LEFT POSITION



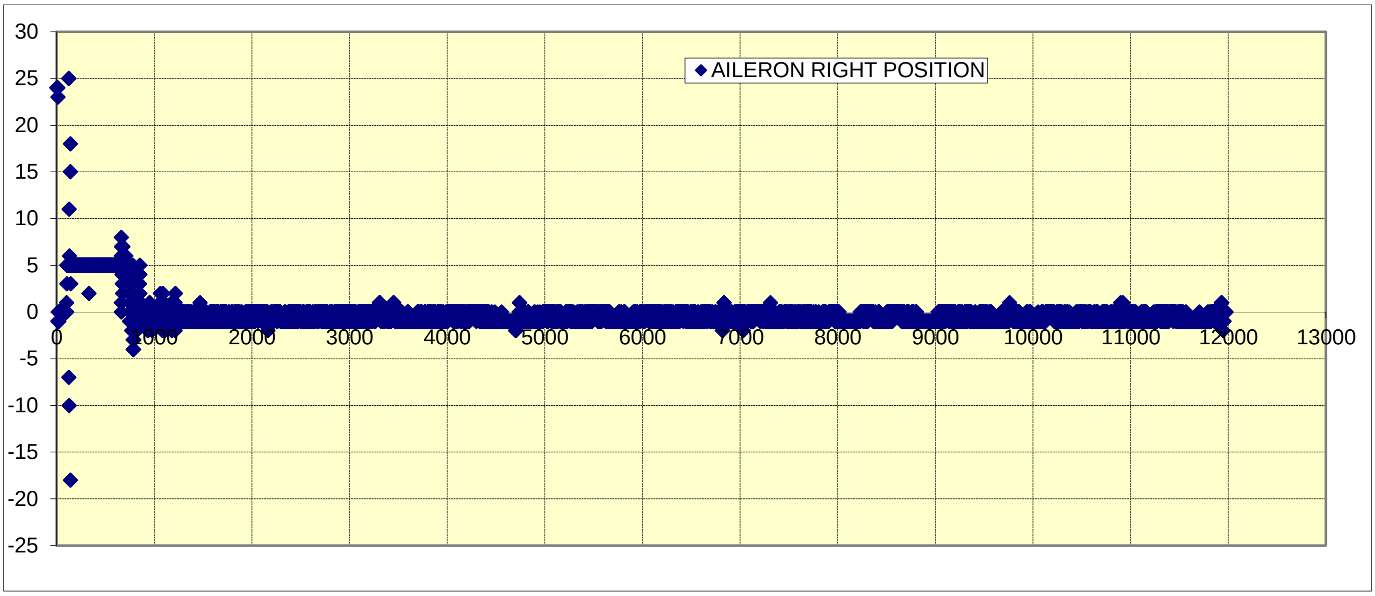


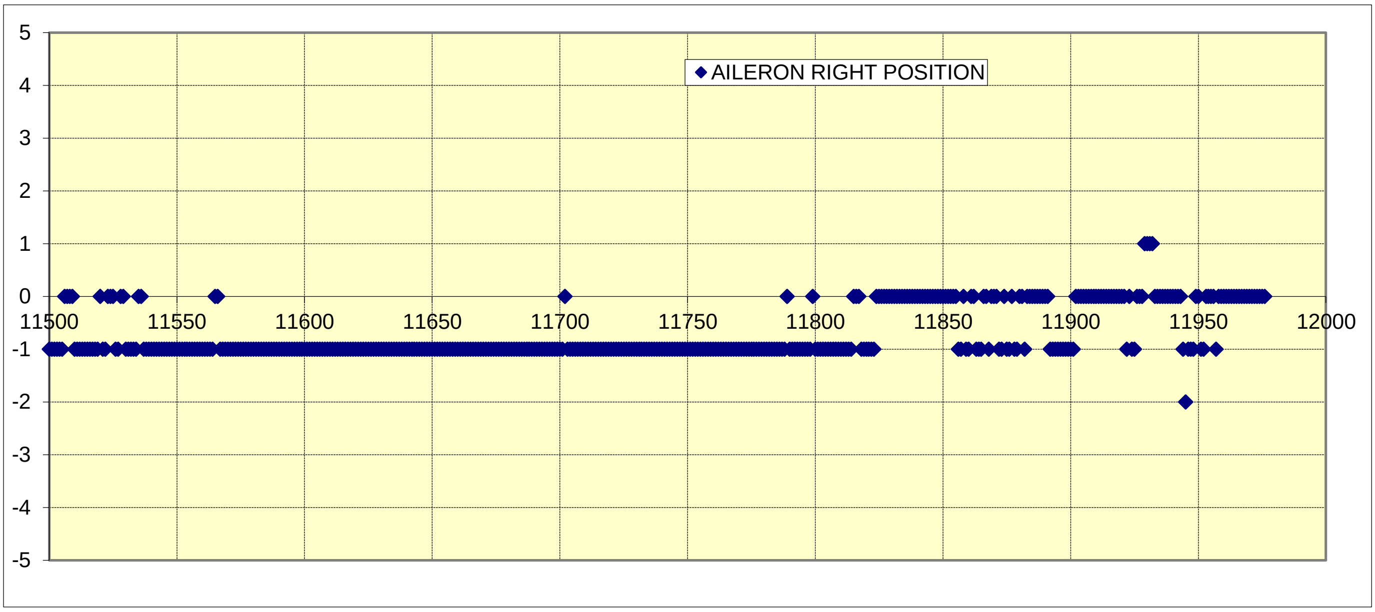
Position shown at the last portion of the recording

Left aileron position was -1 degree almost throughout the whole flight, varying between 0 and -1 degrees (except for very few points it reached -2 degree and +1 degree)

Aileron position for the last 27 seconds -1 degree.

- AILERON RIGHT POSITION

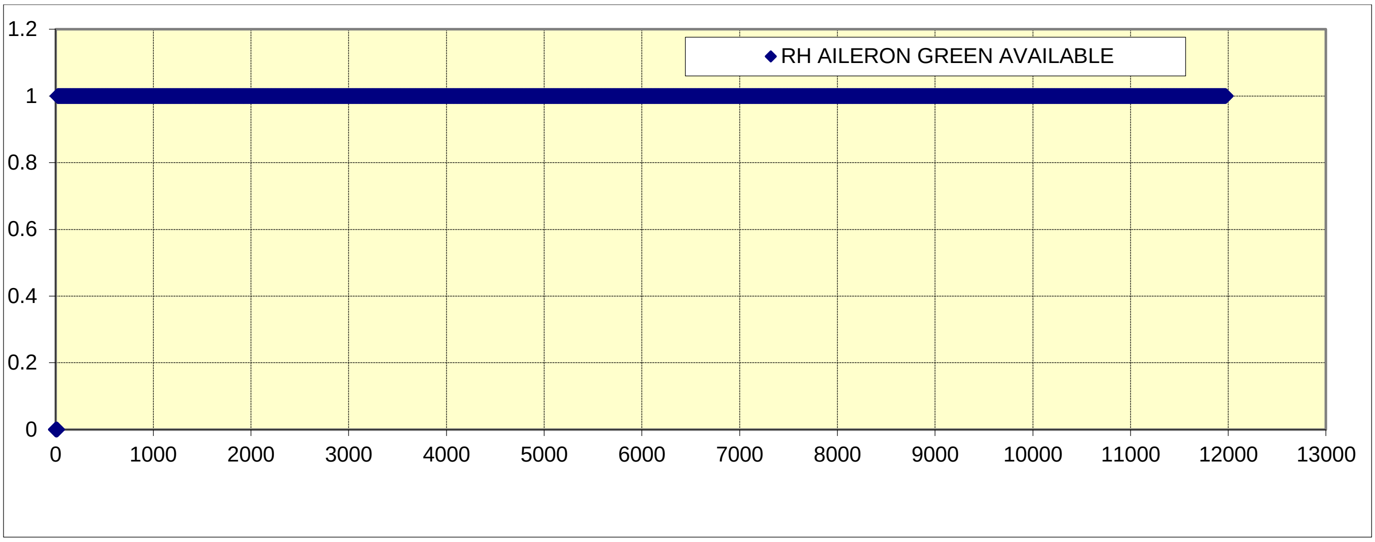




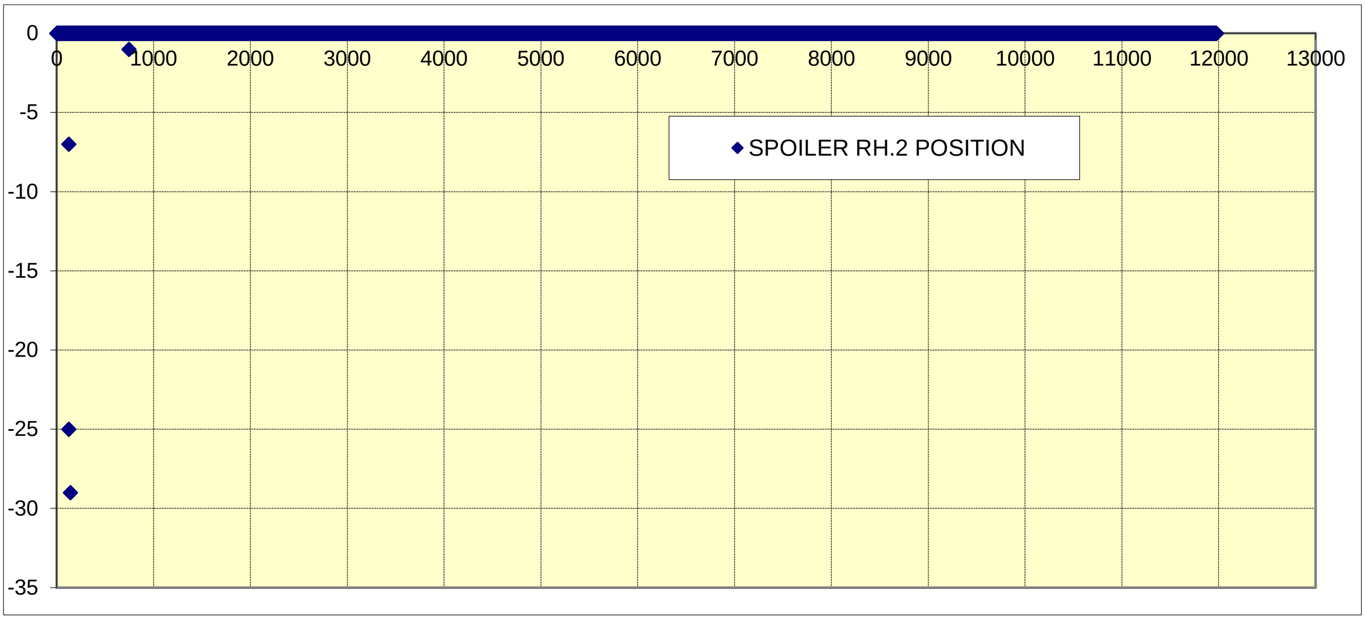
Aileron Right position viewed at the end portion of the recording

Right Aileron movements were almost between 0, -1 degrees (0 at the end of recording)

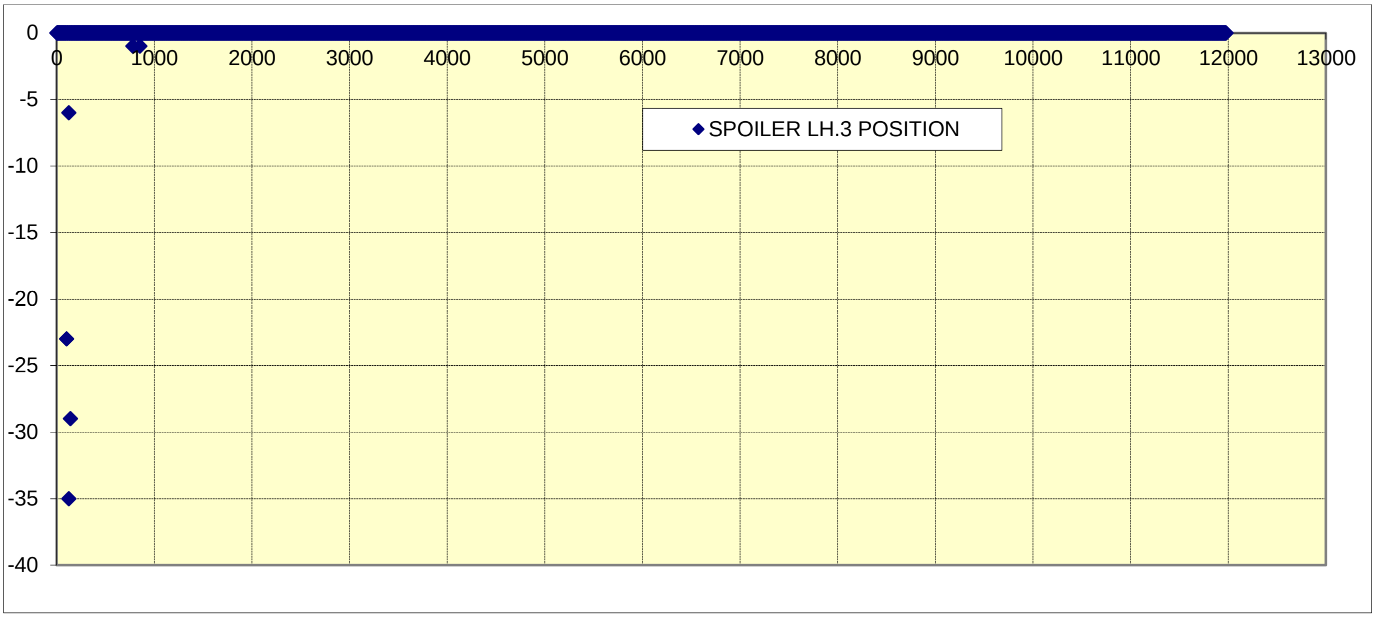
- RH AILERON GREEN AVAILABLE



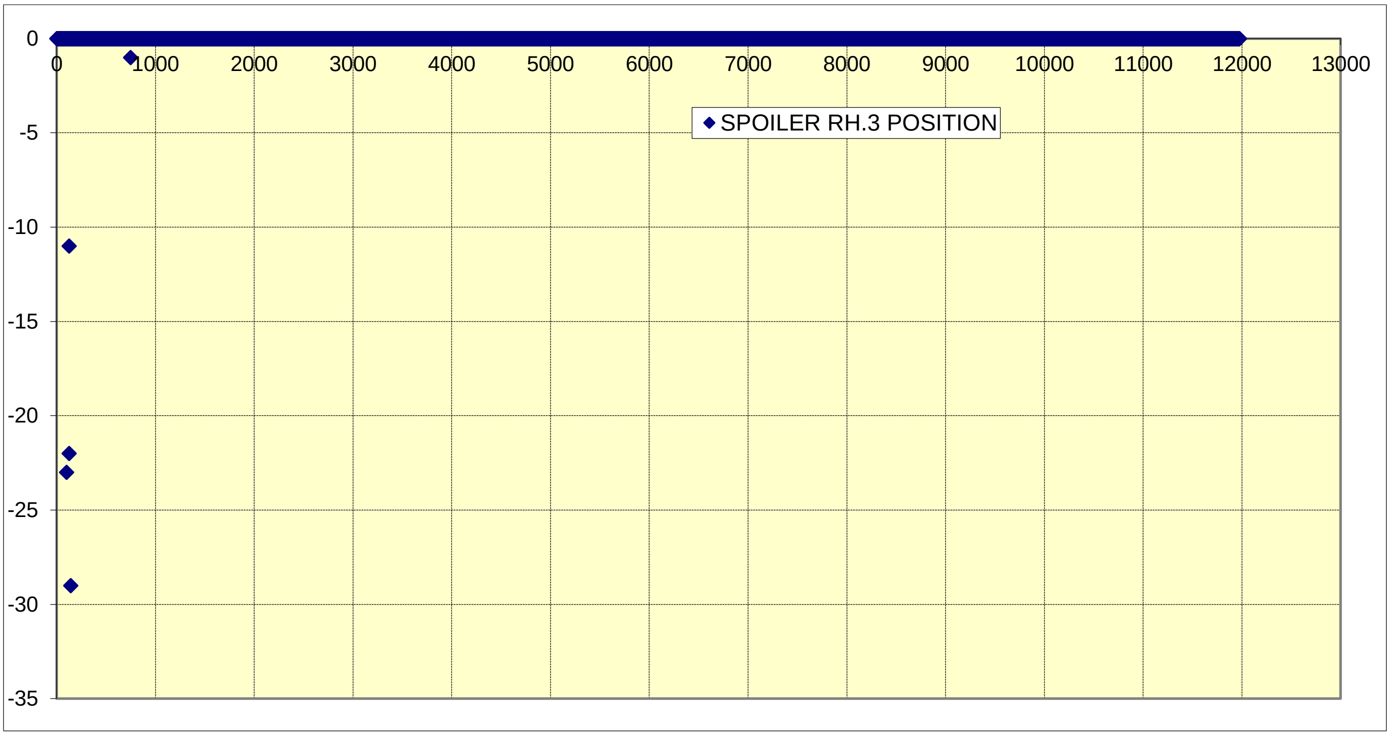
- Spoiler RH 2 Position



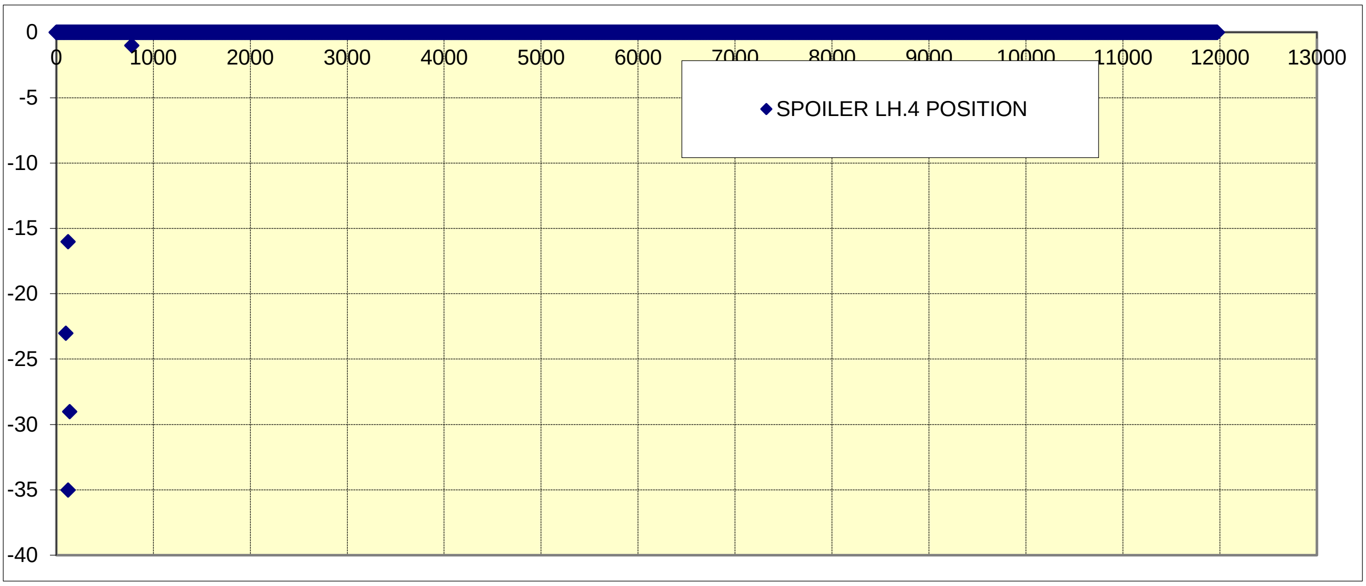
- SPOILER LH.3 POSITION



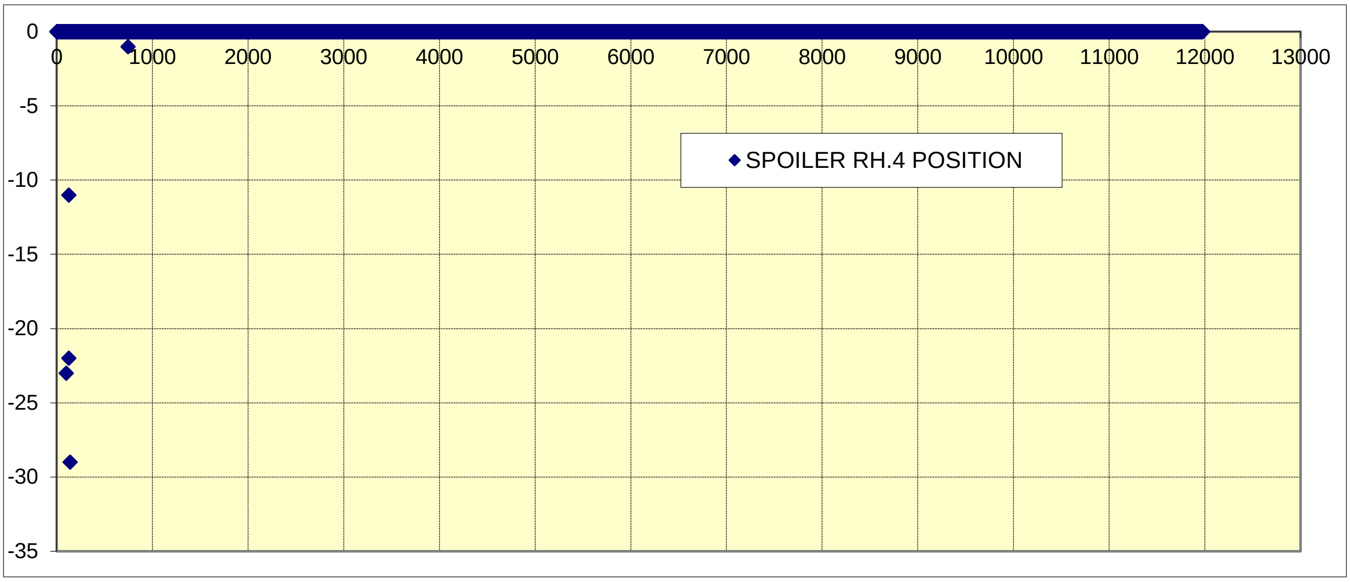
- SPOILER RH.3 POSITION



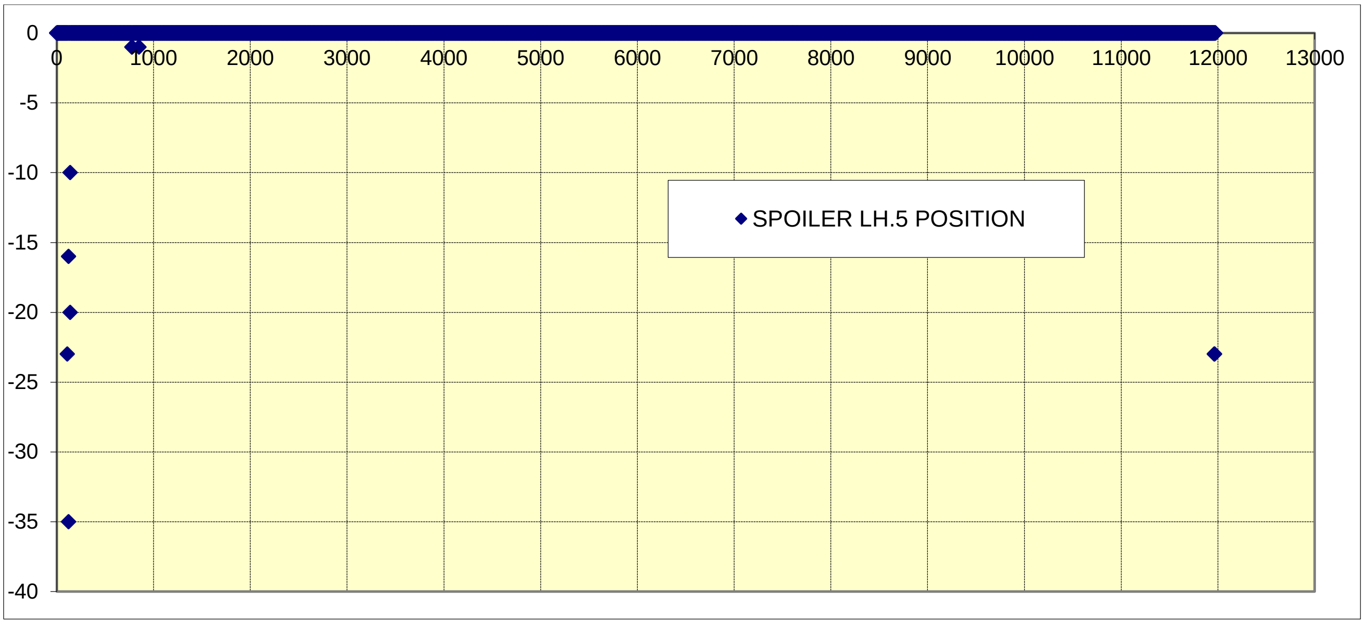
- SPOILER LH.4 POSITION

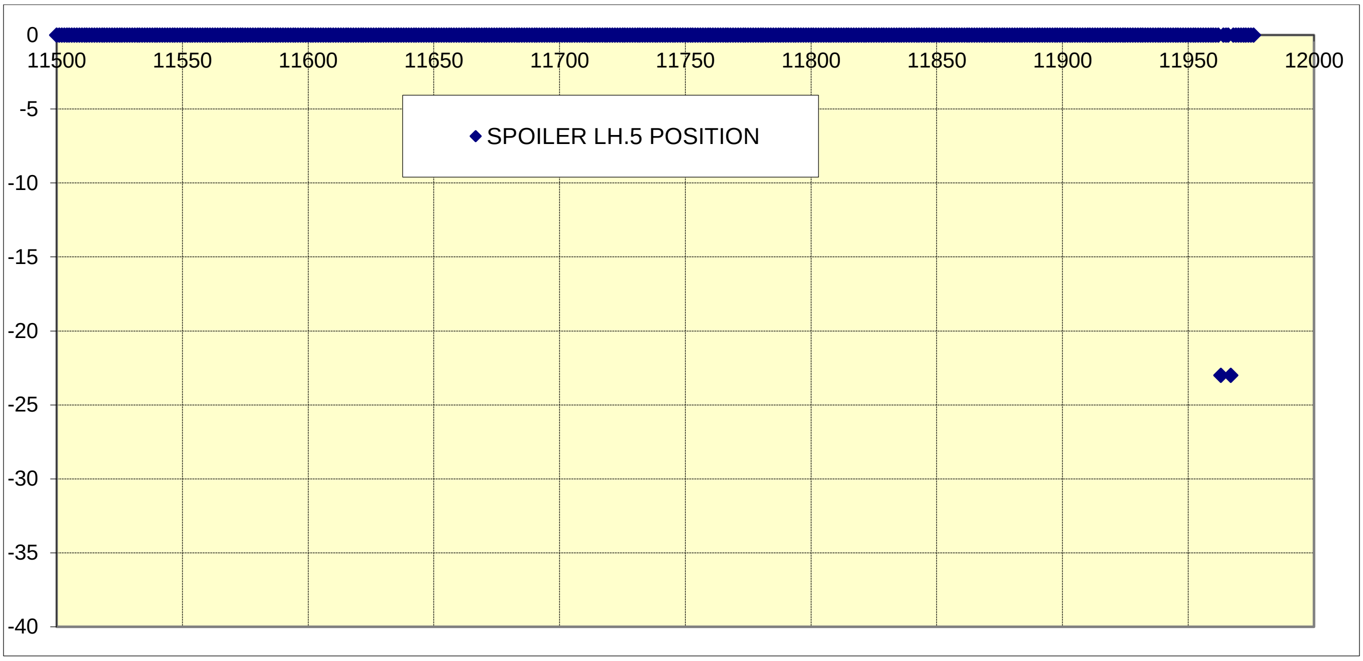


- SPOILER RH.4 POSITION



- SPOILER LH.5 POSITION



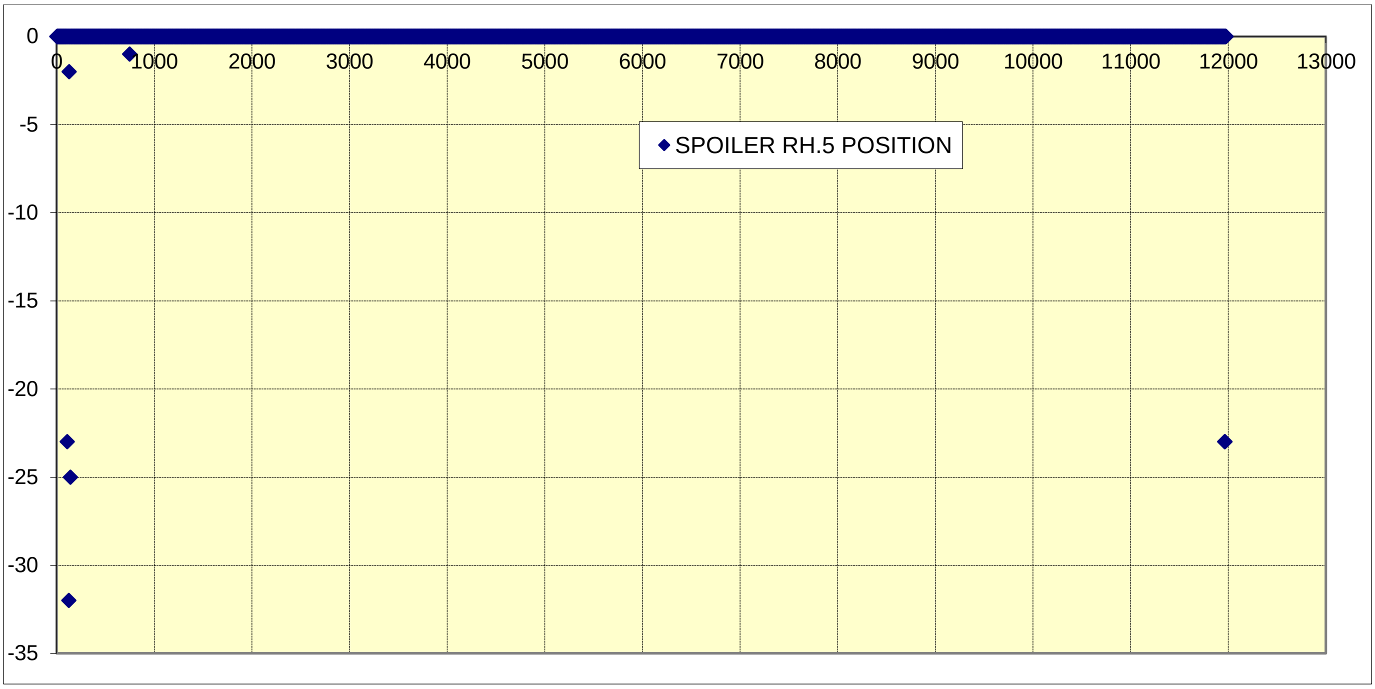


LH spoiler #5 shown at the end portion of the recording

LH spoiler #5 showed up position throughout the flight

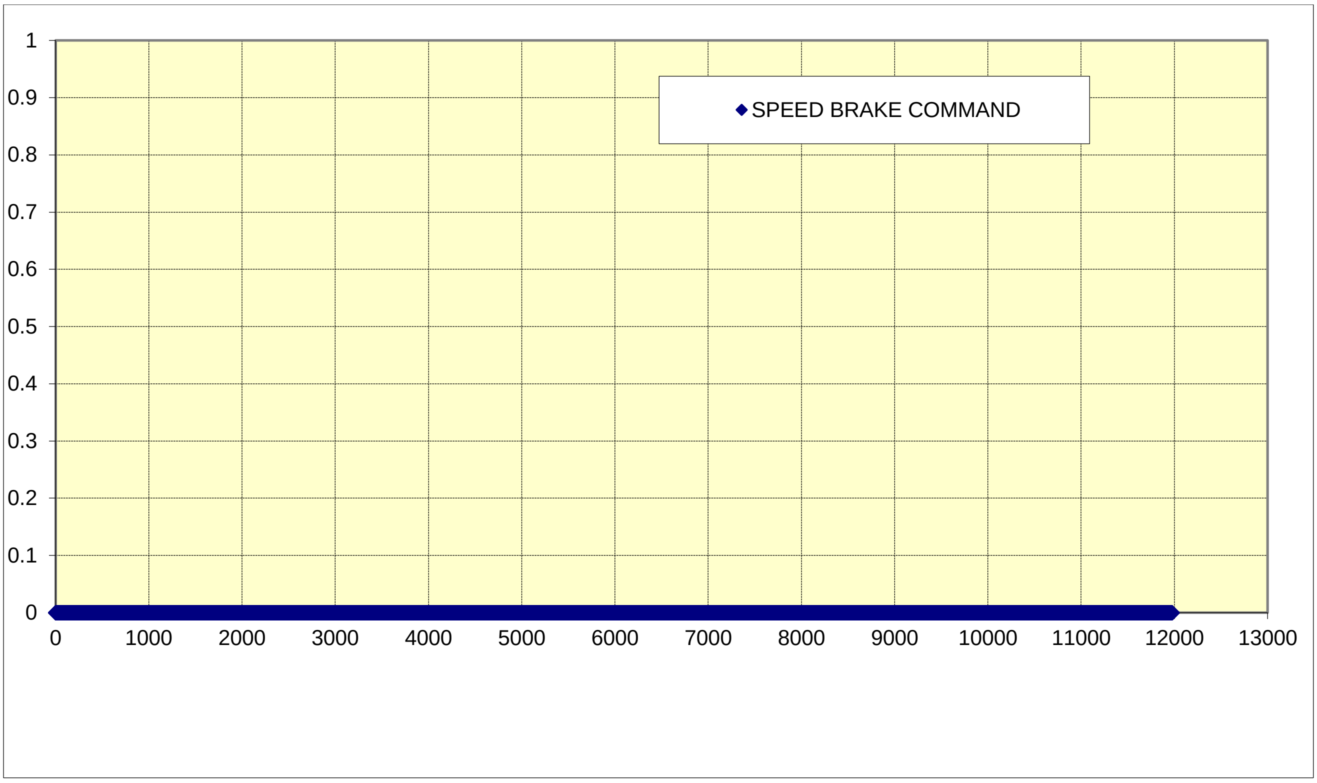
Only at 00:29:32 UTC (11963seconds on the plot) and 00:29 (11976 seconds on the plot, end of recording) the spoiler angle showed -23 degree

- SPOILER RH.5 POSITION

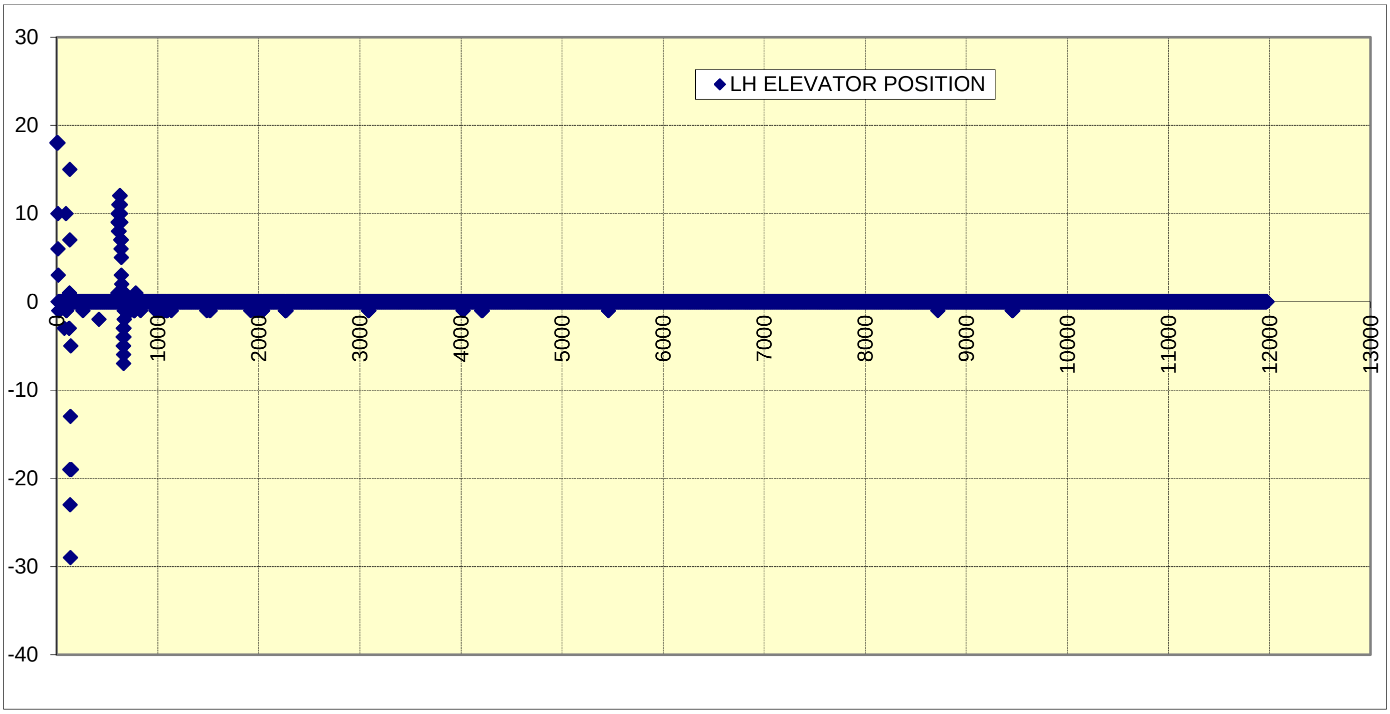


- SPEED BRAKE COMMAND

(0 no command)

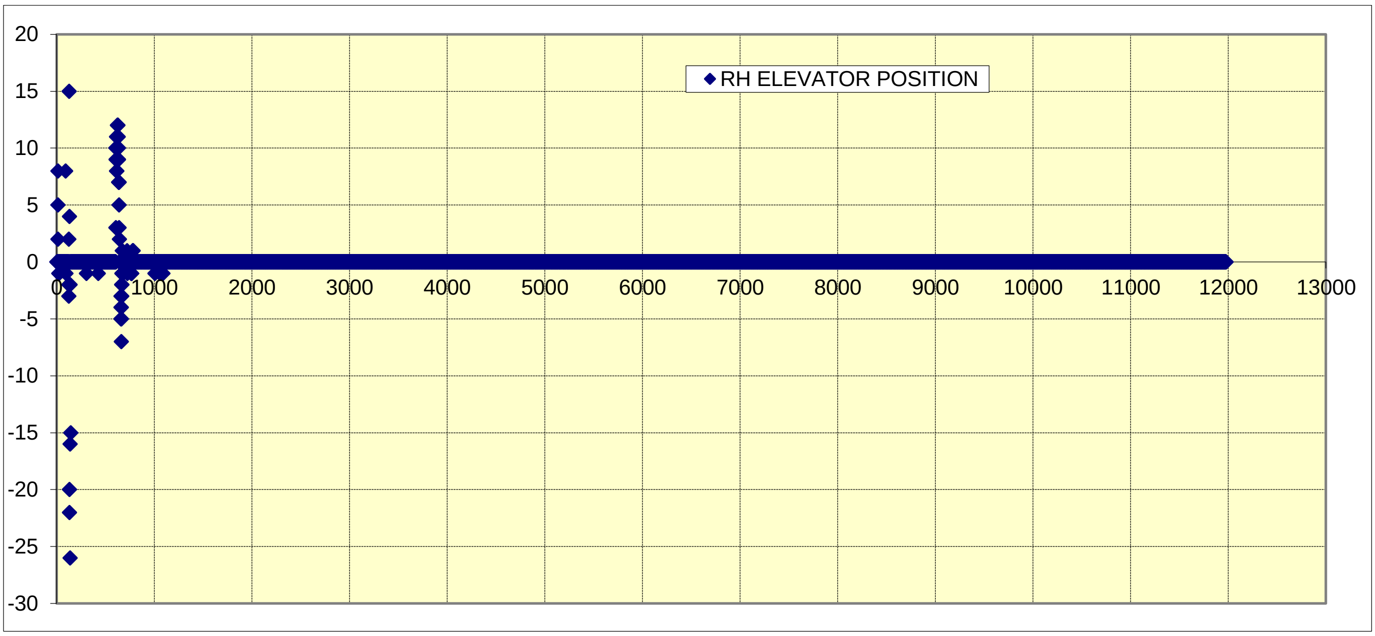


-LH ELEVATOR POSITION



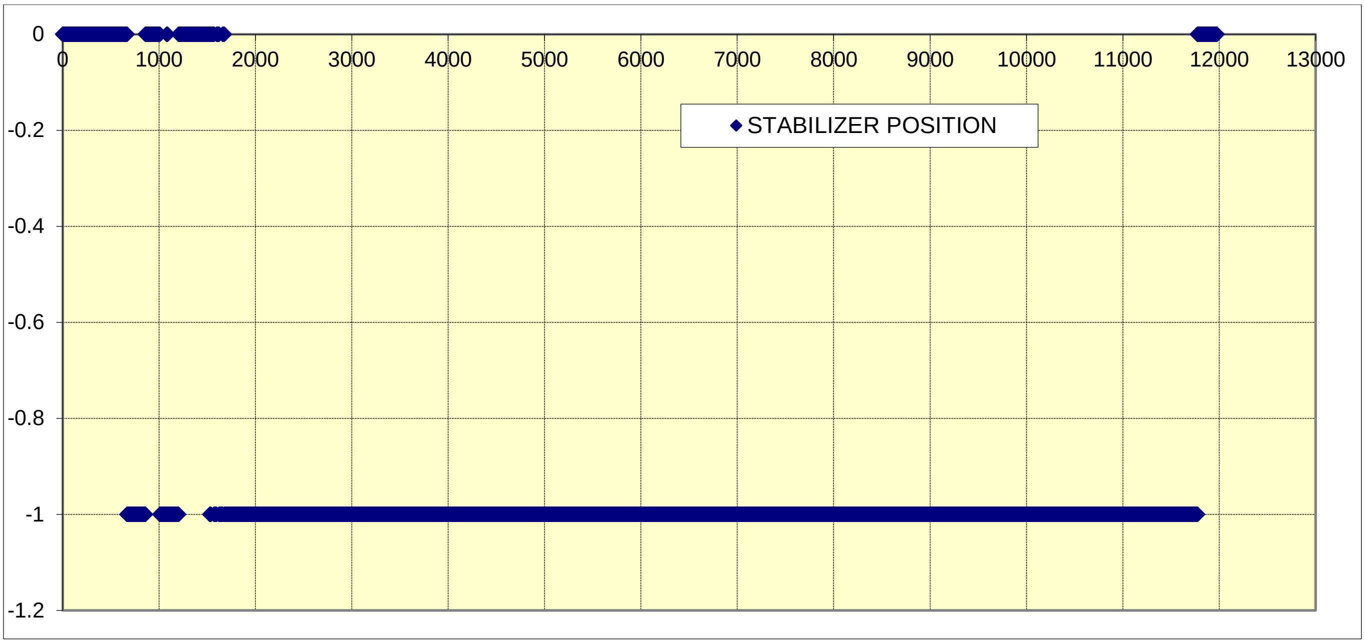
Left elevator showed a value of 0 degree throughout the cruise [hase up to the end of recordingRH

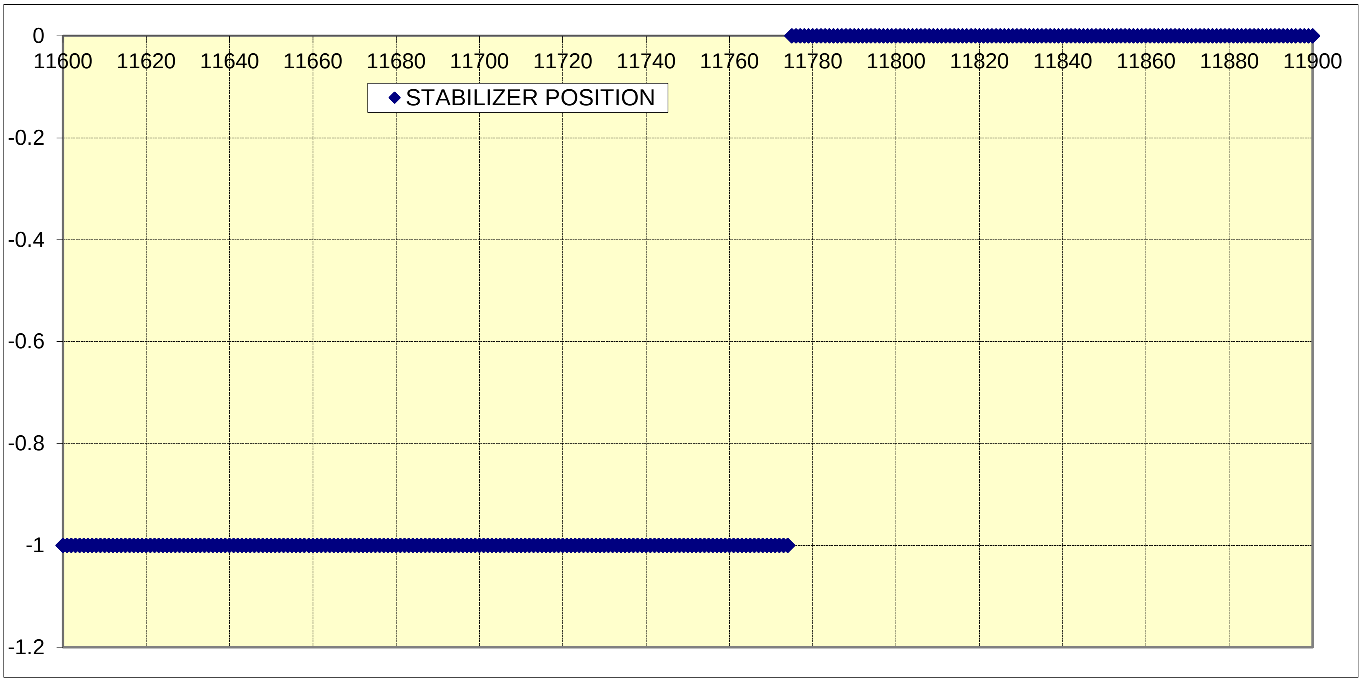
- ELEVATOR POSITION



Right elevator showed a value of 0 degree throughout the cruise [hase up to the end of recording

- STABILIZER POSITION

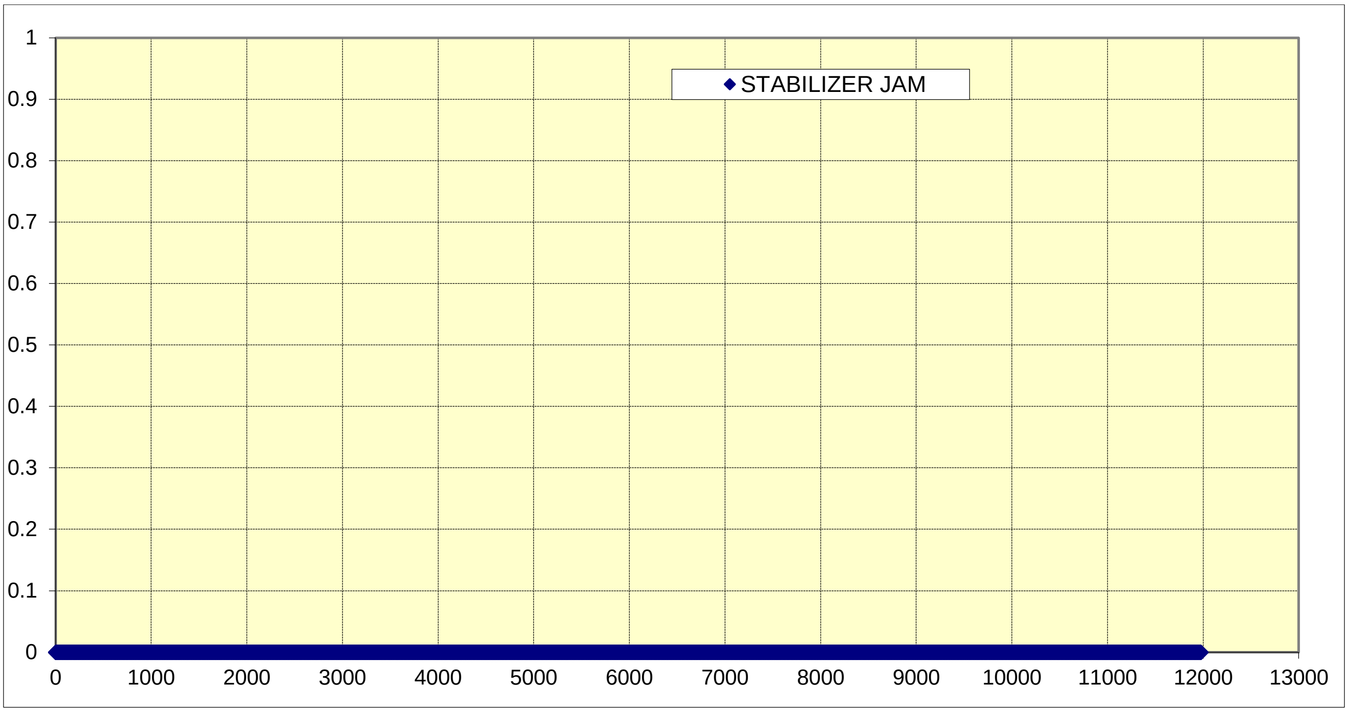




Stabilizer position showed a position of -1 throughout most of the recording time up to 00:26:23 UTC (11774 Seconds on the plot) then it moved to 0 and remained at 0 up to the end of recording at 00:29:45 UTC

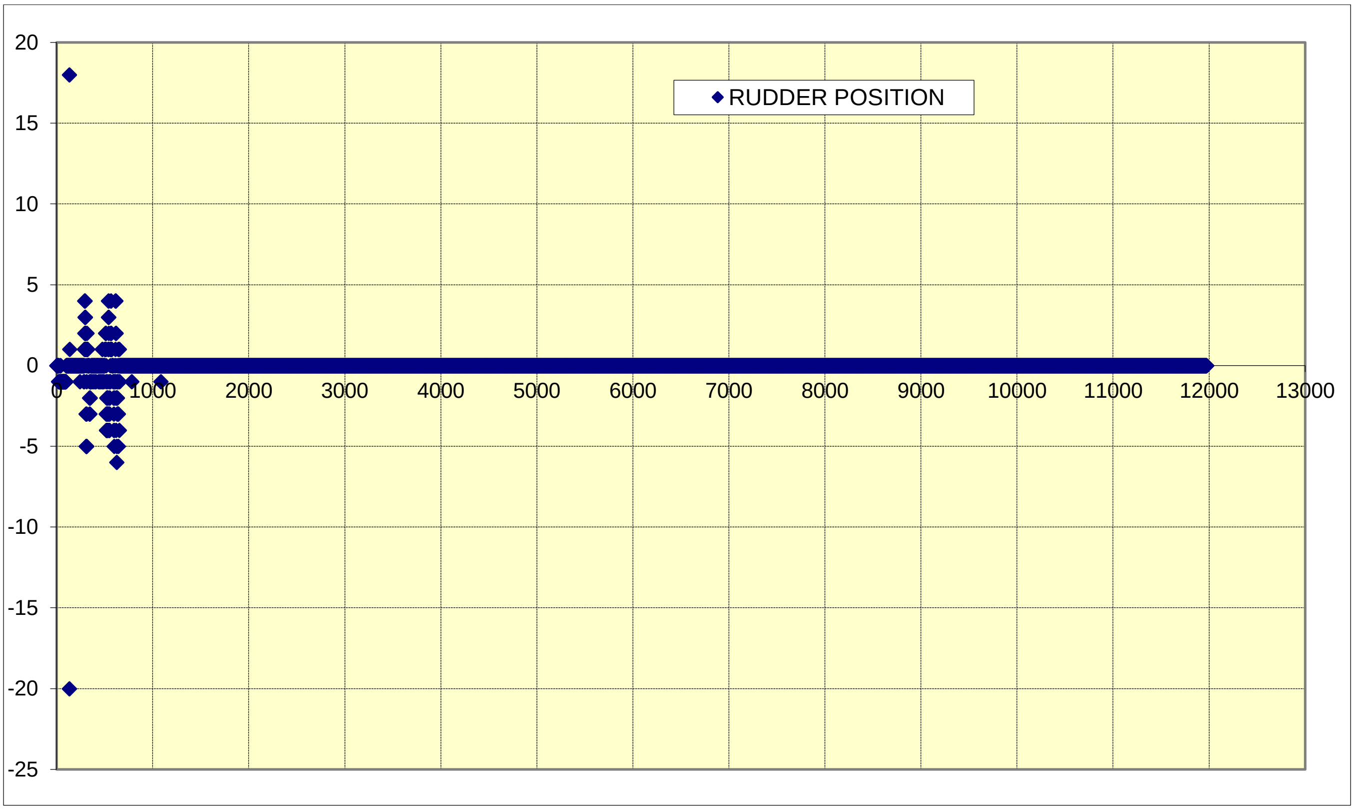
– STABILIZER JAM

(1 jammed)

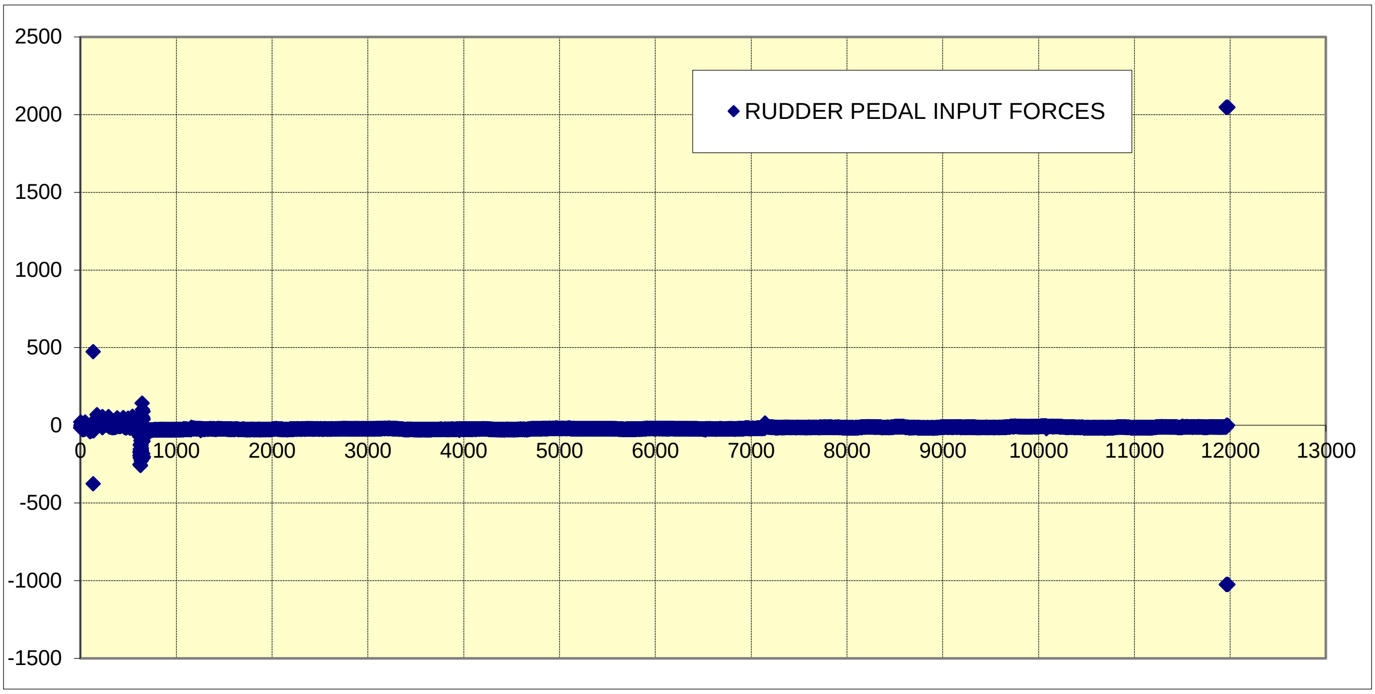


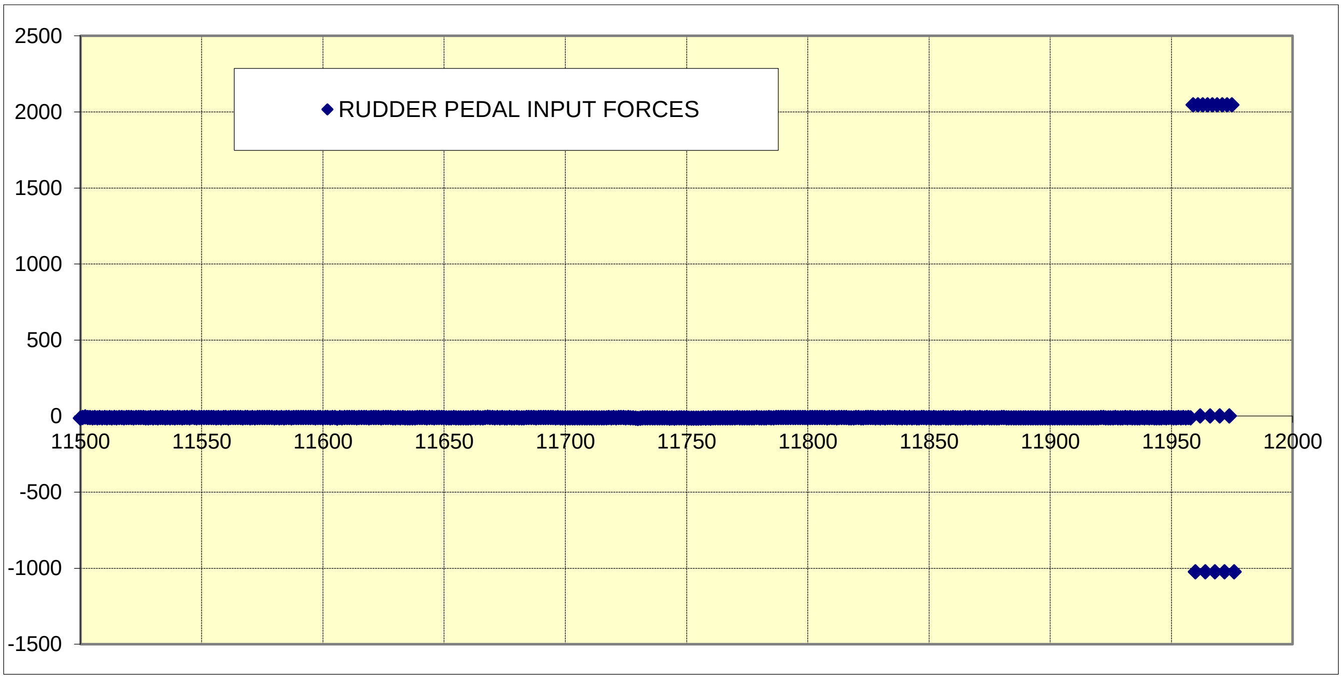
No stabilizer jam

- RUDDER POSITION

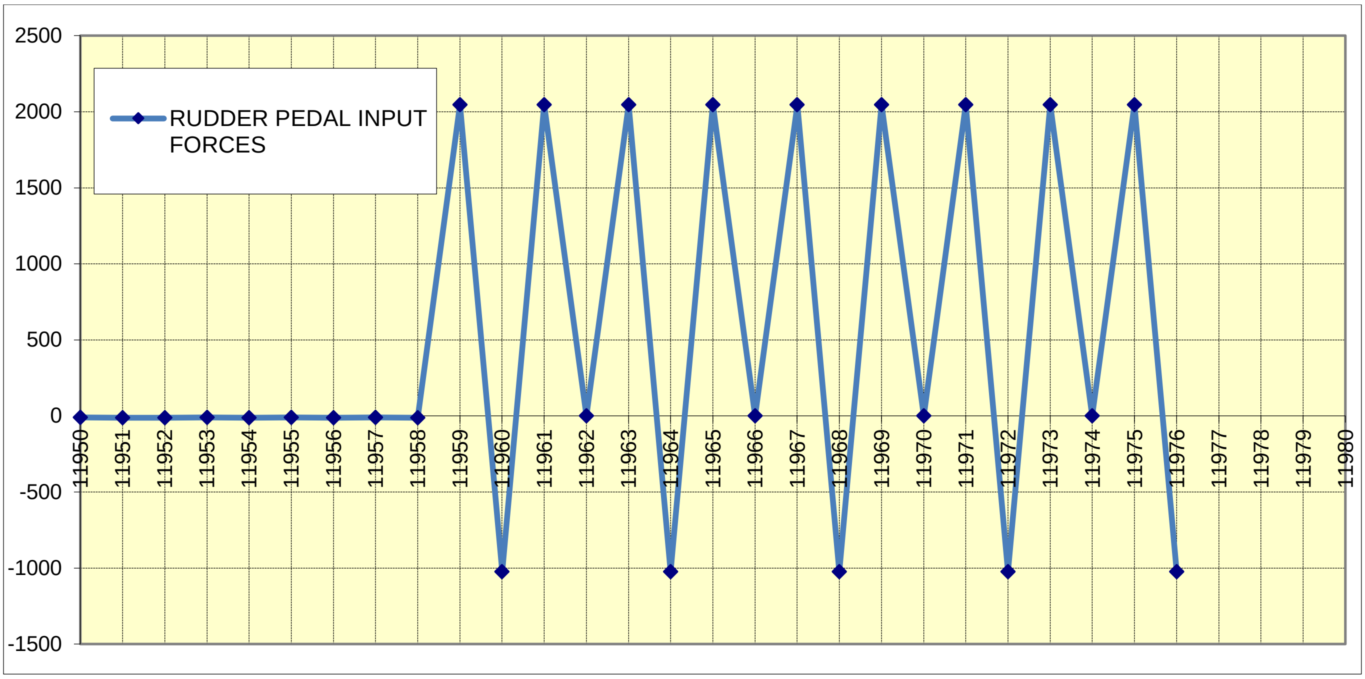


– RUDDER PEDAL INPUT FORCES





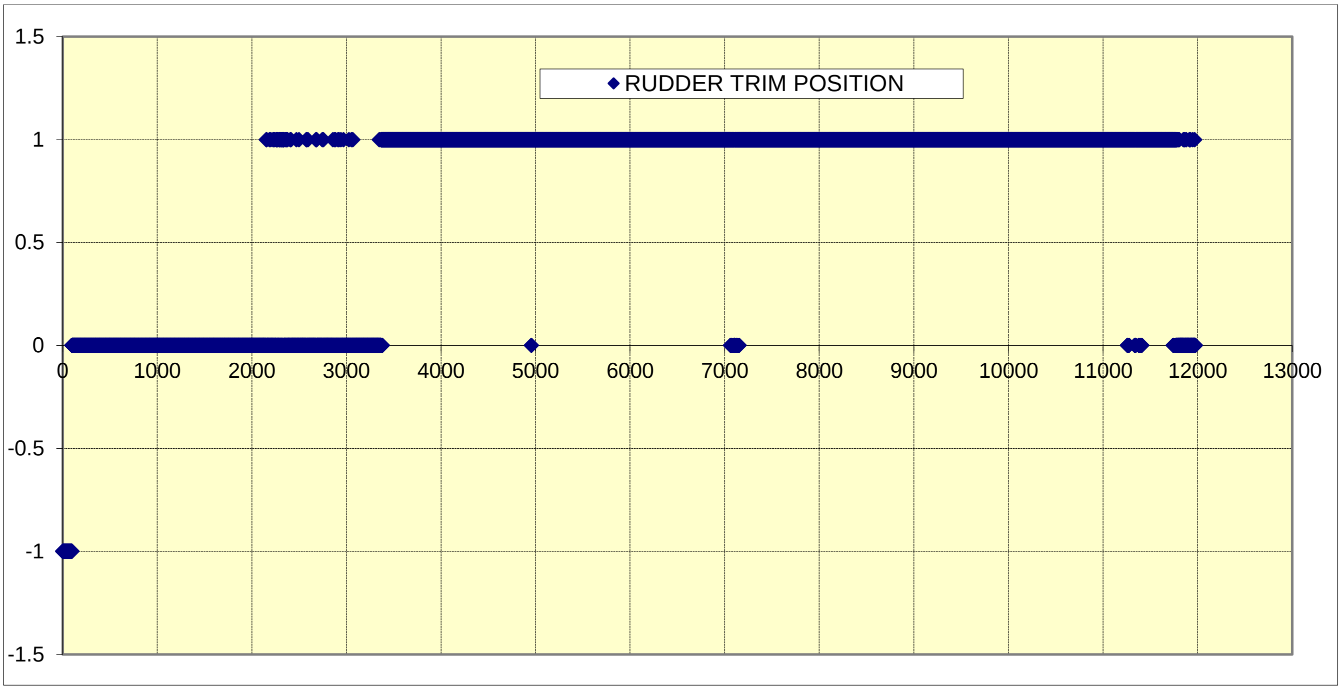
Rudder pedal input forces, closer view at the end of the recording

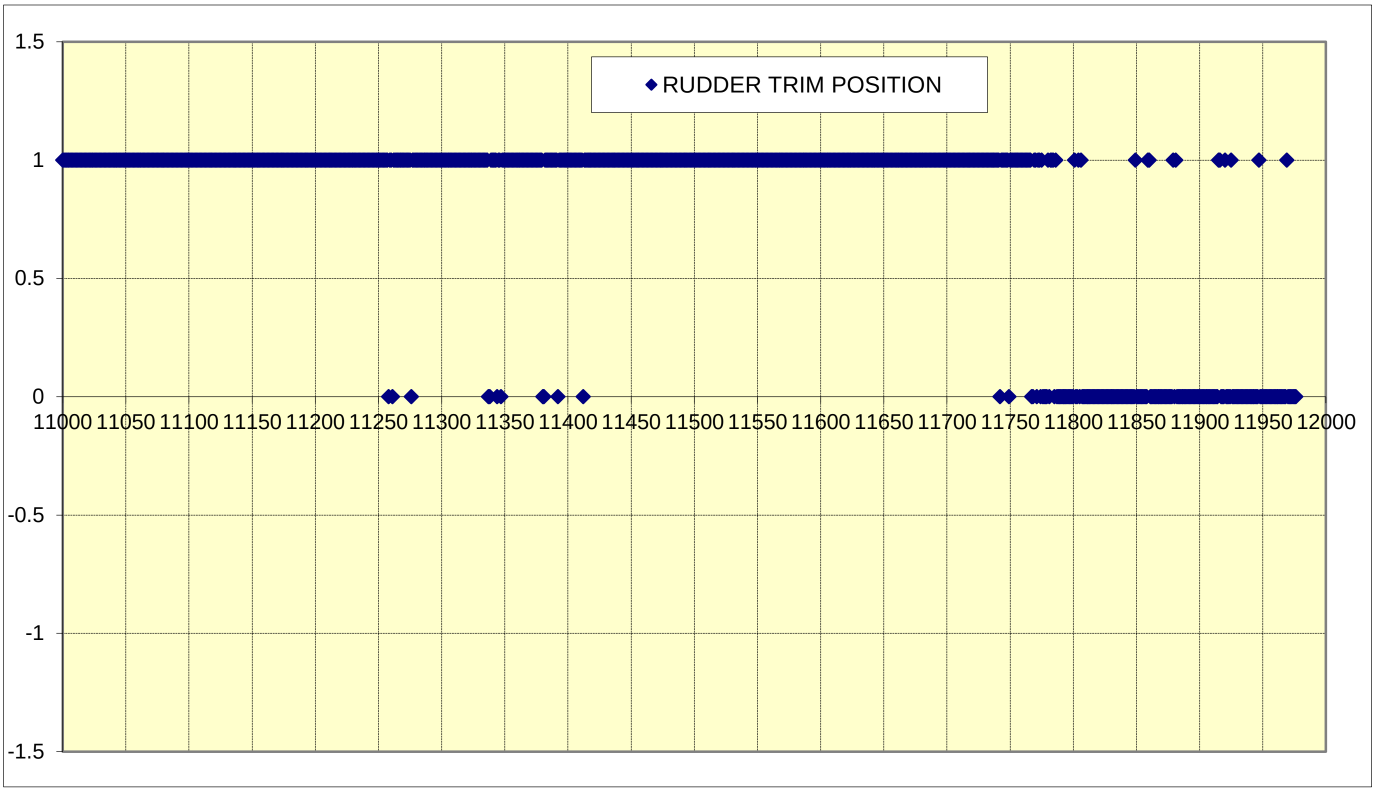


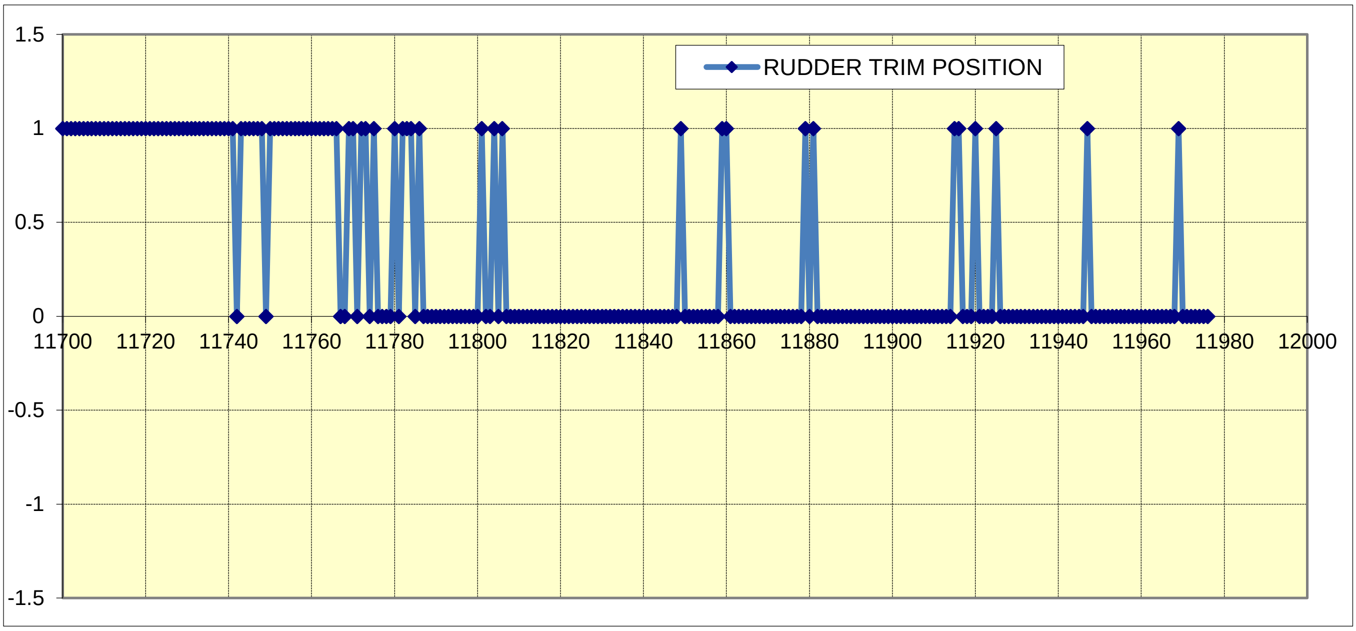
Rudder Pedal Input forces shown at the end of recording

Rudder Pedal Input forces showed a constant value of 0 up to 00:29:27 (11958 seconds on the plot) then it started varying between 2047 and -1024 up to the end of recording 00:29:45 (11976 seconds on the plot)

- RUDDER TRIM POSITION



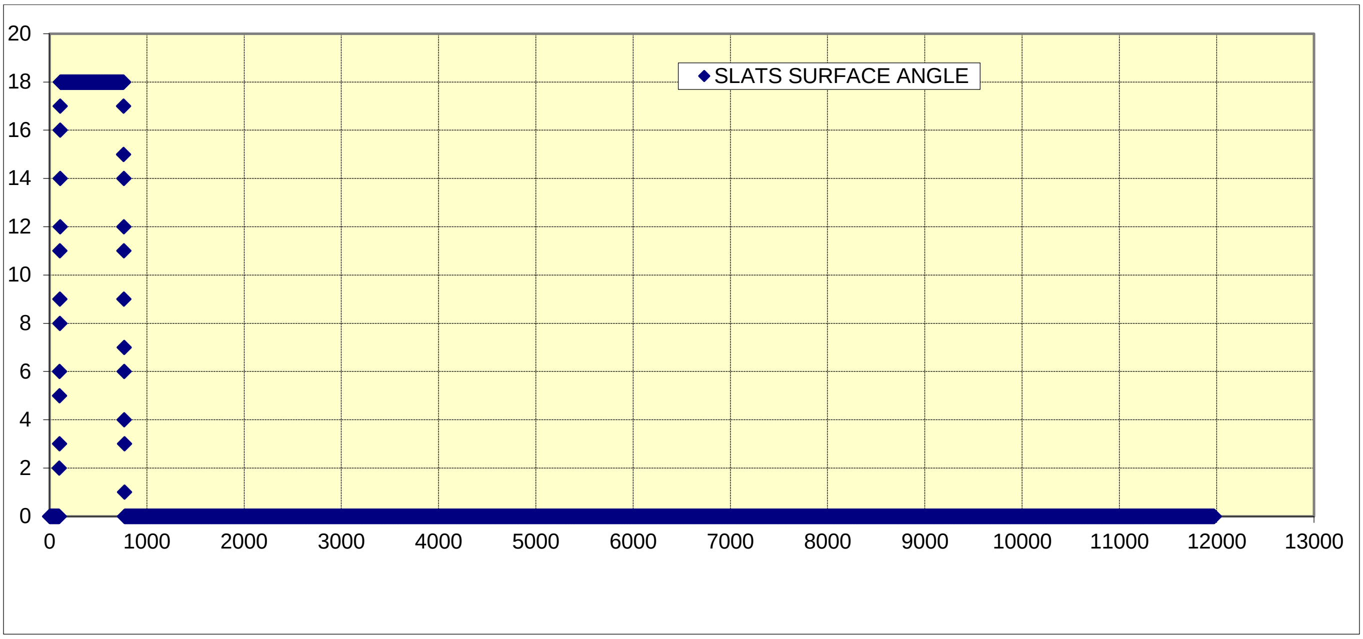




Rudder trim position, closer view at the end of the recording

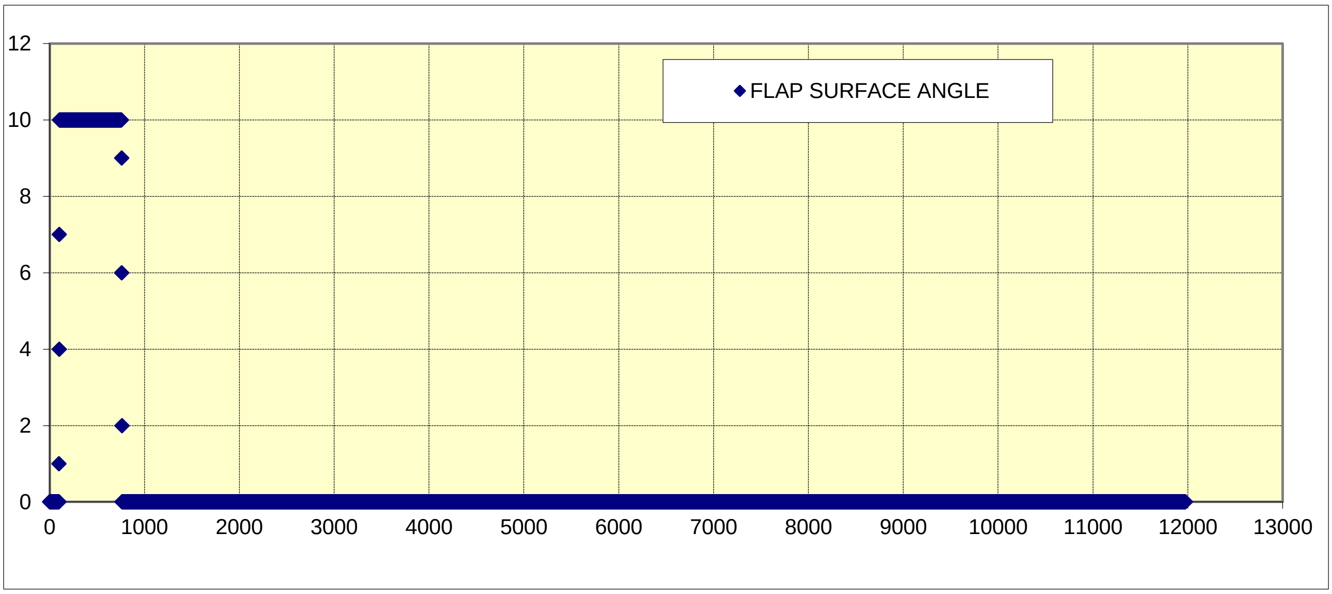
Rudder trim position showed a value of 1 most of the cruise flight. At 00:25:58 (11749 seconds on the plot) the rudder trim position started variation between 1 and 0 until the end of the recording at 00:29:45

- SLATS surface angle



Slats remained retracted up to the end of the recording

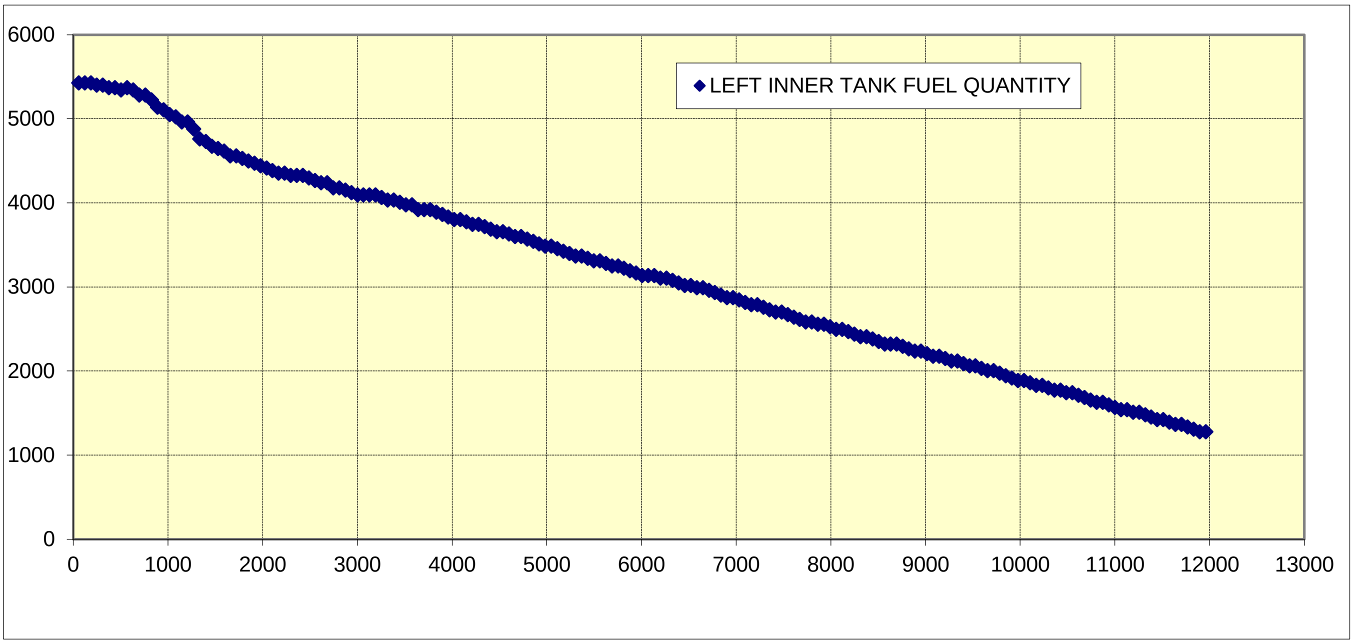
- FLAP SURFACE ANGLE

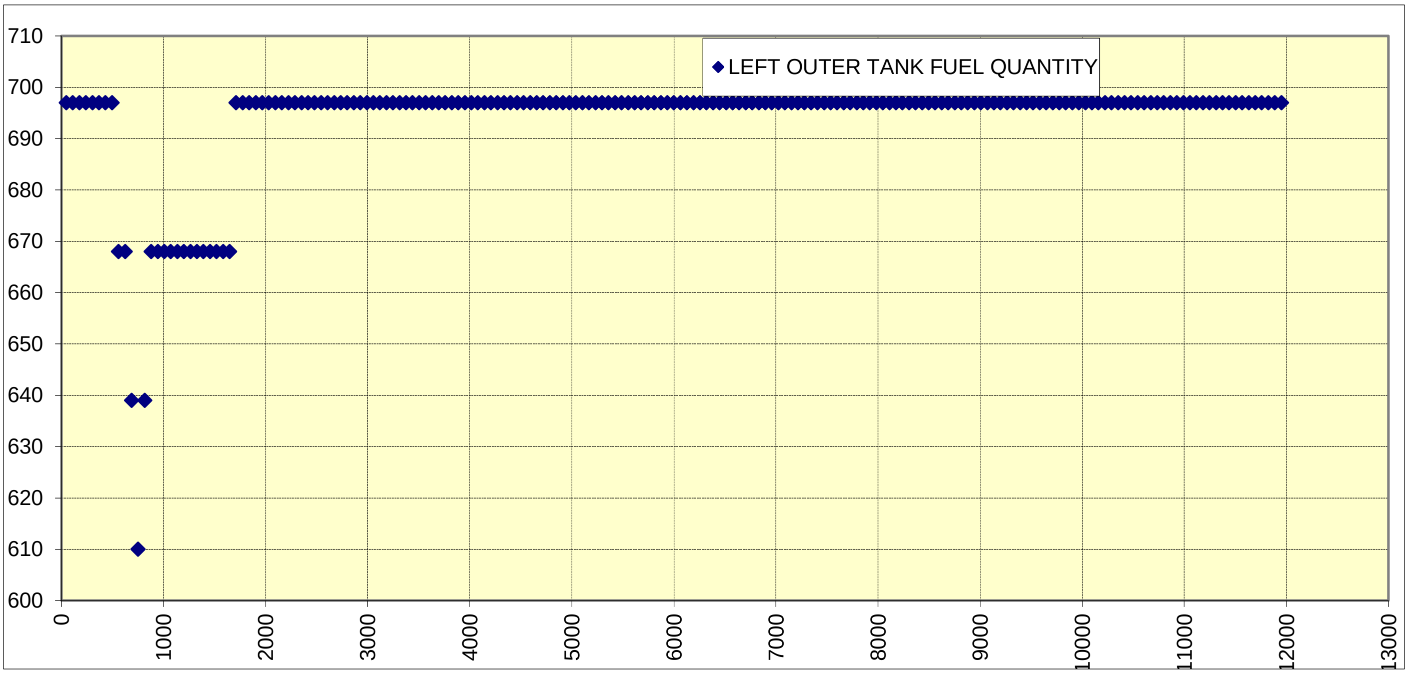


Flaps remained retracted up to the end of the recording

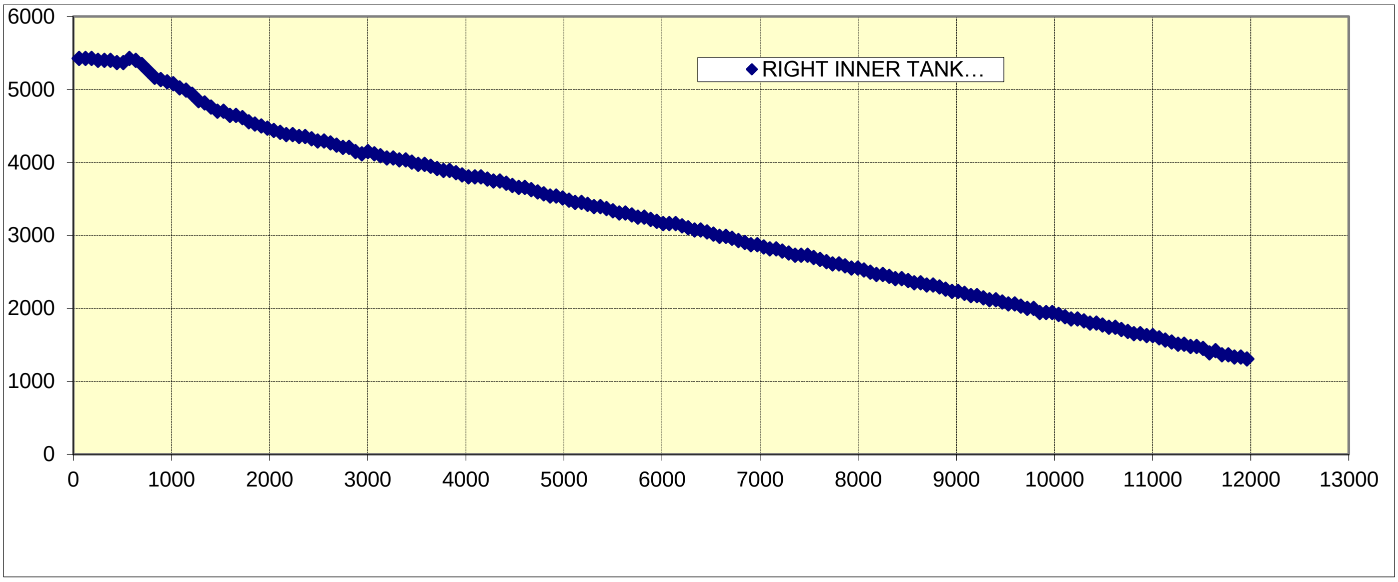
6. Fuel

– LEFT INNER TANK FUEL QUANTITY

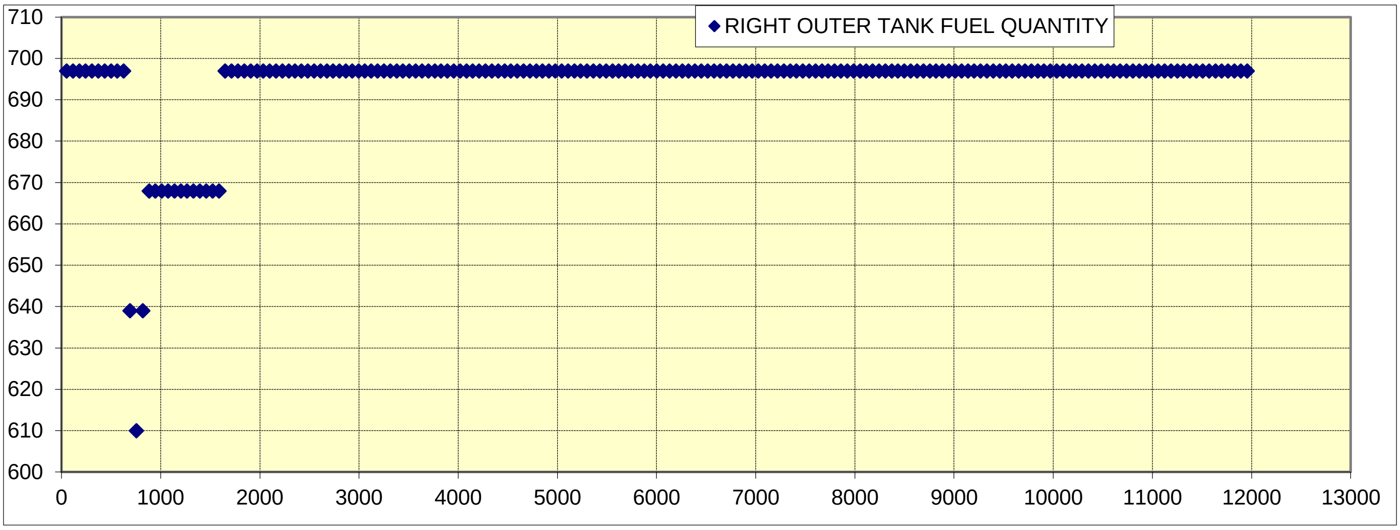




- RIGHT INNER TANK FUEL QUANTITY

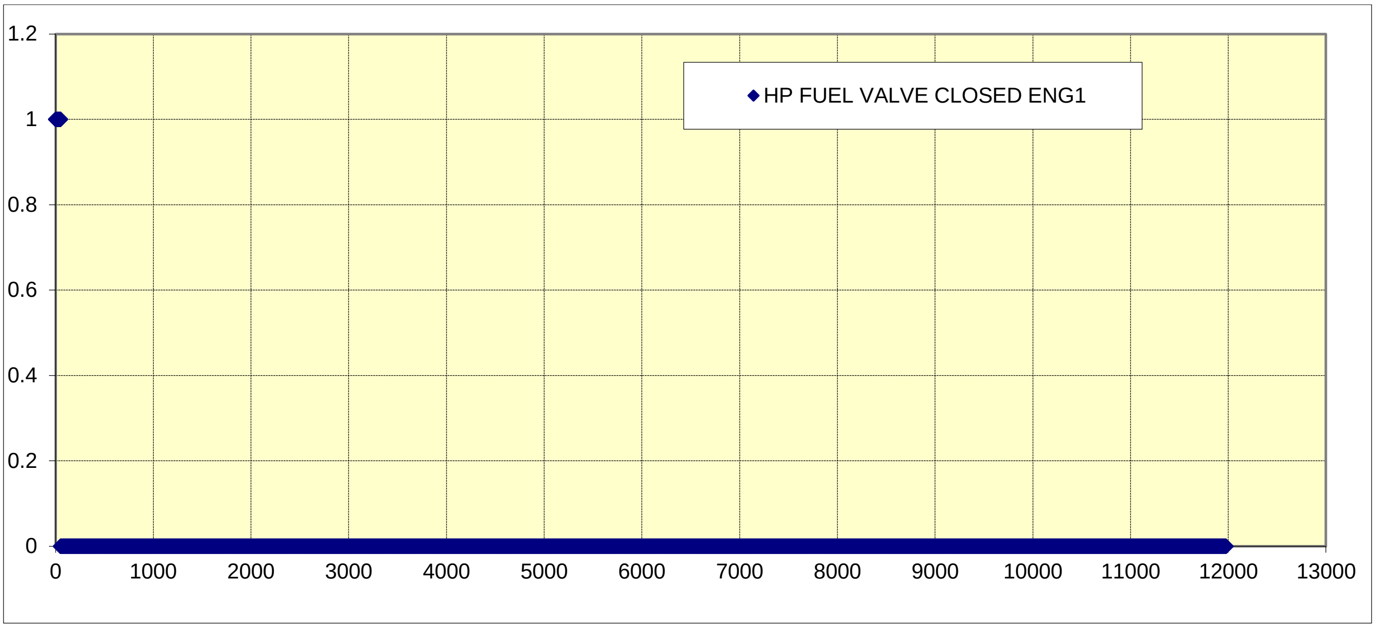


- RIGHT OUTER TANK FUEL QUANTITY



No evidences of anomalies with fuel tanks quantities

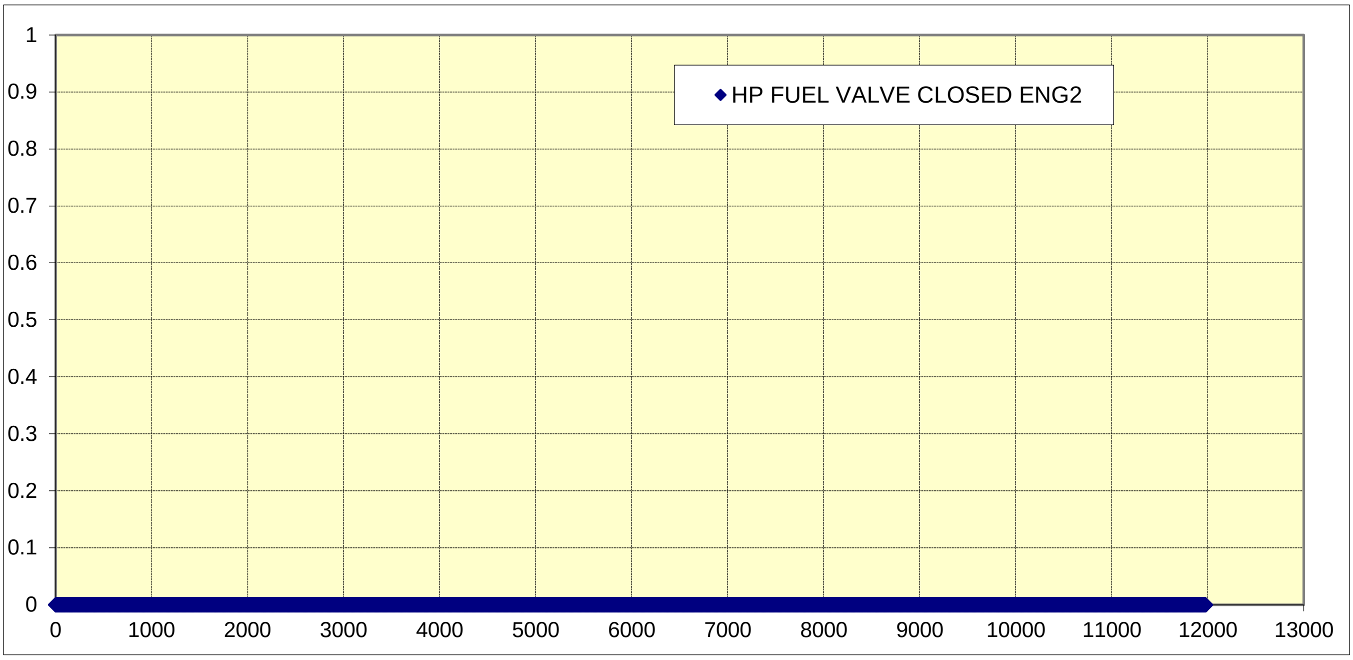
- HP FUEL VALVE CLOSED ENG1



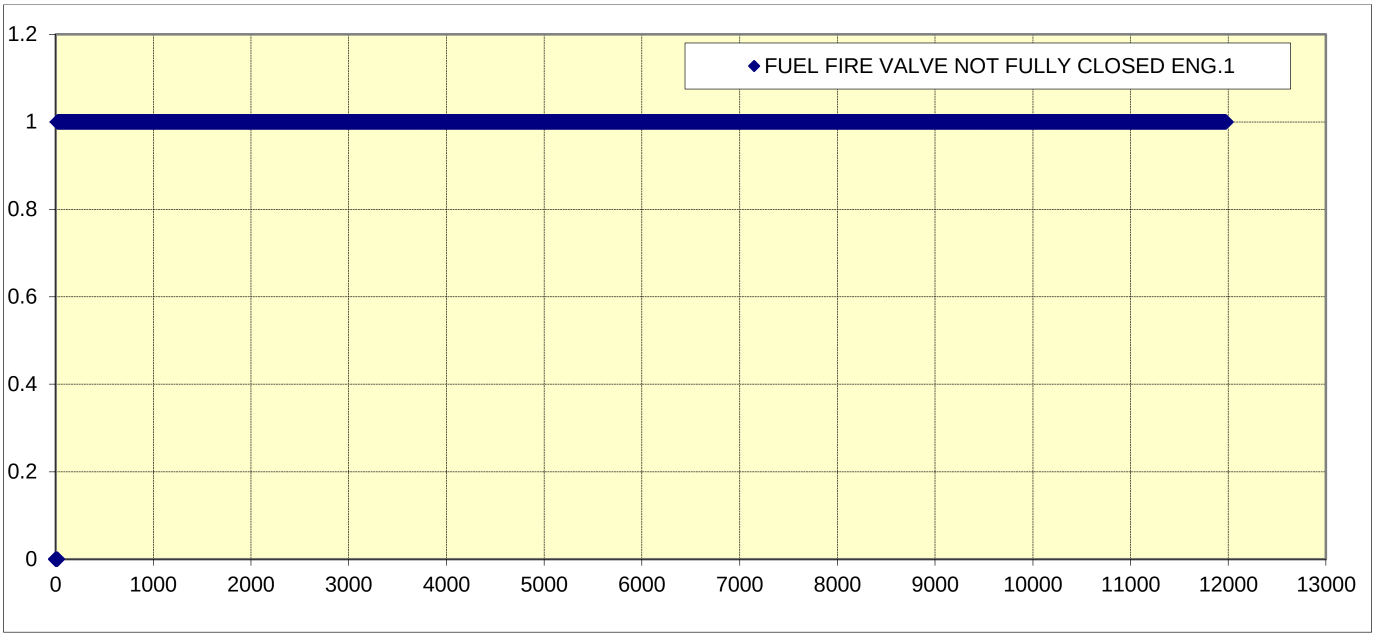
HP FUEL VALVE CLOSED ENG1 was not closed throughout the whole recording

– HP FUEL VALVE CLOSED ENG2

(0 opened)

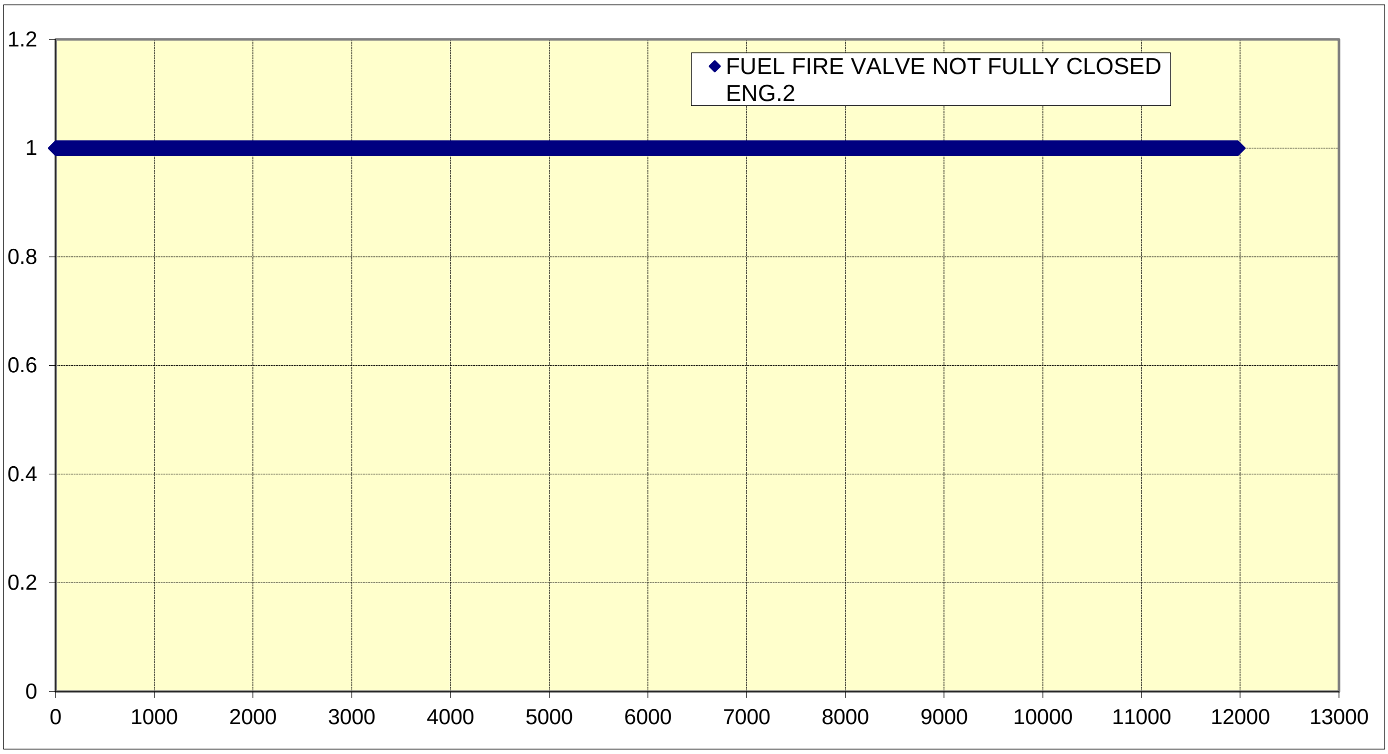


- FUEL FIRE VALVE NOT FULLY CLOSED ENG.1



FUEL FIRE VALVE was NOT FULLY CLOSED ENG.1 throughout the whole recording time

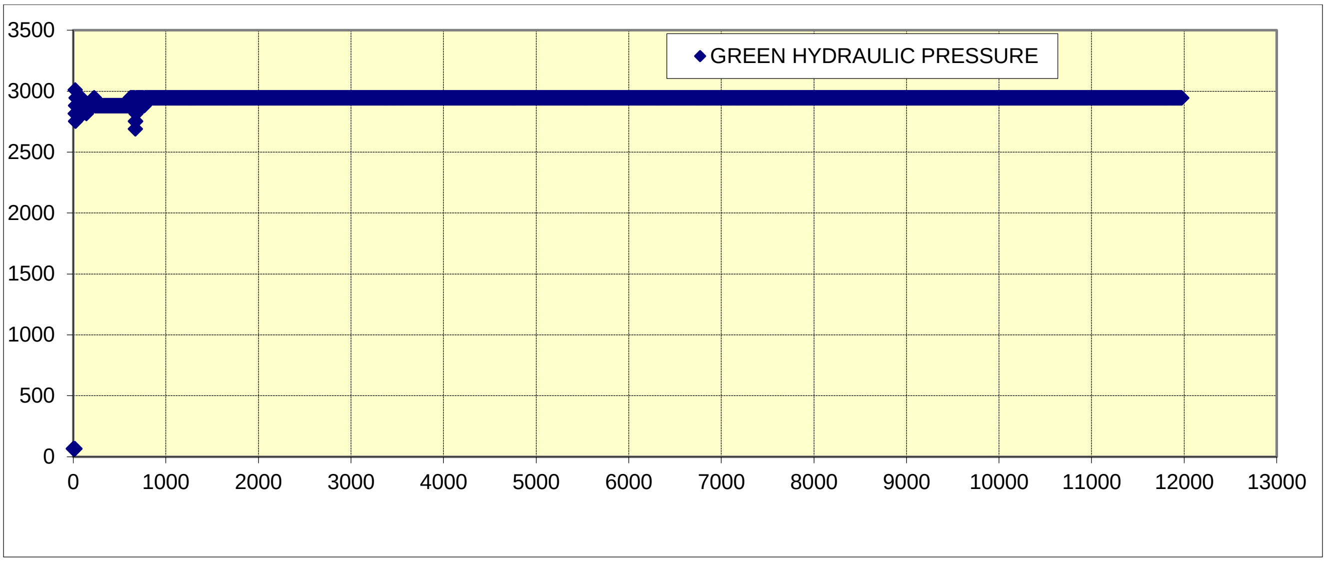
– FUEL FIRE VALVE NOT FULLY CLOSED ENG.2



FUEL FIRE VALVE was NOT FULLY CLOSED ENG.2 throughout the whole recording time

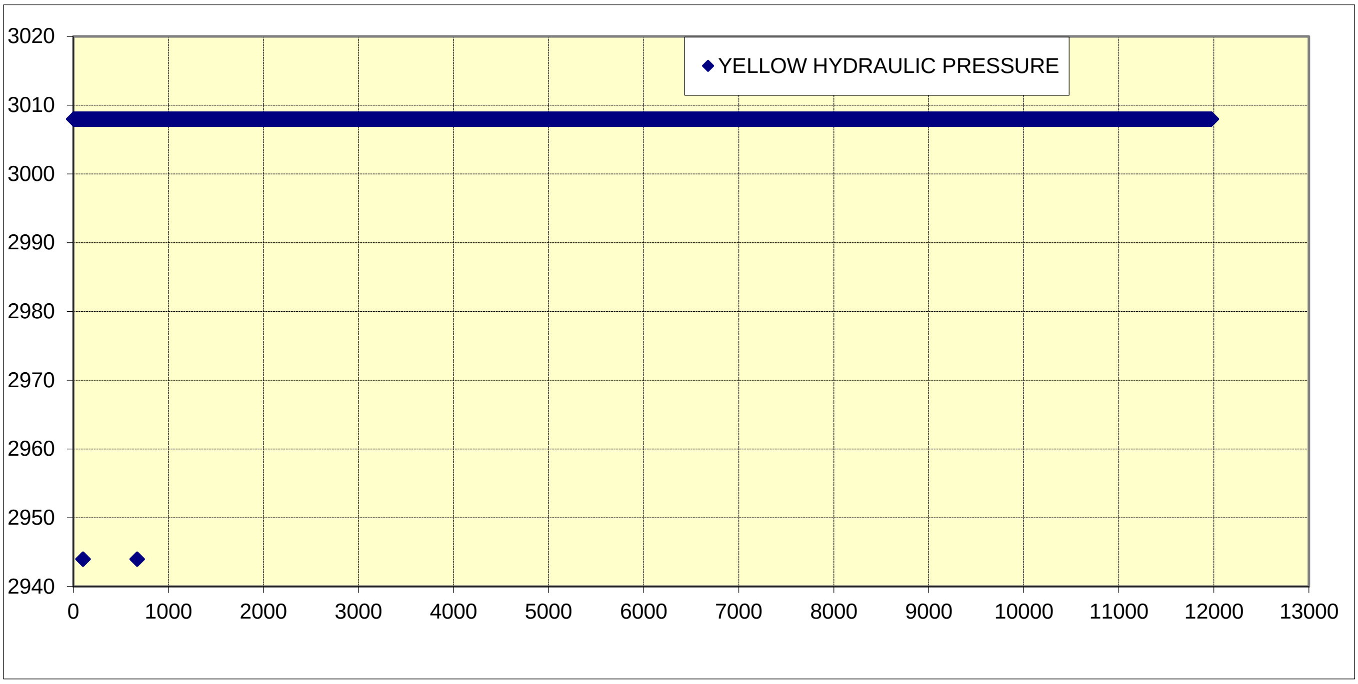
7. Hydraulic

- GREEN HYDRAULIC PRESSURE



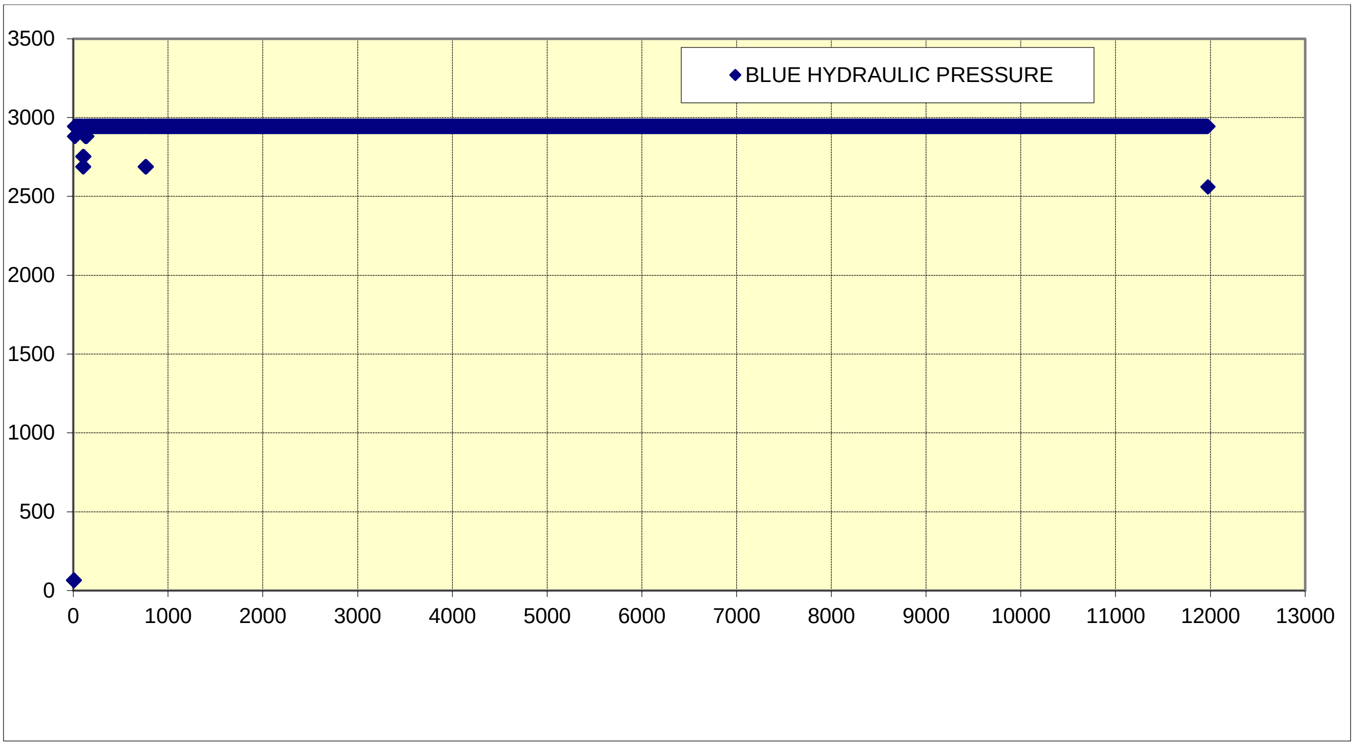
Green hydraulic pressure was almost 2944 psi throughout the whole recording

- YELLOW HYDRAULIC PRESSURE



Yellow hydraulic pressure was almost 3008 psi throughout the whole recording

- BLUE HYDRAULIC PRESSURE

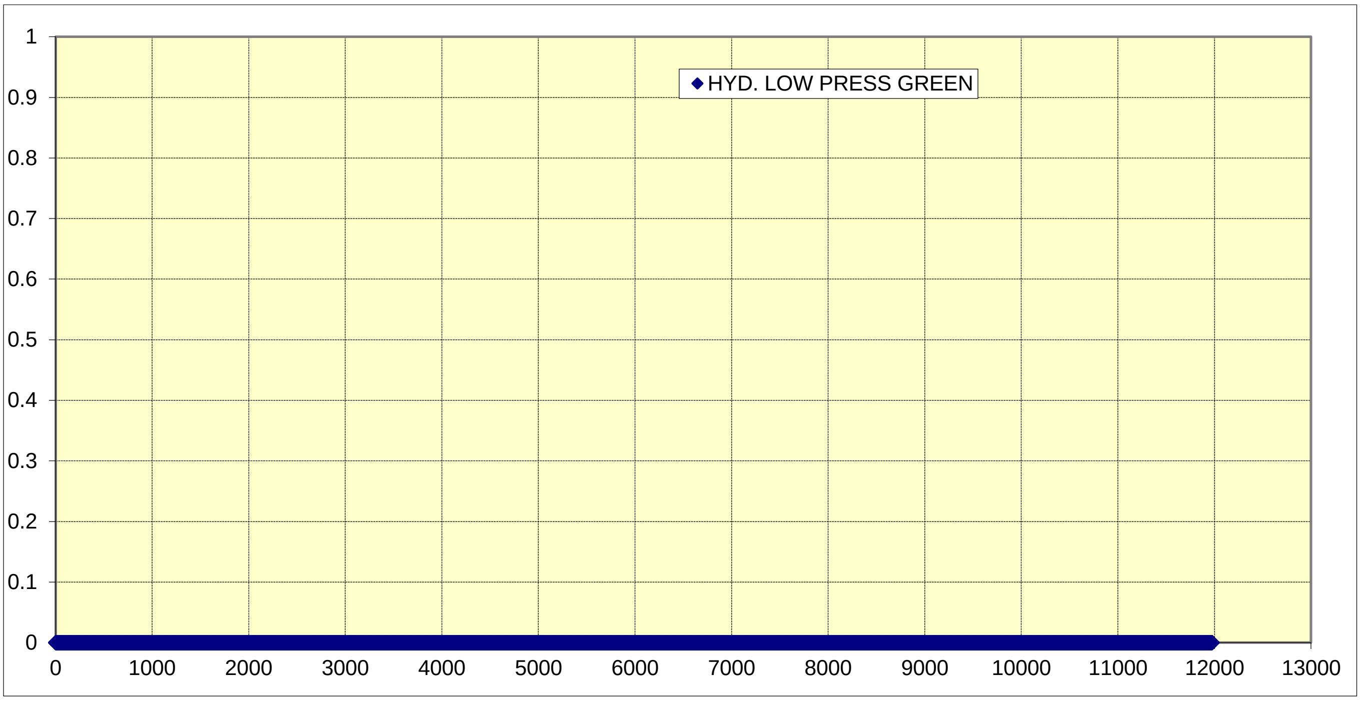


Blue hydraulic pressure was almost 2994 psi throughout the whole recording

Note: only at the last recorded point (11976 seconds on the plot) the Blue hydraulic pressure dropped to 2560 psi

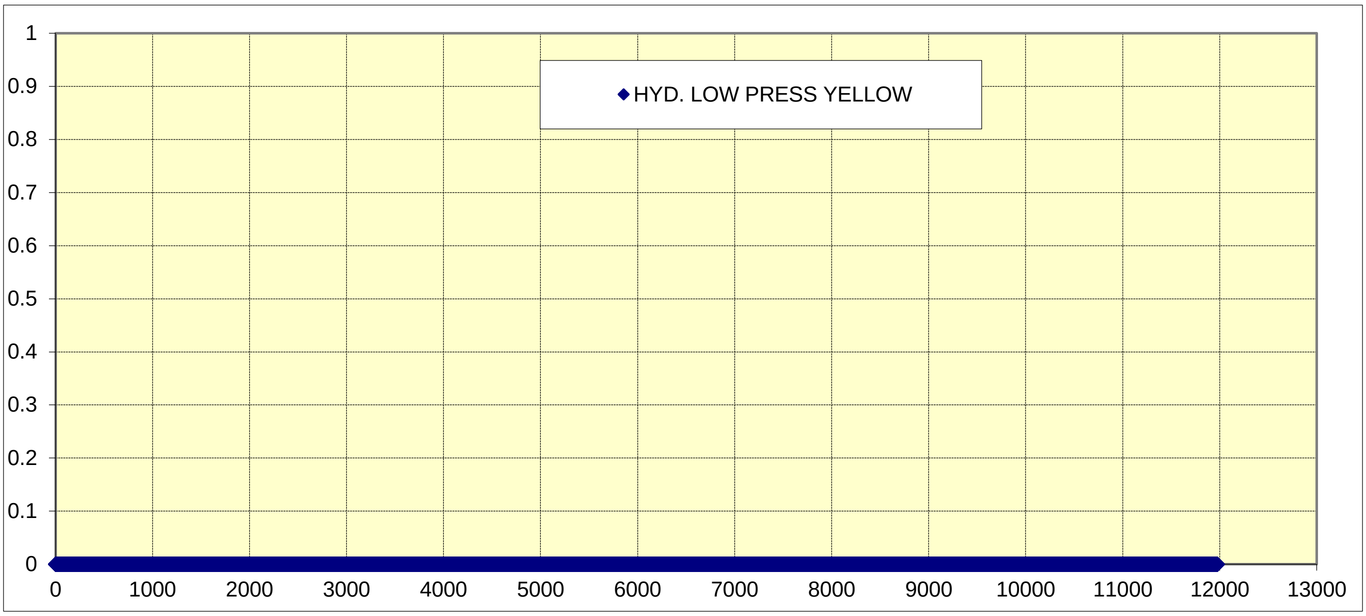
- HYD. LOW PRESS GREEN

(1 Low press)



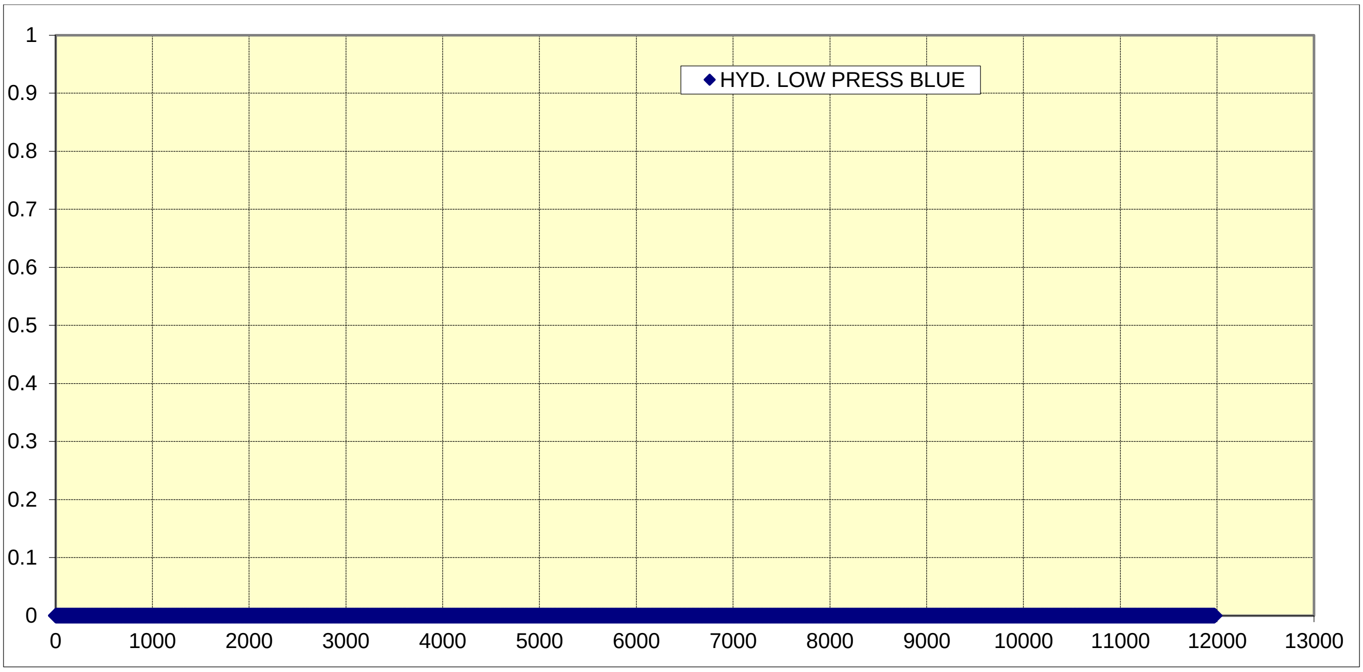
– HYD. LOW PRESS YELLOW

(1 Low press)



- HYD. LOW PRESS BLUE

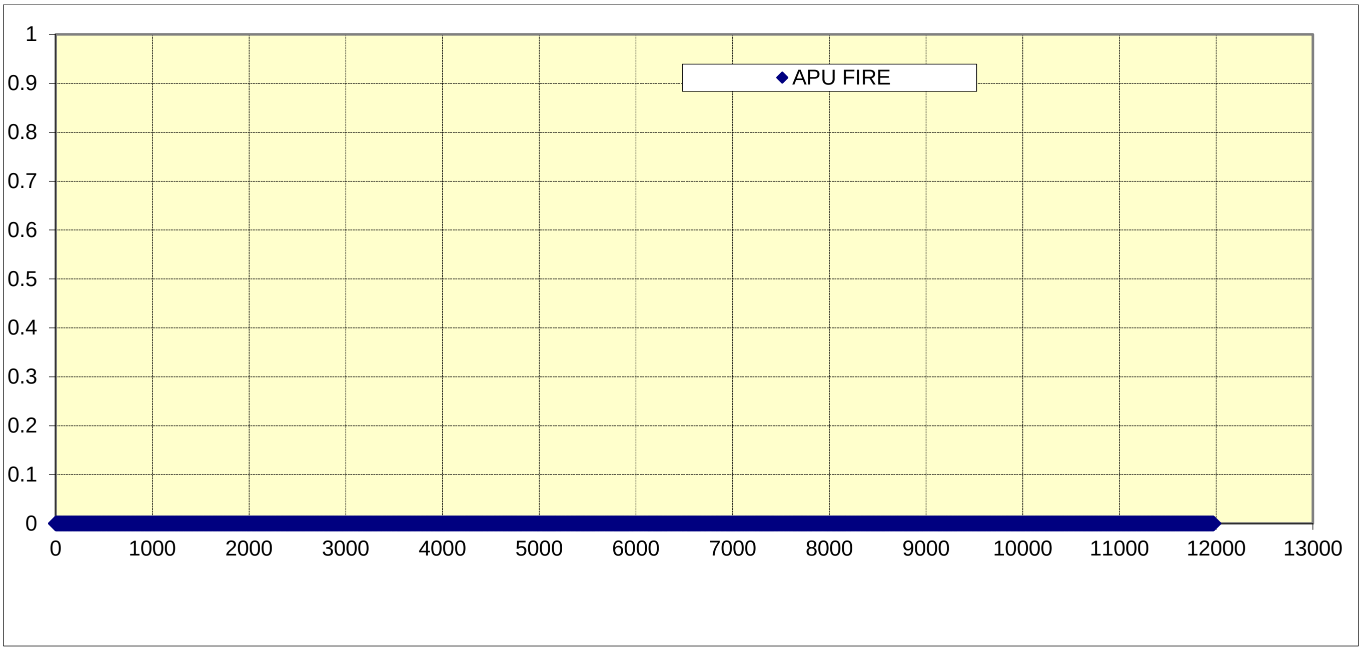
(1 Low press)



8 Warning, Failures

– APU FIRE

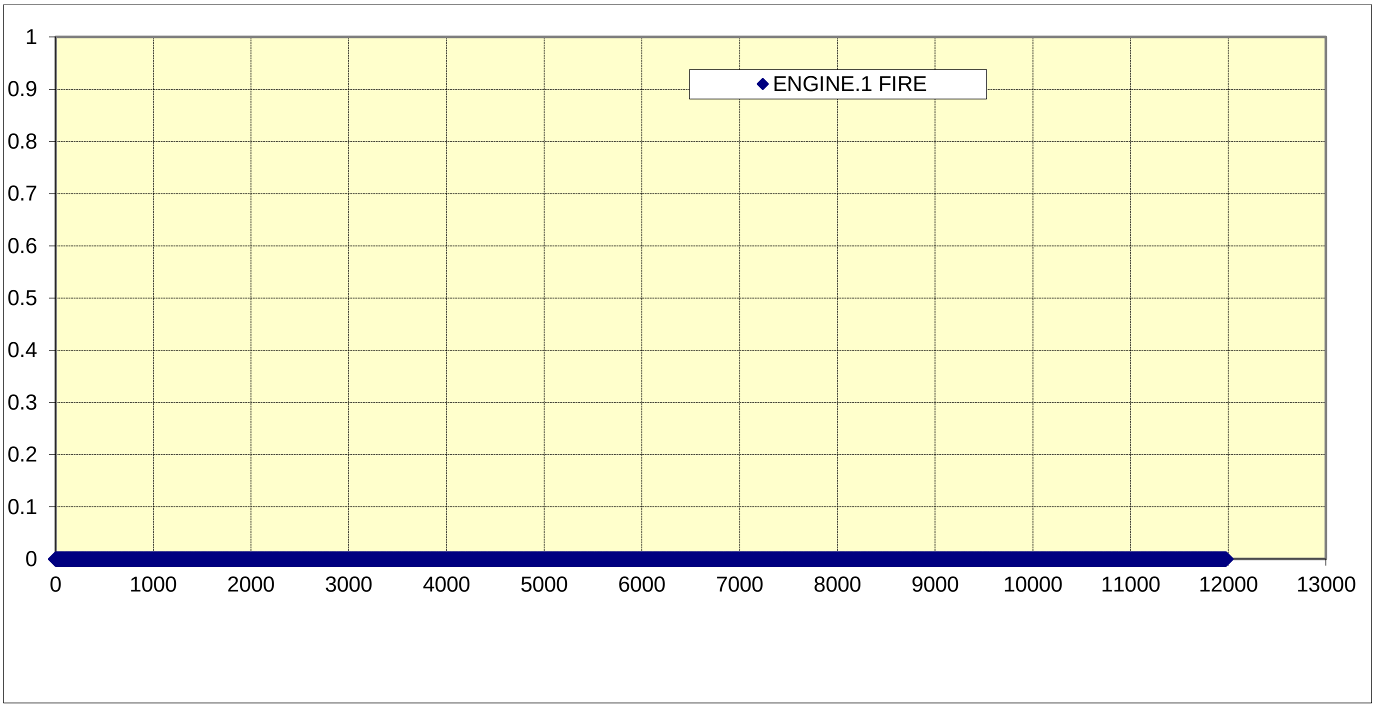
(1 fire)



No APU fire detected

- ENGINE.1 FIRE

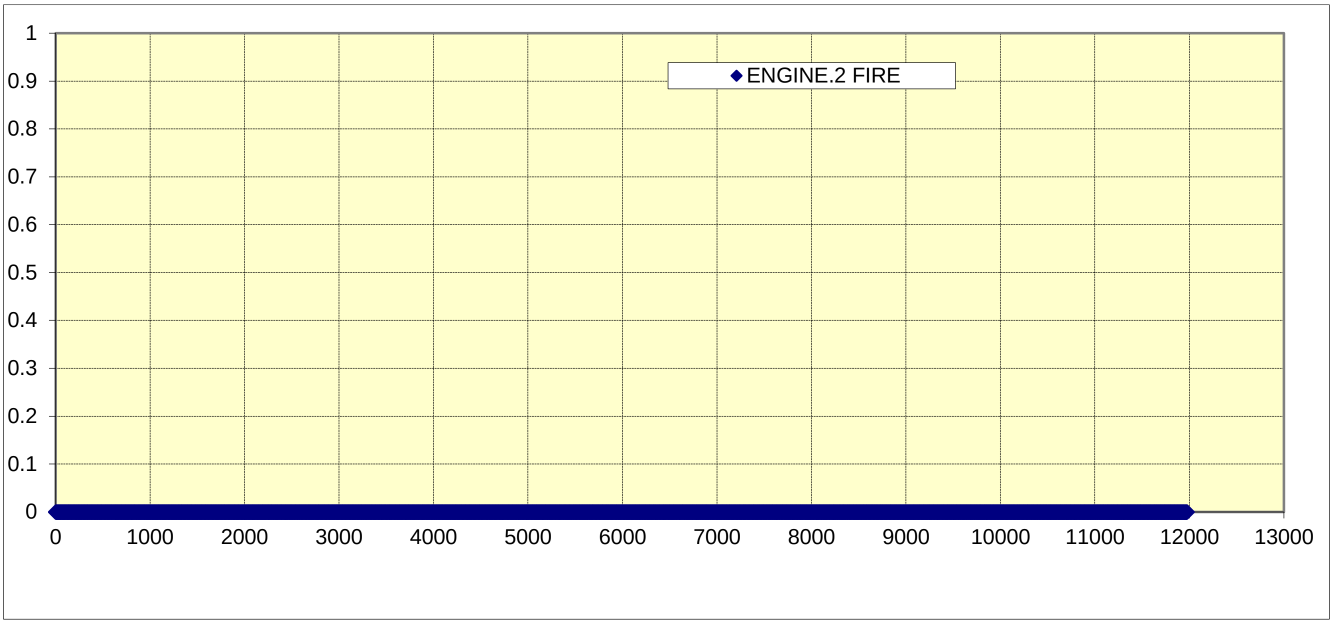
(1 fire)



No fire detected in engine 1

- ENGINE.2 FIRE

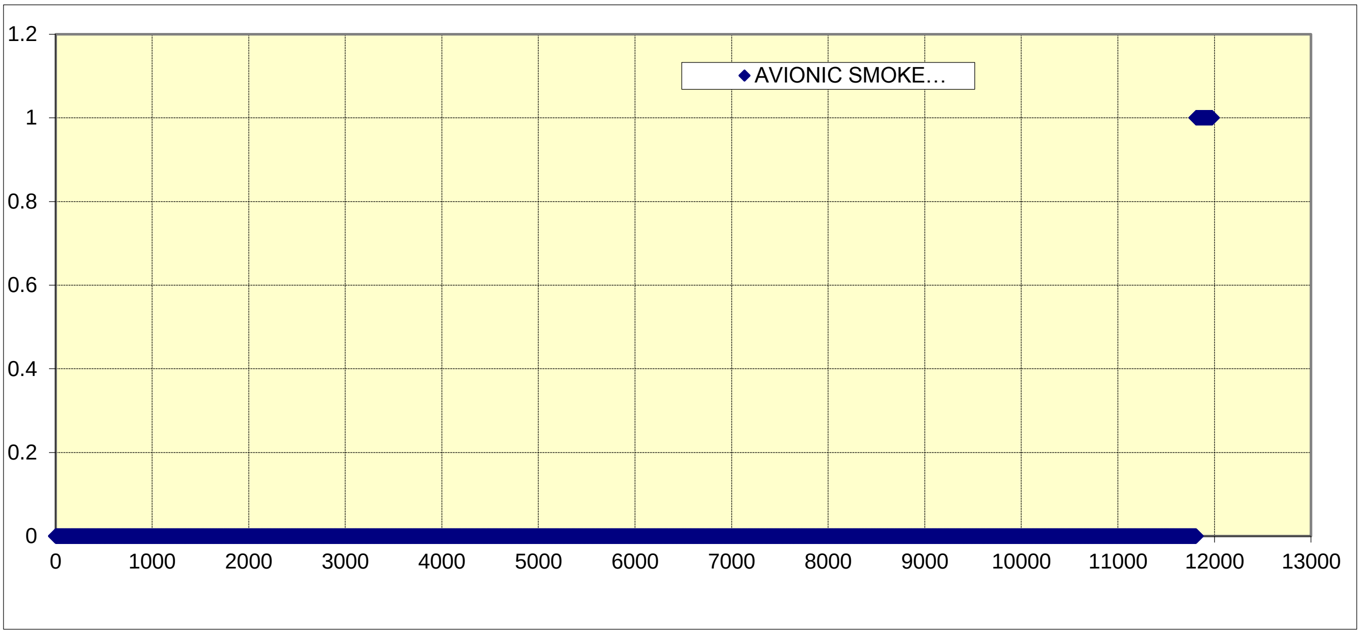
  (1 fire)

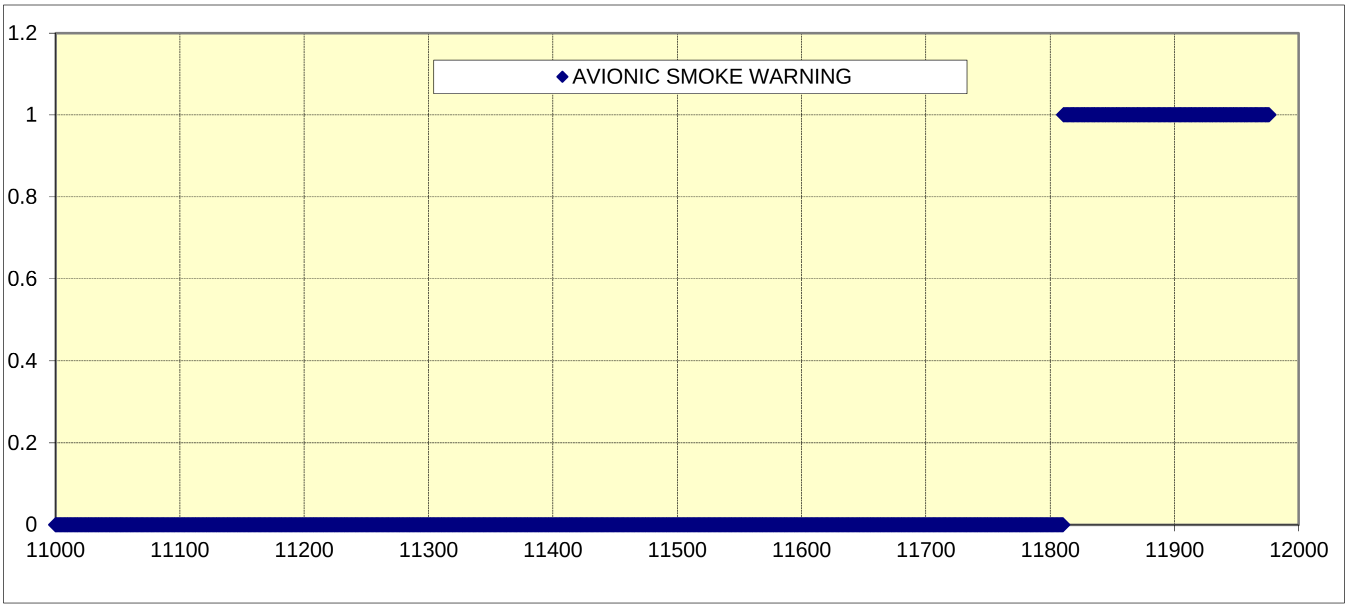


No fire detected in engine 2

- AVIONIC SMOKE WARNING

  (1 smoke warning)





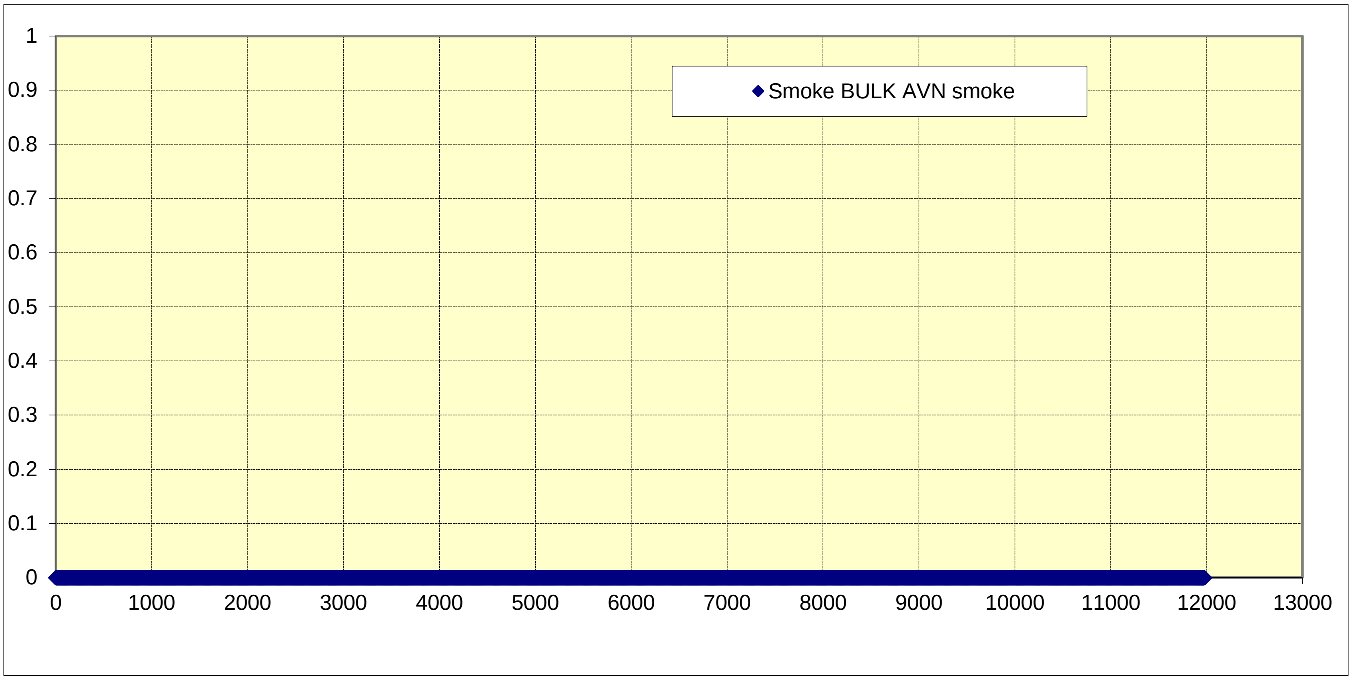
Avionic smoke warning (closer view at the end of the recording)

Avionic smoke started at 00:27:00 UTC (11811 seconds plot time) and continued to the end of the recording 00:29:45 UTC

- Cargo smoke warning

– Smoke BULK AVN smoke

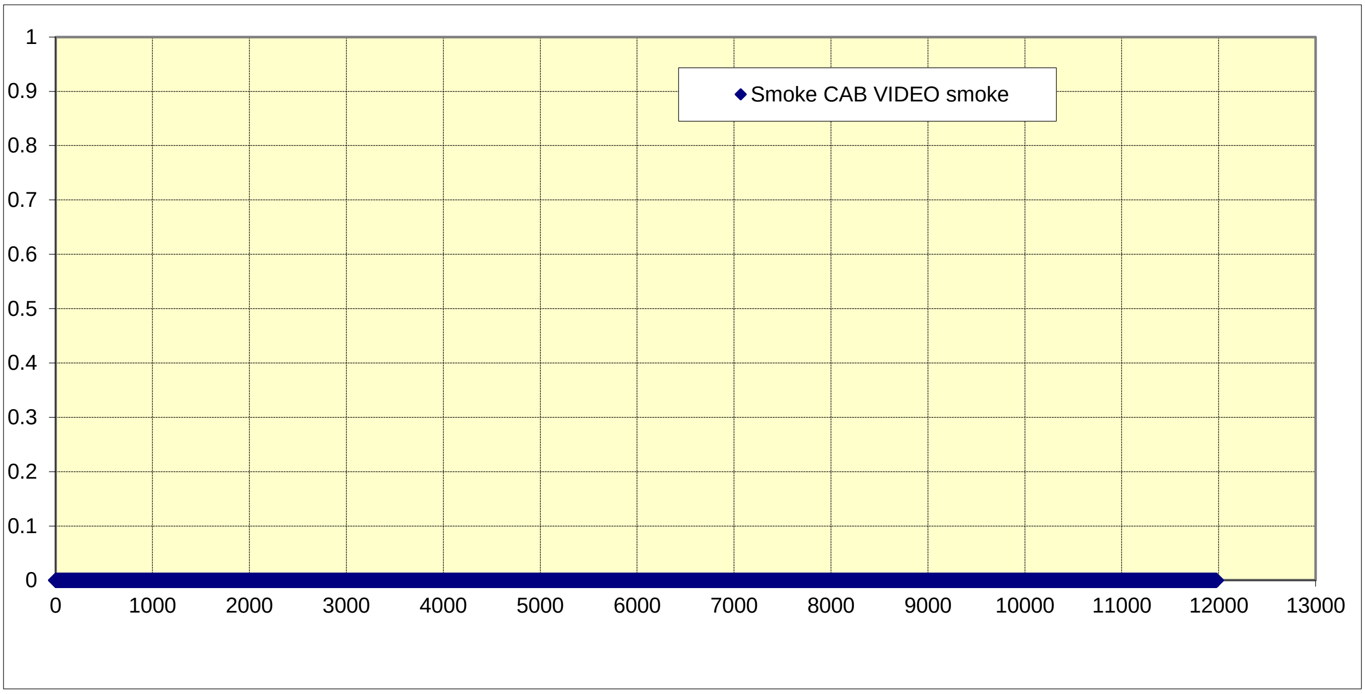
(1 smoke)



No bulk avionics smoke detected

- Smoke CAB VIDEO smoke

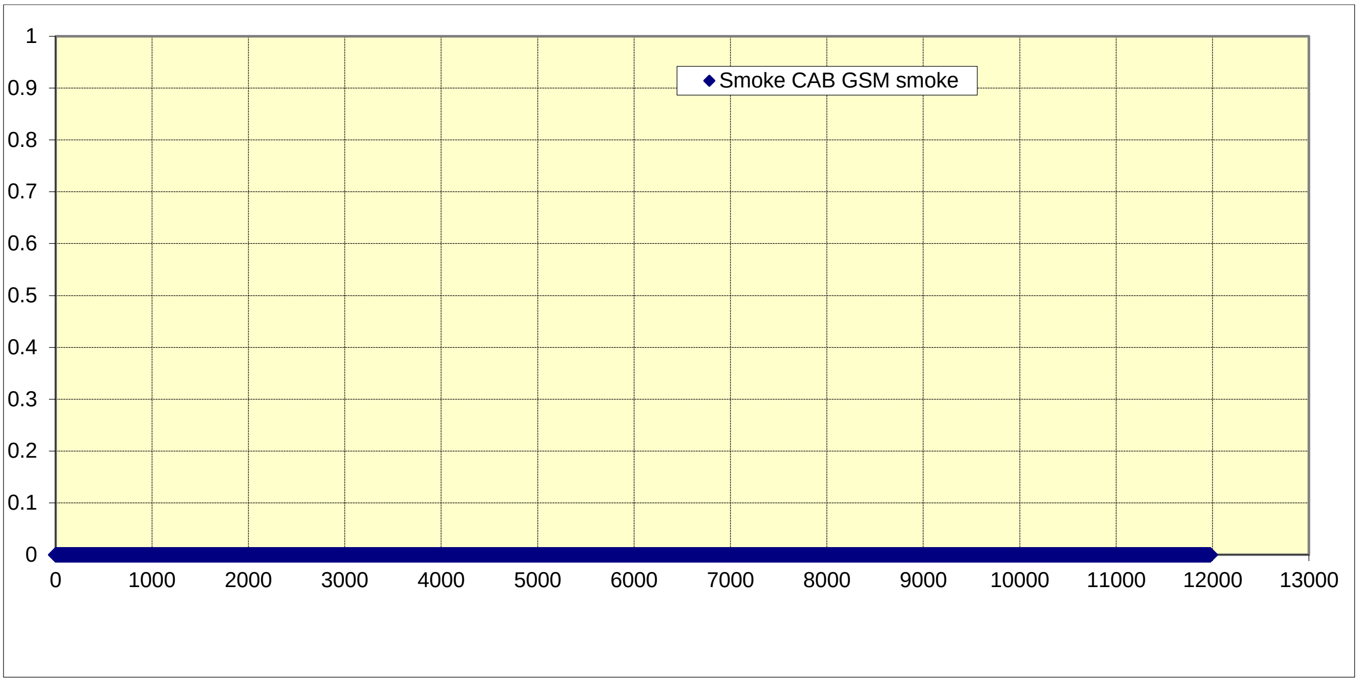
(1 smoke)



No smoke in cabin video

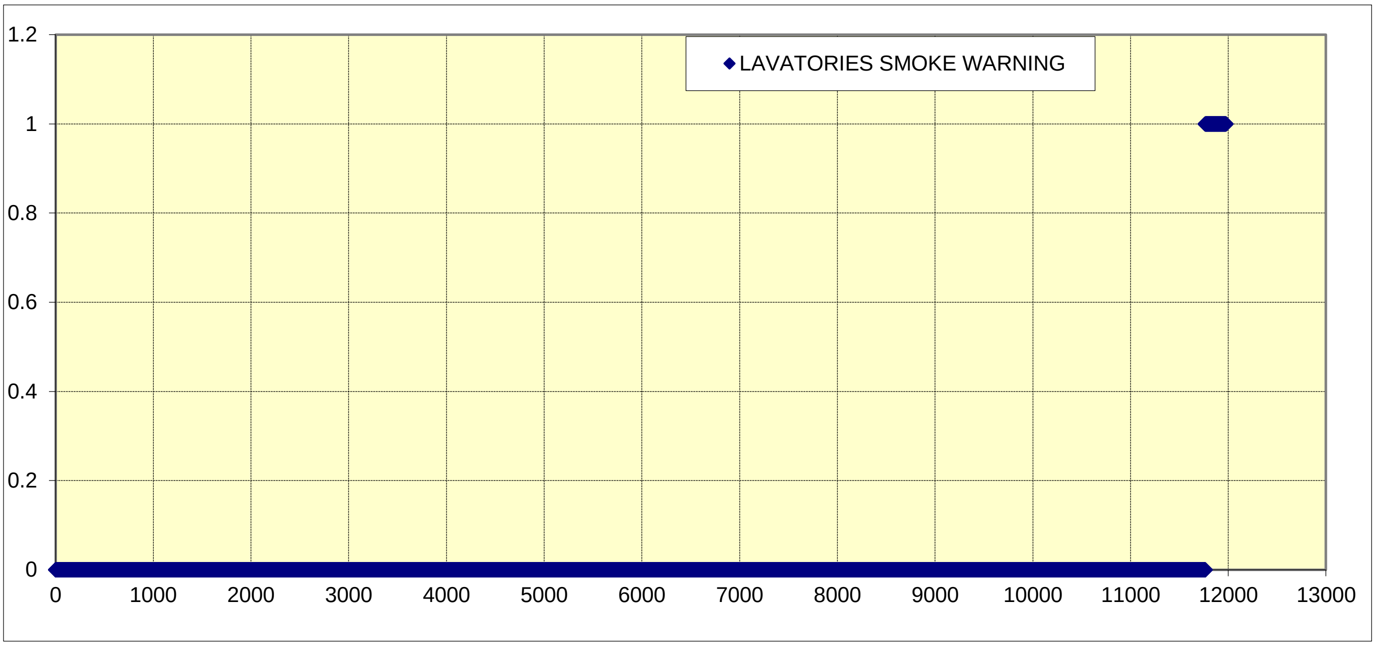
– Smoke CAB GSM smoke

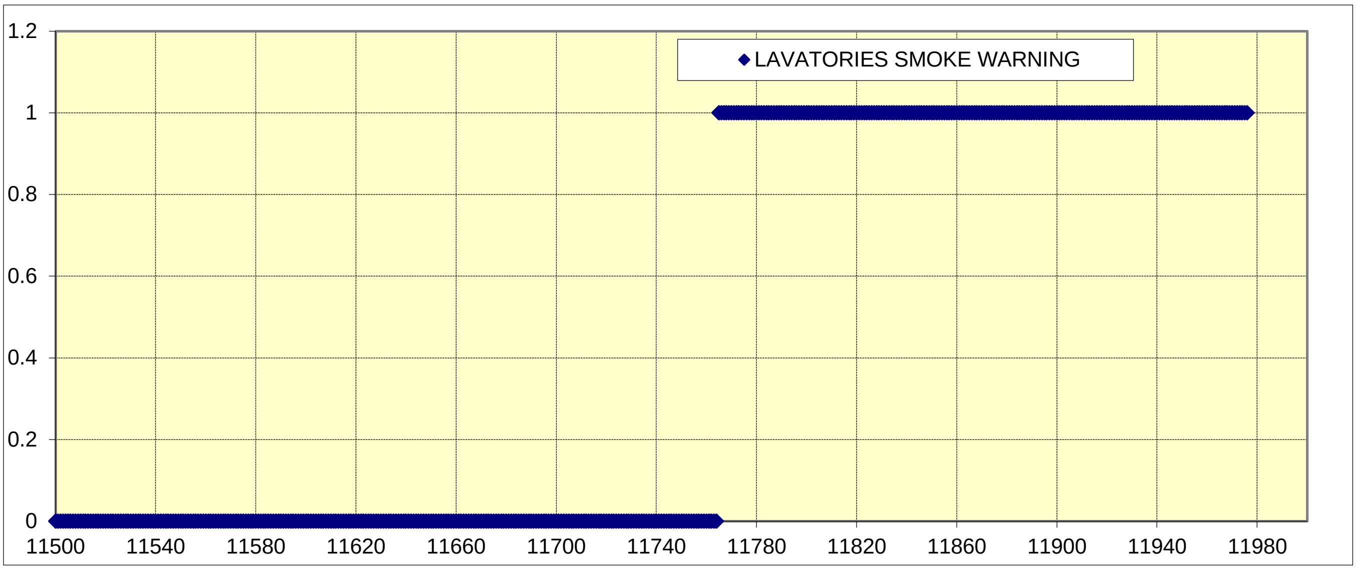
(1 smoke)



- LAVATORIES SMOKE WARNING

(1 smoke)

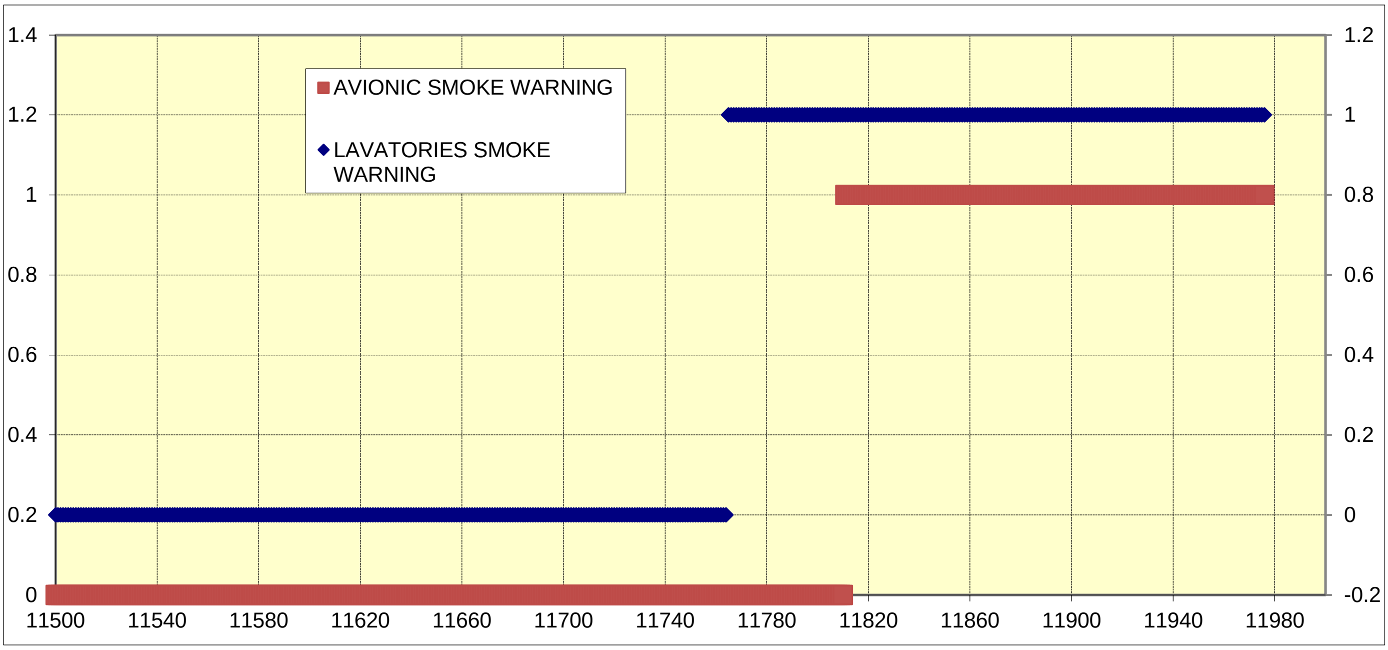




Lavatories smoke warning (closer view at the end of the recording)

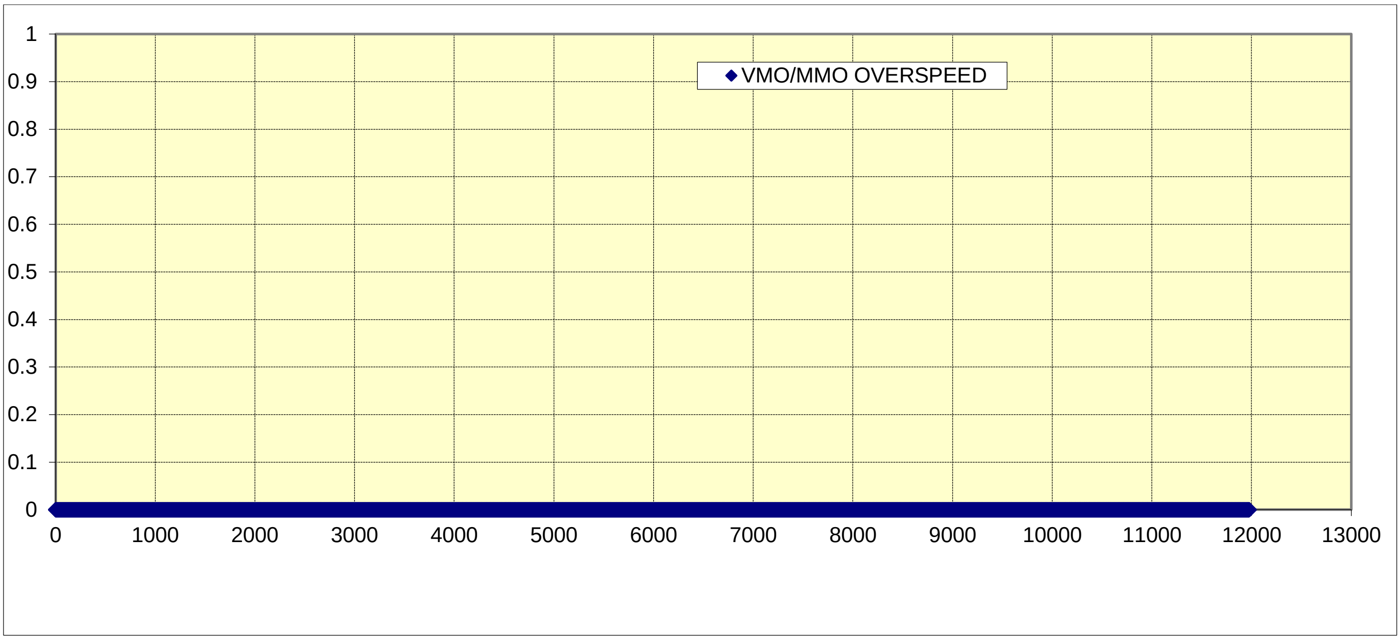
Lavatory smoke started at 00:26:14 UTC (11765 seconds plot time) and continued to the end of the recording 00:29:45

Combined plot for Avionic and lavatory smoke



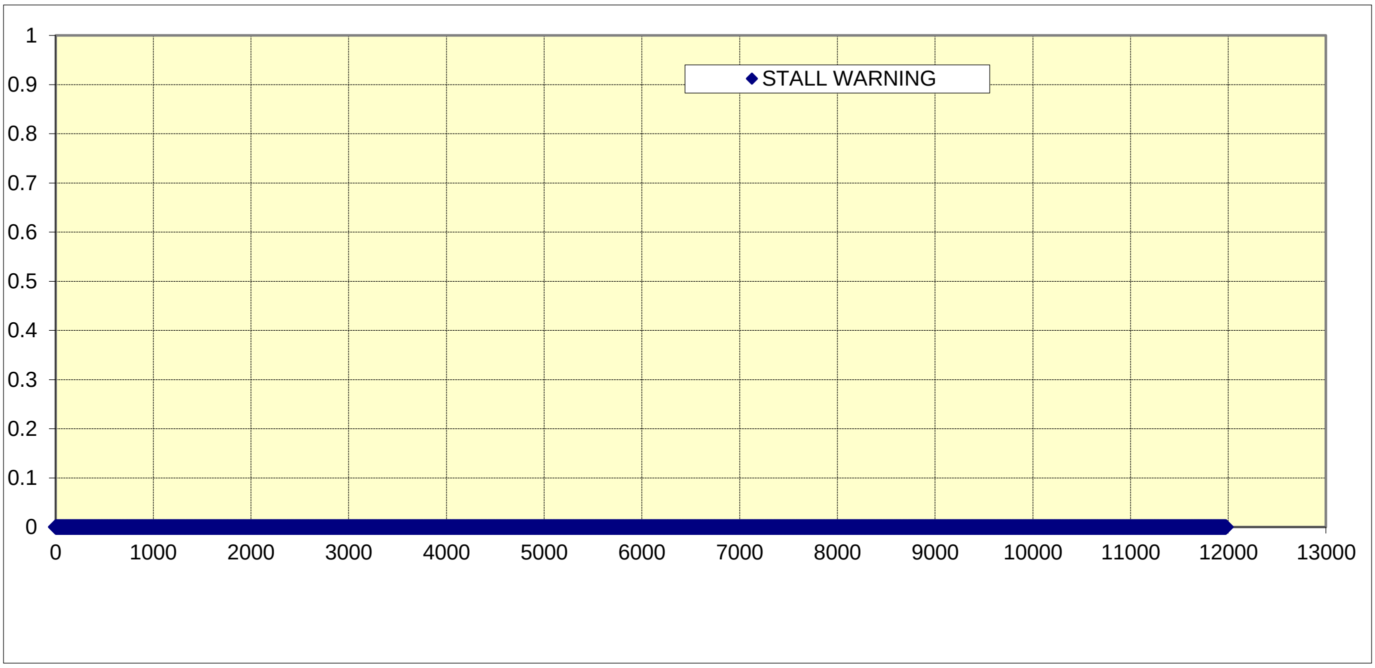
Smoke location	start time	end time
Lavatory smoke	00:26:14 UTC (11765 seconds plot time)	00:29:45
Avionic smoke	00:27:00 UTC (11811 seconds plot time)	00:29:45

– VMO/MMO OVERSPEED
(1 Overspeed)



No overspeed throughout the whole recording

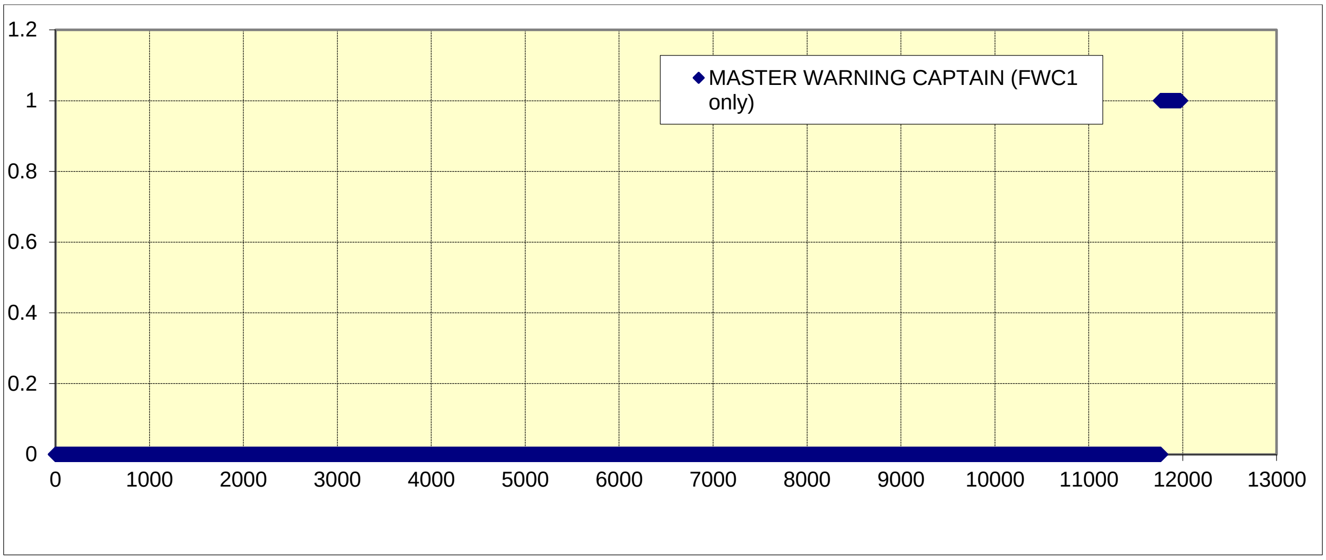
– STALL WARNING
(1 warning)

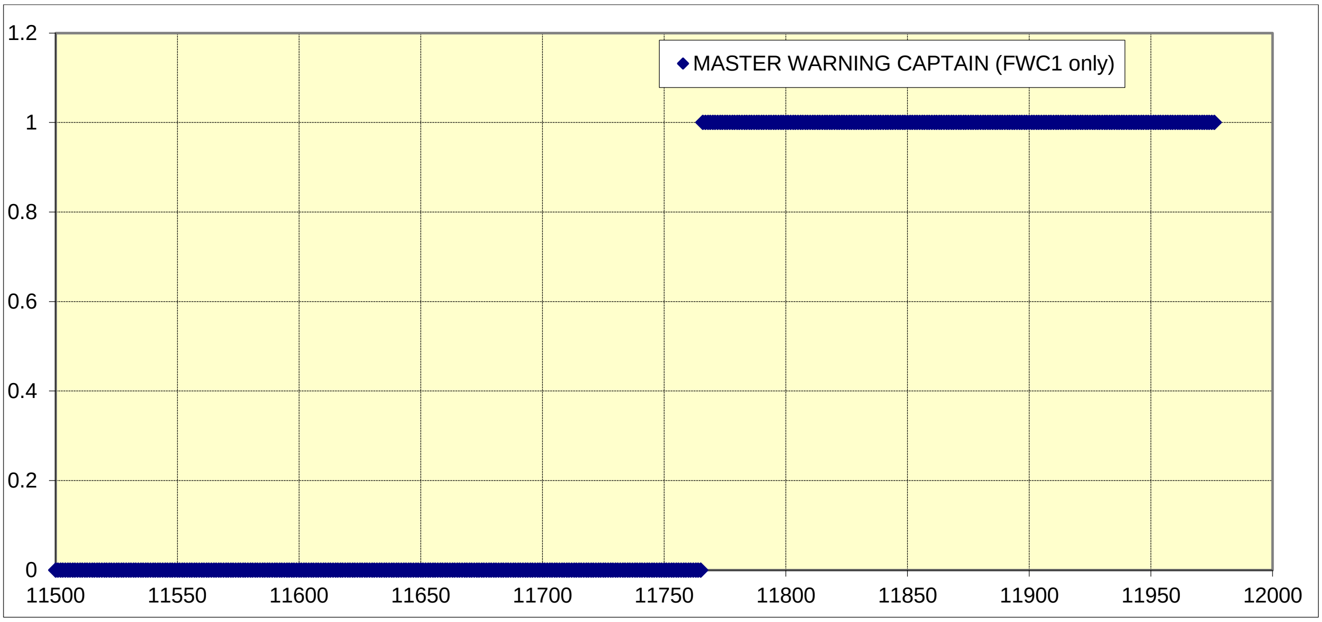


No stall thoughout the whole recording

- MASTER WARNING CAPTAIN (FWC1 only)

(1 Master Caution On)



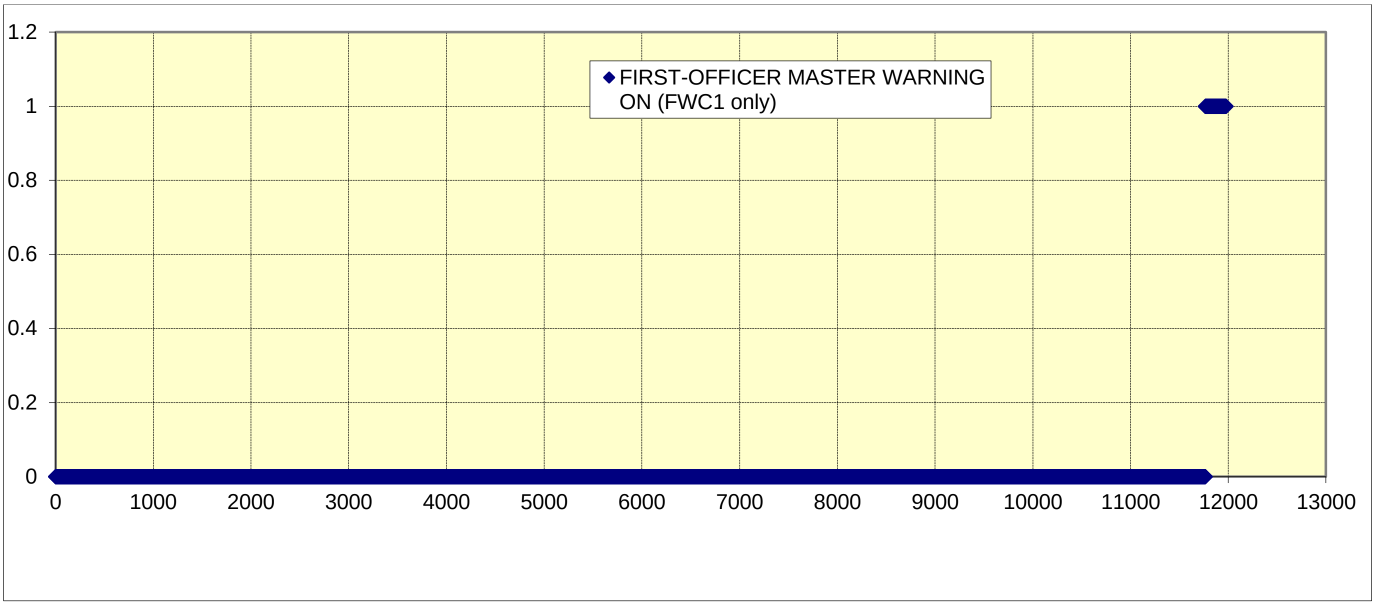


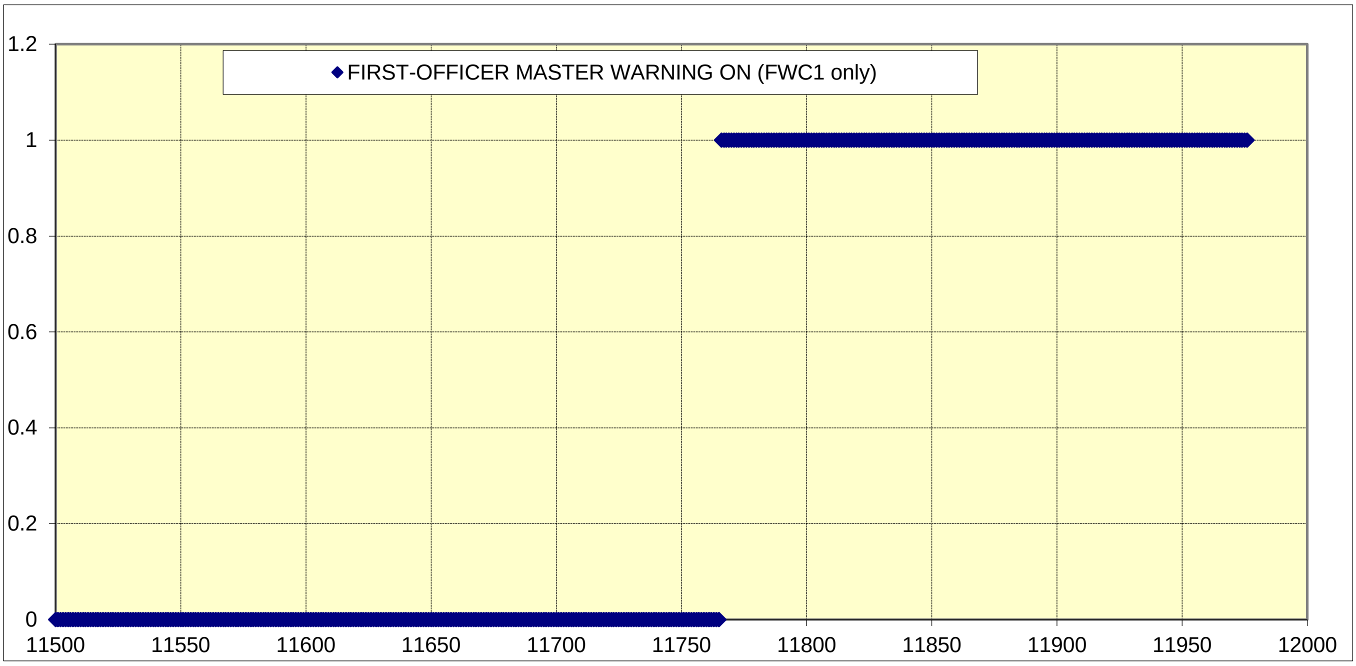
Master warning Captain FWC1 only (closer view at the end of the recording)

"Master warning Captain FWC1 only" started at 00:26:15 UTC (11766 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

– FIRST-OFFICER MASTER WARNING ON (FWC1 only)

(1 Master warning)

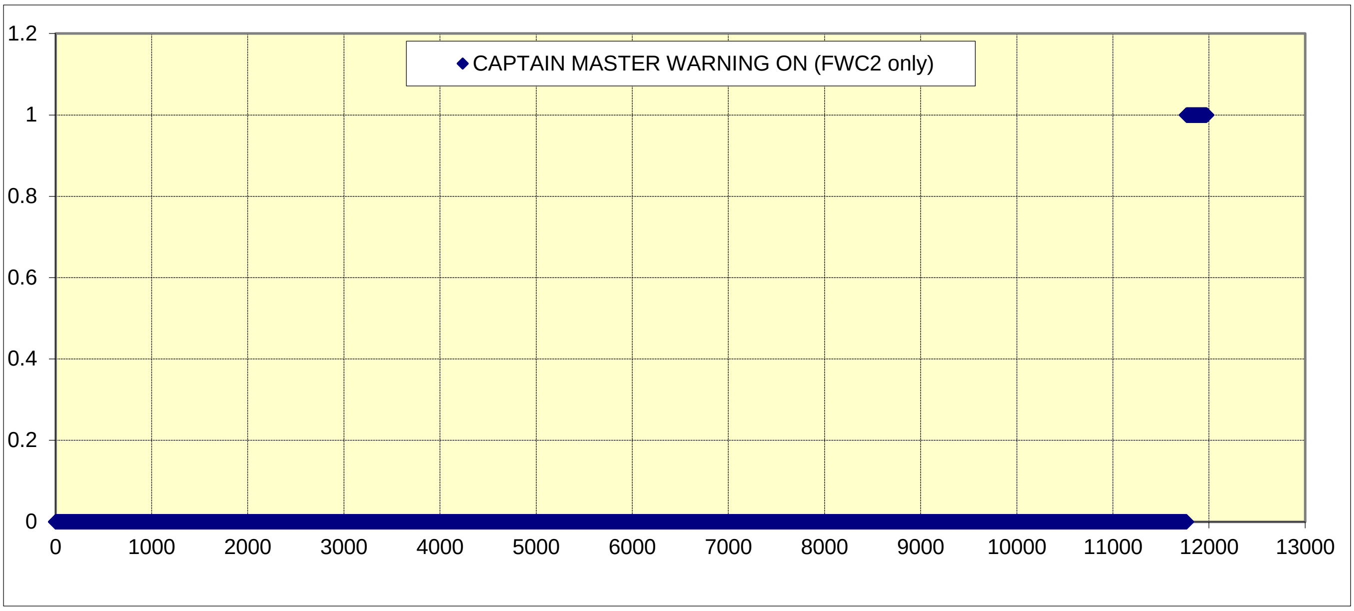


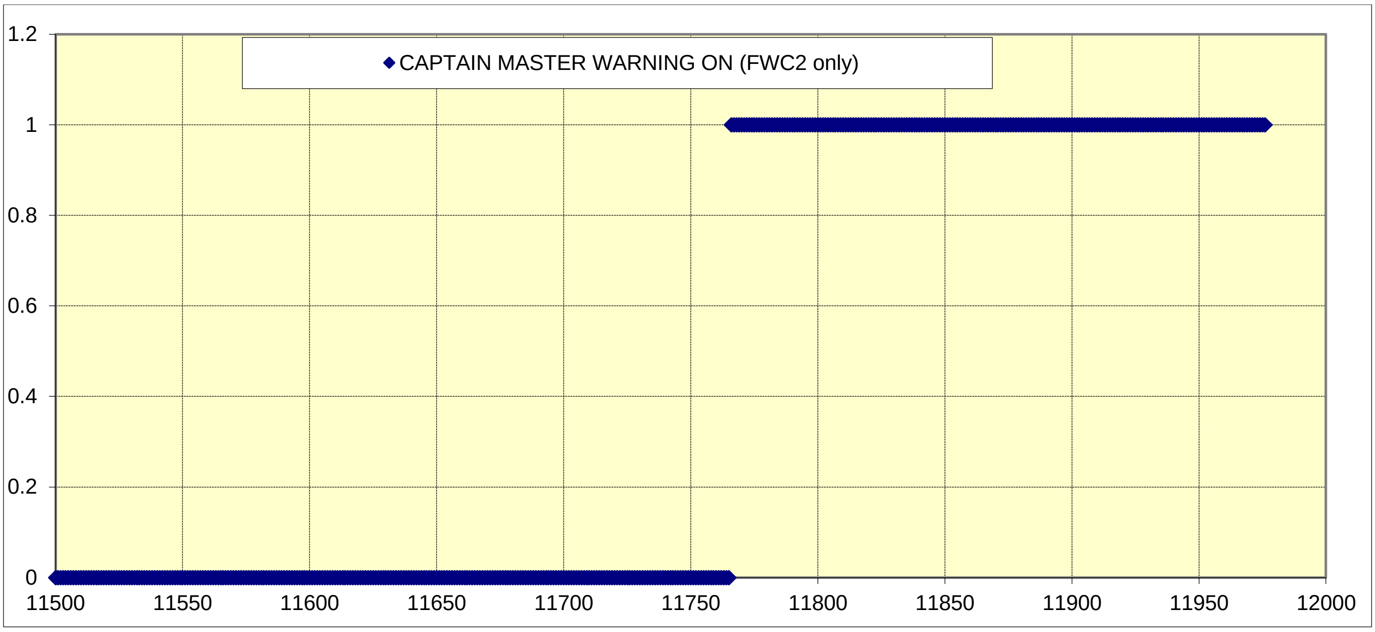


Master warning First Officer FWC1 only (closer view at the end of the recording)

"Master warning F/O FWC1 only" started at 00:26:15 UTC (11766 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

– CAPTAIN MASTER WARNING ON (FWC2 only)



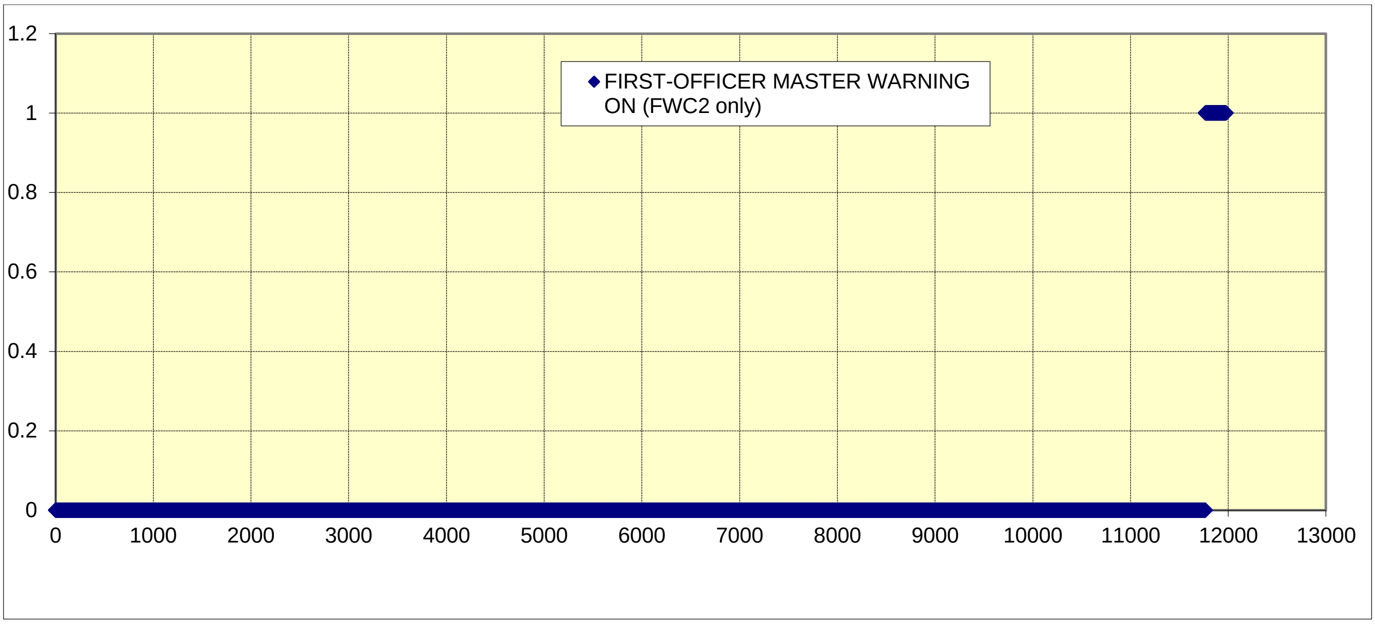


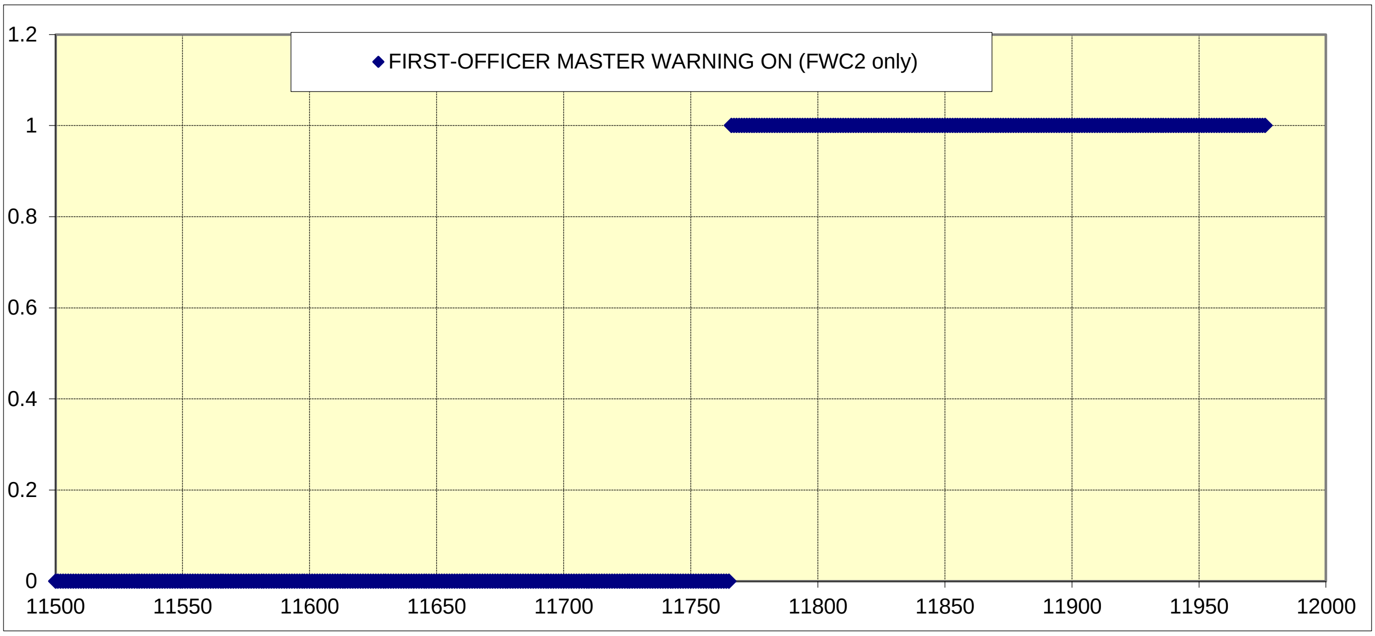
Master warning Captain ON FWC2 only (closer view at the end of the recording)

"Master warning Captain FWC2 only" started at 00:26:15 UTC (11766 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

- FIRST-OFFICER MASTER WARNING ON (FWC2 only)

(1 Master Warning)



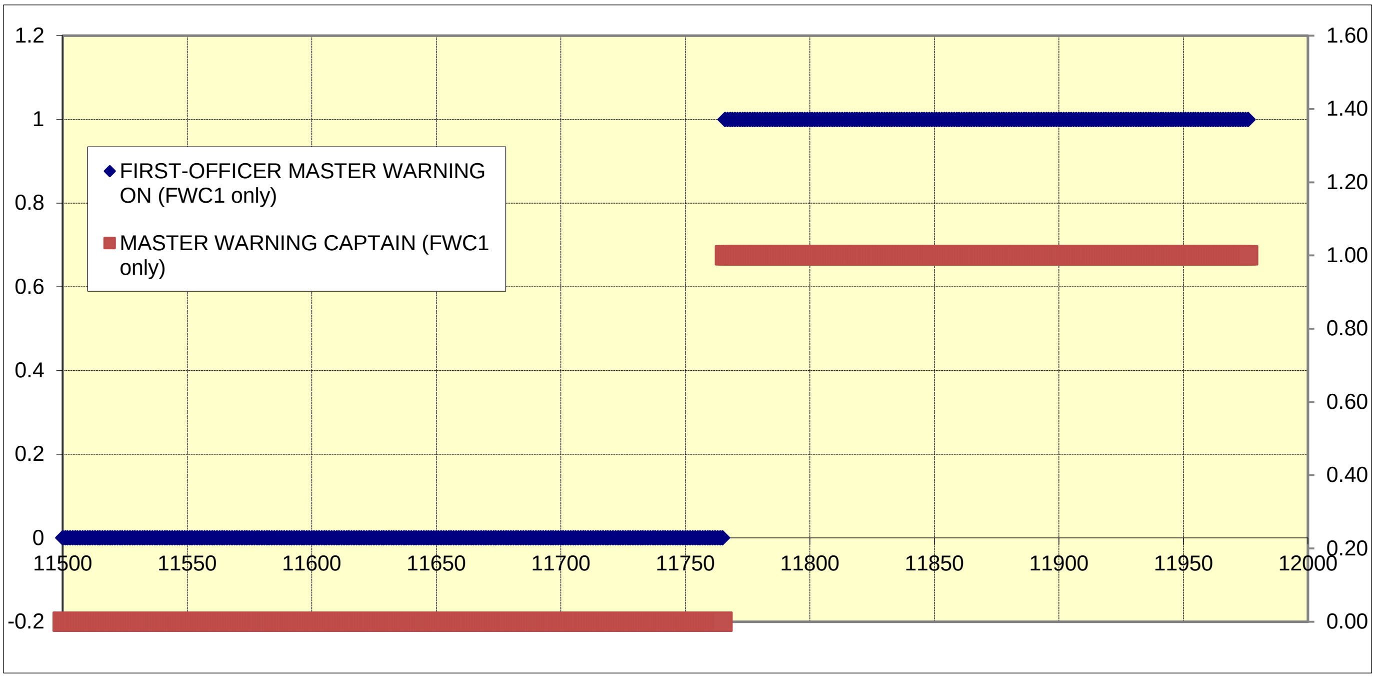


Master warning First Officer FWC2 only (closer view at the end of the recording)

"Master warning F/O FWC2 only" started at 00:26:15 UTC (11766 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

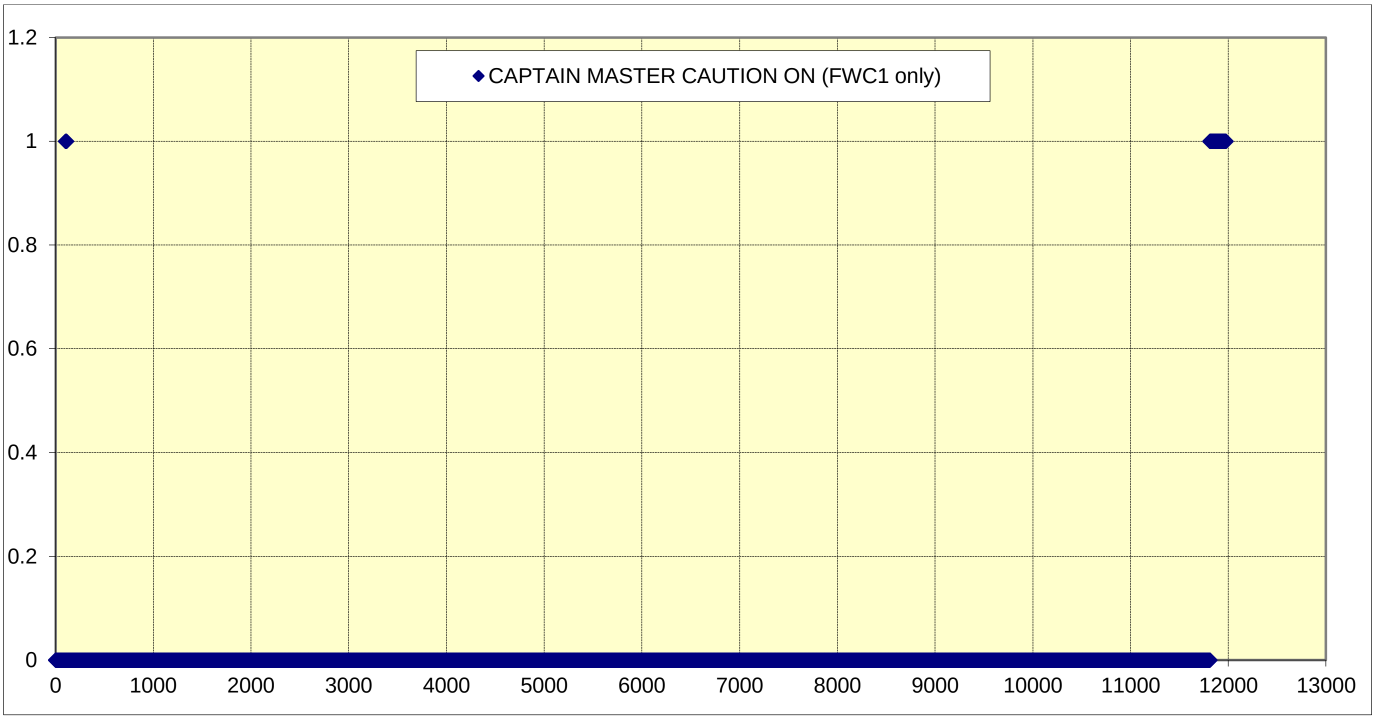
CAPTAIN MASTER WARNING ON (FWC2 only), FIRST-OFFICER MASTER WARNING ON (FWC2 only)

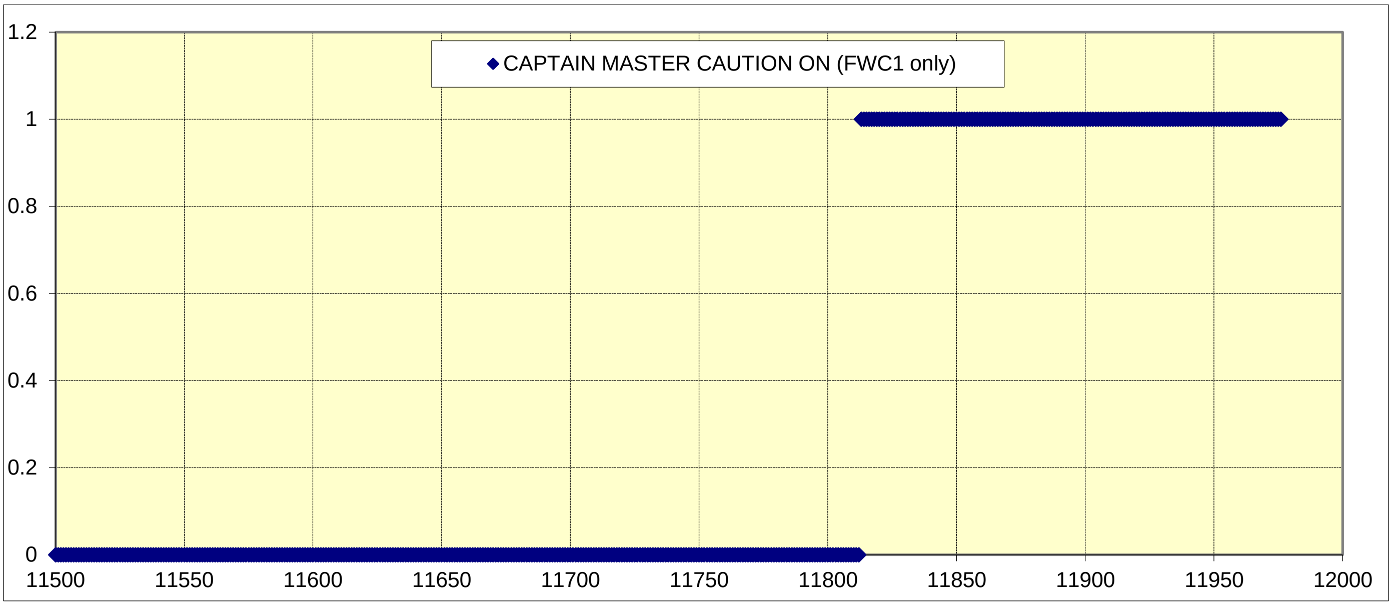
Combined plot



- CAPTAIN MASTER CAUTION ON (FWC1 only)

(1 Master Warning)



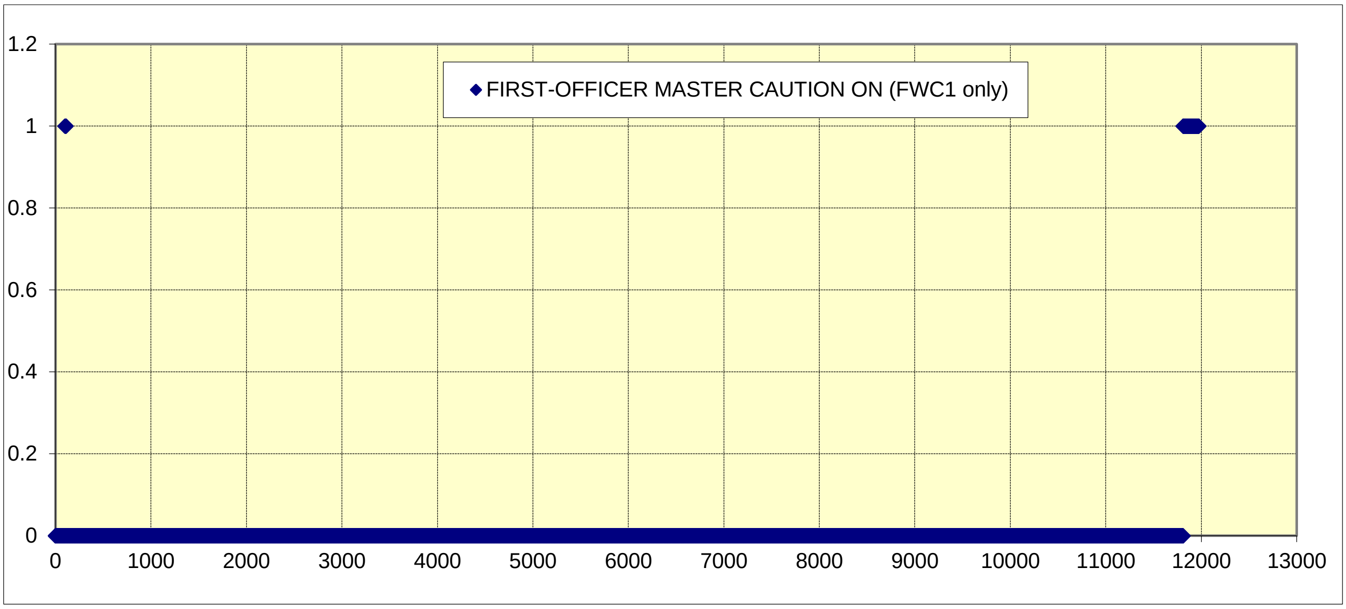


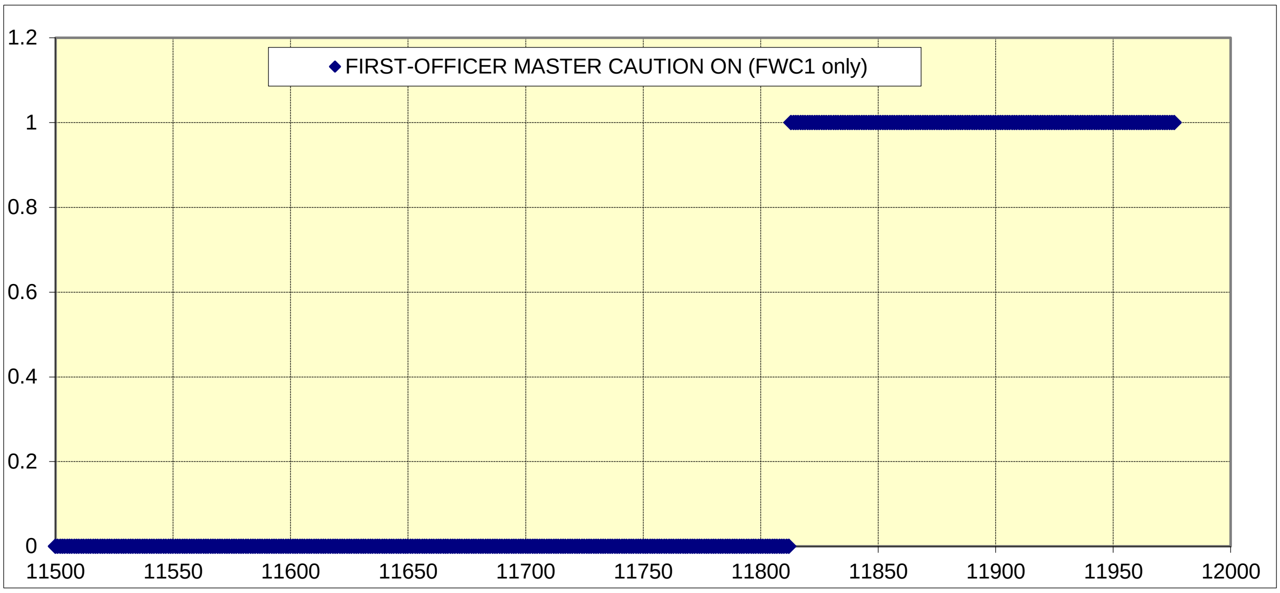
Captain Master Caution on FWC1 only (closer view at the end of the recording)

"Master Caution Captain FWC1 only" started at 00:27:02 UTC (11813 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

- FIRST-OFFICER MASTER CAUTION ON (FWC1 only)

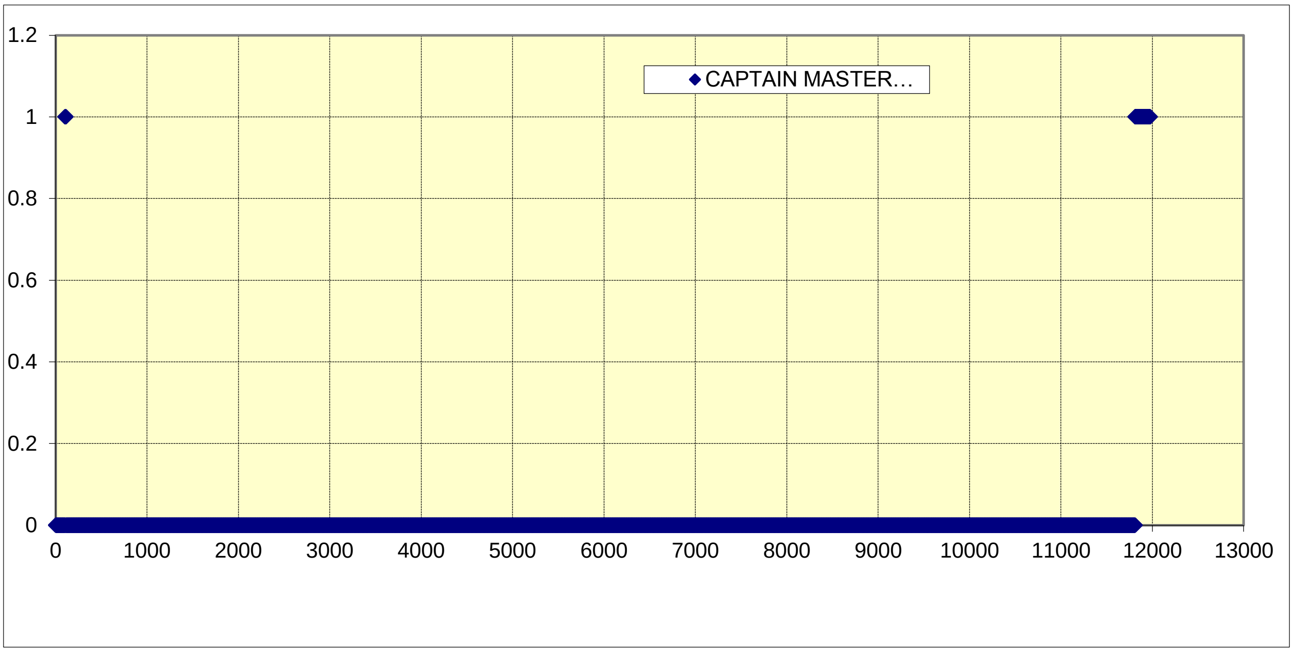
(1 Master Caution)

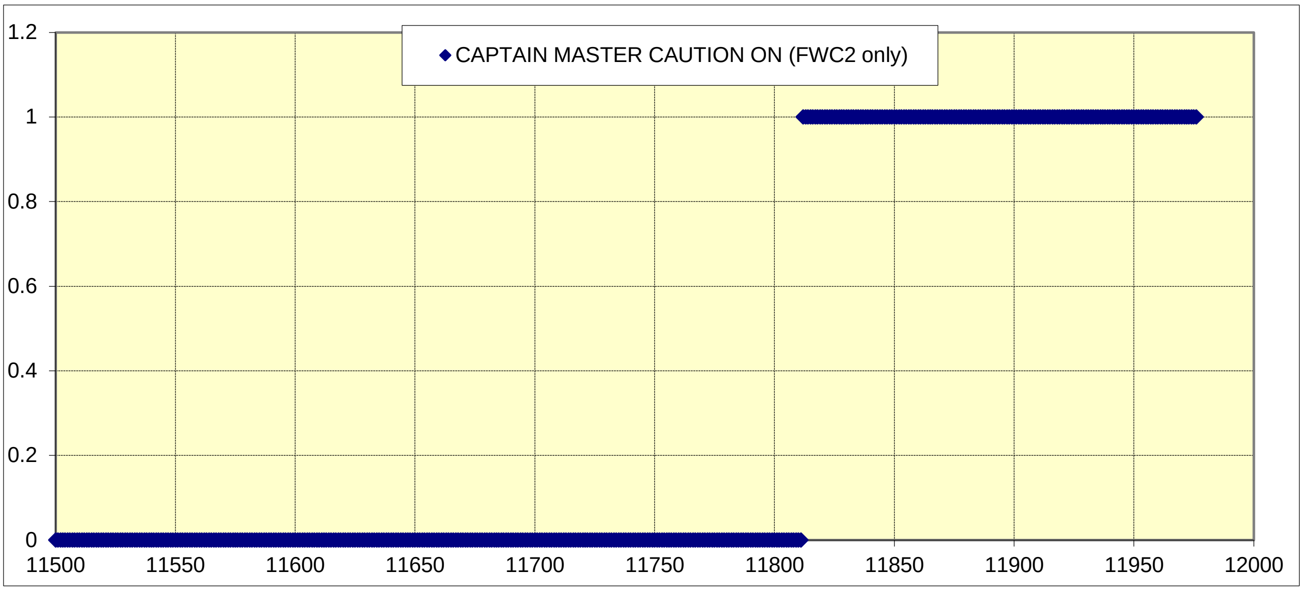




"Master Caution F/O FWC1 only" started at 00:27:02 UTC (11813 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

– CAPTAIN MASTER CAUTION ON (FWC2 only)
(1 Master Caution)

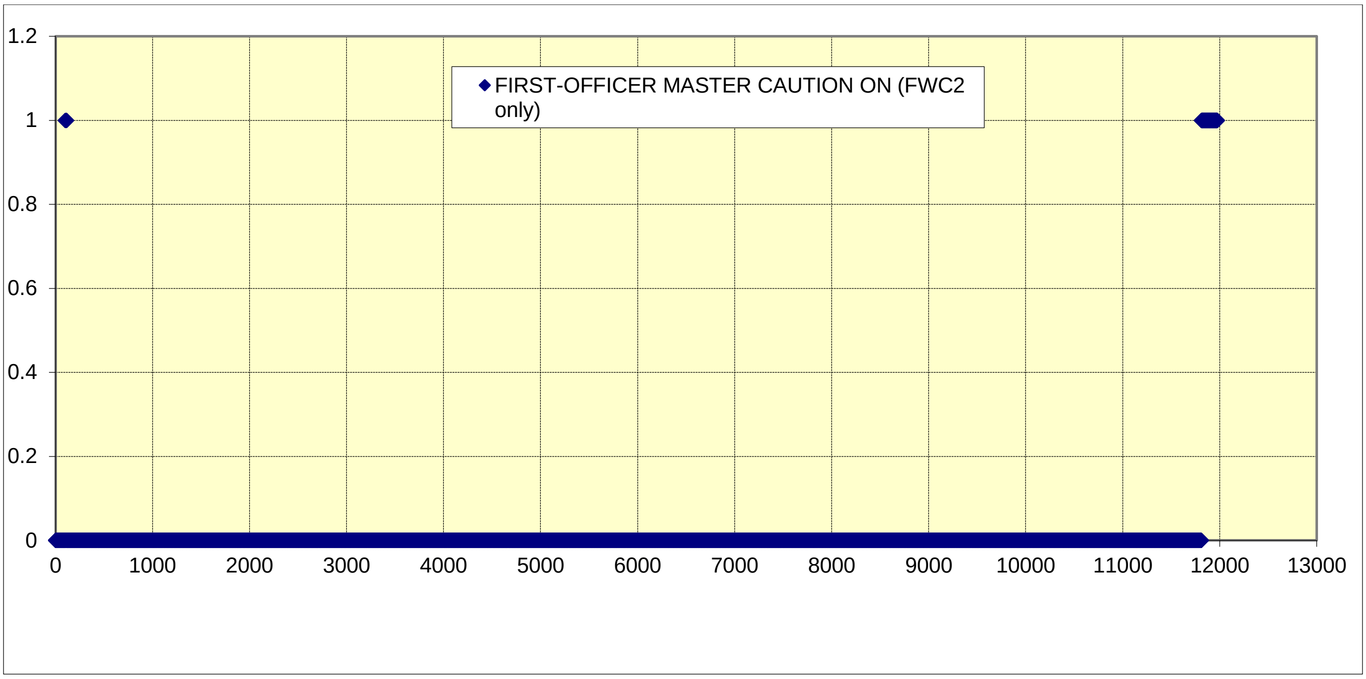


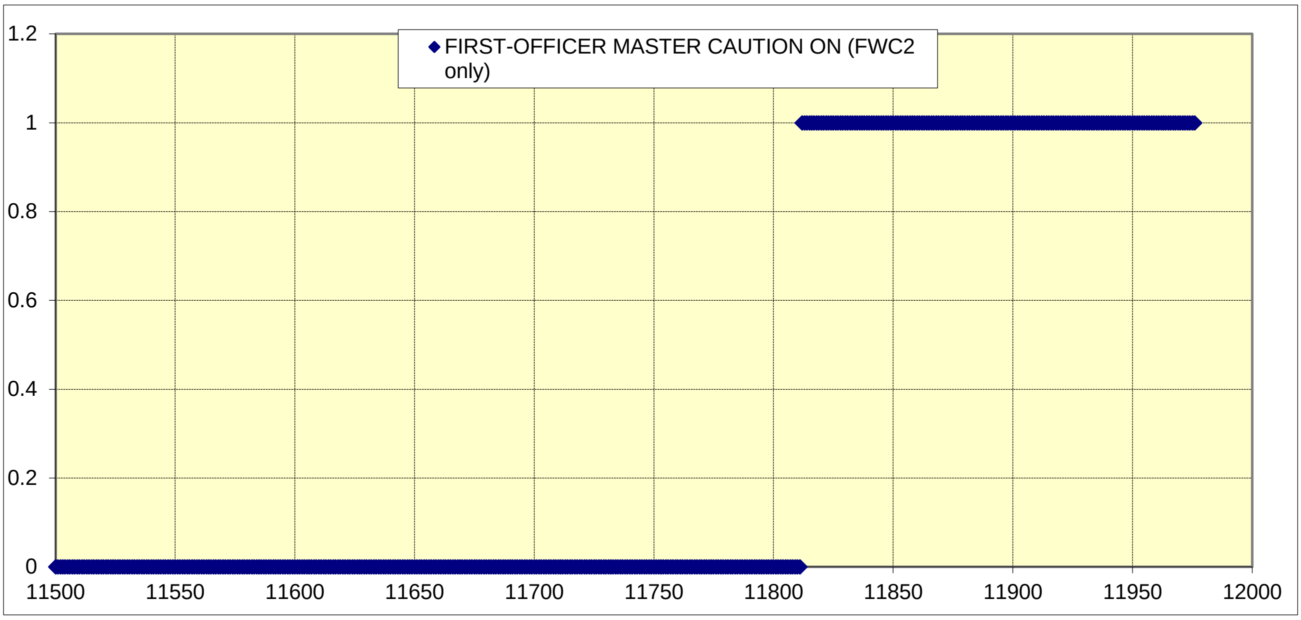


Captain Master Caution on FWC2 only (closer view at the end of the recording)

"Master Caution Captain FWC2 only" started at 00:27:01 UTC (11812 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

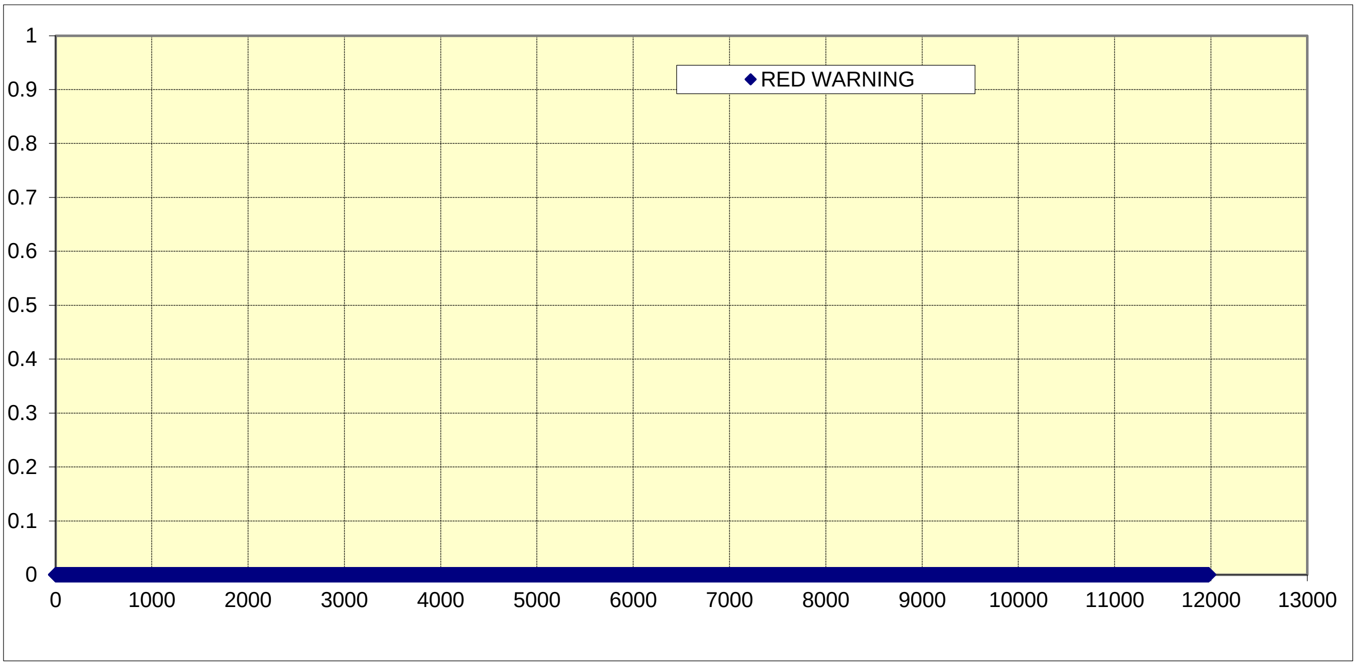
- FIRST-OFFICER MASTER CAUTION ON (FWC2 only)
  (Master Caution)

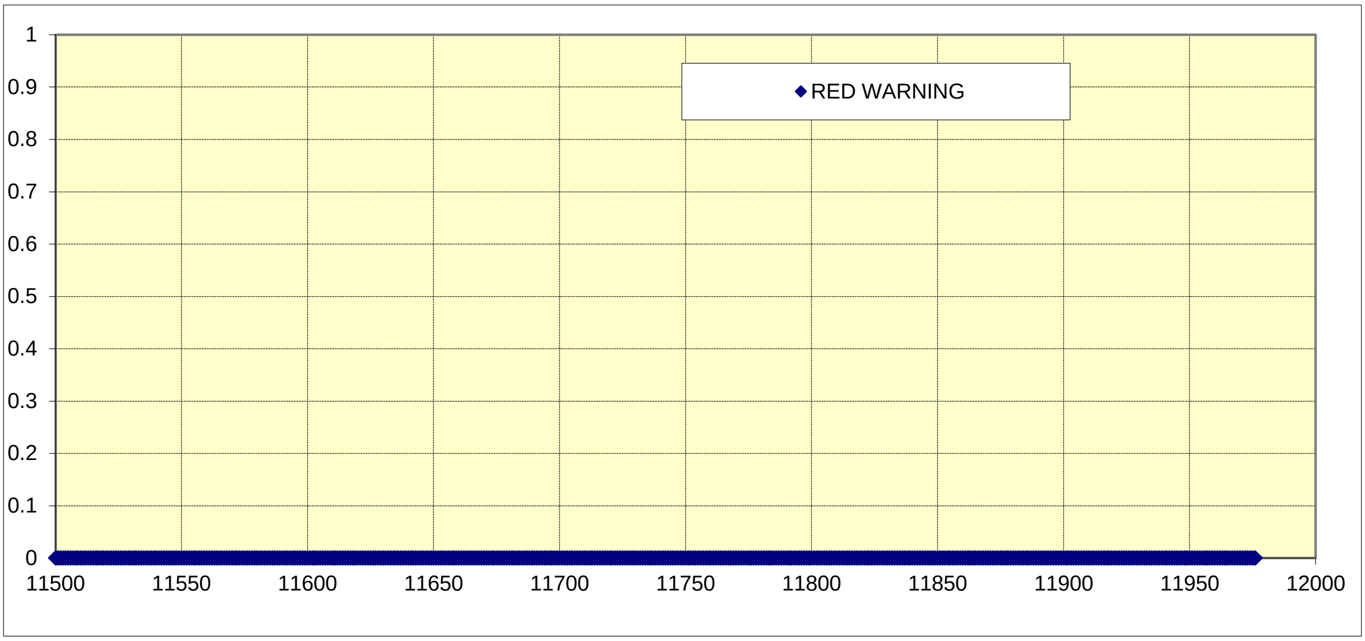




"Master Caution F/O FWC2 only" started at 00:27:01 UTC (11812 seconds plot time) continued up to the end of the recording at 00:29:45 (11976 seconds plot time)

- RED WARNING

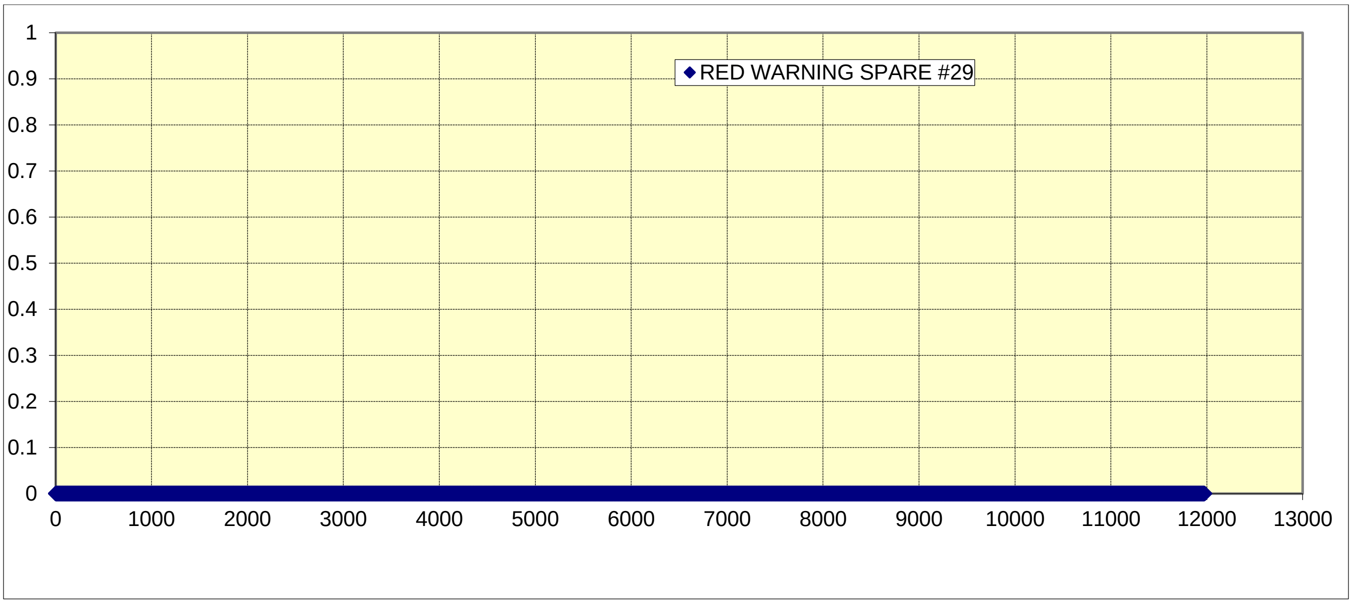




Red Warning shown at the end portion of the recording

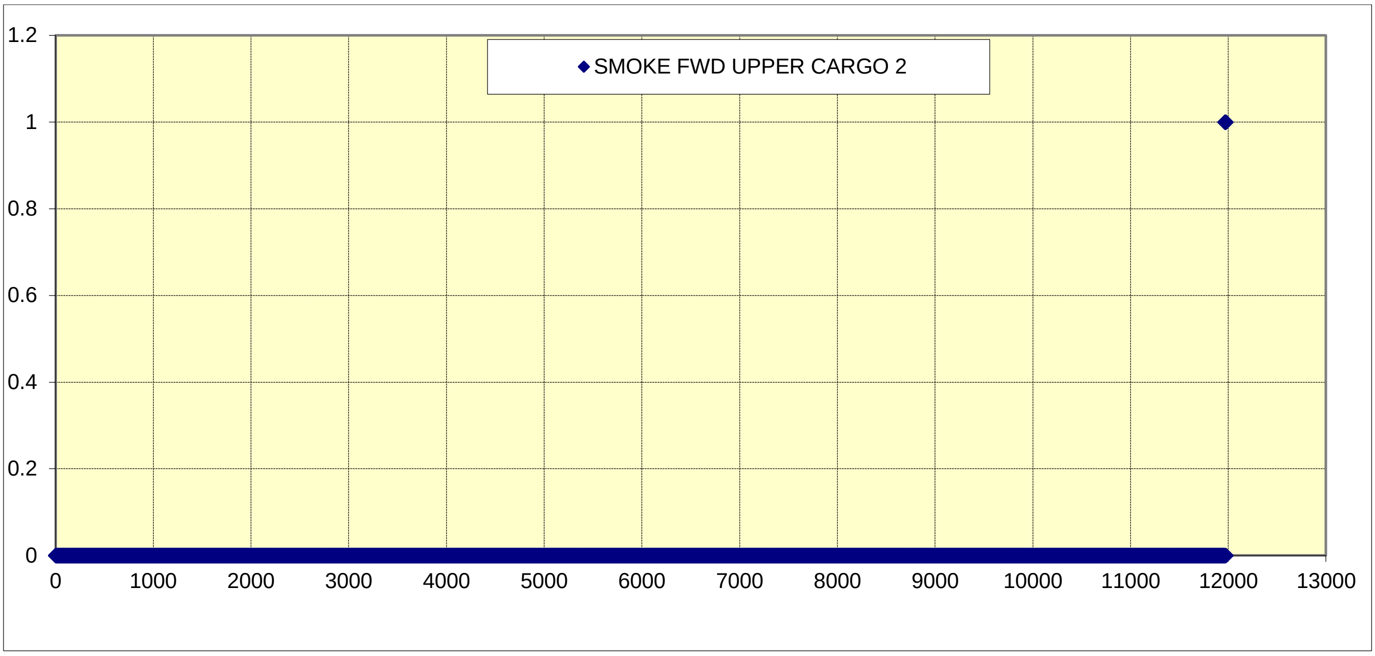
No detected Red Warning

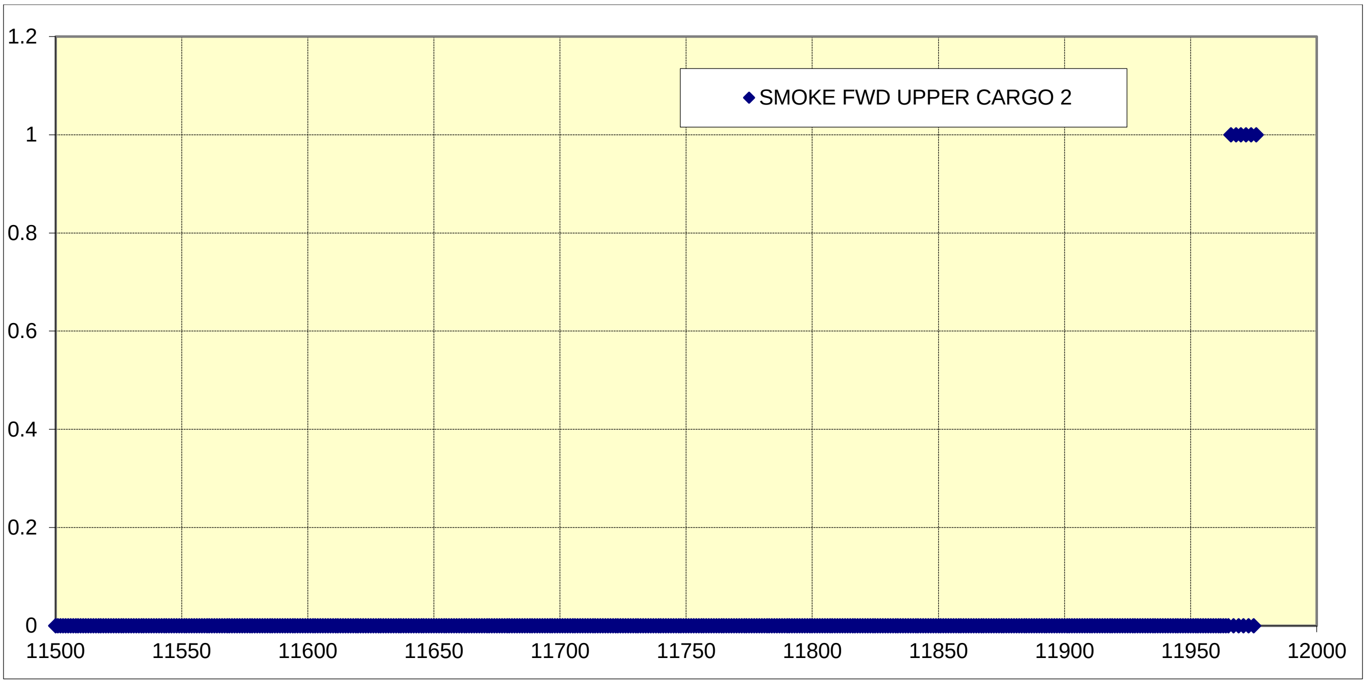
- RED WARNING spare



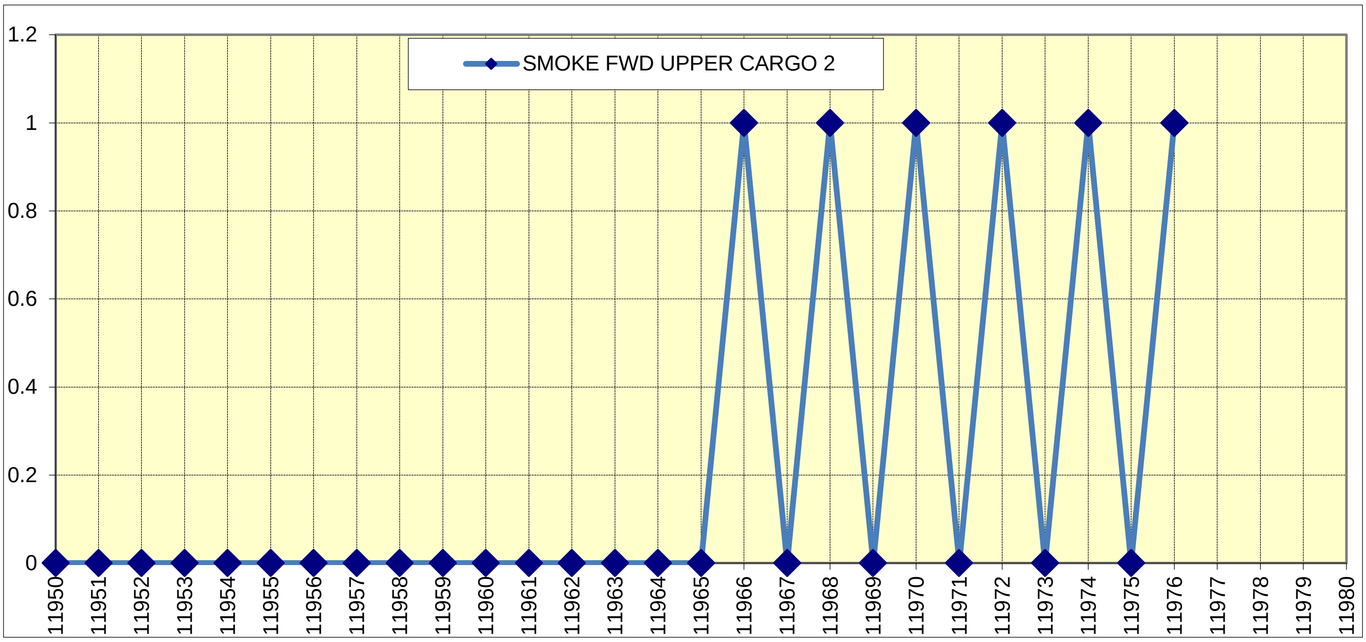
– SMOKE FWD UPPER CARGO 2

(1 smoke warning)





SMOKE FWD UPPER CARGO 2 at the last portion of the recording

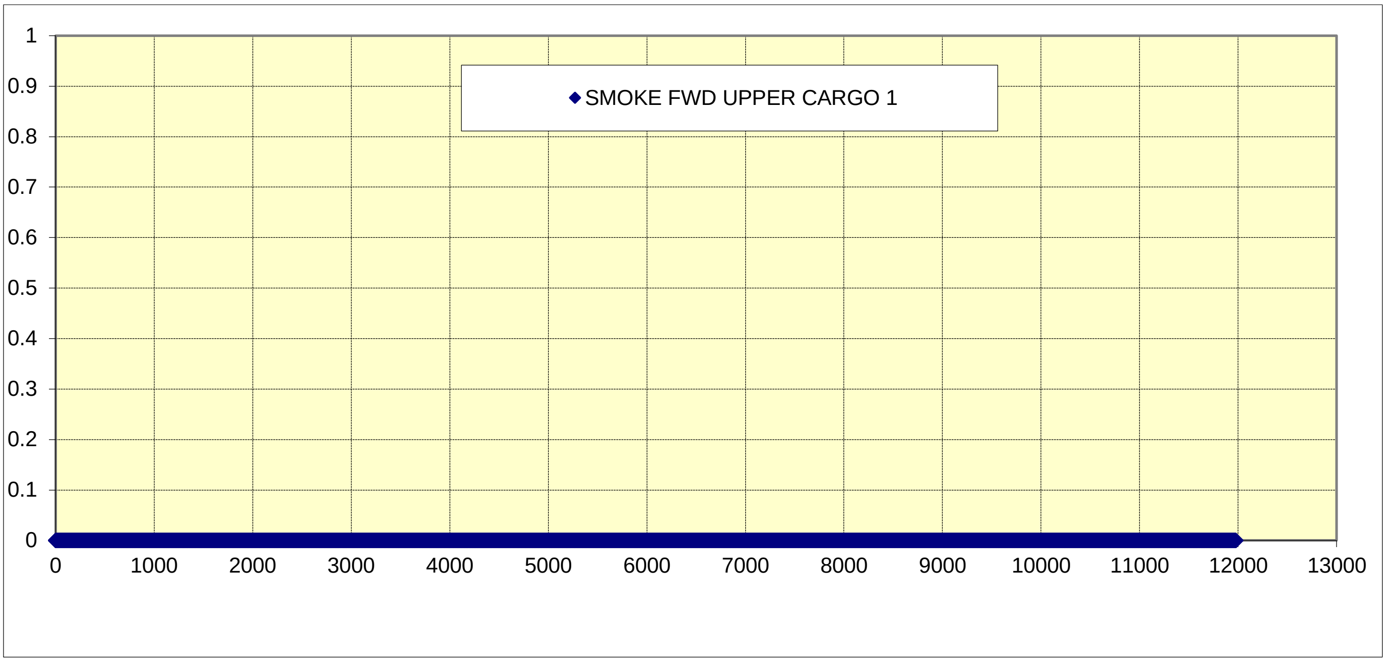


SMOKE FWD UPPER CARGO 2 very close to the recording end

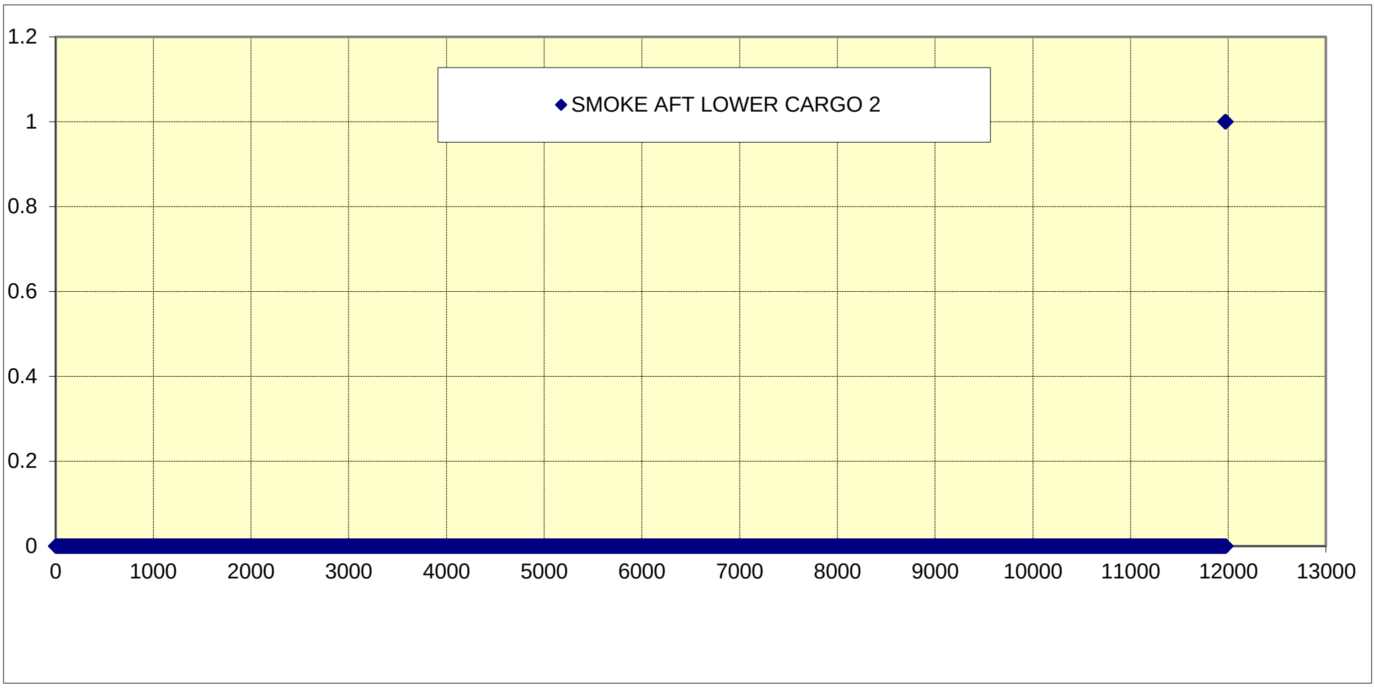
Smoke FWD upper cargo 2 showed smoke six times in the interval between 00:29:34 UTC (11965 seconds plot time) and the end of recording 00:29: 45 UTC (11976 seconds plot time)

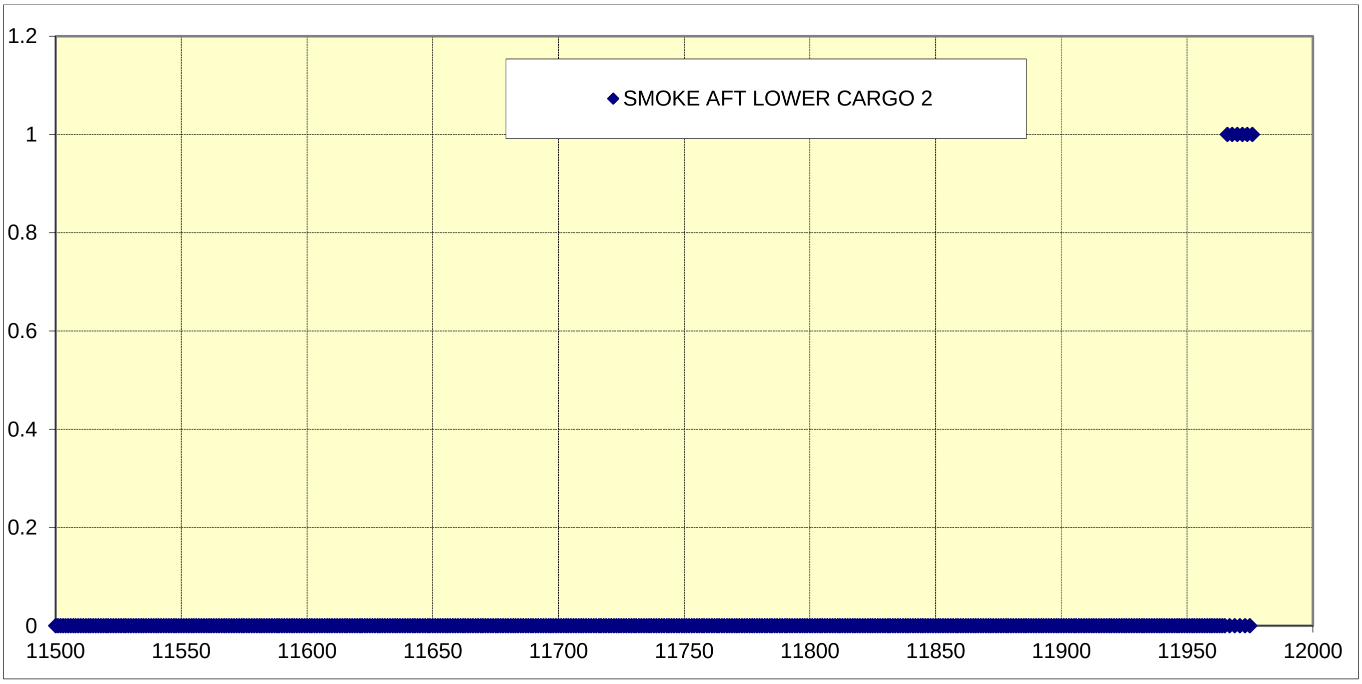
- SMOKE FWD UPPER CARGO 1

(1 smoke warning)

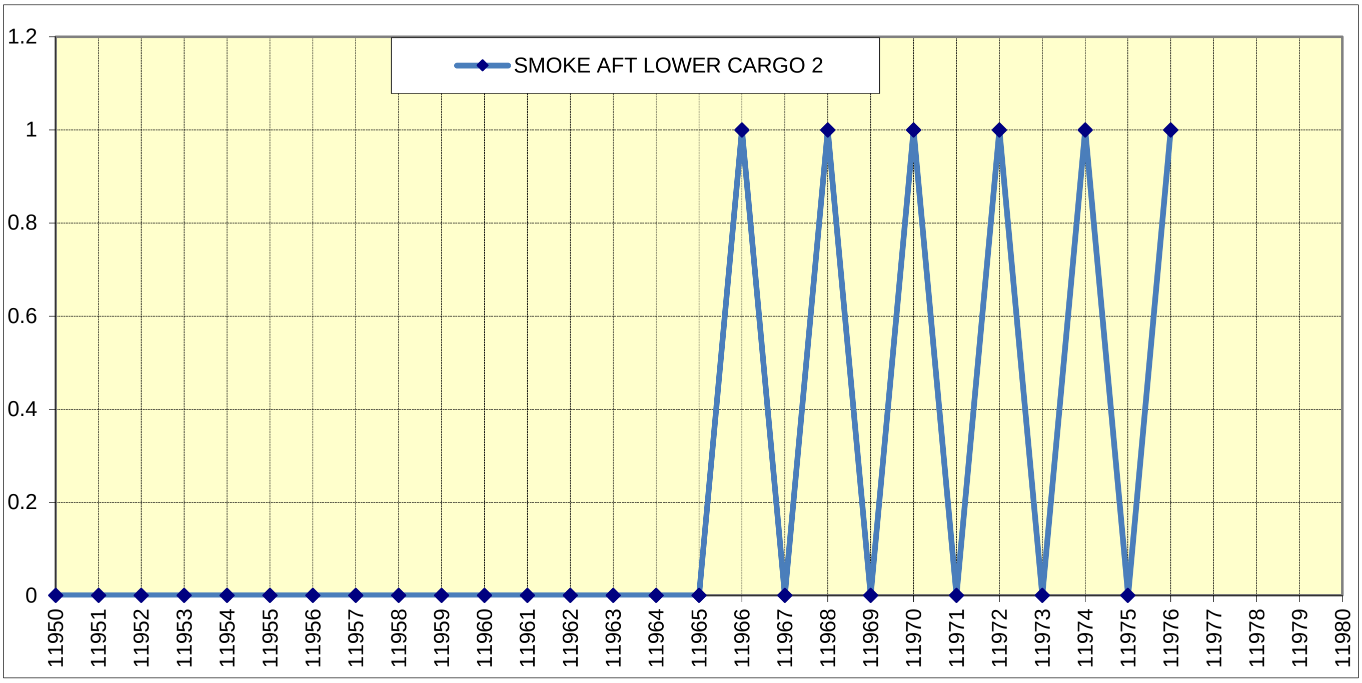


– SMOKE AFT LOWER CARGO 2
(1 smoke warning)





SMOKE AFT LOWER CARGO 2 shown at the end portion of the recording

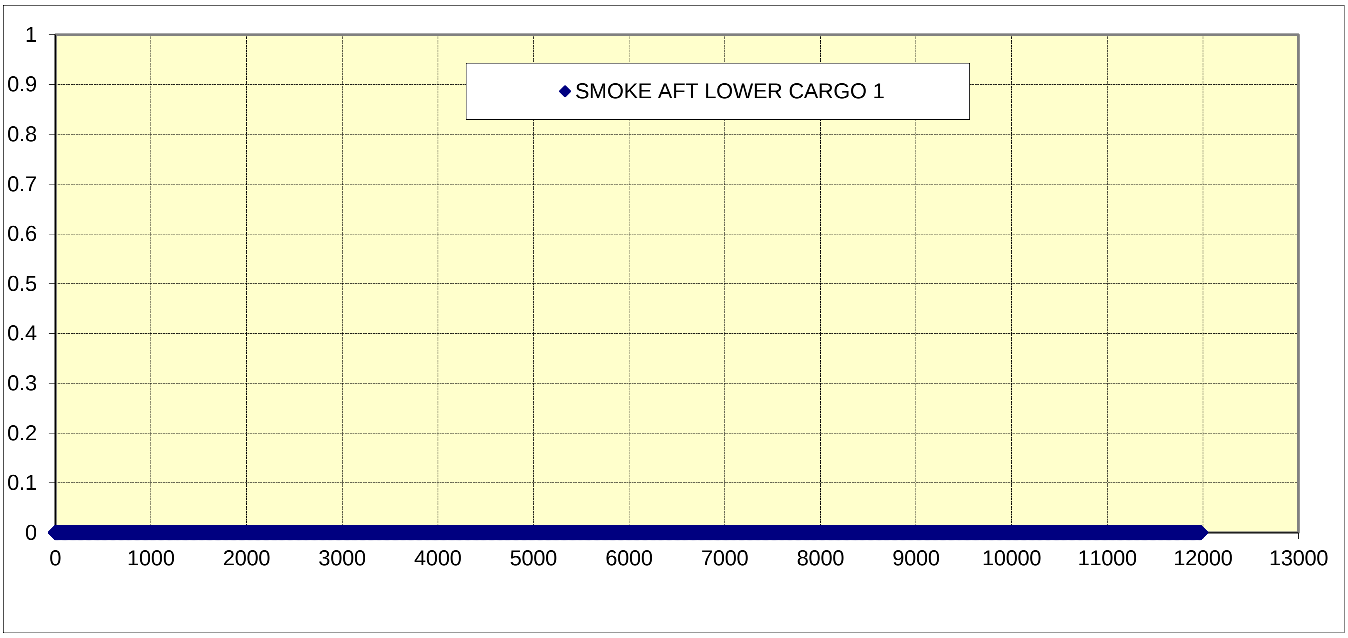


SMOKE AFT LOWER CARGO 2 very close to the recording end

Smoke AFT lower cargo 2 showed smoke six times in the interval between 00:29:34 UTC (11965 seconds plot time) and the end of recording 00:29:45 UTC (11976 seconds plot time)

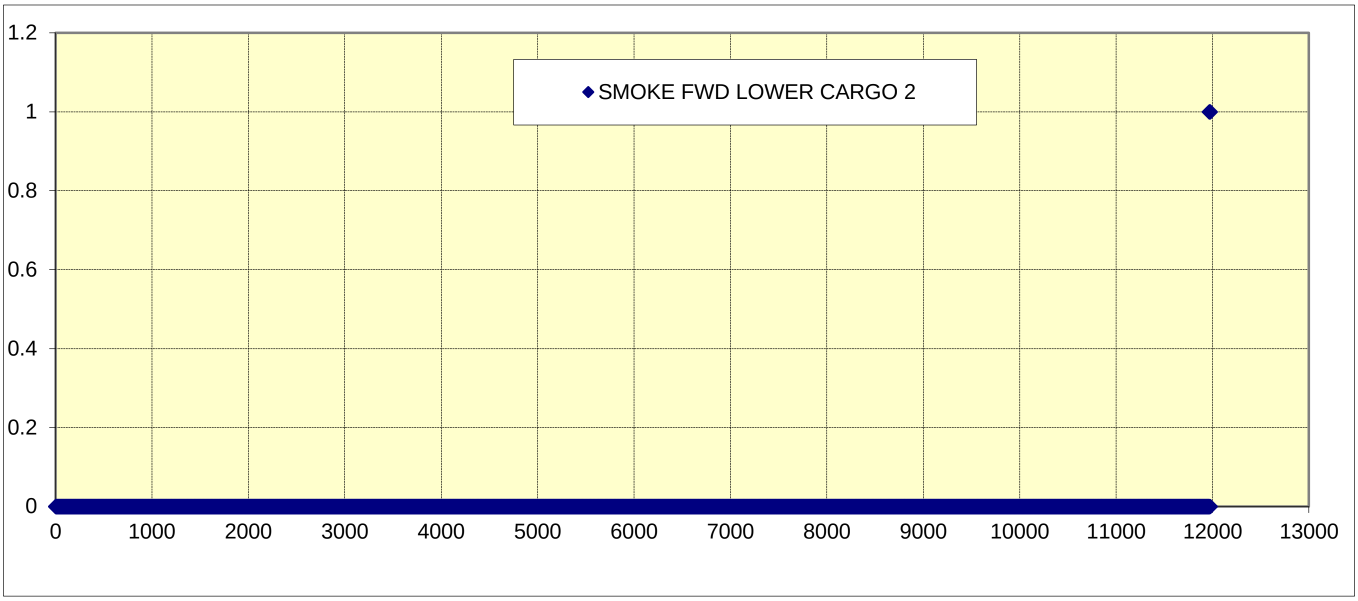
- SMOKE AFT LOWER CARGO 1

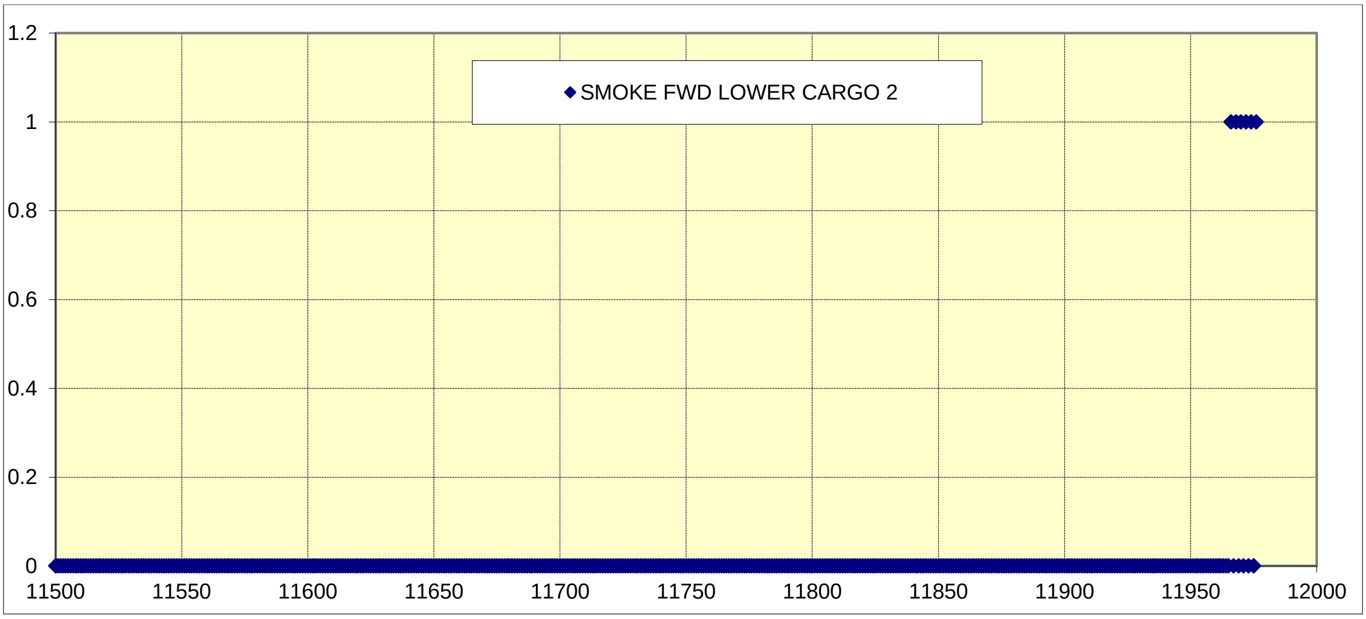
  (1 smoke warning)



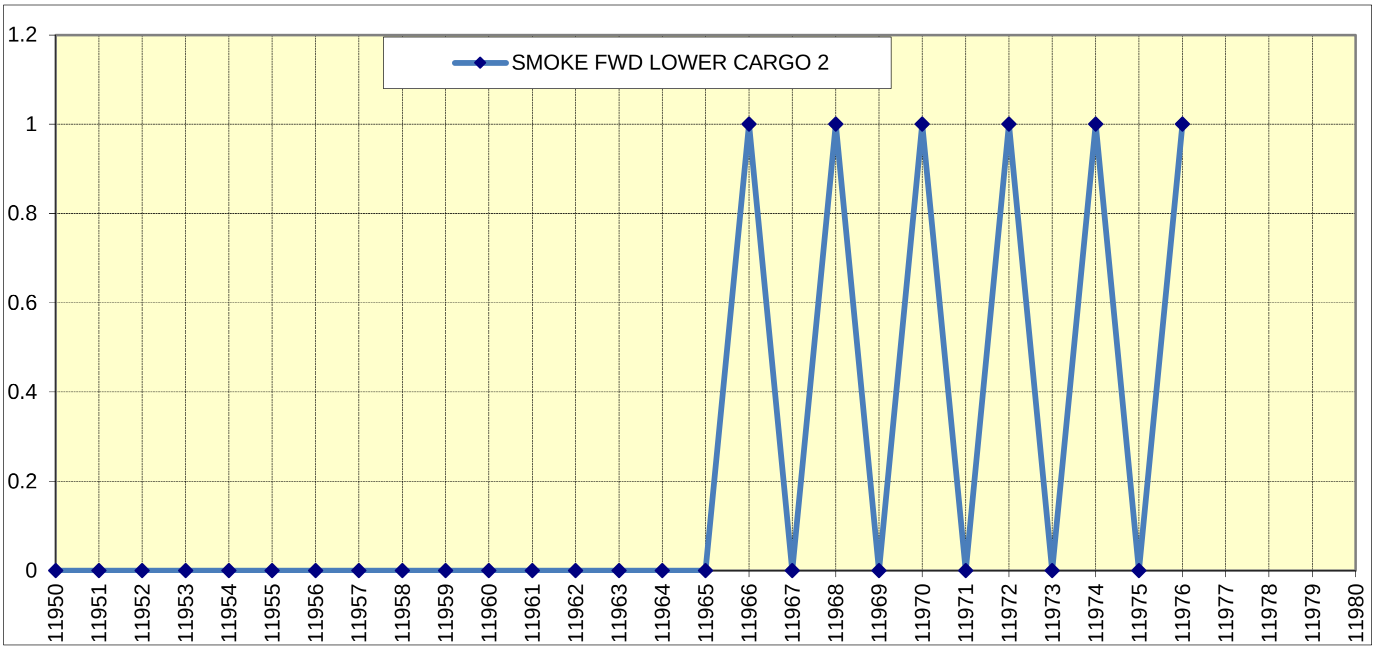
– SMOKE FWD LOWER CARGO 2

(1 smoke warning)





SMOKE FWD LOWER CARGO 2 shown at the end portion of recording

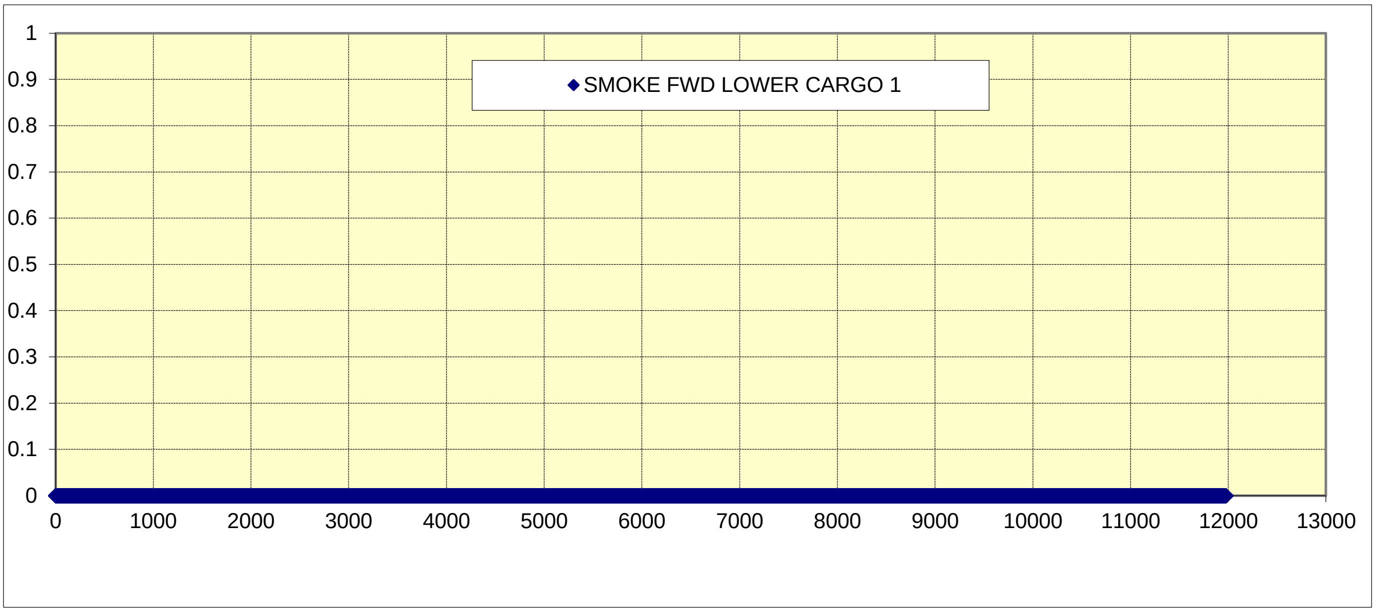


SMOKE FWD LOWER CARGO 2 very close to the recording end

Smoke FWD lower cargo 2 showed smoke six times in the interval between 00:29:34 UTC (11965 seconds plot time) and the end of recording 00:29: 45 UTC (11976 seconds plot time)

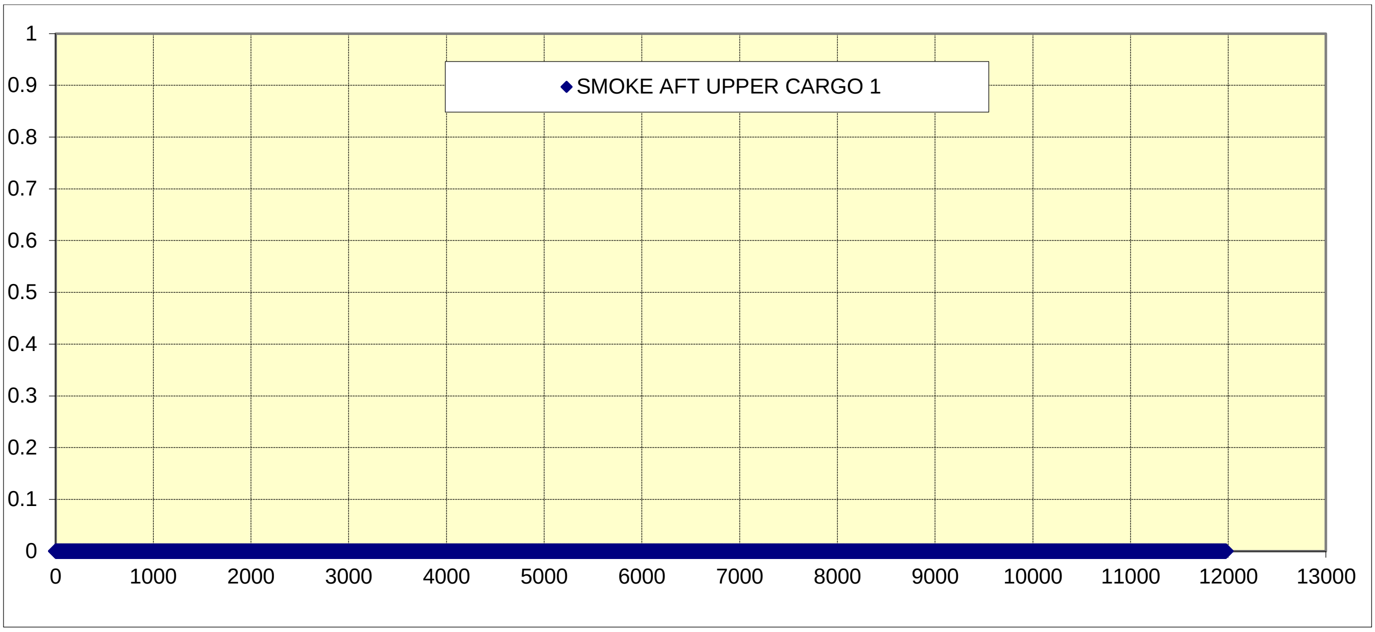
– SMOKE FWD LOWER CARGO 1

(1 smoke warning)



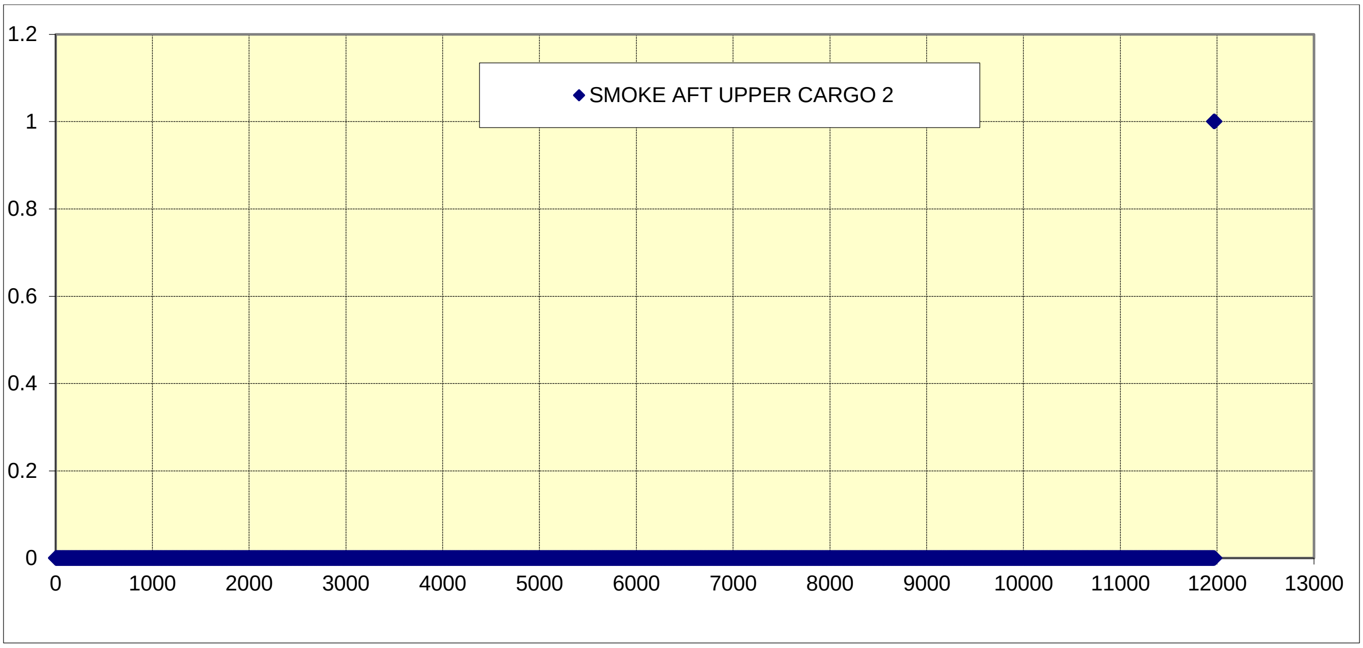
- SMOKE AFT UPPER CARGO 1

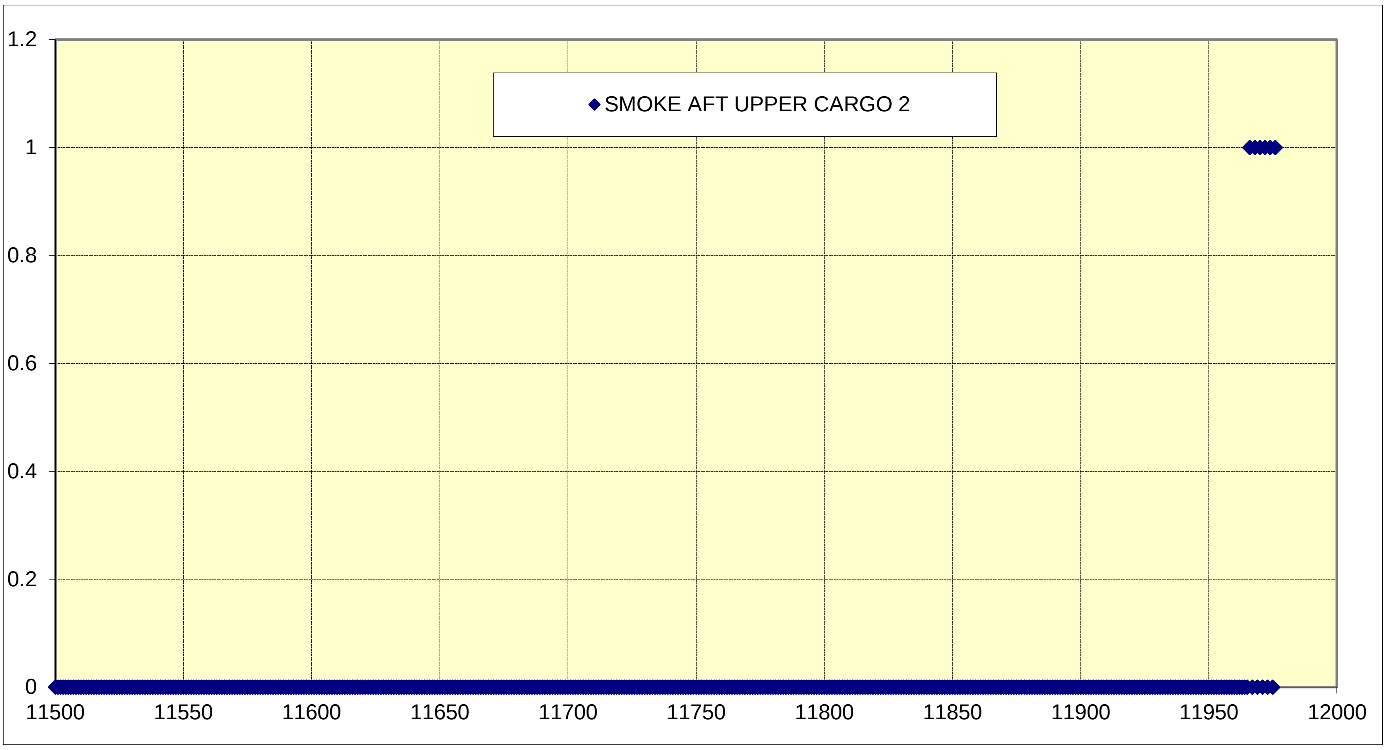
(1 Smoke Warning)



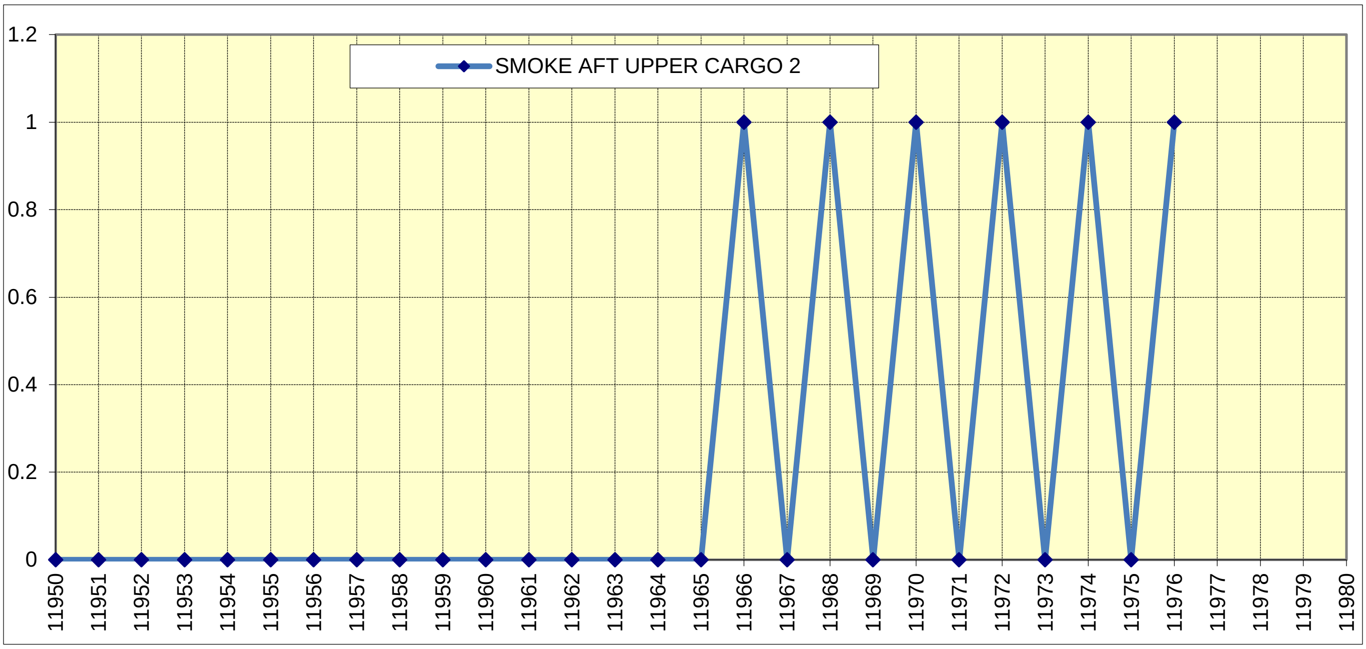
- SMOKE AFT UPPER CARGO 2

(1 Smoke Warning)





SMOKE AFT UPPER CARGO 2 t the end portion of recording

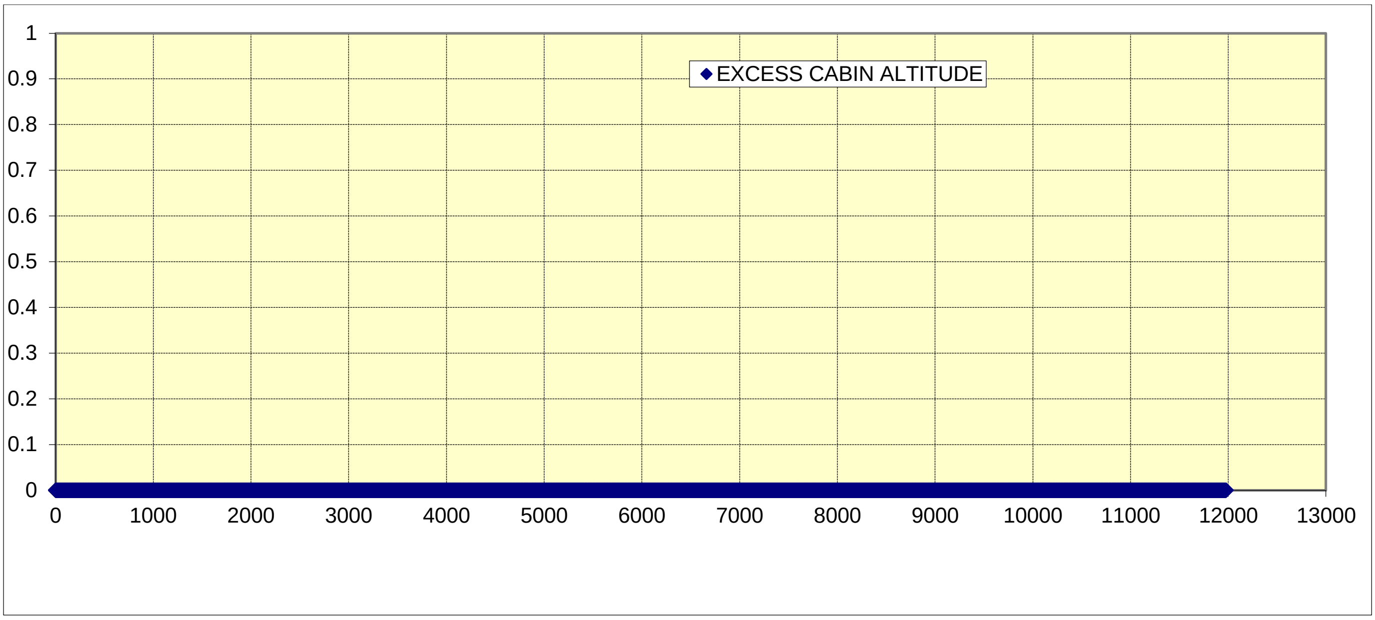


SMOKE AFT UPPER CARGO 2 very close to the recording end

Smoke AFT UPPER cargo 2 showed smoke six times in the interval between 00:29:34 UTC (11965 seconds plot time) and the end of recording 00:29: 45 UTC (11976 seconds plot time)

- EXCESS CABIN ALTITUDE

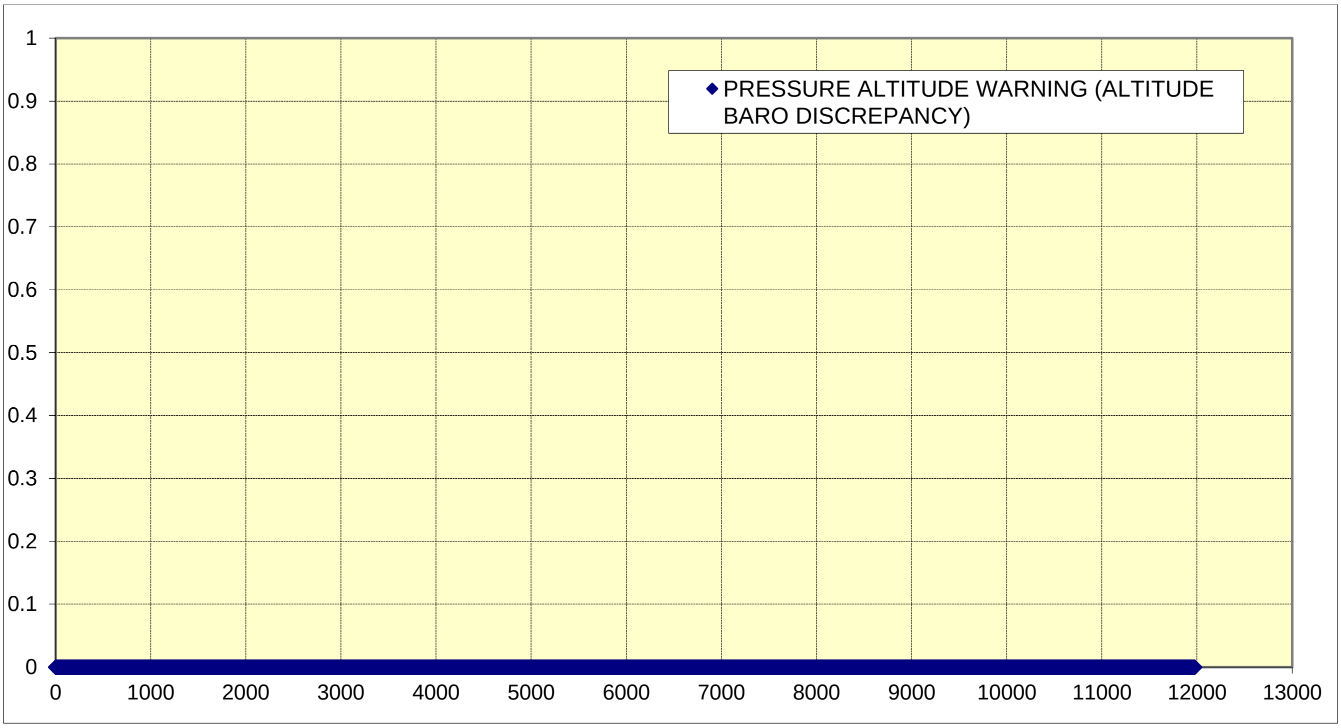
(1 Excess altitude)



No Cabin Altitude Excess

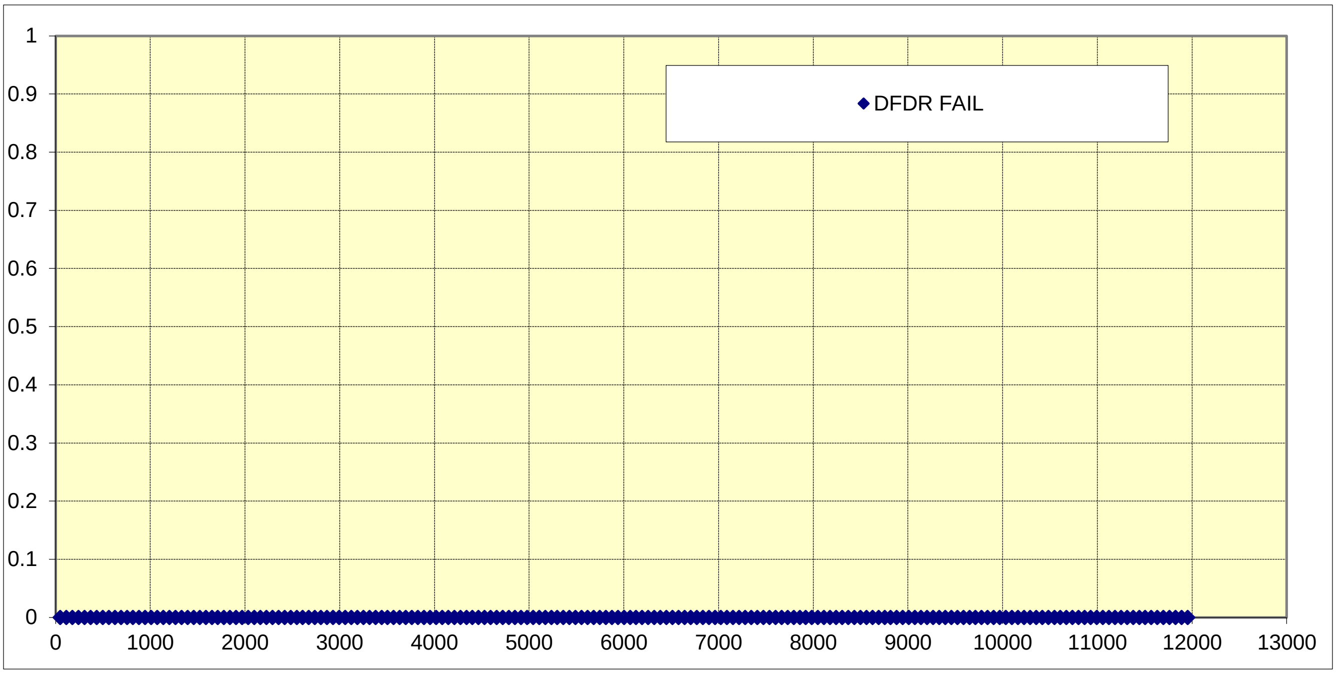
- PRESSURE ALTITUDE WARNING (ALTITUDE BARO DISCREPANCY)

(1 Altitude warning baro discrepancy)



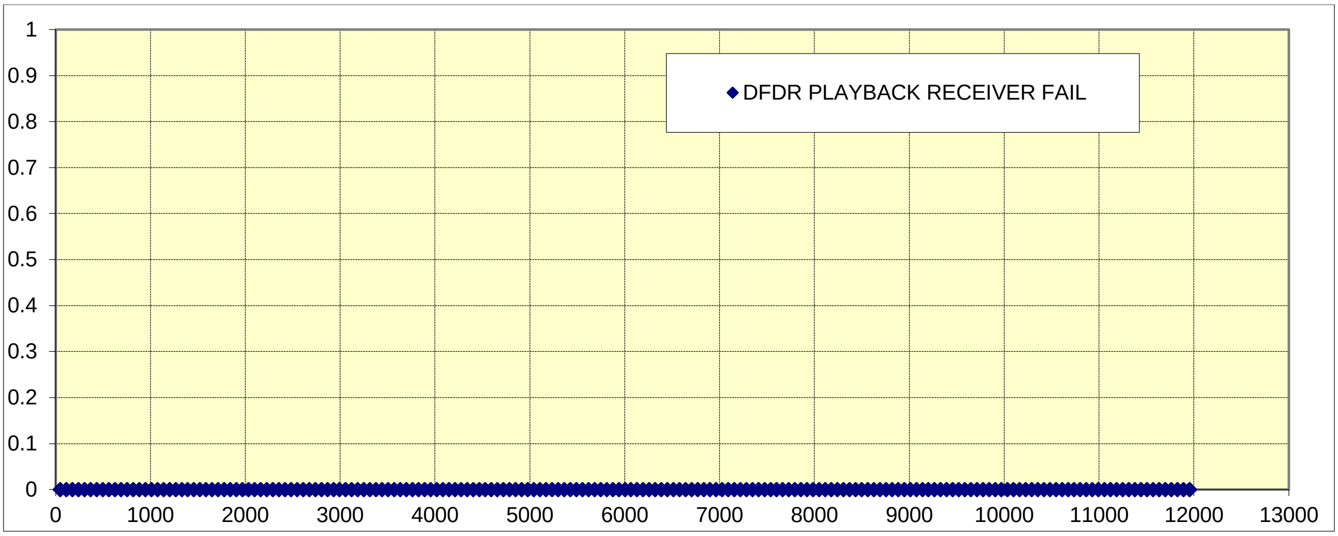
Failure Modes

- DFDR FAIL (Digital Flight Data Recorder Fail)



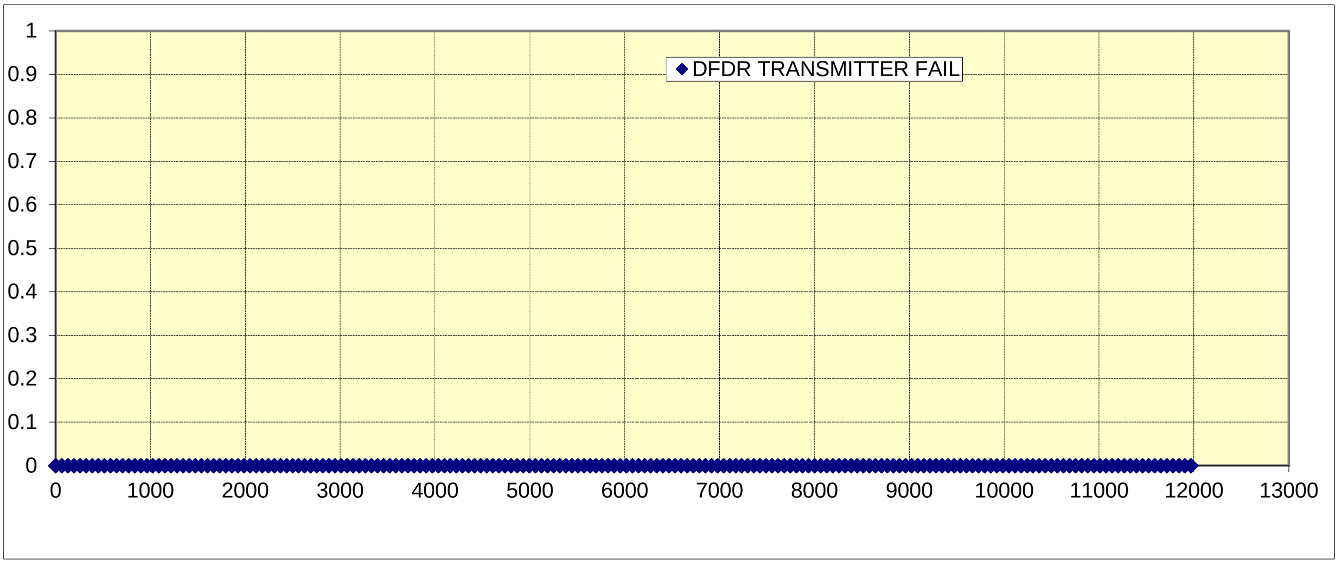
- No detected failure up to the end of the valid data

- DFDR PLAYBACK RECEIVER FAIL (Digital Flight Data Recorder Playback receiver fail)



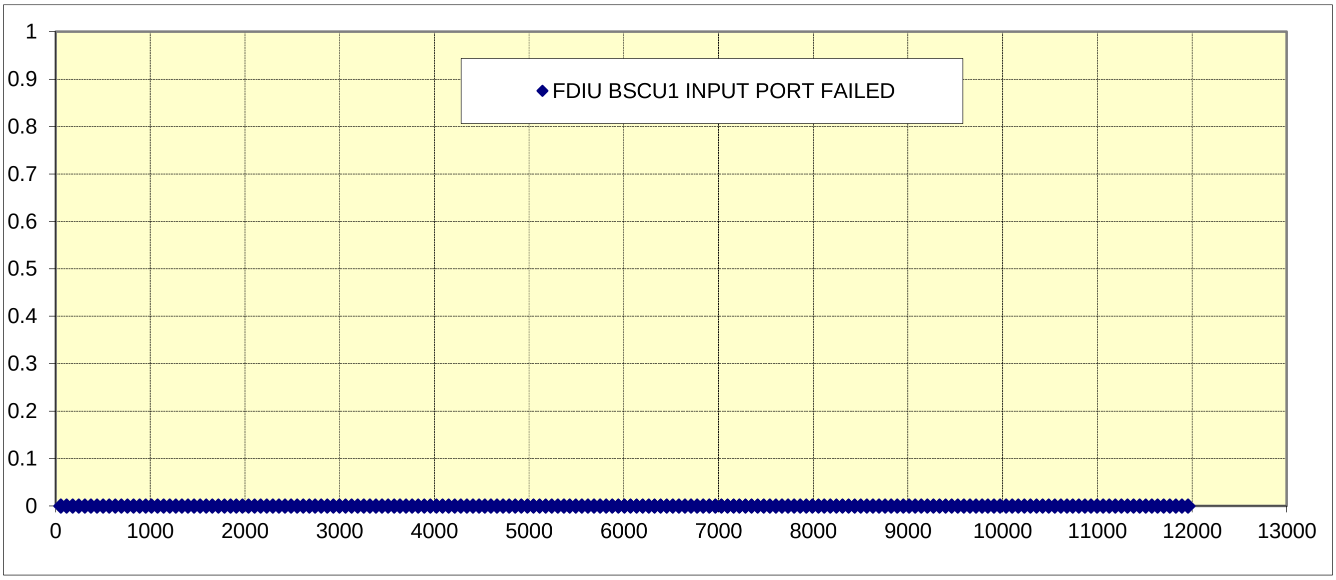
- No detected failure up to the end of the valid data

- DFDR TRANSMITTER FAIL (Digital Flight Data Recorder Transmitter fail)



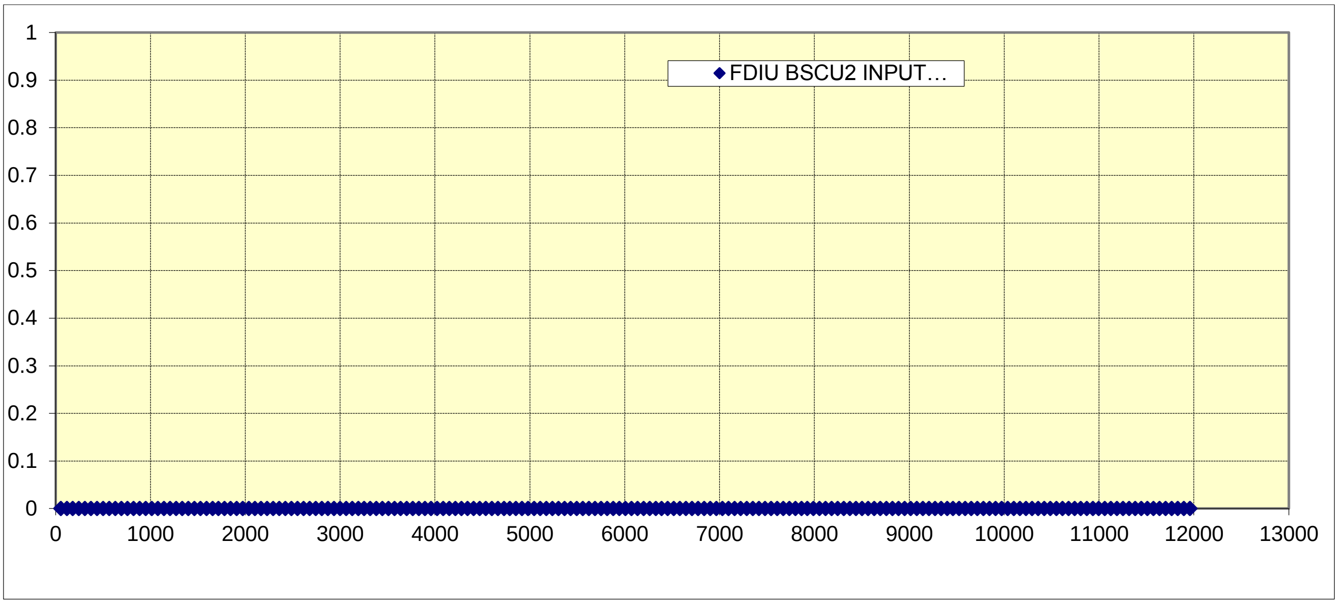
- No detected failure up to the end of the valid data

- FDIU BSCU1 INPUT PORT FAILED (Flight Data Interface Unit Braking/Steering Control Unit 1 input port failed)



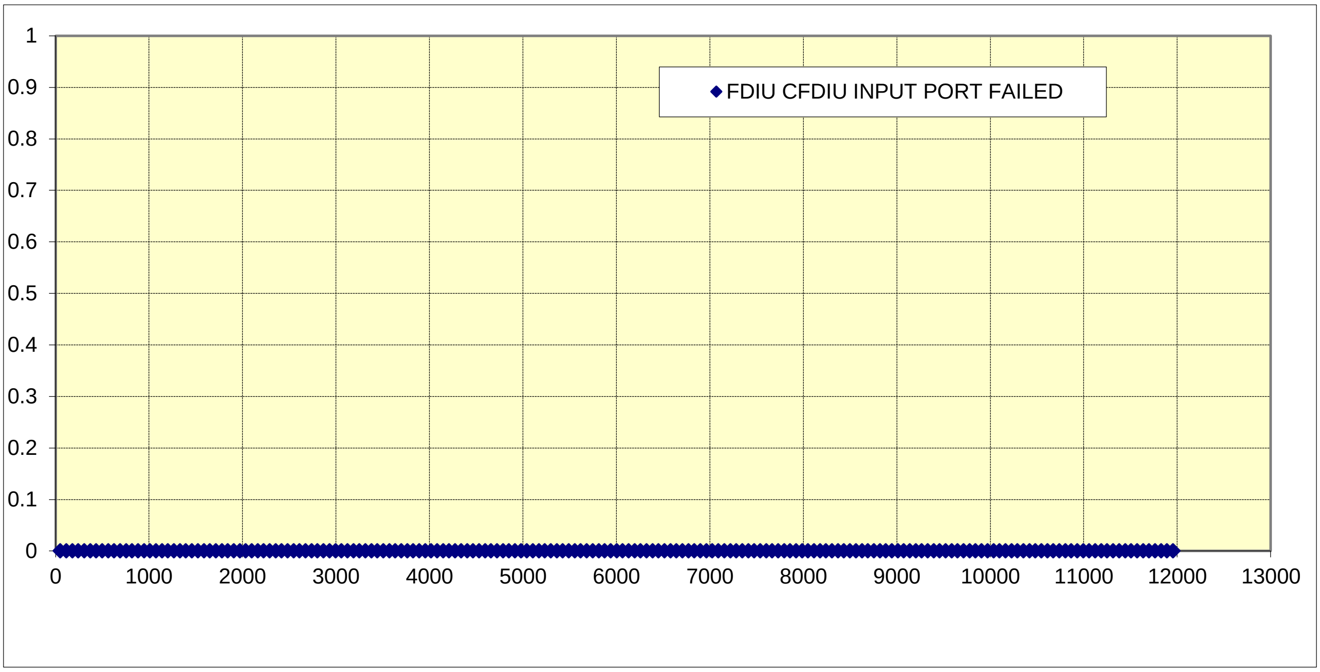
- No detected failure up to the end of the valid data

- FDIU BSCU2 INPUT PORT FAILED (Flight Data Interface Unit Braking/Steering Control Unit 2 input port failed)



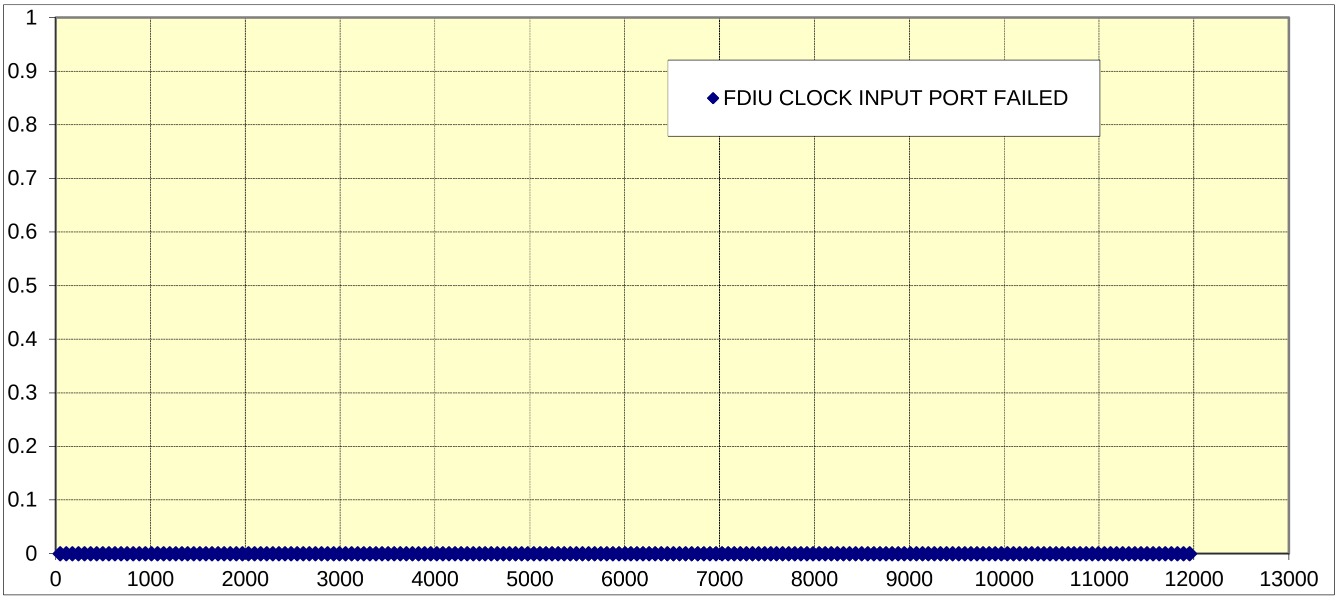
  - No detected failure up to the end of the valid data

- FDIU CFDIU INPUT PORT FAILED (Flight Data Interface Unit Centralized Fault Display Interface Unit input port failed)



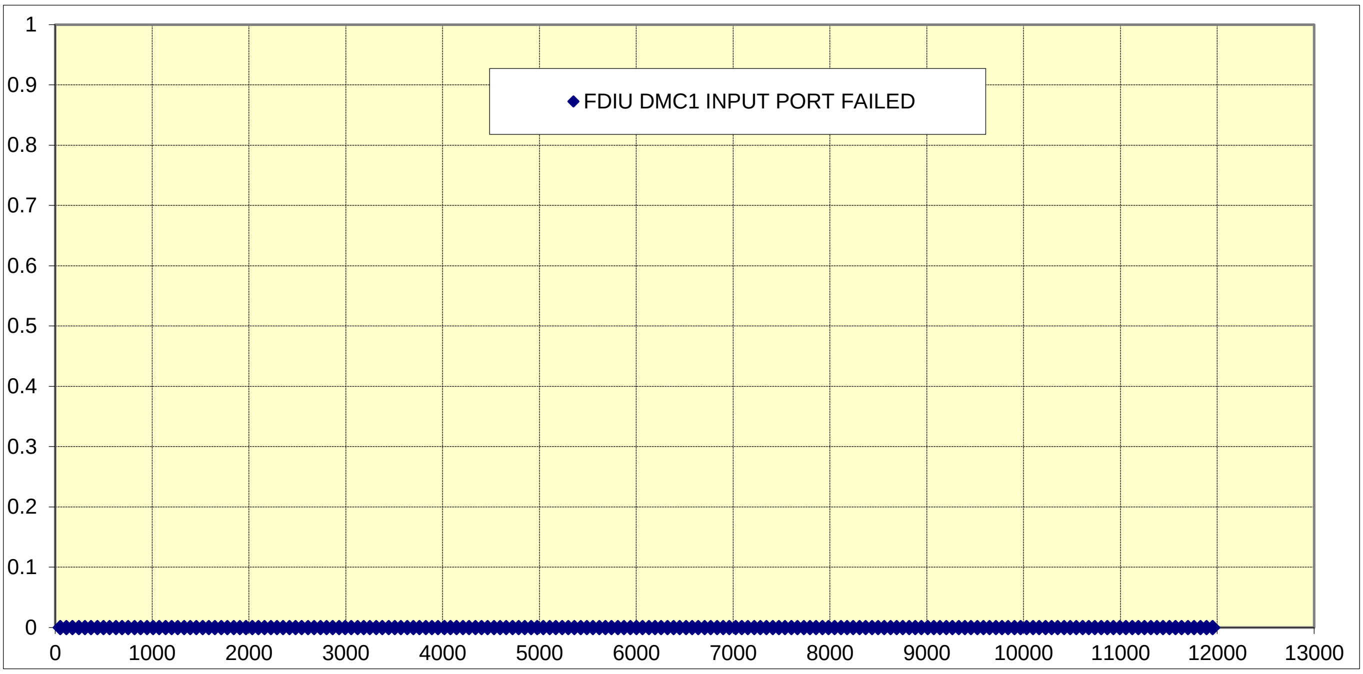
  - No detected failure up to the end of the valid data

- FDIU CLOCK INPUT PORT FAILED (Flight Data Interface Unit Clock input port failed)



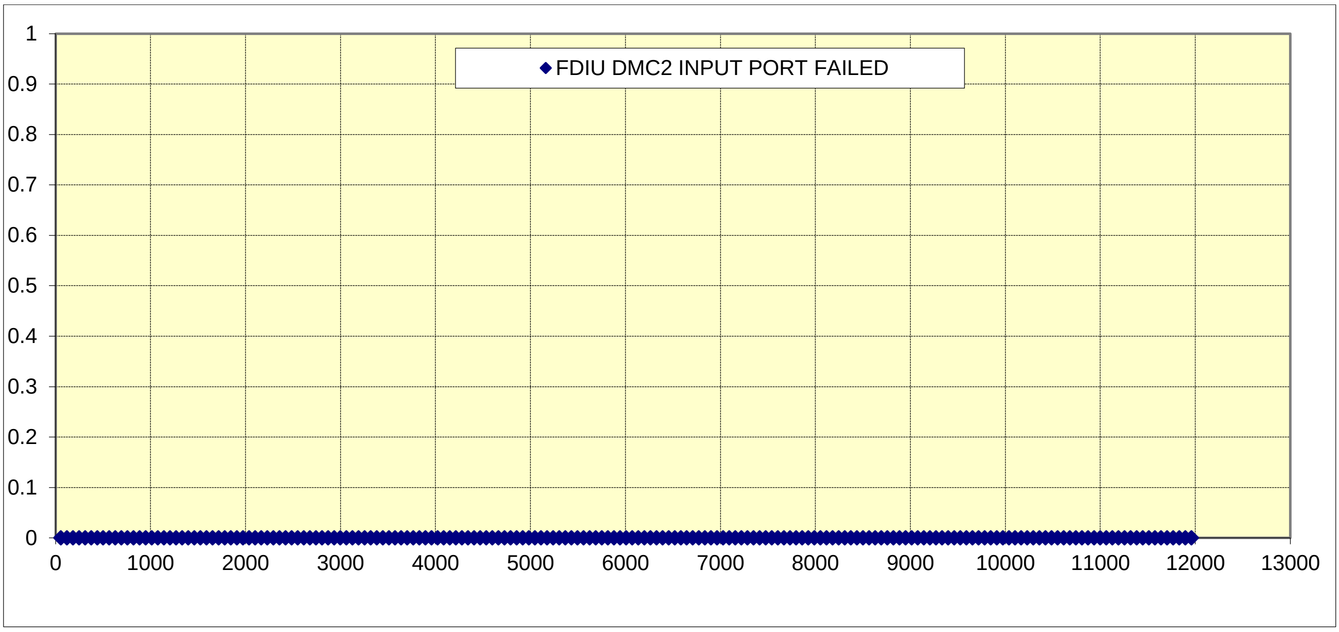
- No detected failure up to the end of the valid data

- FDIU DMC1 INPUT PORT FAILED (Flight Data Interface Unit Display Management Computer 1 input port failed)



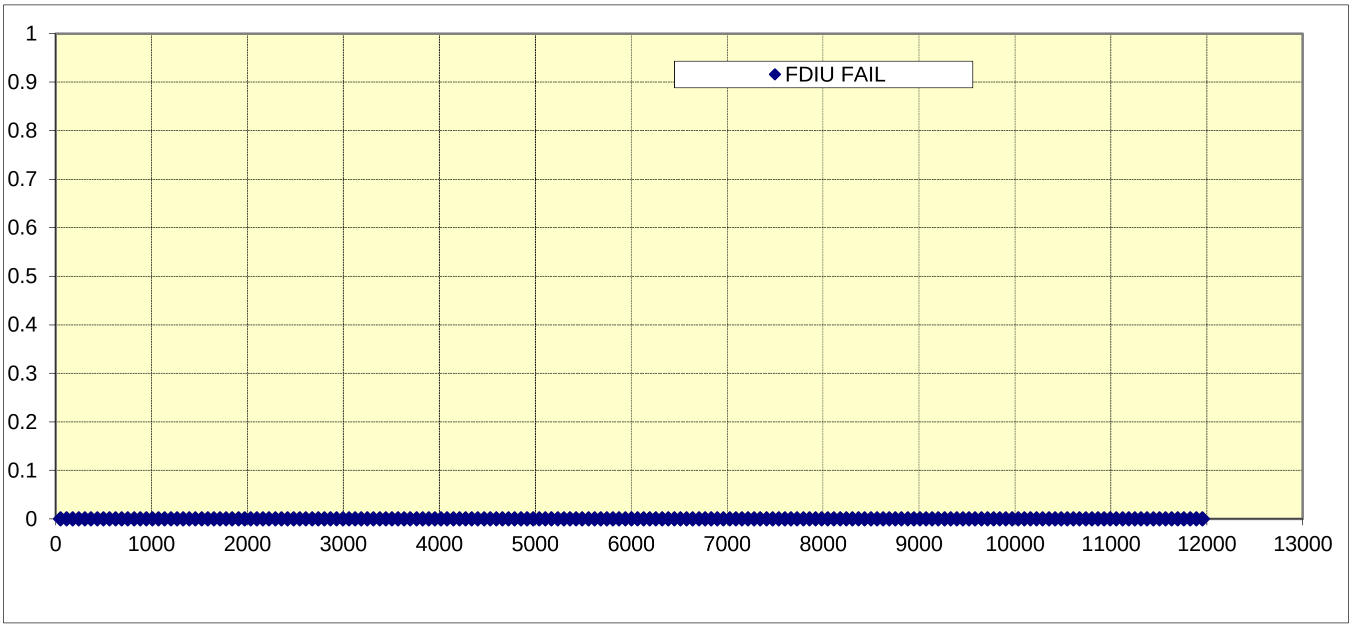
- No detected failure up to the end of the valid data

- FDIU DMC2 INPUT PORT FAILED (Flight Data Interface Unit Display Management Computer 1 input port failed)



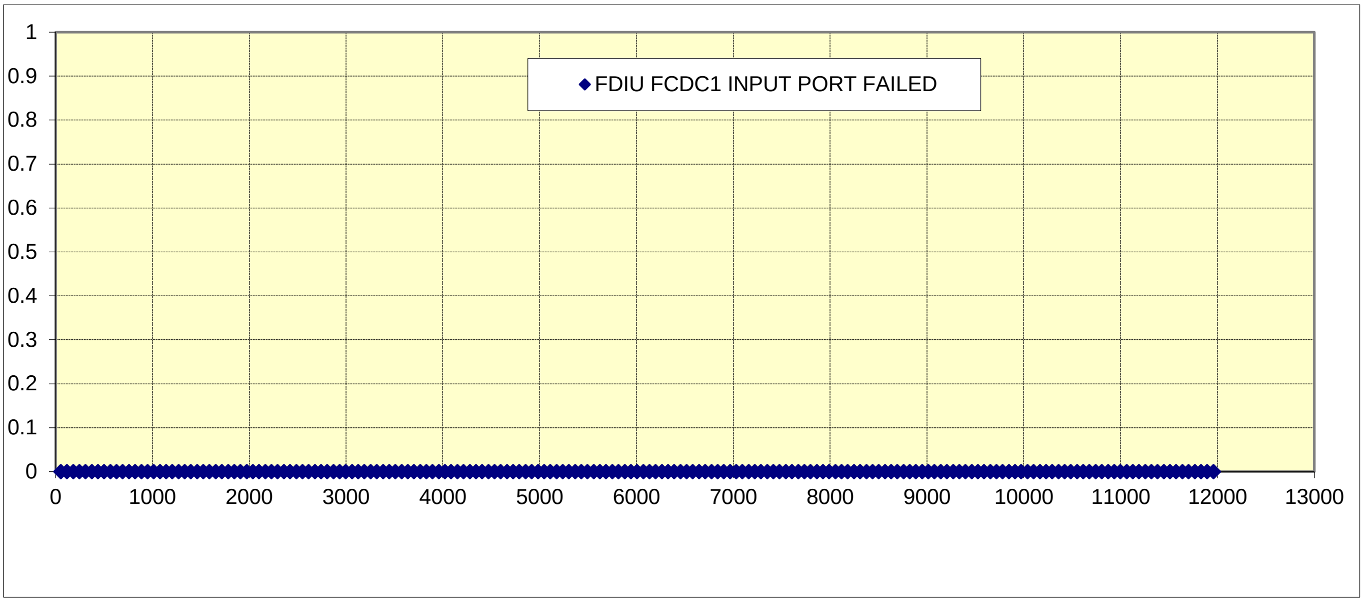
  - No detected failure up to the end of the valid data

- FDIU FAIL (Flight Data Interface Unit)



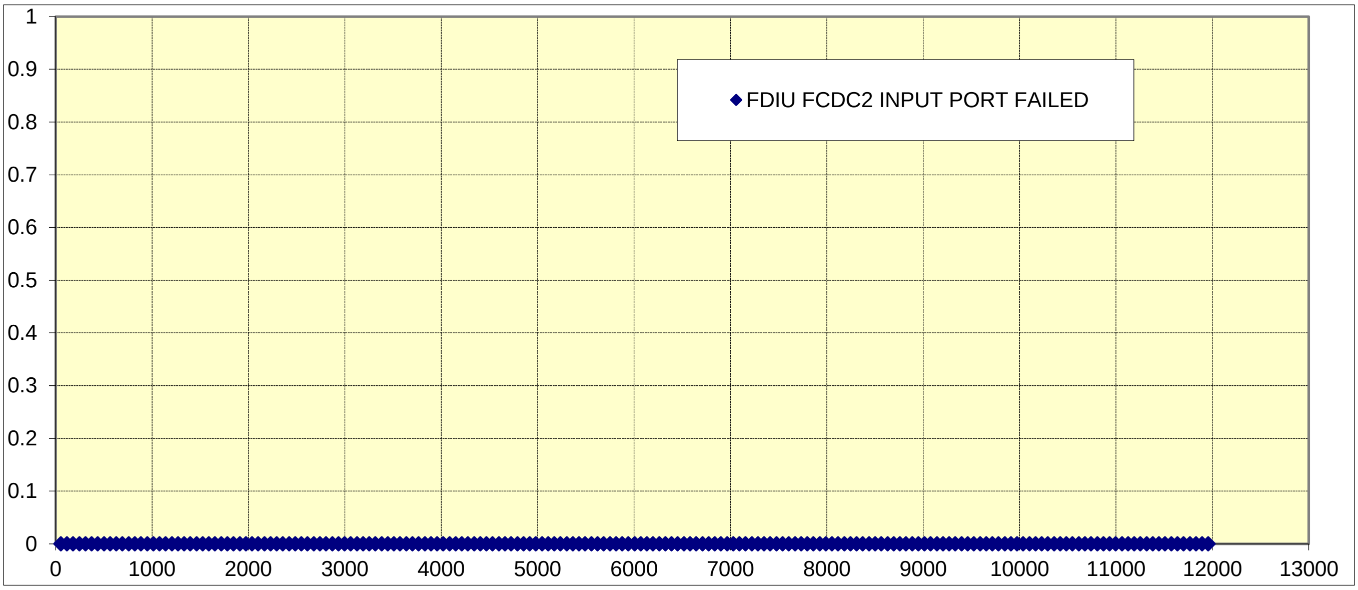
  - No detected failure up to the end of the valid data

- FDIU FCDC1 INPUT PORT FAILED (Flight Data Interface UnitFlight Control Data Concentrator 1 failed



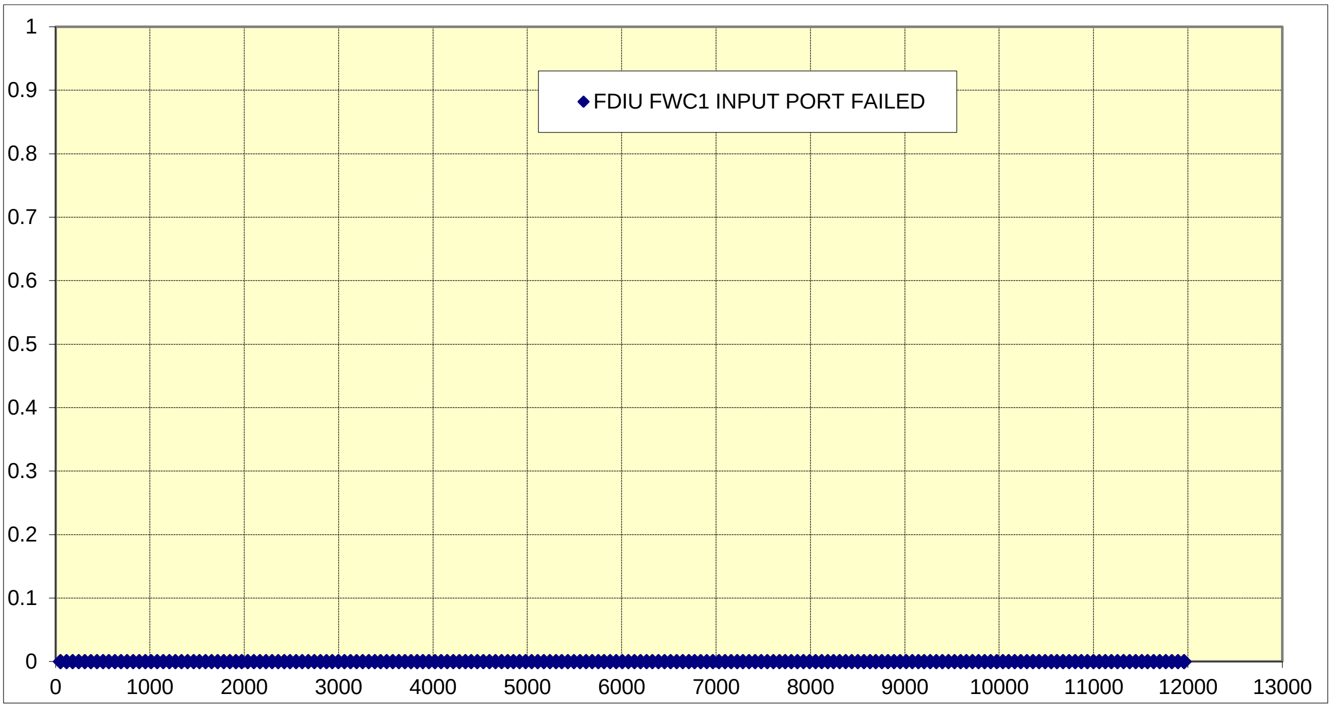
  - No detected failure up to the end of the valid data

- FDIU FCDC2 INPUT PORT FAILED Flight Data Interface UnitFlight Control Data Concentrator 2 failed)



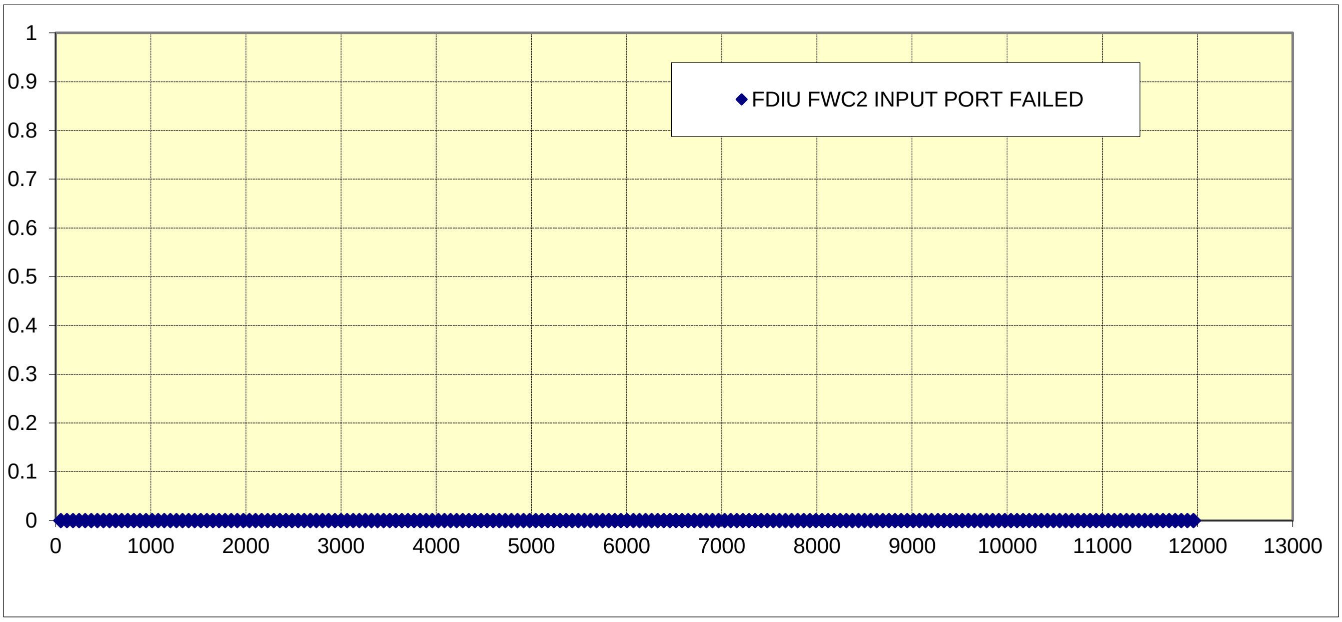
  - No detected failure up to the end of the valid data

- FDIU FWC1 INPUT PORT FAILED (Flight Data Interface Unit Flight Warning Computer 1 failed)



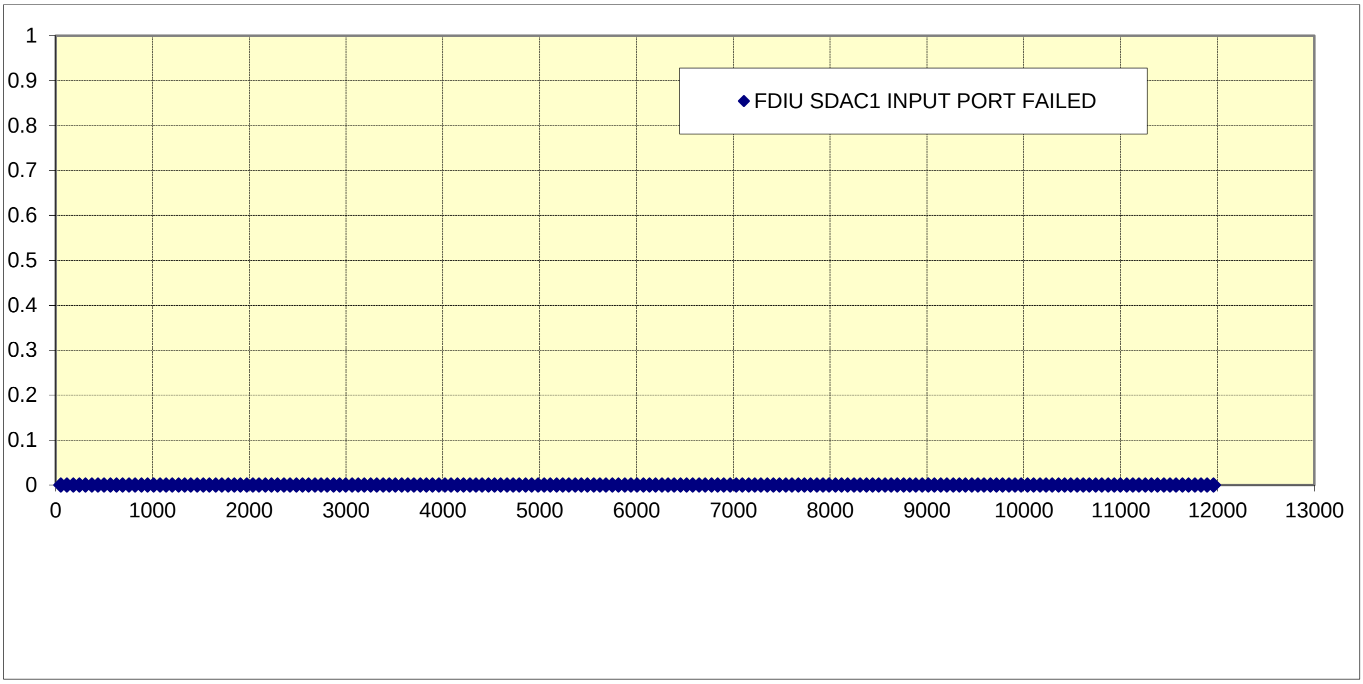
- No detected failure up to the end of the valid data

- DIU FWC2 INPUT PORT FAILED (Flight Data Interface Unit Flight Warning Computer 2 failed)



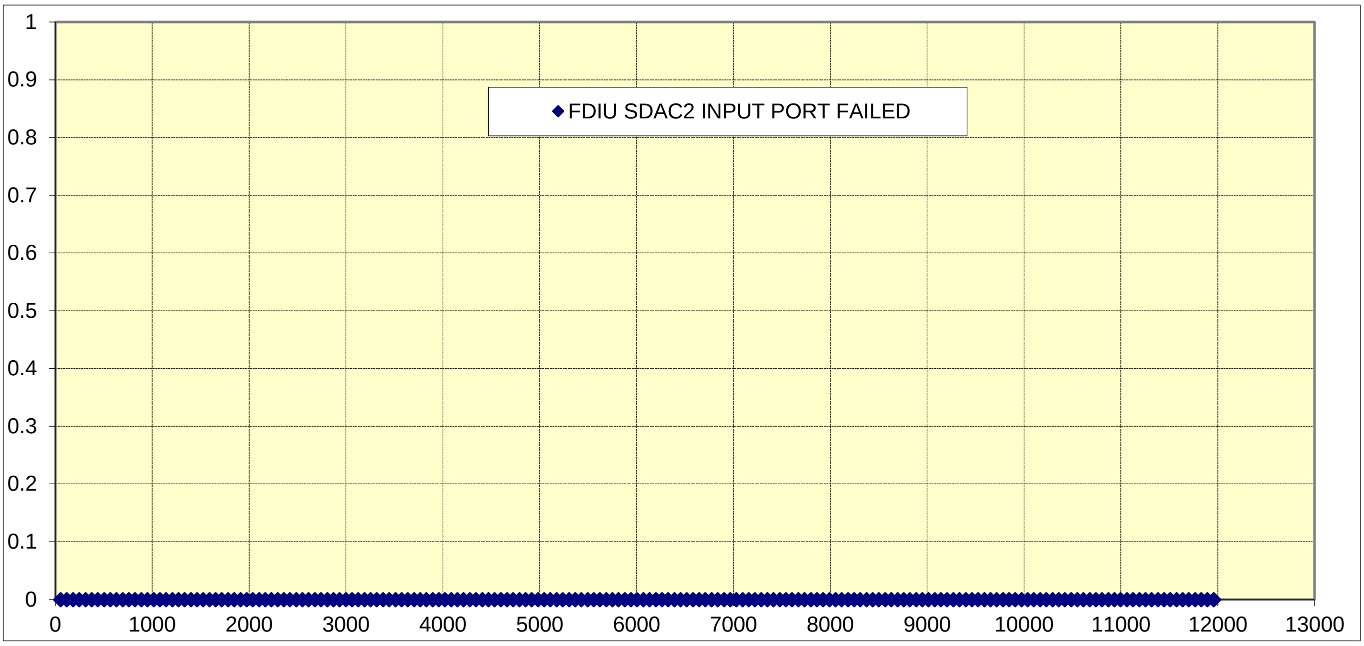
- No detected failure up to the end of the valid data

- FDIU SDAC1 INPUT PORT FAILED (Flight Data Interface Unit System Data Analog Converter 1 failed)



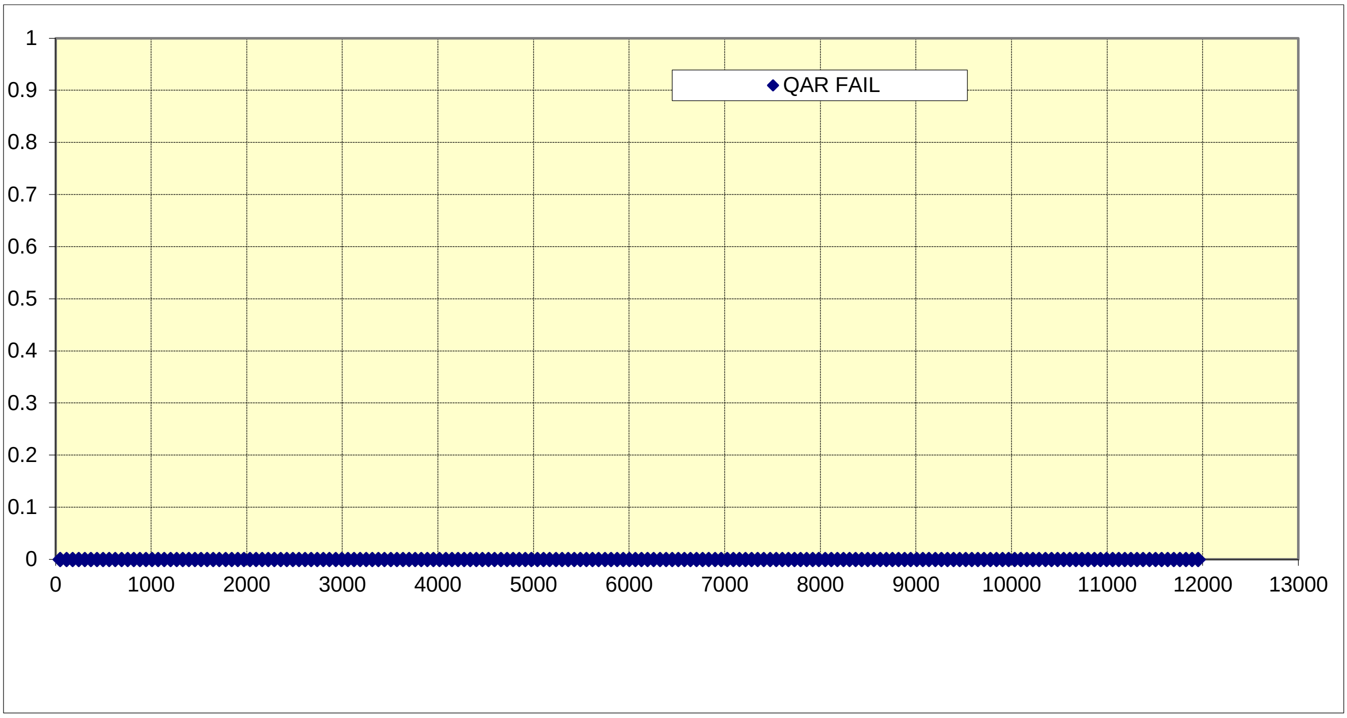
- No detected failure up to the end of the valid data

- FDIU SDAC2 INPUT PORT FAILED (Flight Data Interface Unit System Data Analog Converter 1 failed)



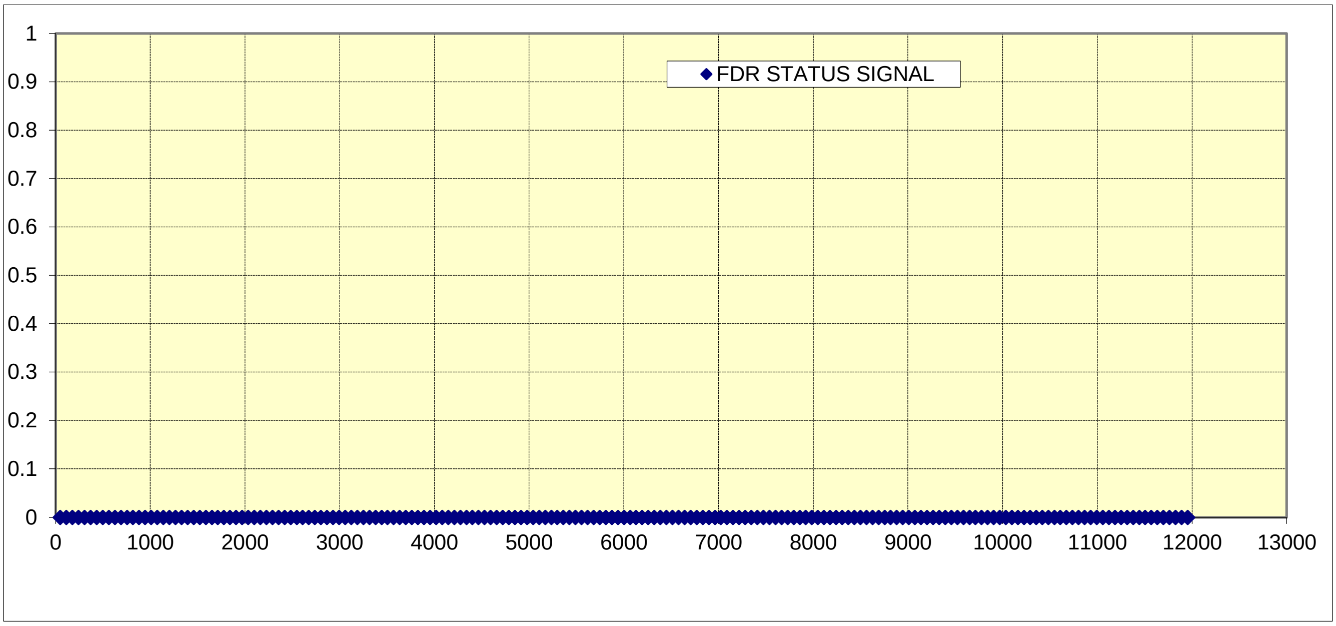
- No detected failure up to the end of the valid data

- QAR FAIL (Quick Access Recorder)



- No detected failure up to the end of the valid data

- FDR STATUS SIGNAL (Flight Data Recorder Status Signa)



- No detected failure up to the end of the valid data

Failure Modes summary:

No detected failure up to the end of the valid data with these following parameters

- DFDR FAIL Digital Flight Data Recorder Fail
- DFDR PLAYBACK RECEIVER FAIL Digital Flight Data Recorder Playback receiver fail
- DFDR TRANSMITTER FAILDigital Flight Data Recorder Transmitter fail
- FDIU BSCU1 INPUT PORT FAILED Flight Data Interface Unit Braking/Steering Control Unit 1 input port failed
- FDIU BSCU2 INPUT PORT FAILED Flight Data Interface Unit Braking/Steering Control Unit 2 input port failed
- FDIU CFDIU INPUT PORT FAILED Flight Data Interface Unit Centralized Fault Display Interface Unit input port failed
- FDIU CLOCK INPUT PORT FAILED Flight Data Interface Unit Clock input port failed
- FDIU DMC1 INPUT PORT FAILED Flight Data Interface Unit Display Management Computer 1 input port failed
- FDIU DMC2 INPUT PORT FAILED Flight Data Interface Unit Display Management Computer 1 input port failed
- FDIU FAIL Flight Data Interface Unit
- FDIU FCDC1 INPUT PORT FAILED Flight Data Interface UnitFlight Control Data Concentrator 1 failed
- FDIU FCDC2 INPUT PORT FAILED Flight Data Interface UnitFlight Control Data Concentrator 2 failed
- FDIU FWC1 INPUT PORT FAILED Flight Data Interface Unit Flight Warning Computer 1 failed
- FDIU FWC2 INPUT PORT FAILED Flight Data Interface Unit Flight Warning Computer 2 failed
- FDIU SDAC1 INPUT PORT FAILED Flight Data Interface Unit System Data Analog Converter 1 failed
- FDIU SDAC2 INPUT PORT FAILED Flight Data Interface Unit System Data Analog Converter 1 failed
- QAR FAIL Quick Access Recorder
- FDR STATUS SIGNAL Flight Data Recorder Status Signal

8.a

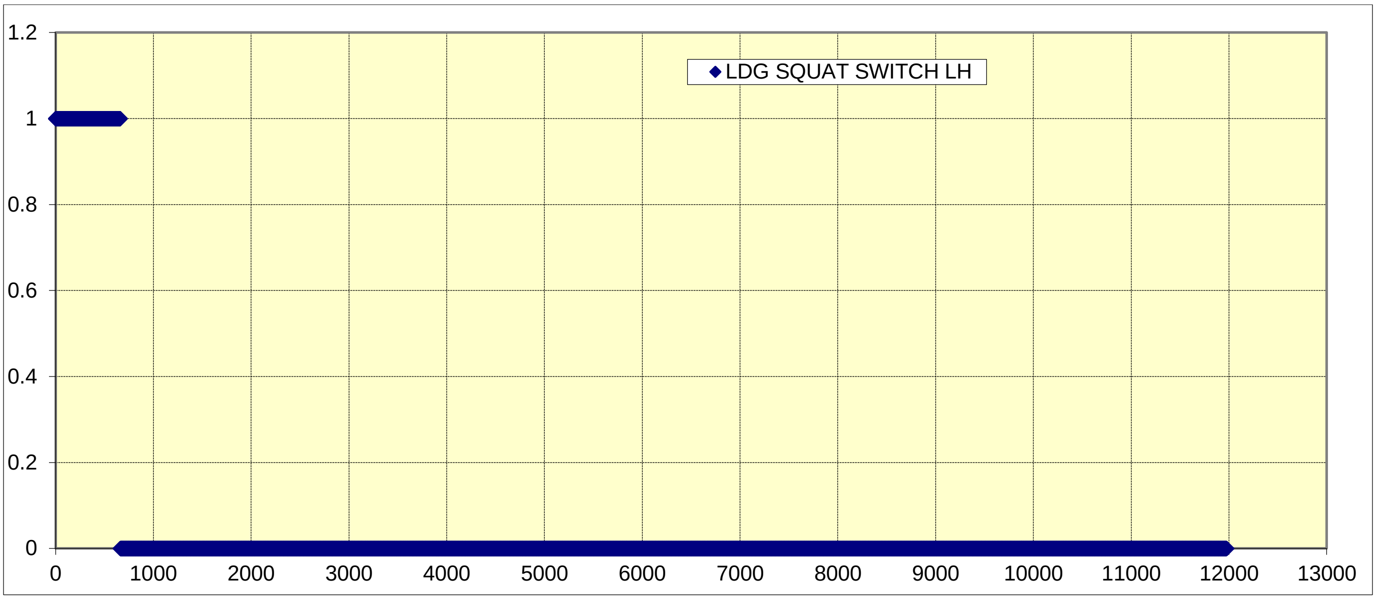
Failed computers

Equipment Lost	Nomenclature	Time of loss	Location of computers
SEC3	Spoiler, Elevator computer	0:29:26	90VU
TCAS	Traffic Alert and Collision Avoidance System	0:29:28	80VU
	Rudder Pedal Force Sensor	0:29:28	cockpit
SEC2	Spoiler, Elevator computer #2	0:29:34	80VU
SDCU	Smoke Detection Control Unit	0:29:35	90VU
FAC2	Flight Augmentation Computer	0:29:36	80VU
Weather radar	weather radar	0:29:36	109VU
FMGC 2	Flight Management Guidance Computer	Between 00:29:37 and 00:29:42	80VU
EEC2 Channel B	Electronic Engine Computer # Channel B	Between 00:29:37 and 00:29:42	Engine 2
DMC 3	Display Management Computer #3	Between 00:29:37 and 00:29:42	80VU
FCDC2	Flight Control Data Concentrator	Between 00:29:37 and 00:29:42	80VU
EVMU	Engine Vibration Monitor Unit	0:29:45	80VU
DFDR	Digital Flight Data Recorder	0:29:47	Aircraft Tail

Reference: BEA study

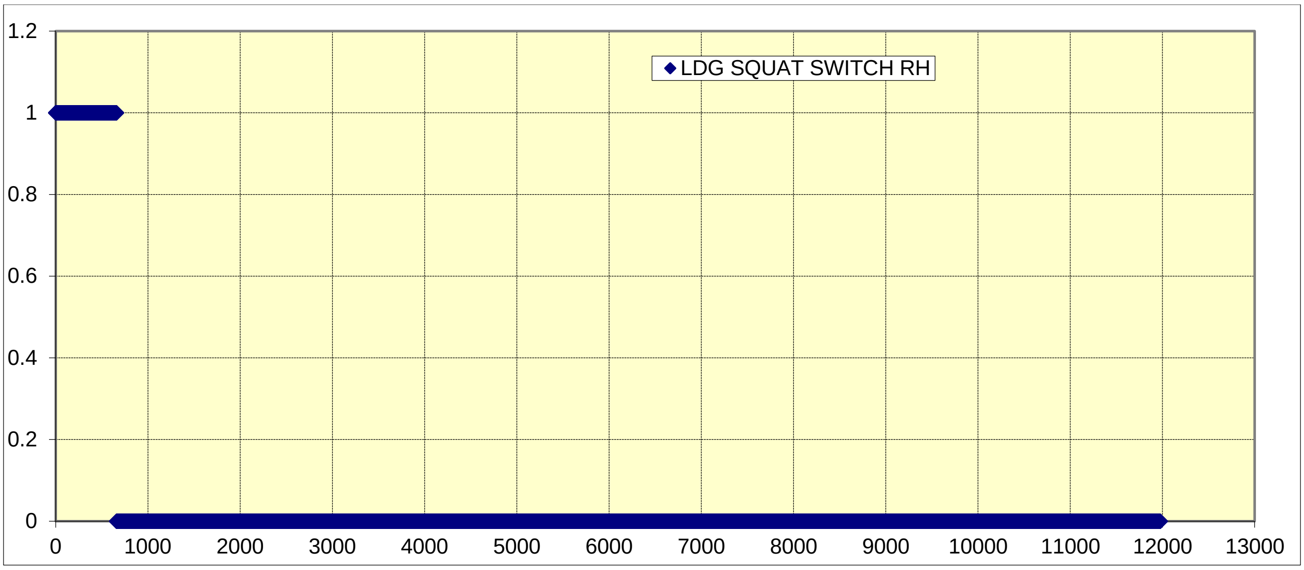
9. Landing Gears

– LDG SQUAT SWITCH LH



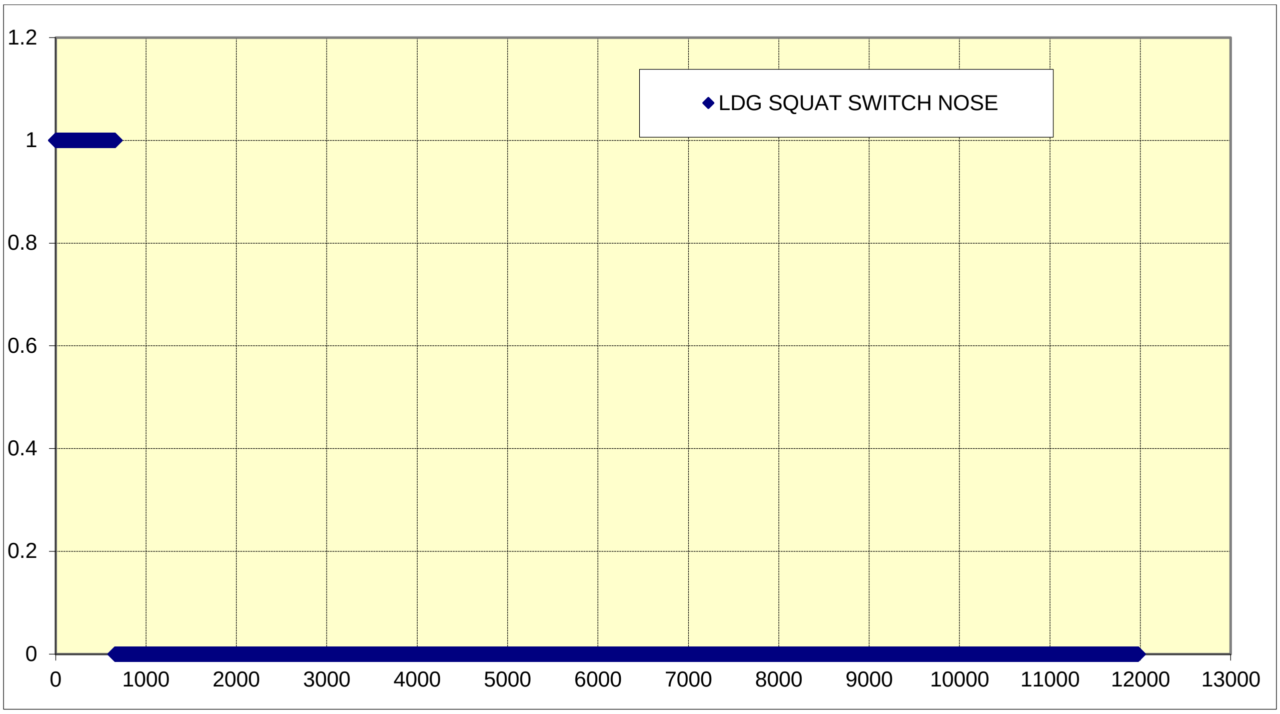
LDG LH Squat switch changed status from ground to flight at 21:21:10 UTC (661 seconds on the plot)

- LDG SQUAT SWITCH RH



LDG RH Squat switch changed status from ground to flight at 21:21:09 UTC (660 seconds on the plot)

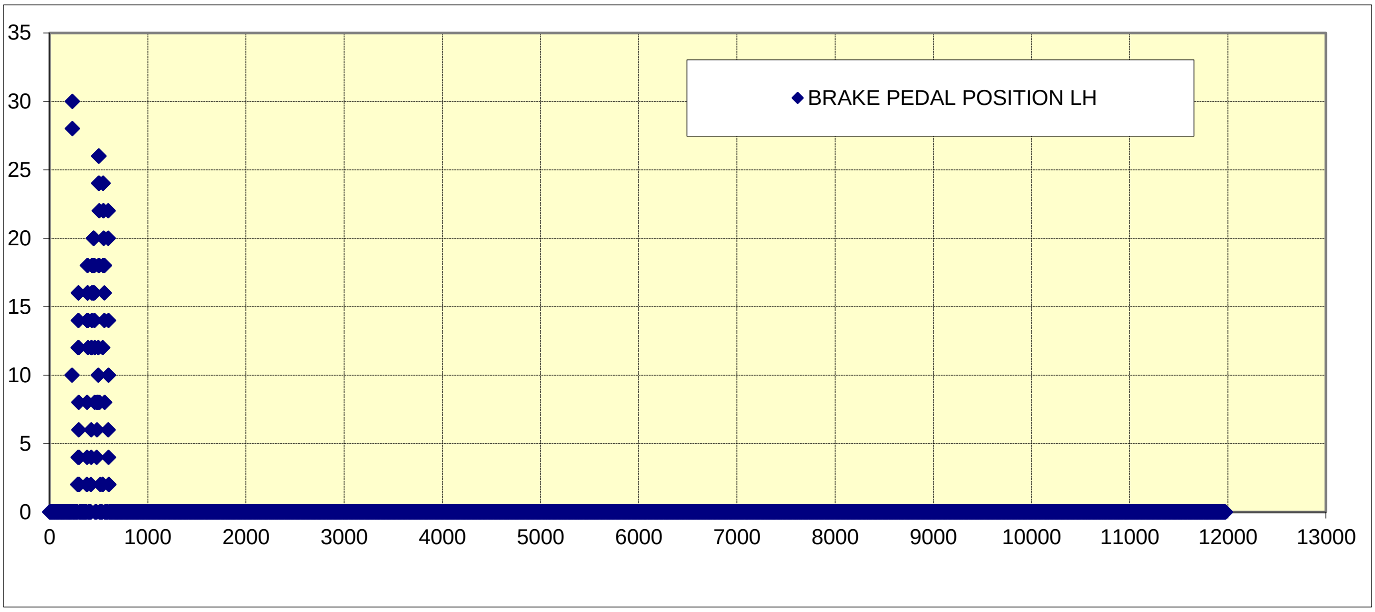
- LDG SQUAT SWITCH NOSE



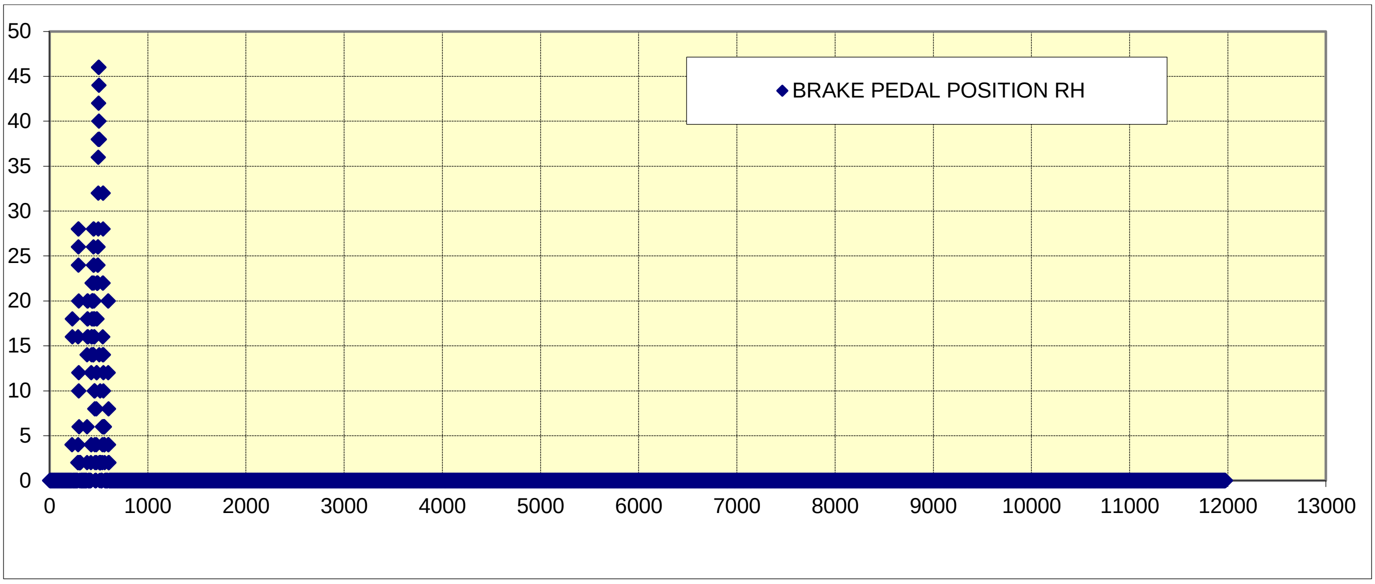
LDG NOSE Squat switch changed status from ground to flight at 21:21:06 UTC (657 seconds on the plot)

No anomalies detected with the landing gear position

- BRAKE PEDAL POSITION LH

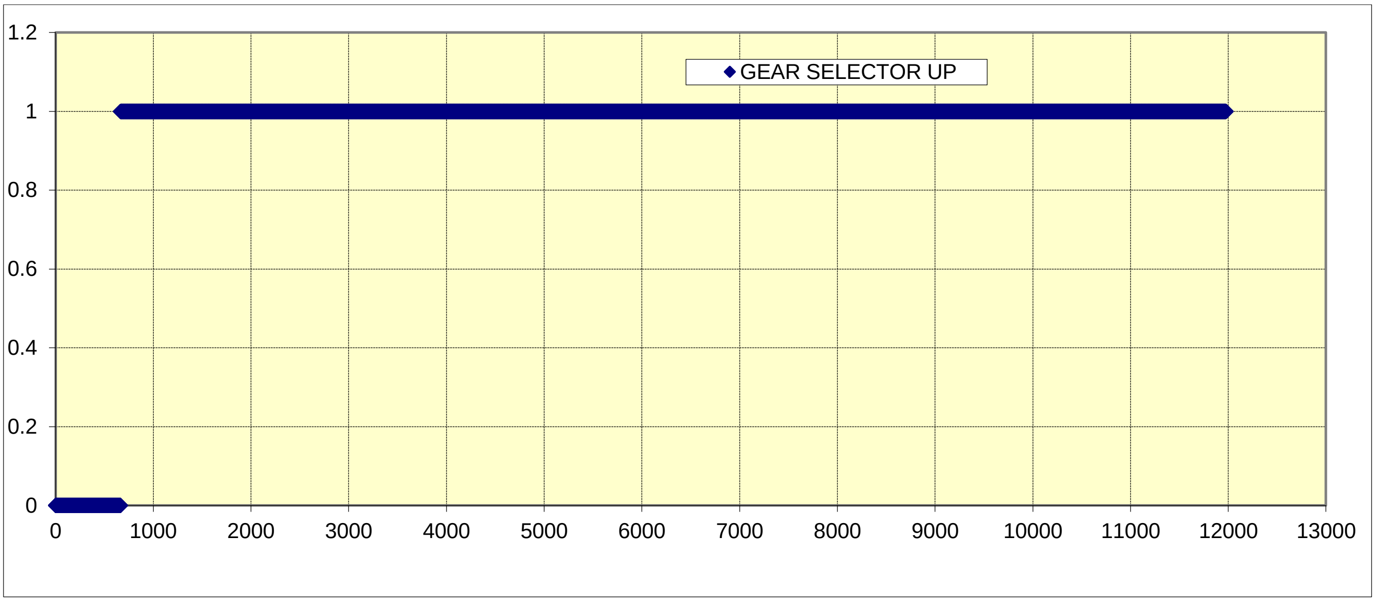


- BRAKE PEDAL POSITION RH



- GEAR SELECTOR UP

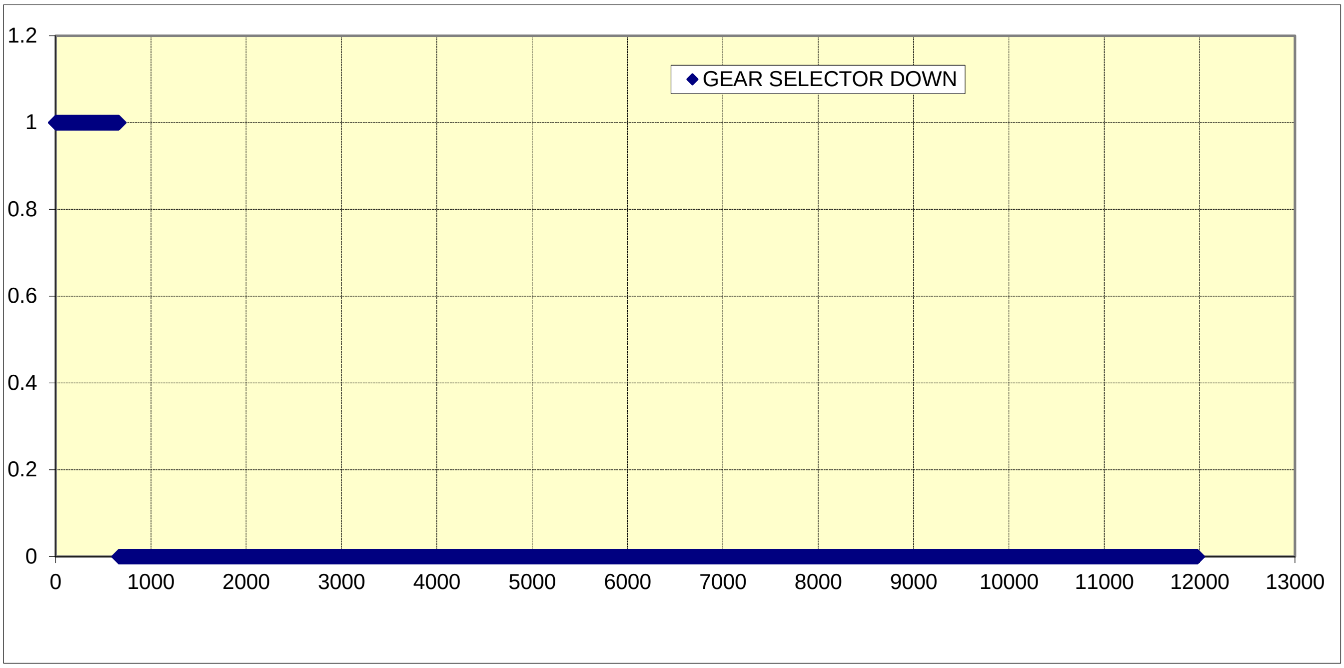
(1 selected up)



The L/G lever was selected up at 21:21:14 UTC (665 seconds on the plot)

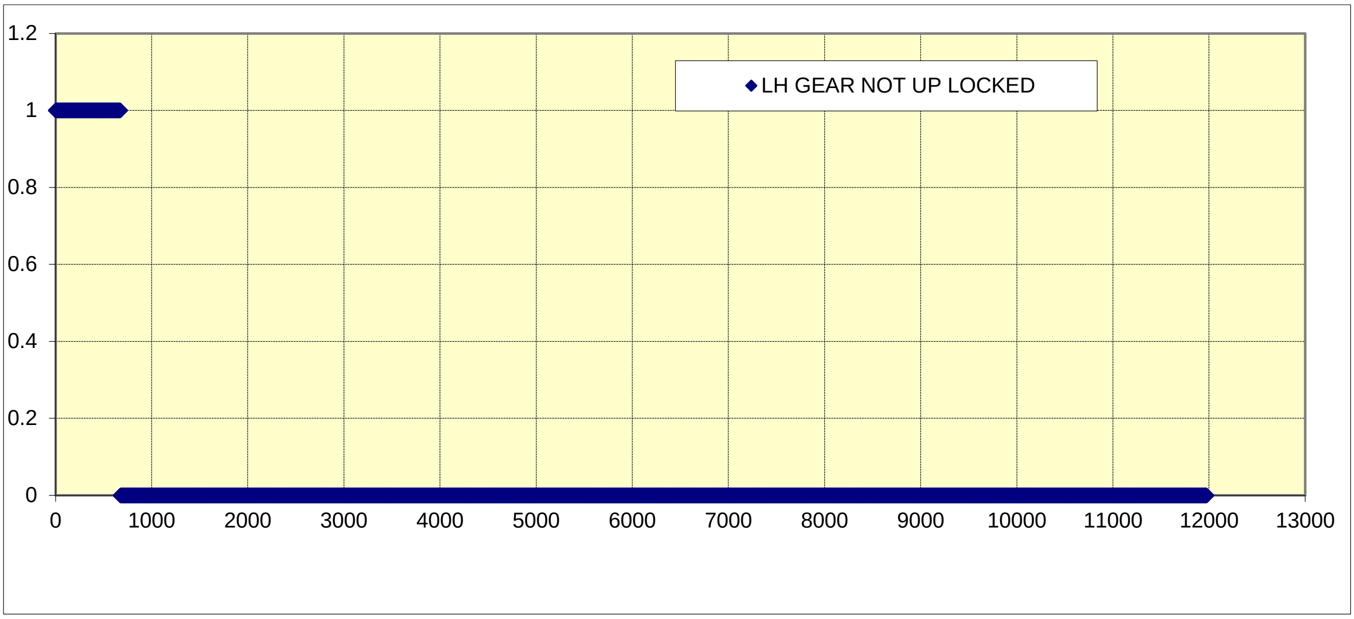
- GEAR SELECTOR DOWN

(1 Selected Down)



- LH GEAR NOT UP LOCKED

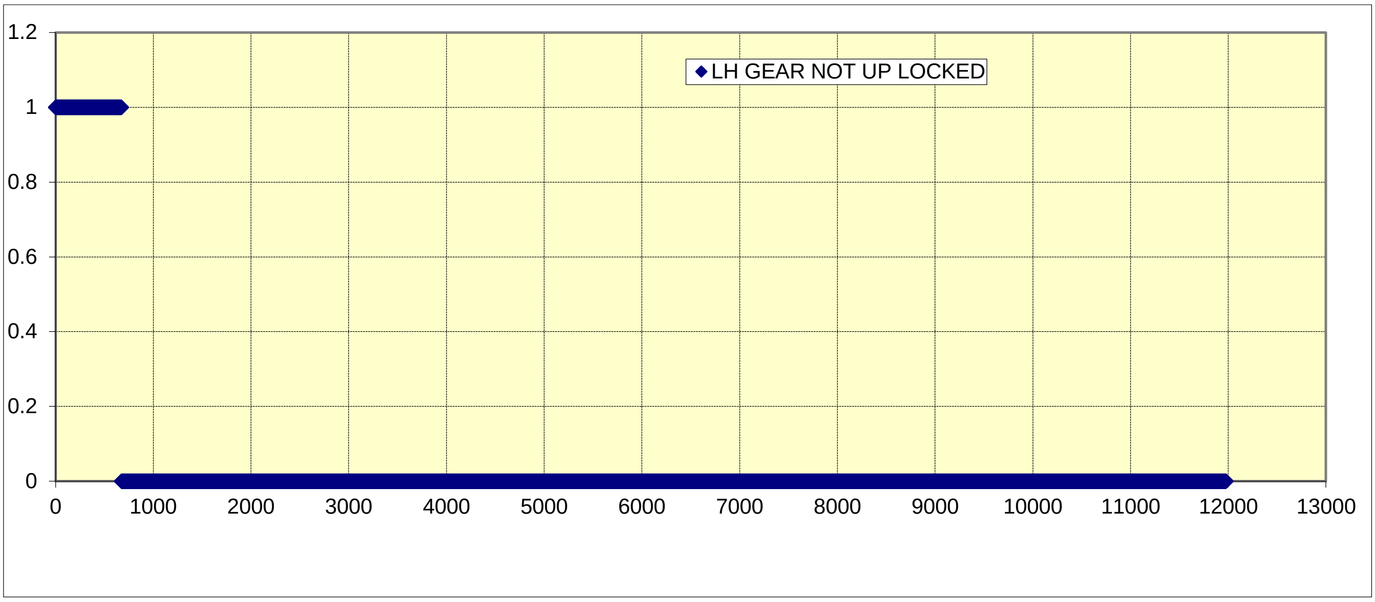
(1 not up locked)



- LH GEAR DOWN LOCKED

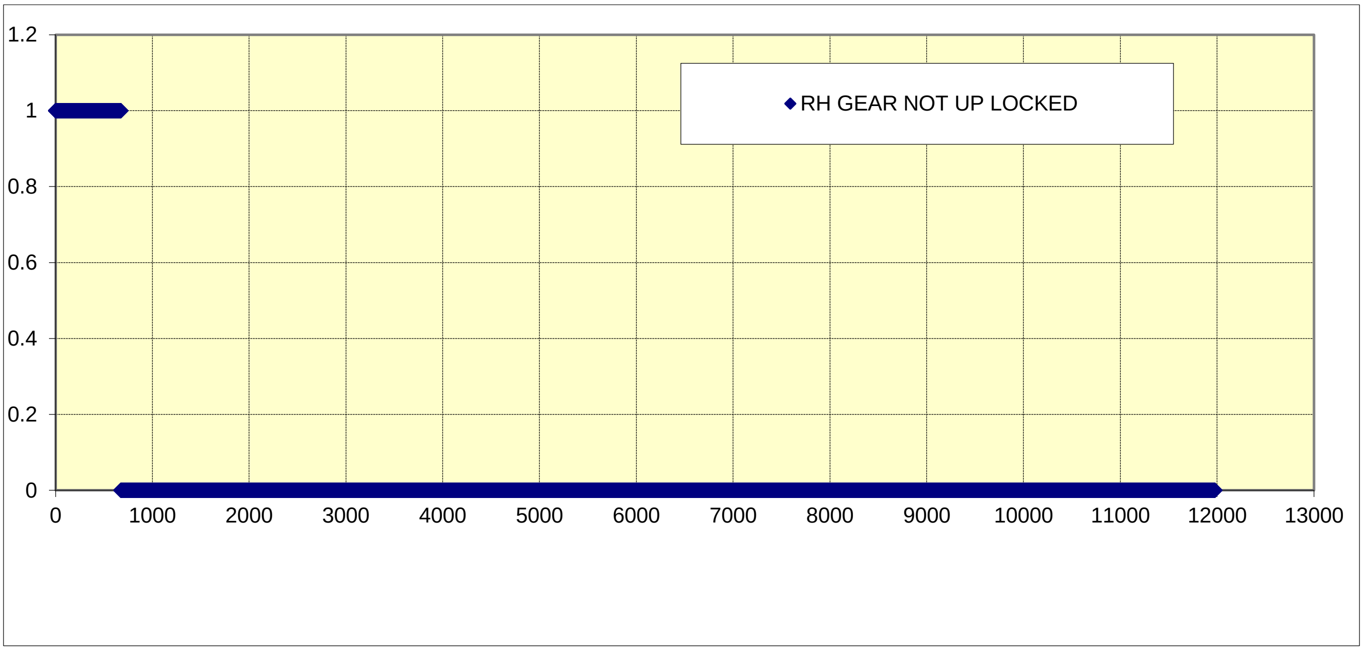
(Ref 2)

(1 down locked)



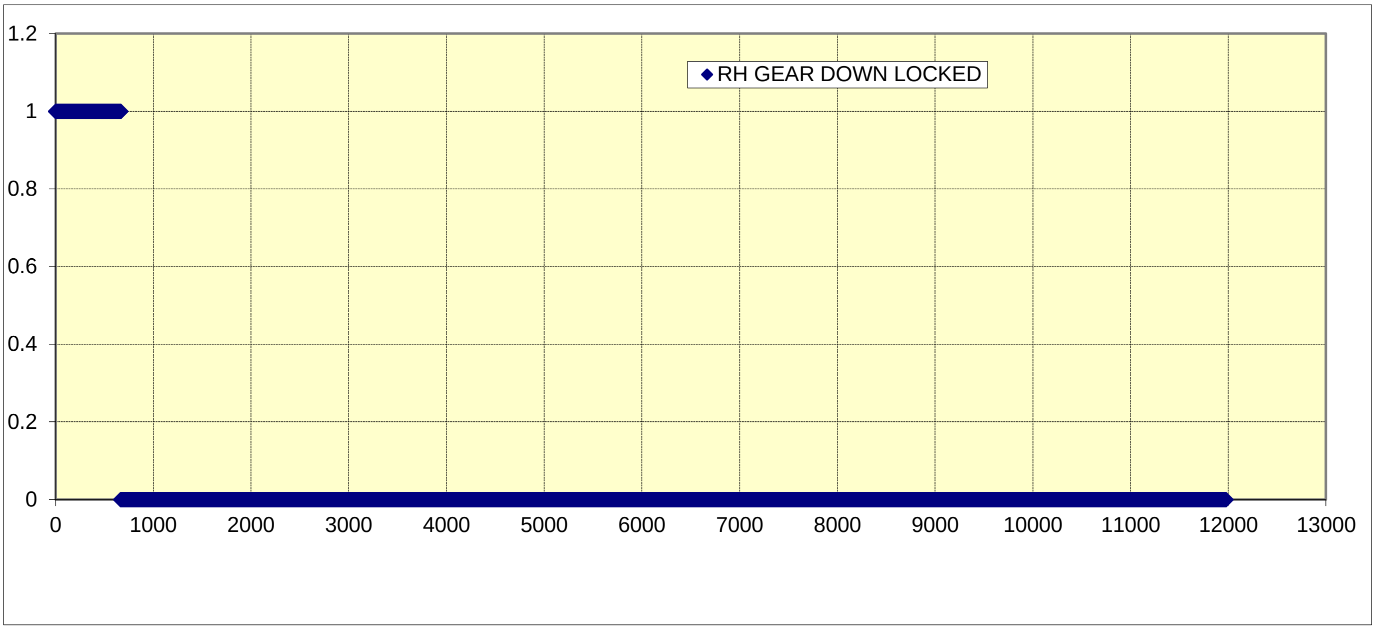
- RH GEAR NOT UP LOCKED

(1 not up locked)



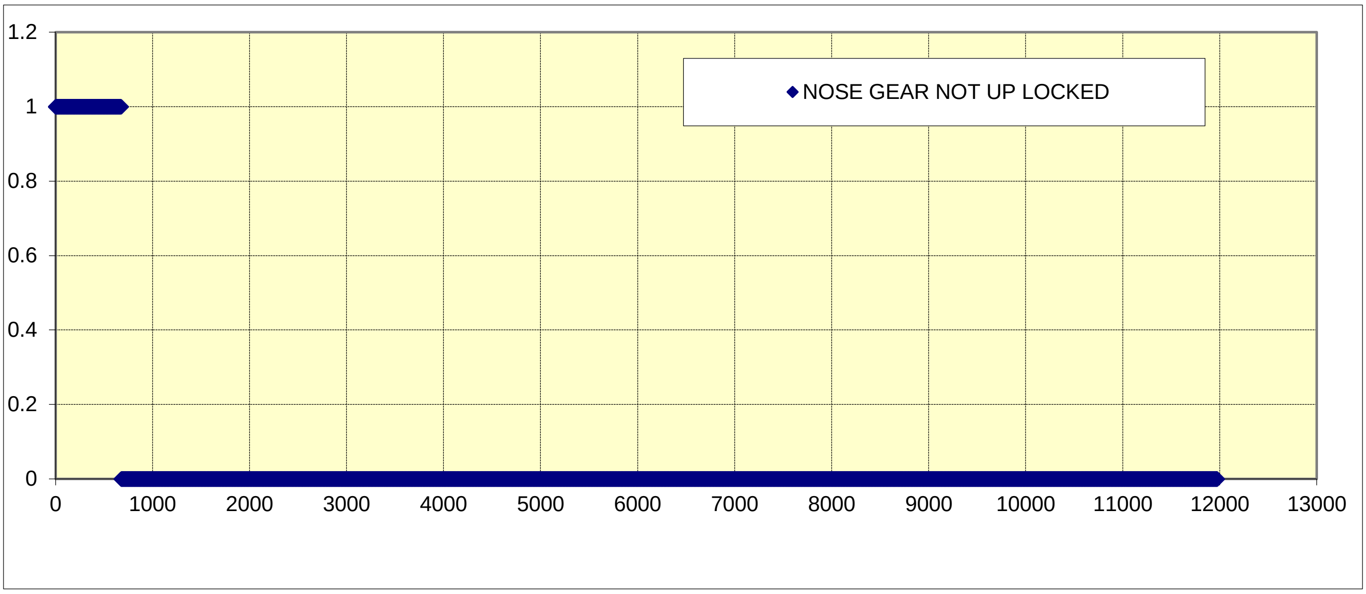
- RH GEAR DOWN LOCKED

(1 Down locked)



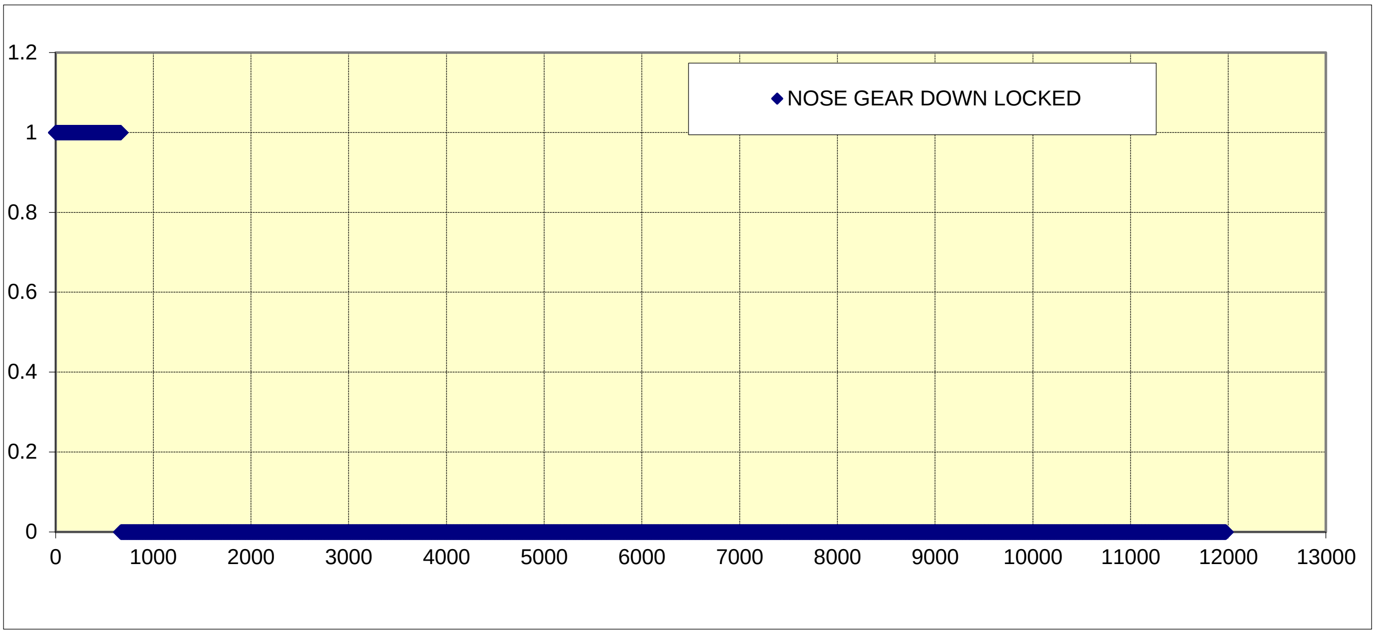
- NOSE GEAR NOT UP LOCKED

(1 not up locked)

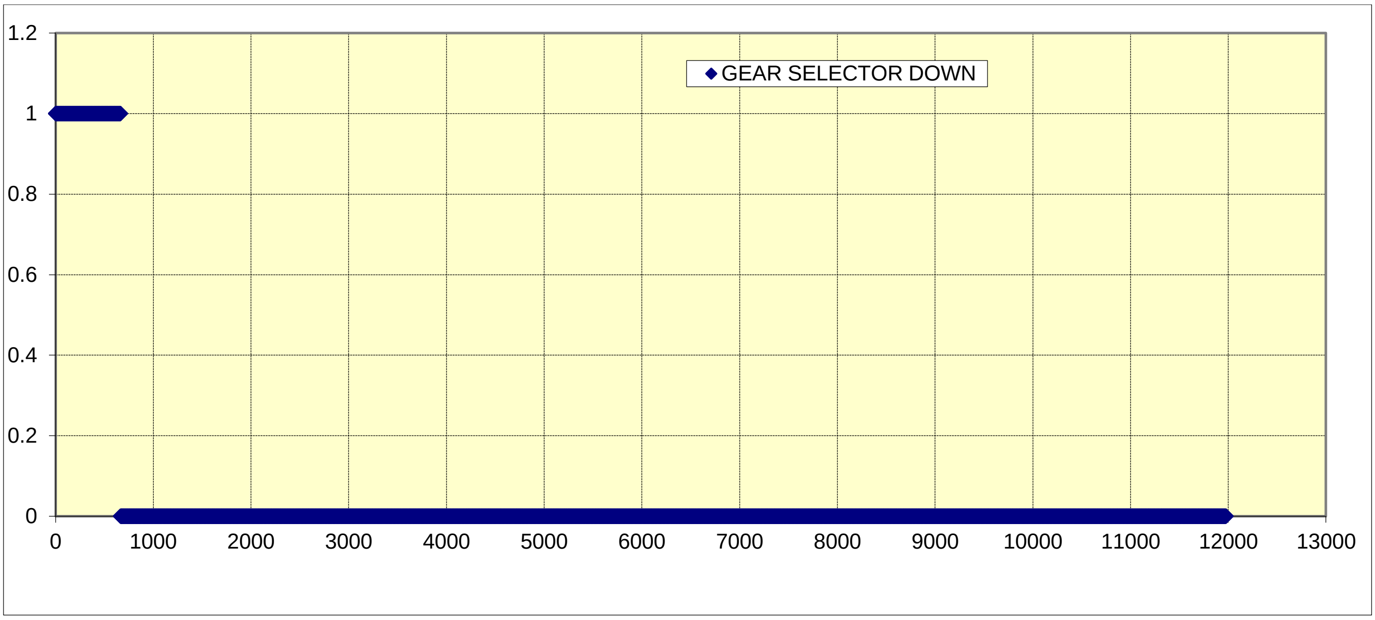


- NOSE GEAR DOWN LOCKED

(1 Down locked)



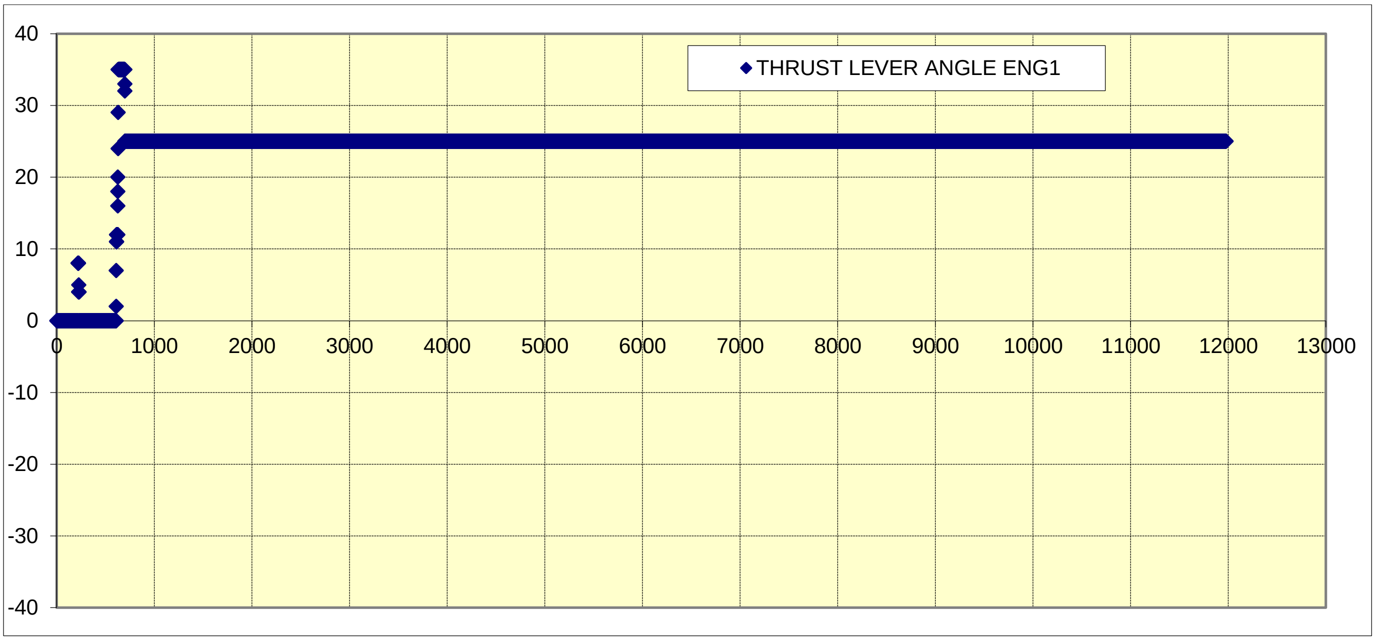
- GEAR SELECTED DOWN



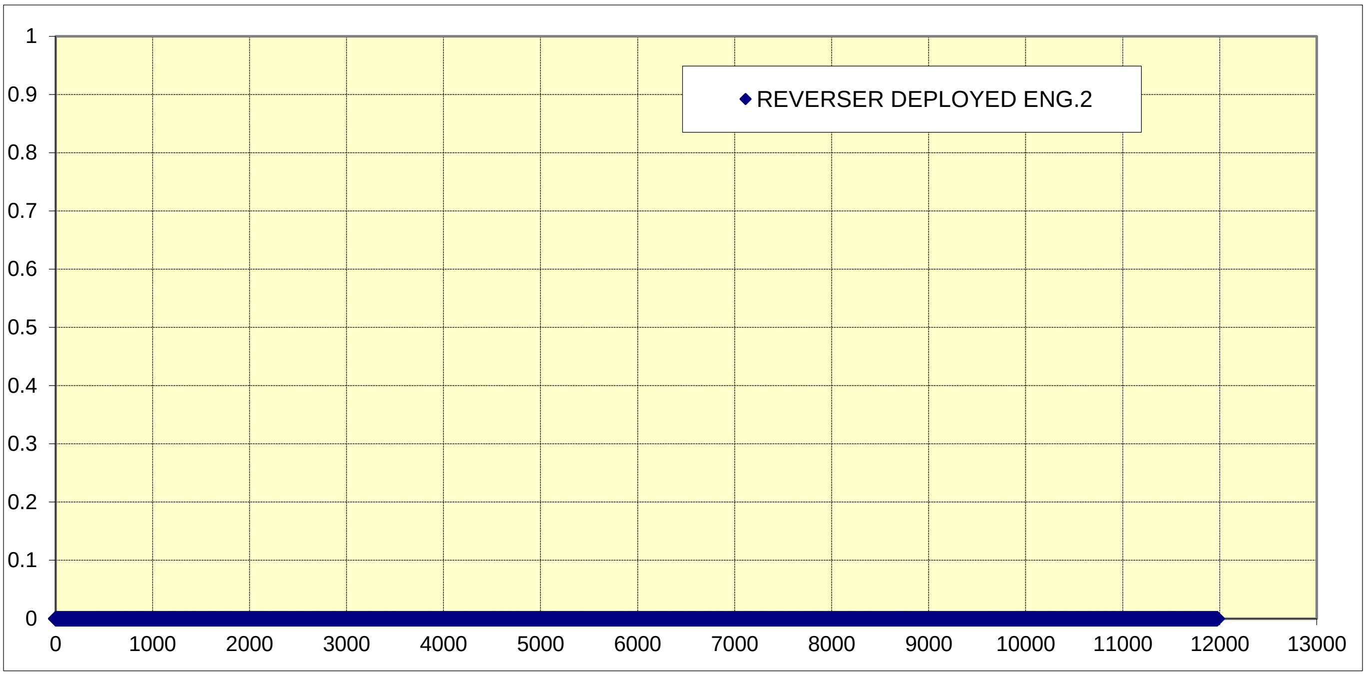
10 Engines

- THRUST LEVER ANGLE ENG1

  (Ref 2)

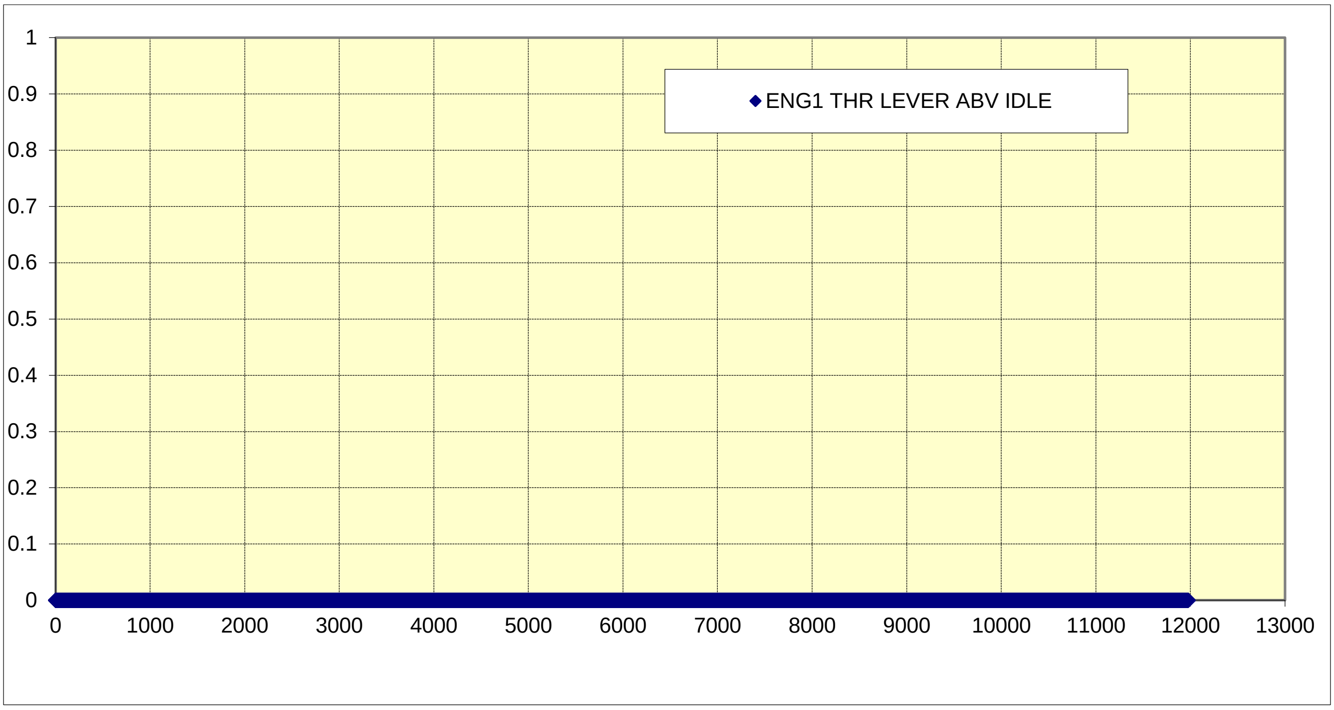


- REVERSER DEPLOYED ENG2



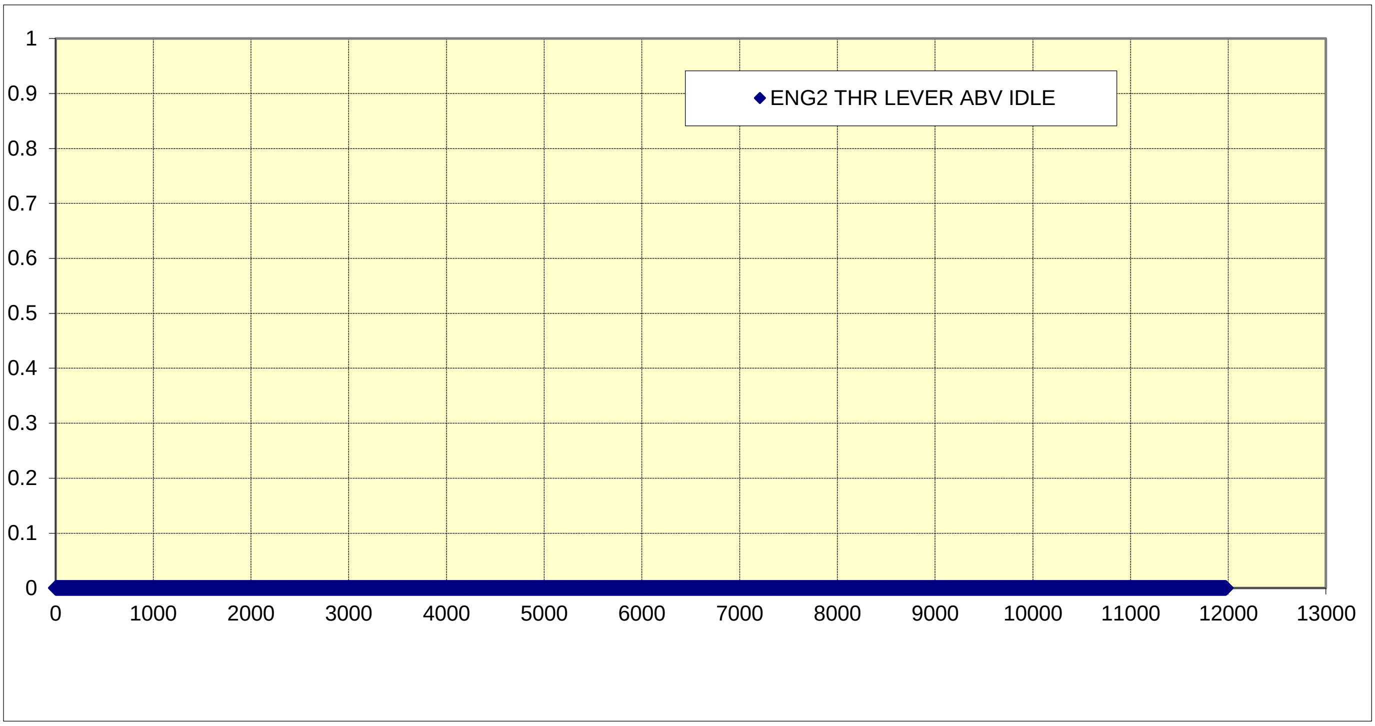
- ENG1 THR LEVER ABV IDLE

(0 Thrust lever above idle)

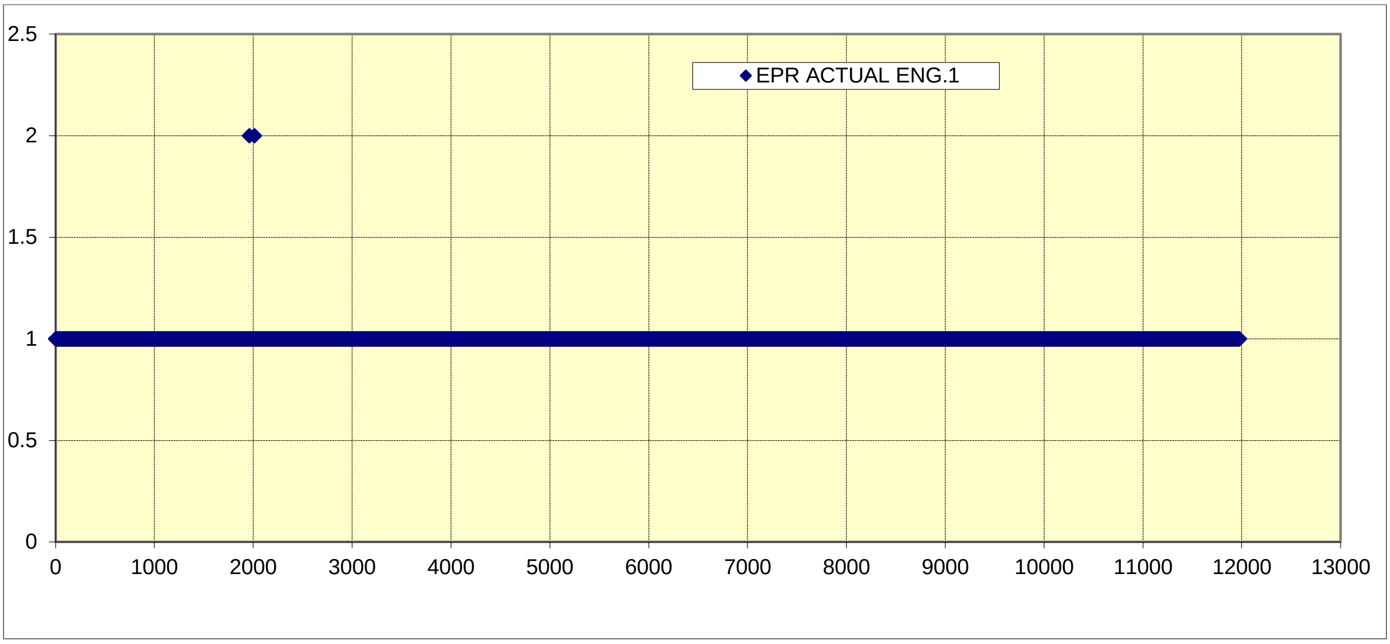


- ENG2 THR LEVER ABV IDLE

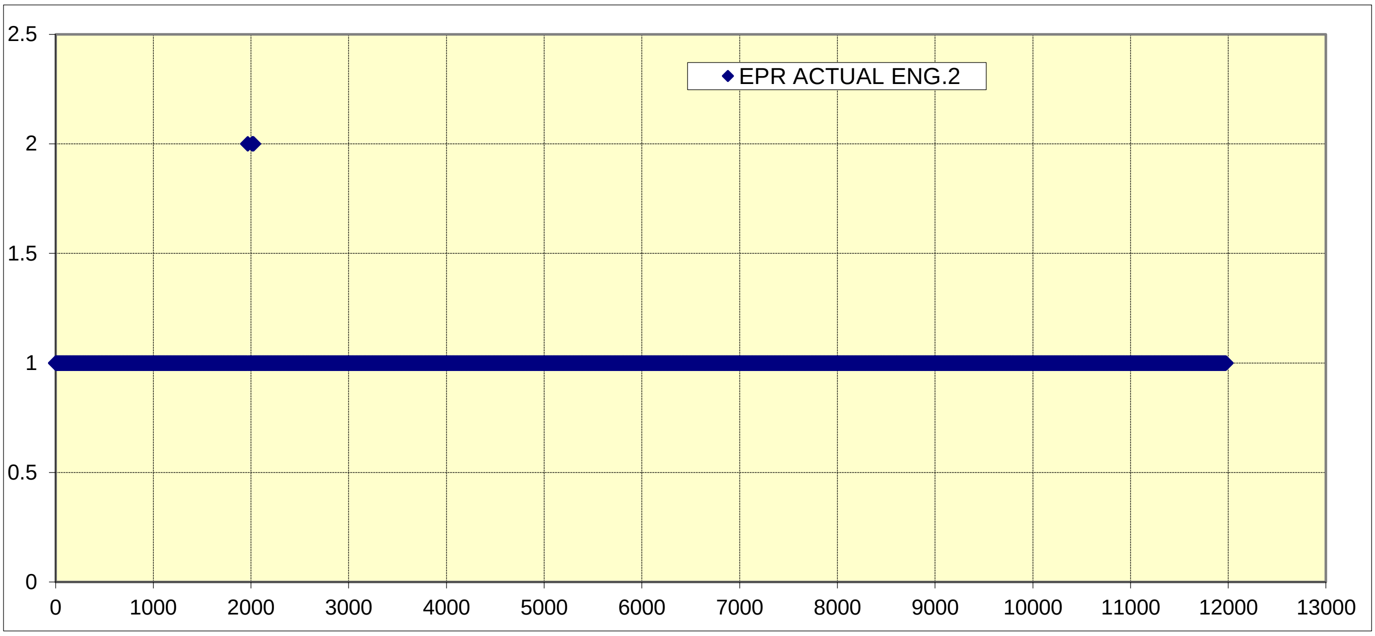
(0 Thrust lever above idle)



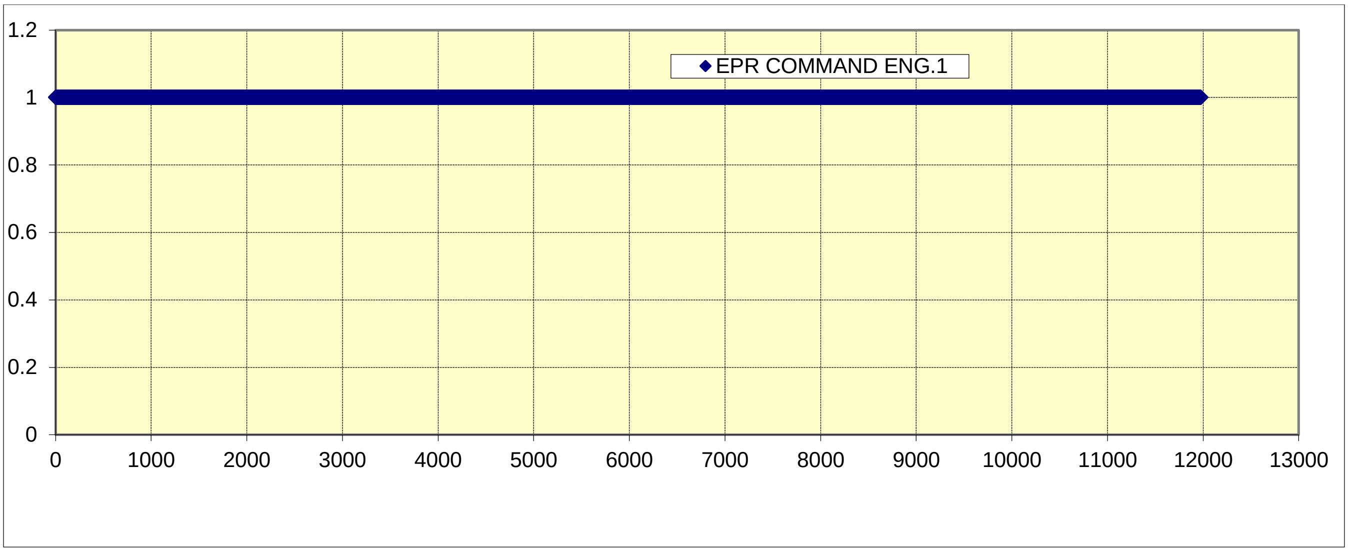
- EPR ACTUAL ENG.1



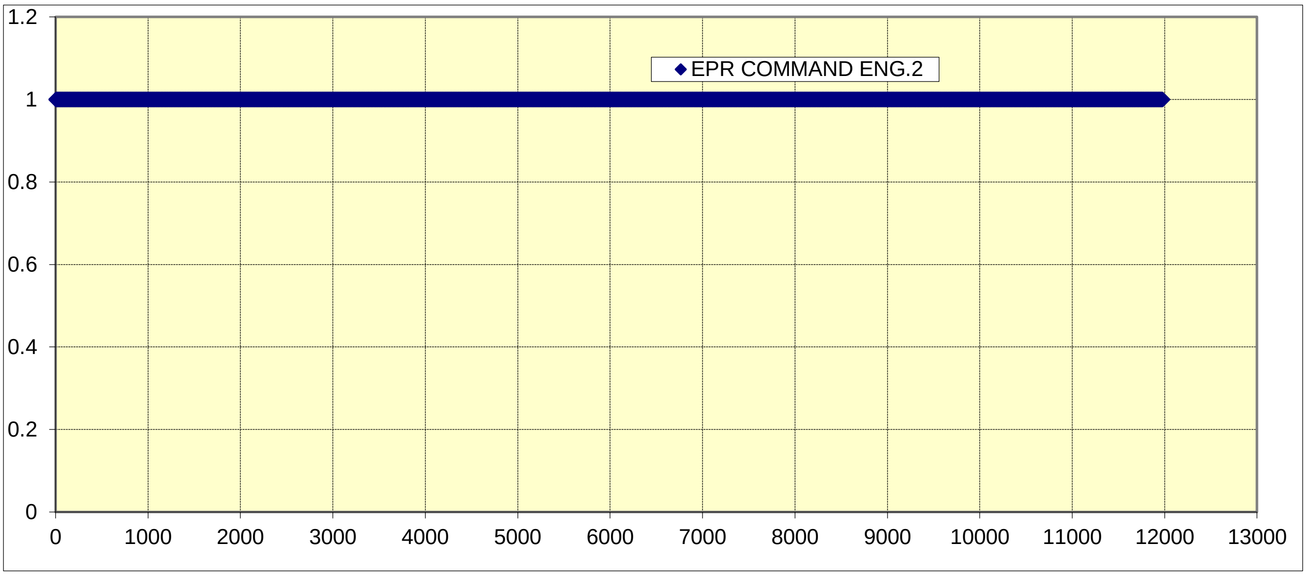
- EPR ACTUAL ENG.2



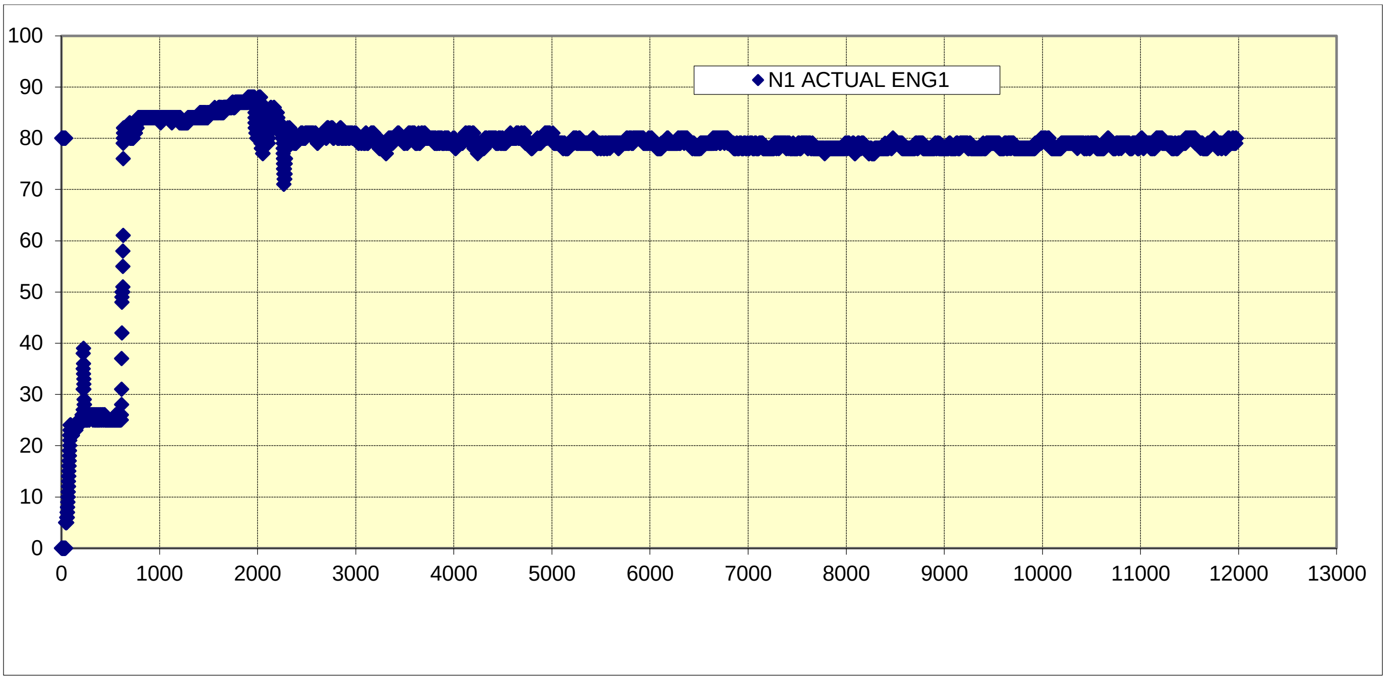
- EPR COMMAND ENG.1



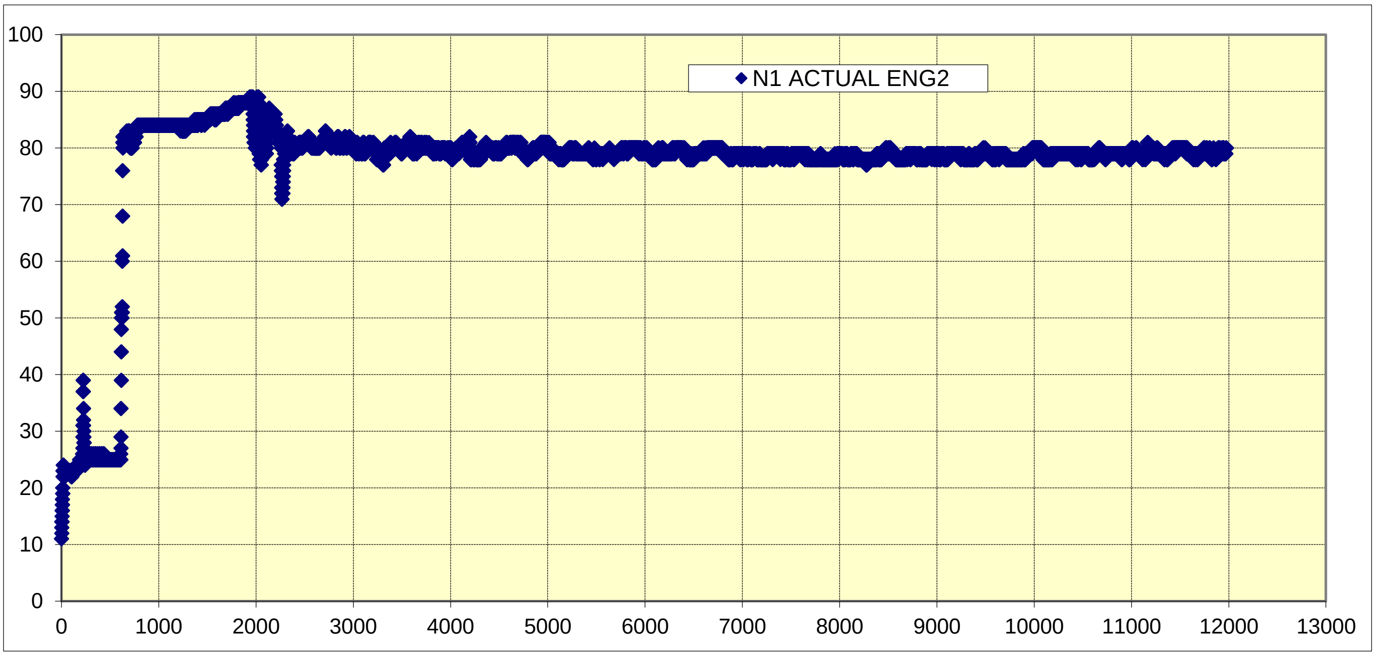
- EPR COMMAND ENG.2



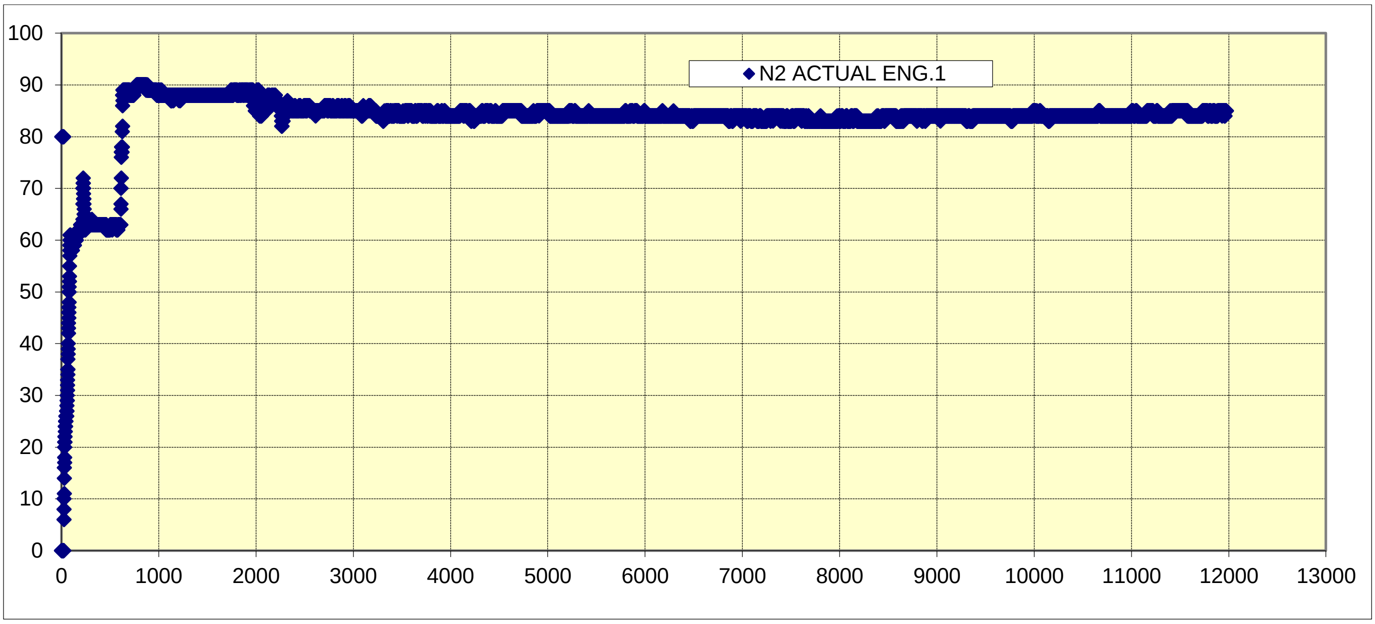
- N1 ACTUAL ENG1



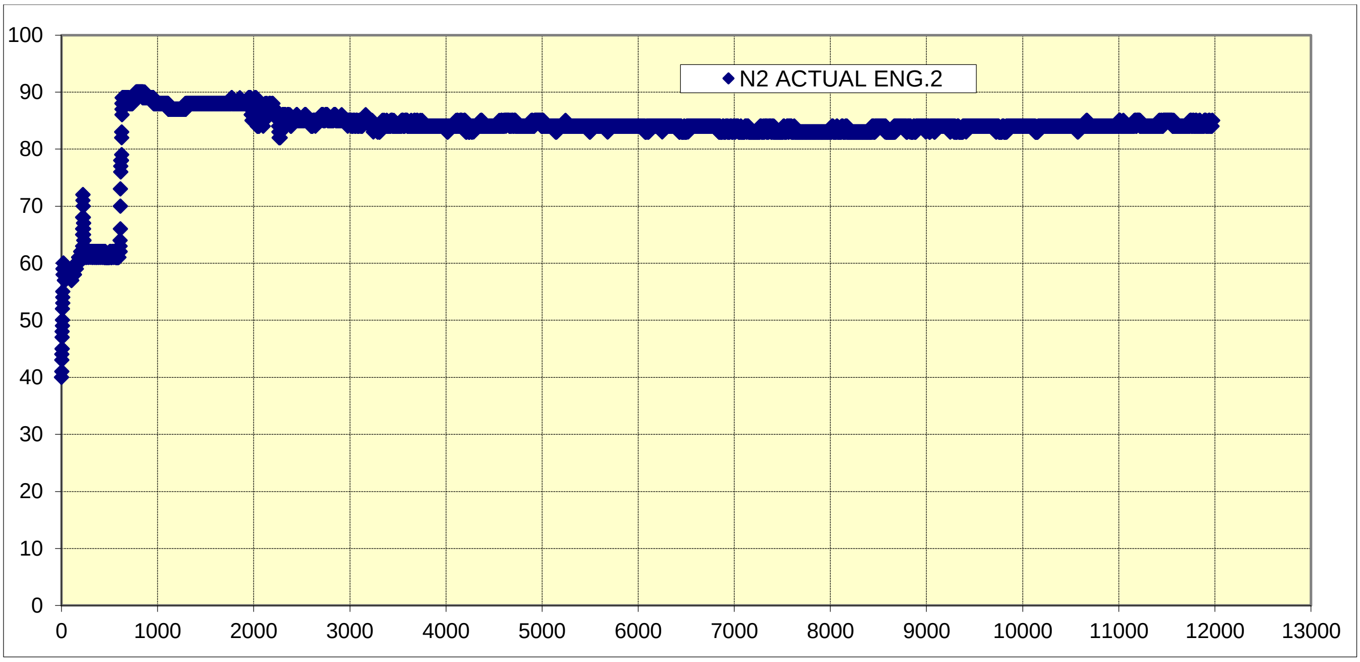
- N1 ACTUAL ENG2



- N2 ACTUAL ENG.1

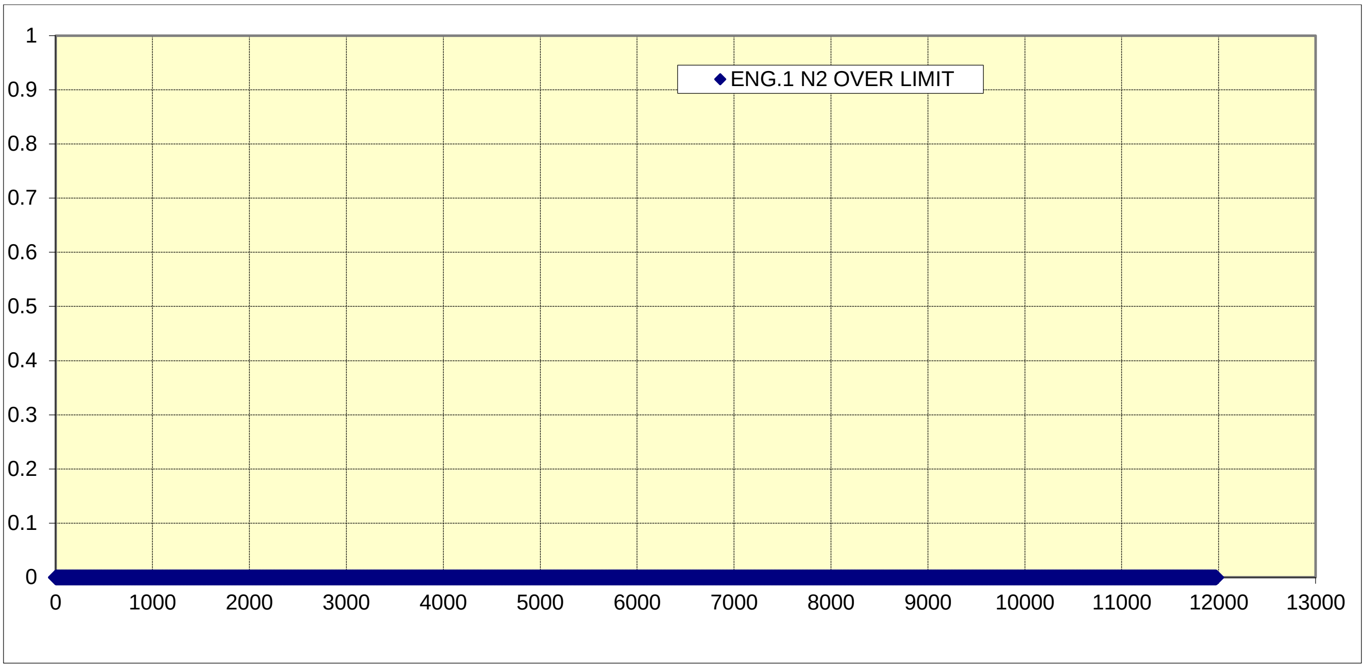


- N2 ACTUAL ENG.2



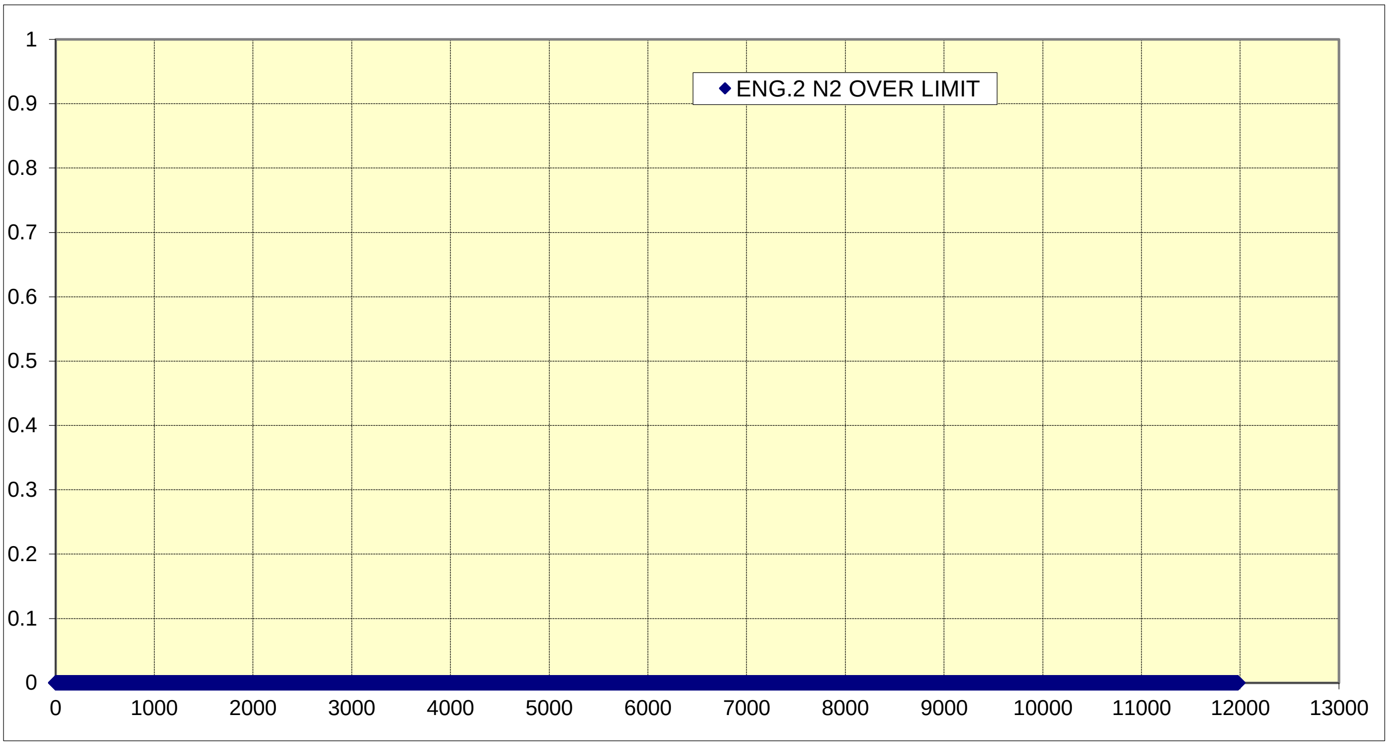
– ENG.1 N2 OVER LIMIT

(1 Overlimit)

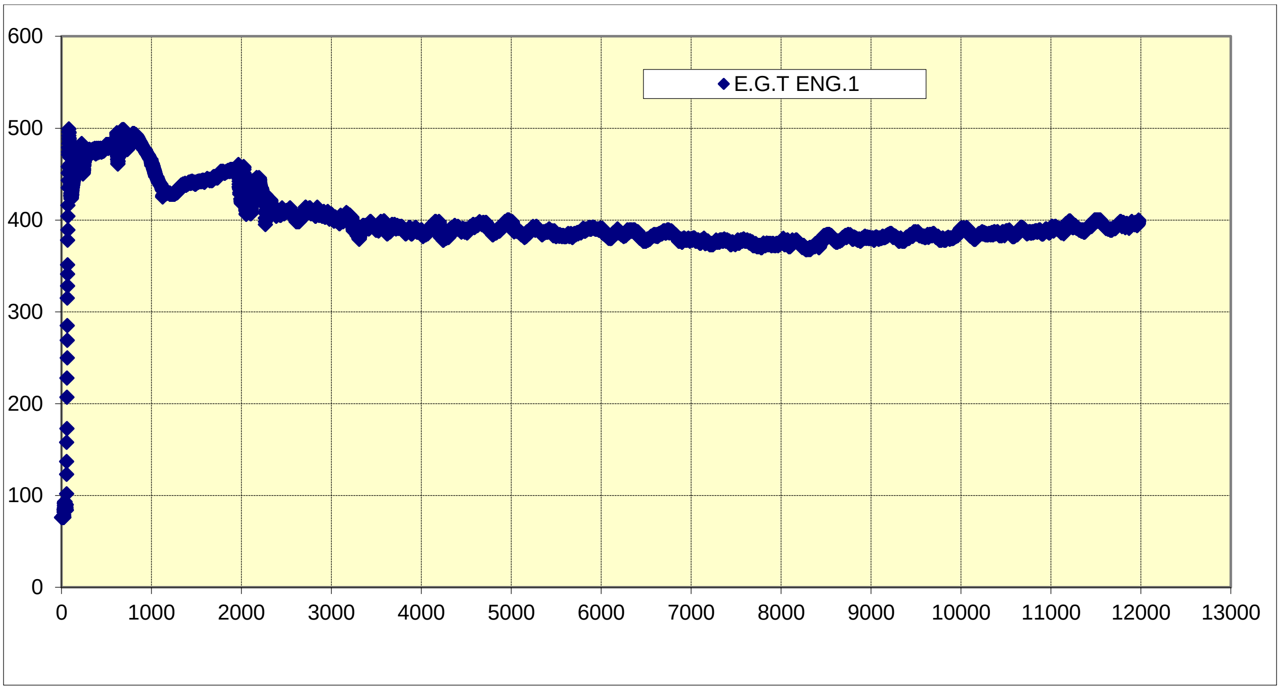


- ENG.2 N2 OVER LIMIT

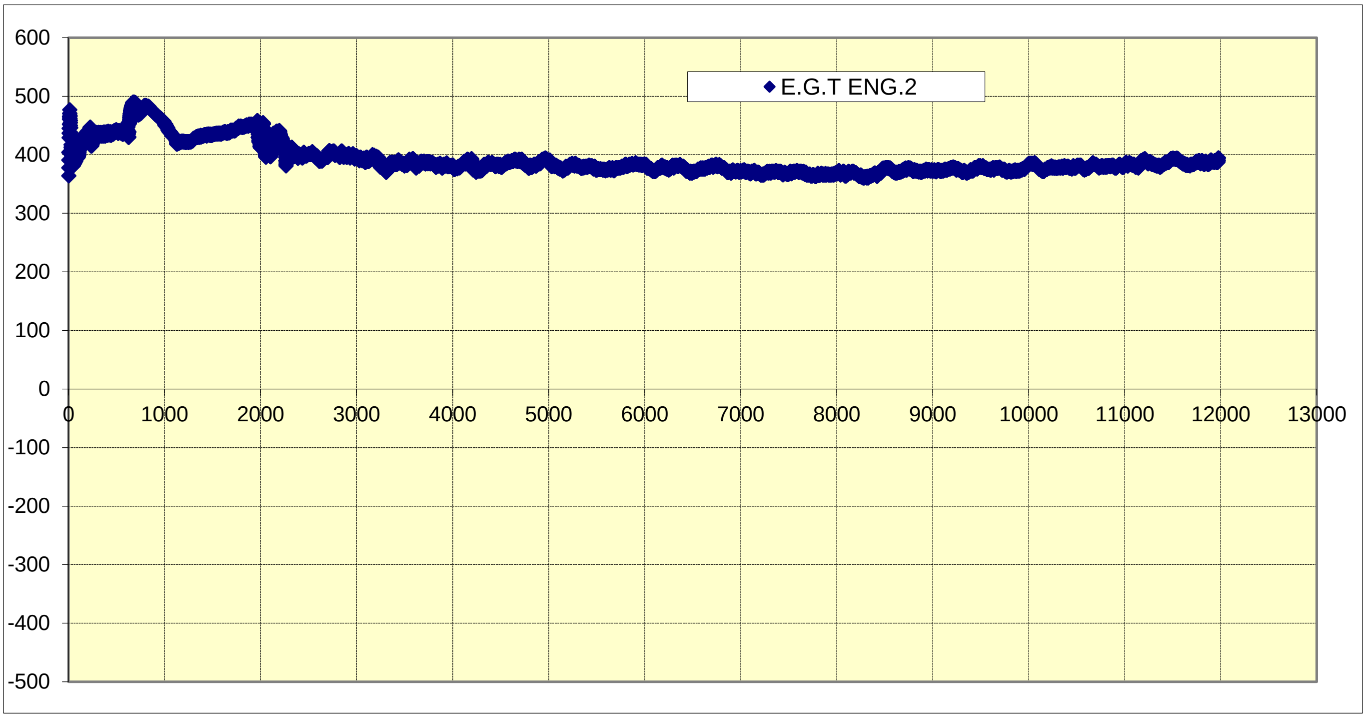
(1 Overlimit)



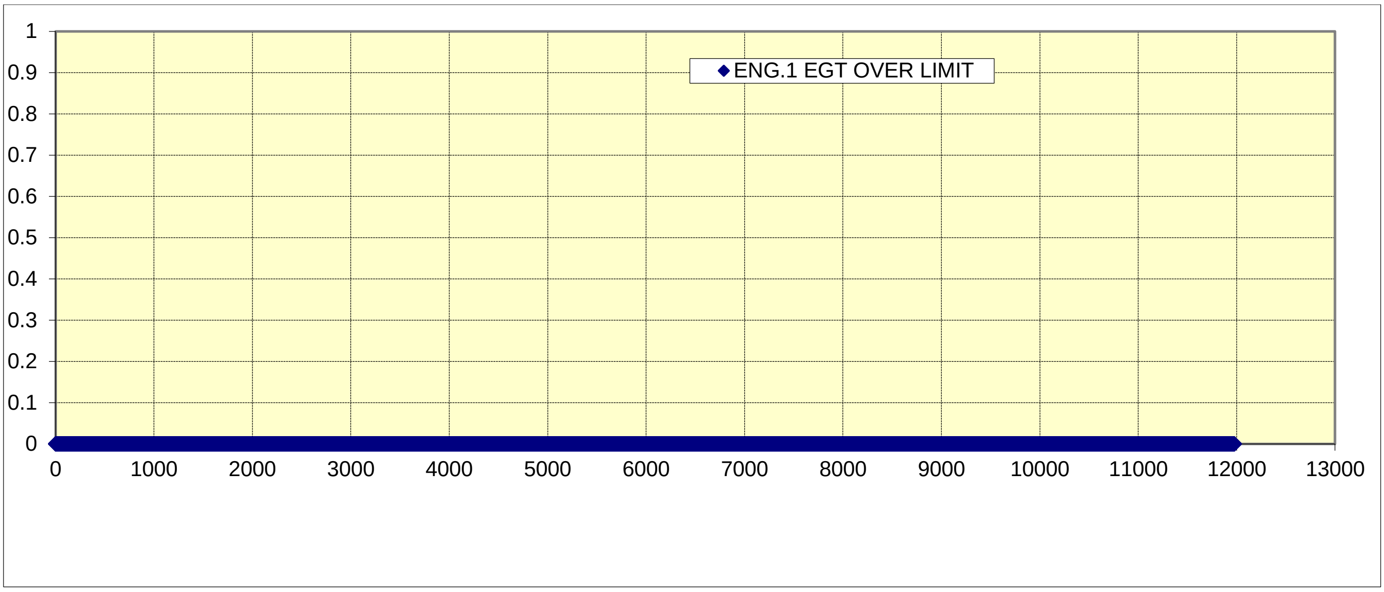
- EGT ENG.1



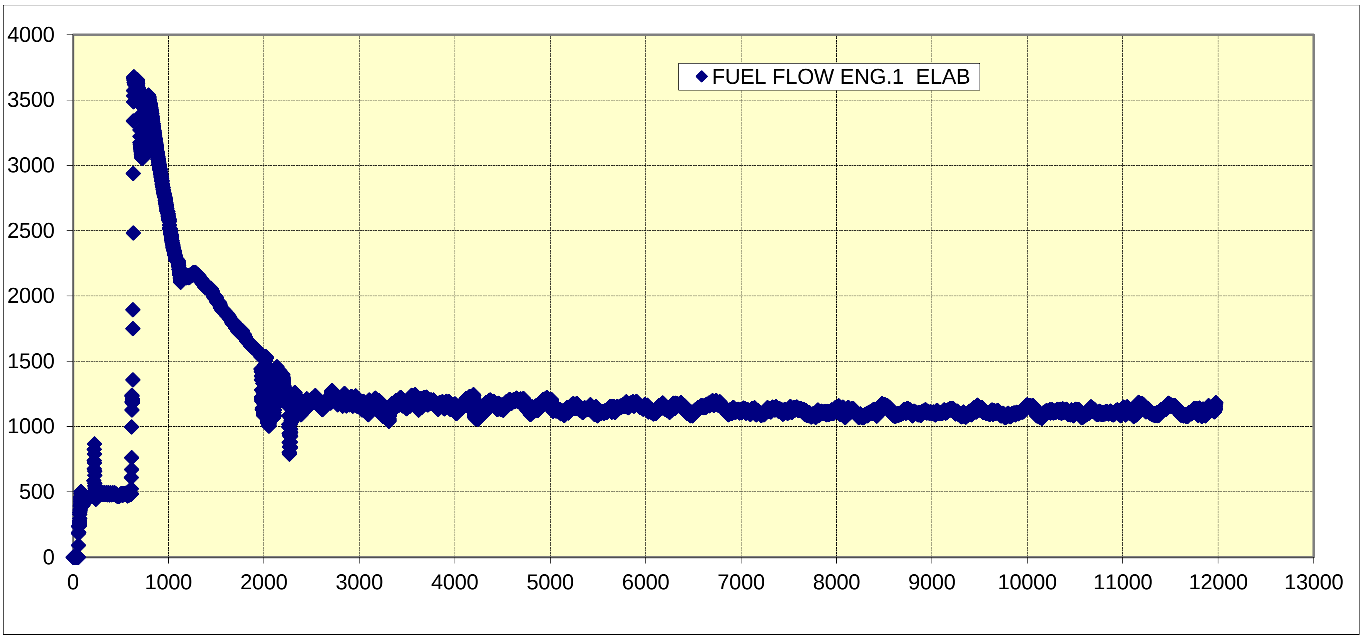
(2 - EGT ENG.2



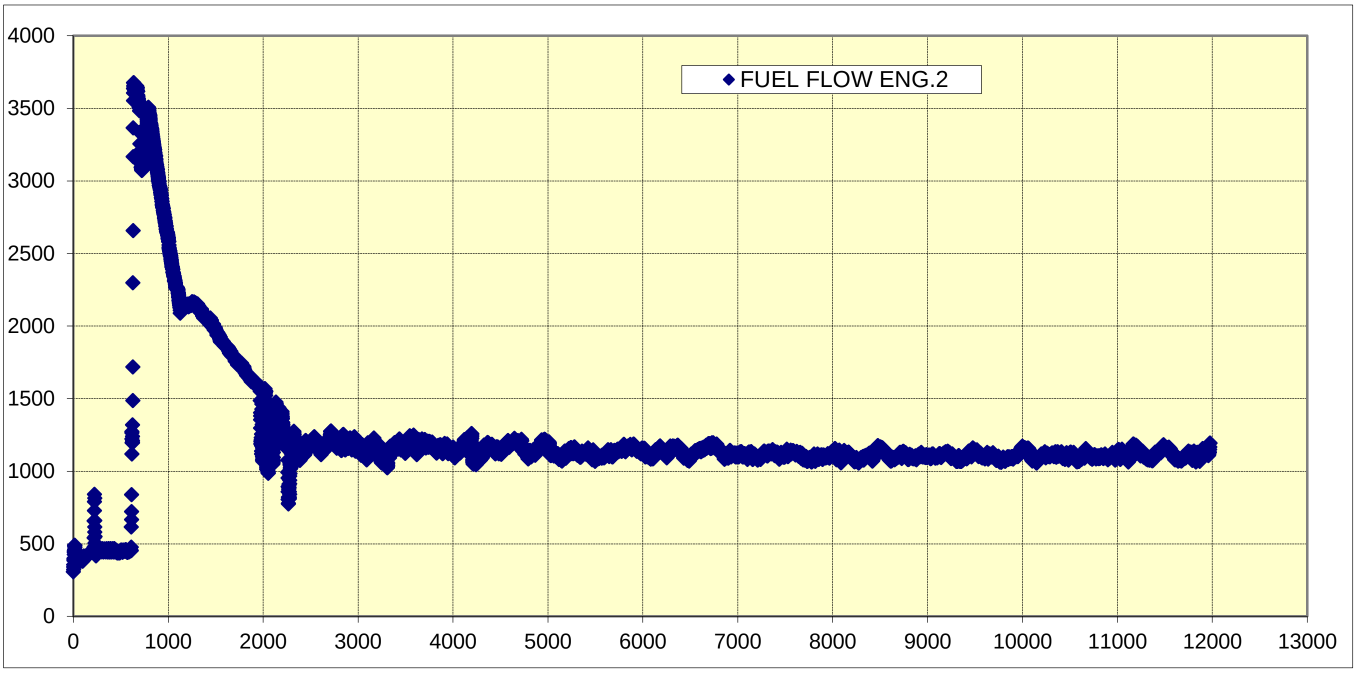
(3 - ENG.1 EGT OVER LIMIT



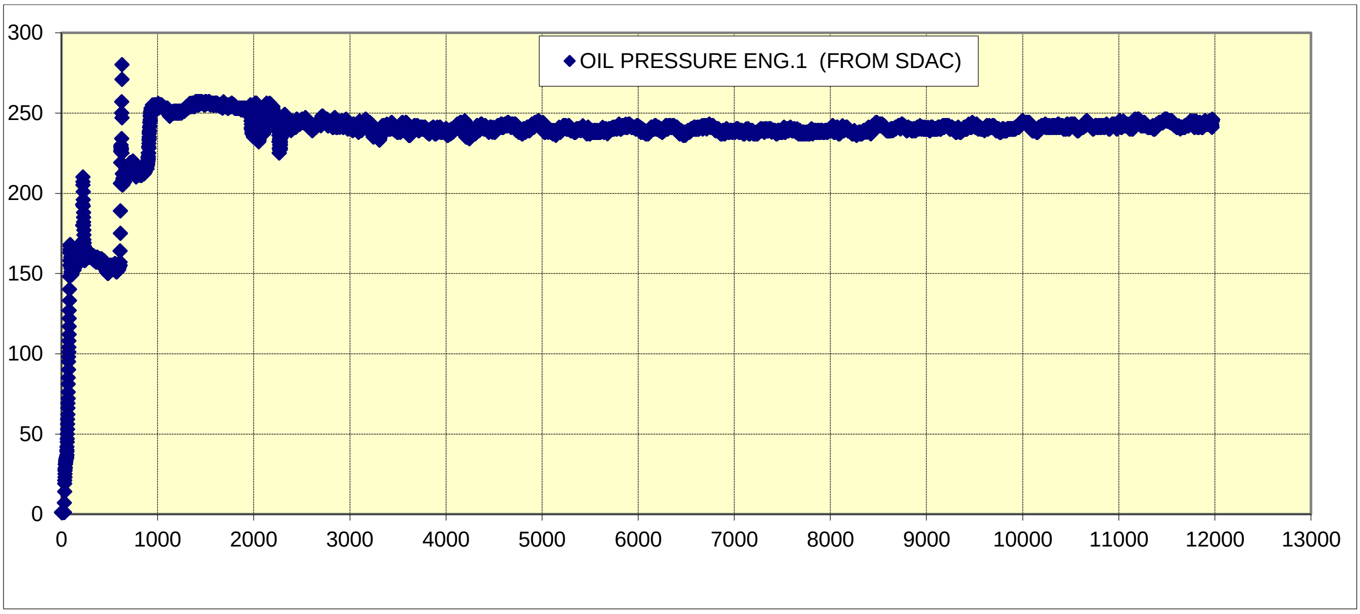
(4 - FUEL FLOW ENG.1 ELAB



– FUEL FLOW ENG.2

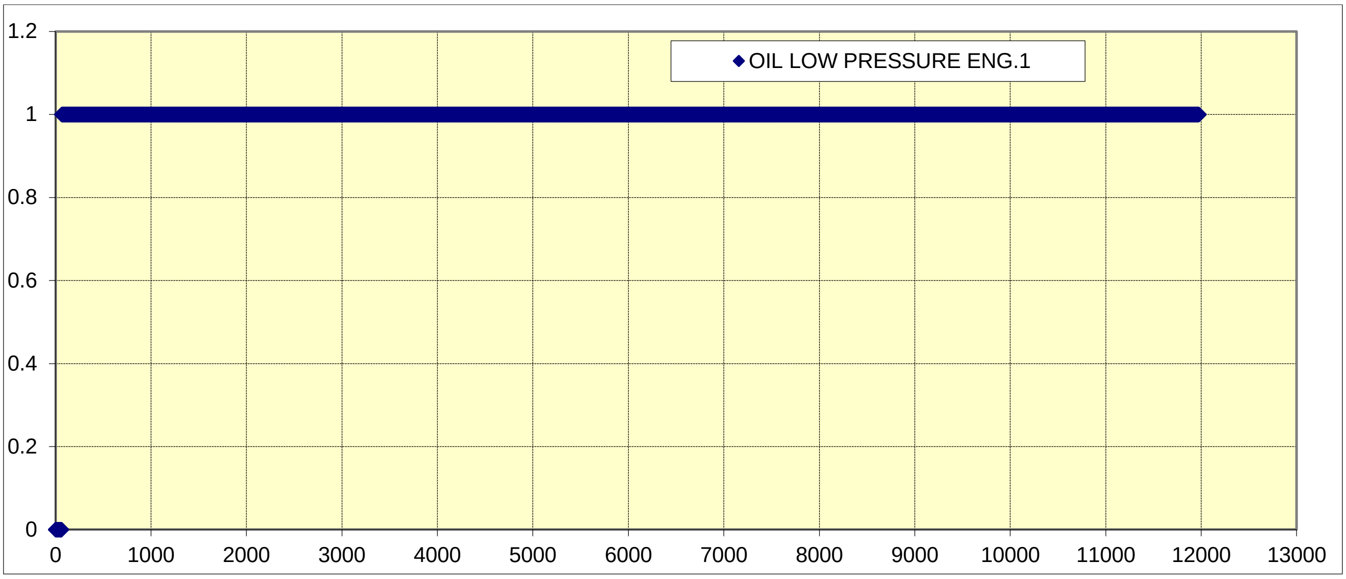


(5 - OIL PRESSURE ENG.1 (FROM SDAC) (System Data Acquisition Concentrator)



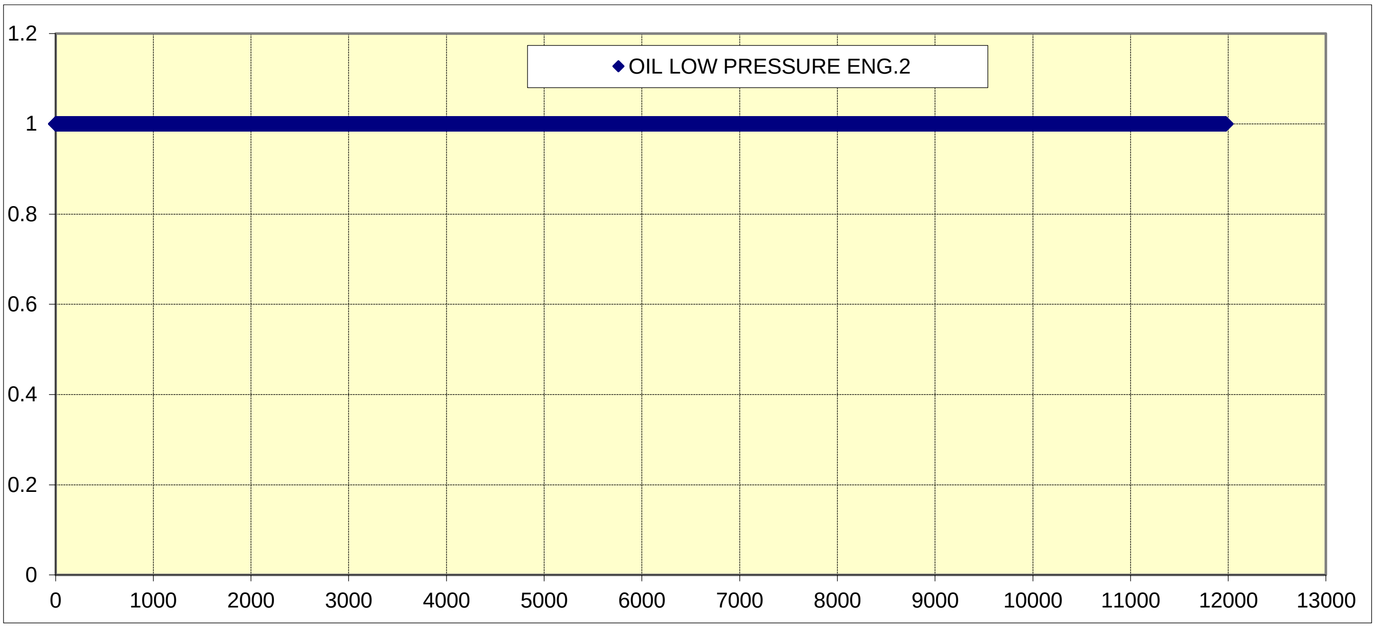
– OIL LOW PRESSURE ENG.1

(0 Low pressure)

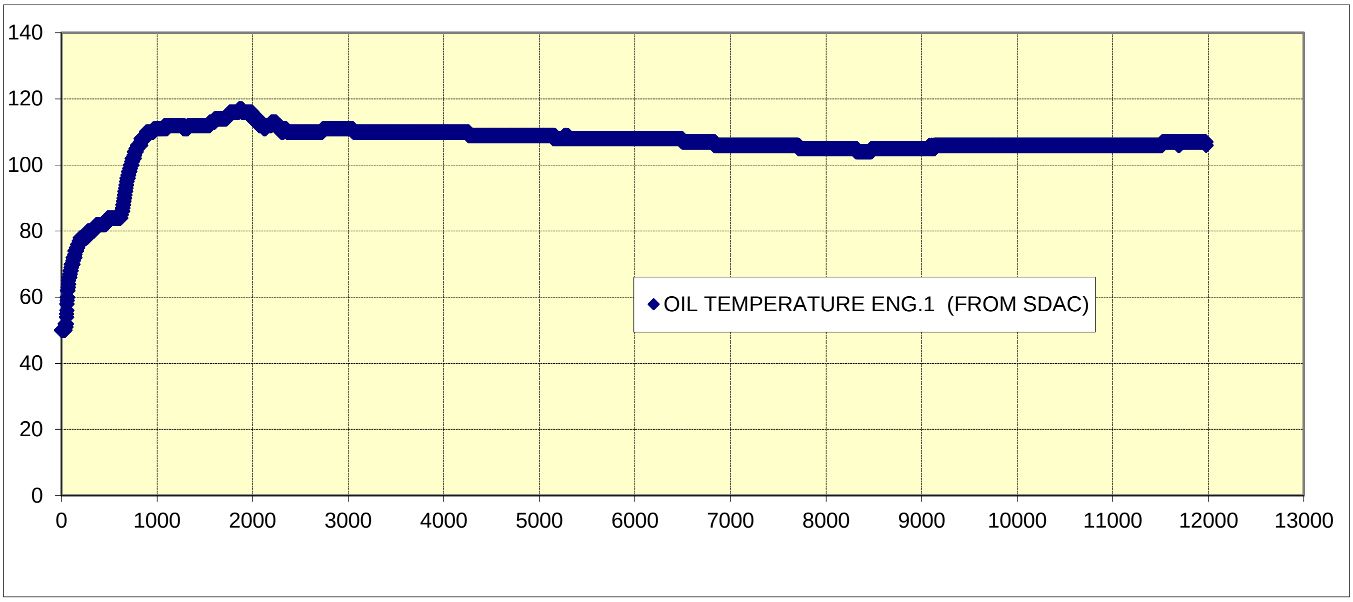


- OIL LOW PRESSURE ENG.2

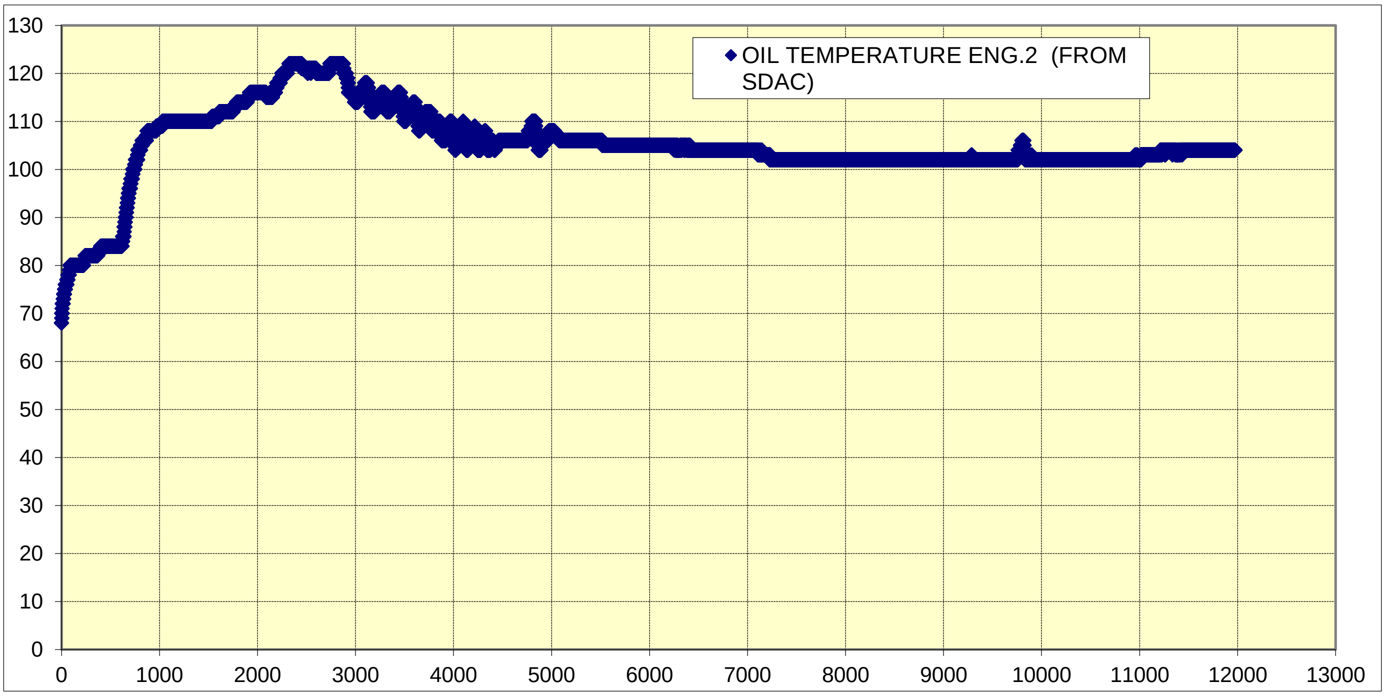
(0 Low pressure)



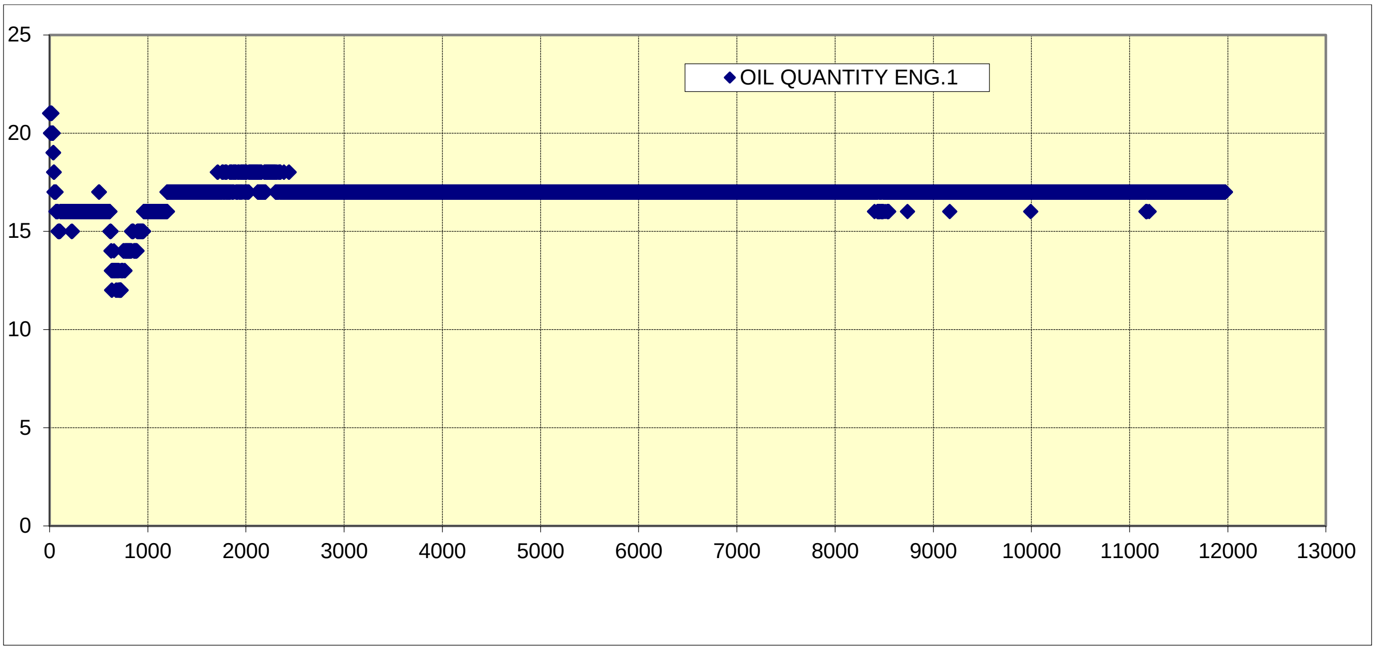
(1 - OIL TEMPERATURE ENG.1 (FROM SDAC) (System Data Acquisition Concentrator)



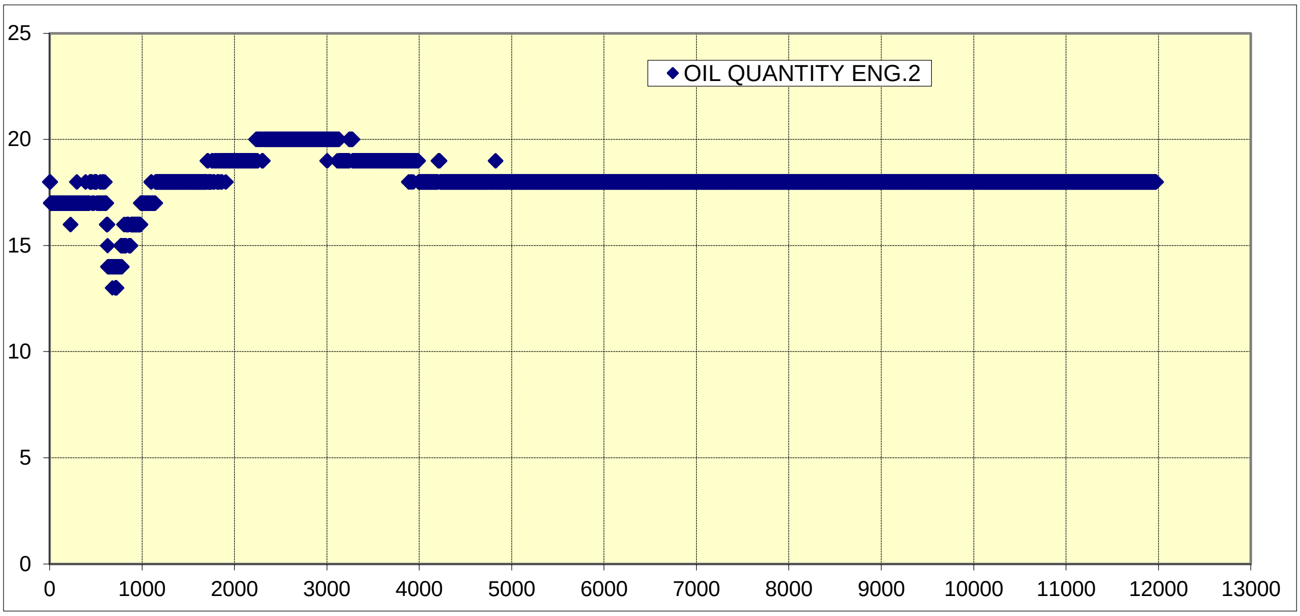
(2 - OIL TEMPERATURE ENG.2 (FROM SDAC) (System Data Acquisition Concentrator)



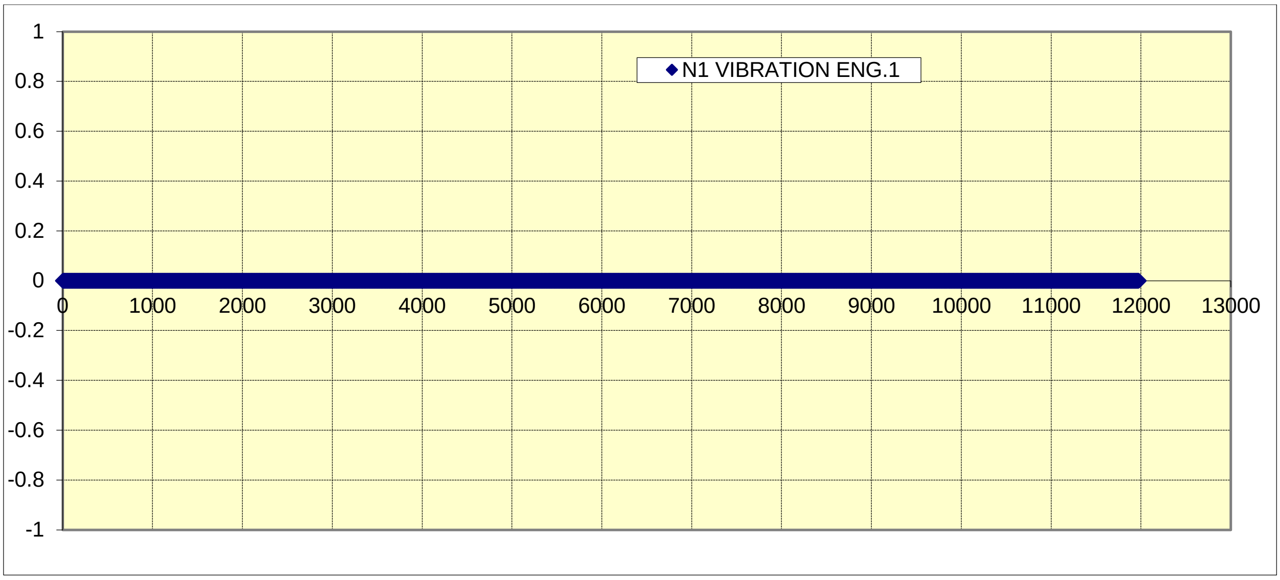
(3 - OIL QUANTITY ENG.1



– OIL QUANTITY ENG.2

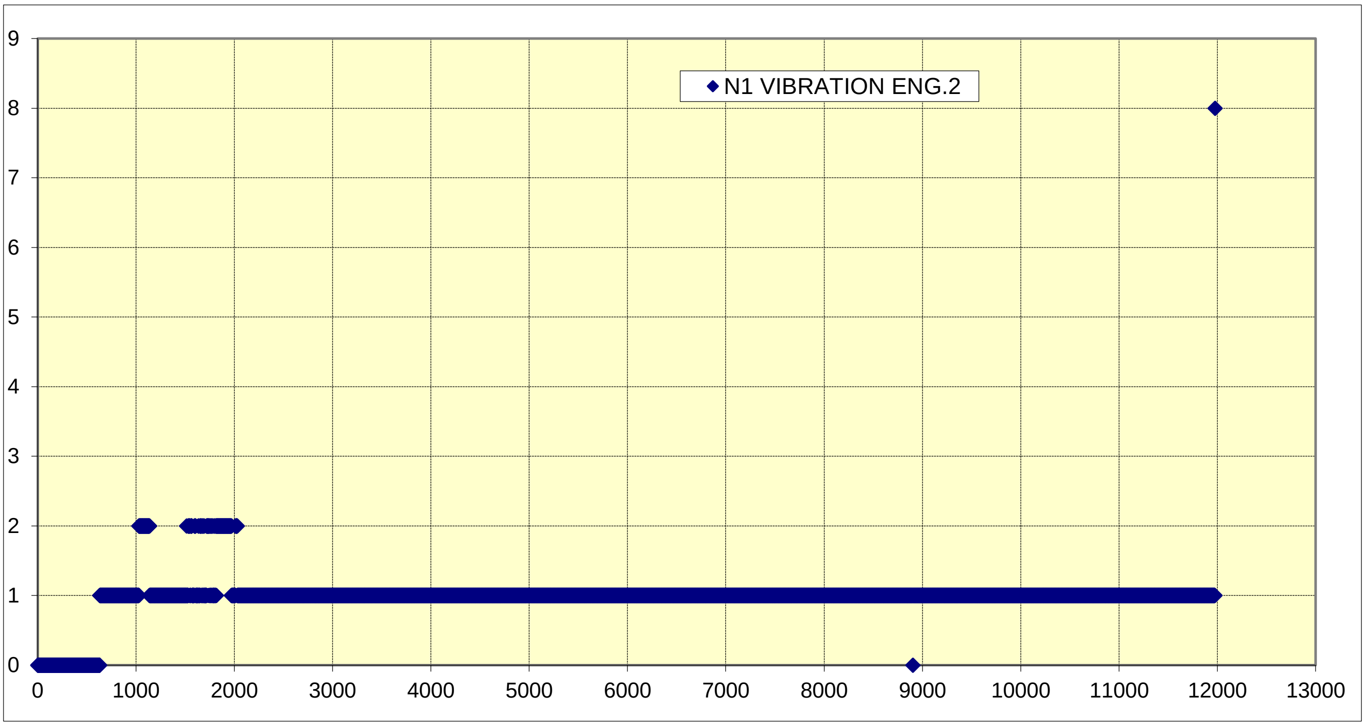


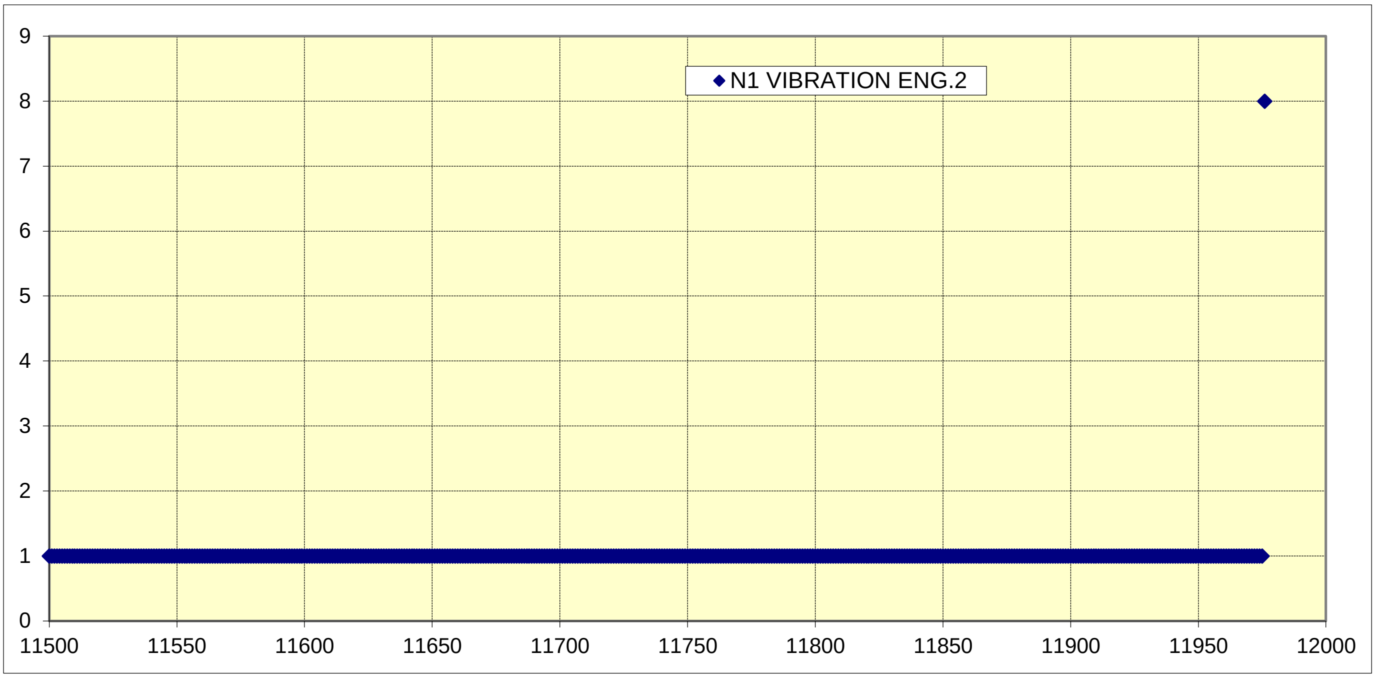
(4 - N1 VIBRATION ENG.1



N1 VIBRATION ENG.1 was 0 throughout the whole recording

(5 - N1 vibration Engine 2

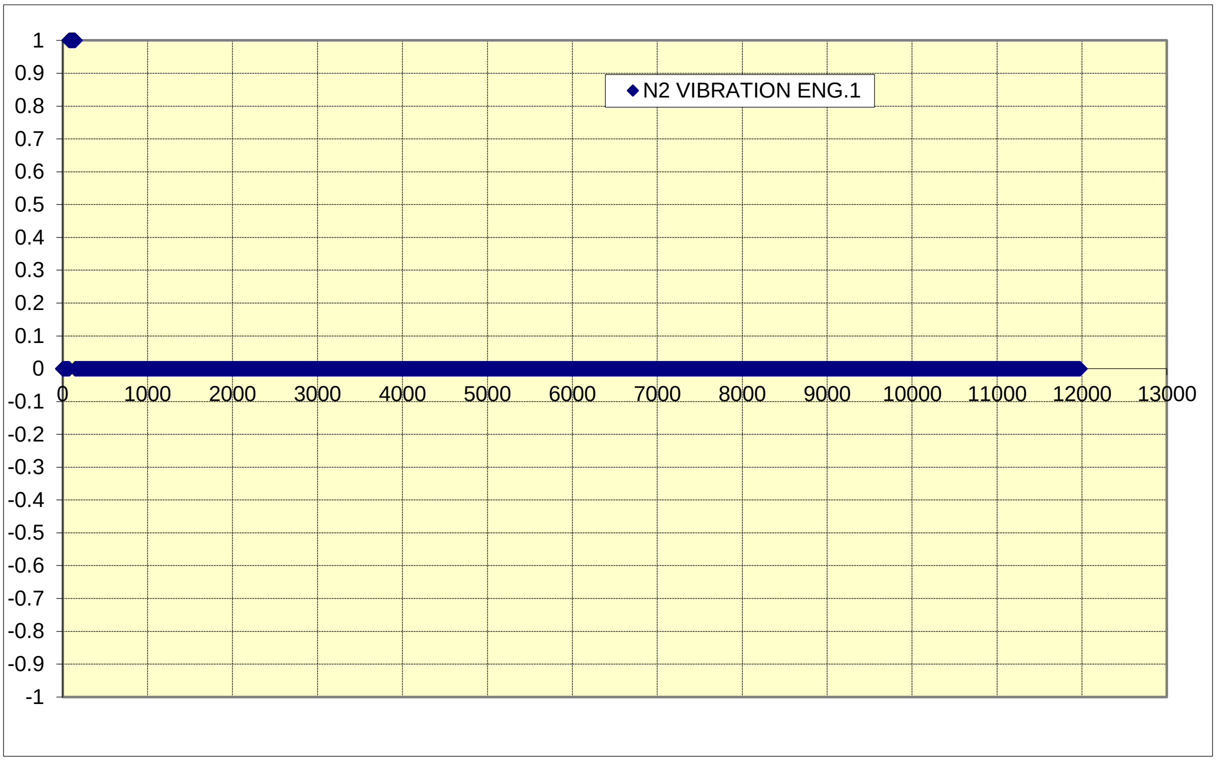




ENG 2 Vibration N1 shown at the end portion of the recording

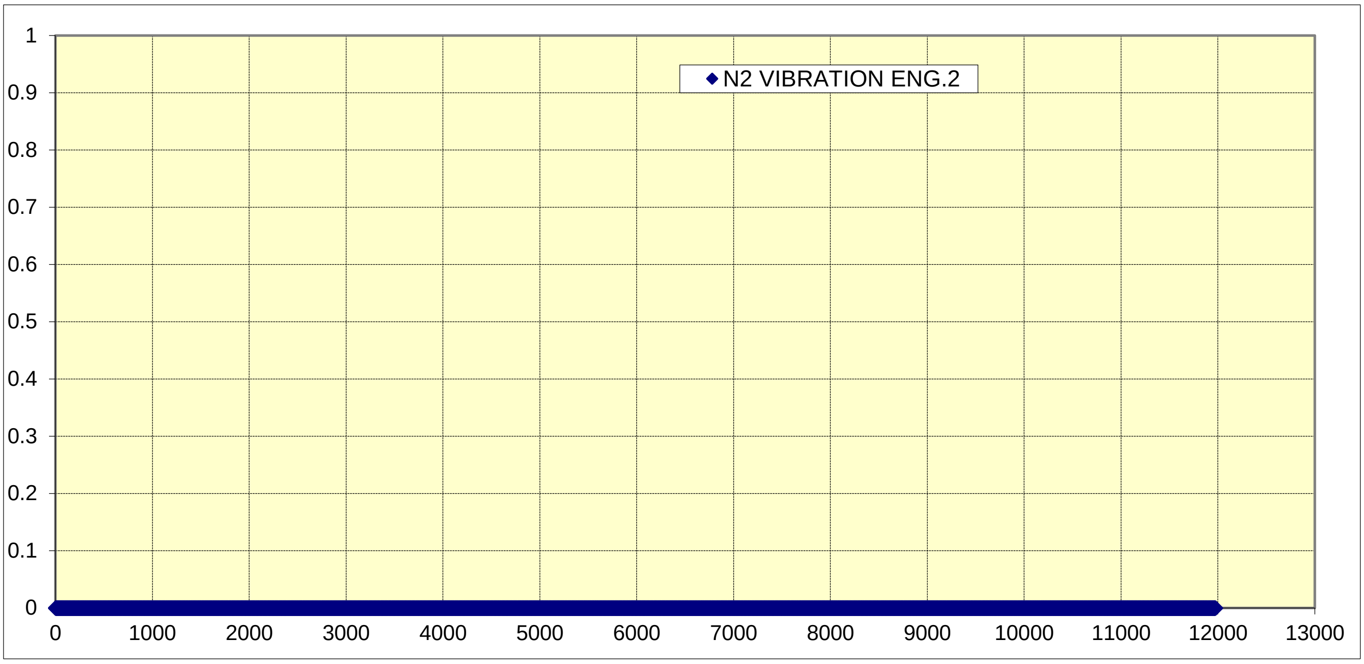
Only at one point 00:29:45 (11976 seconds on the plot) the ENG 2 Vibration N1 value changed from 0 to 8

(6 - N2 VIBRATION ENG.1

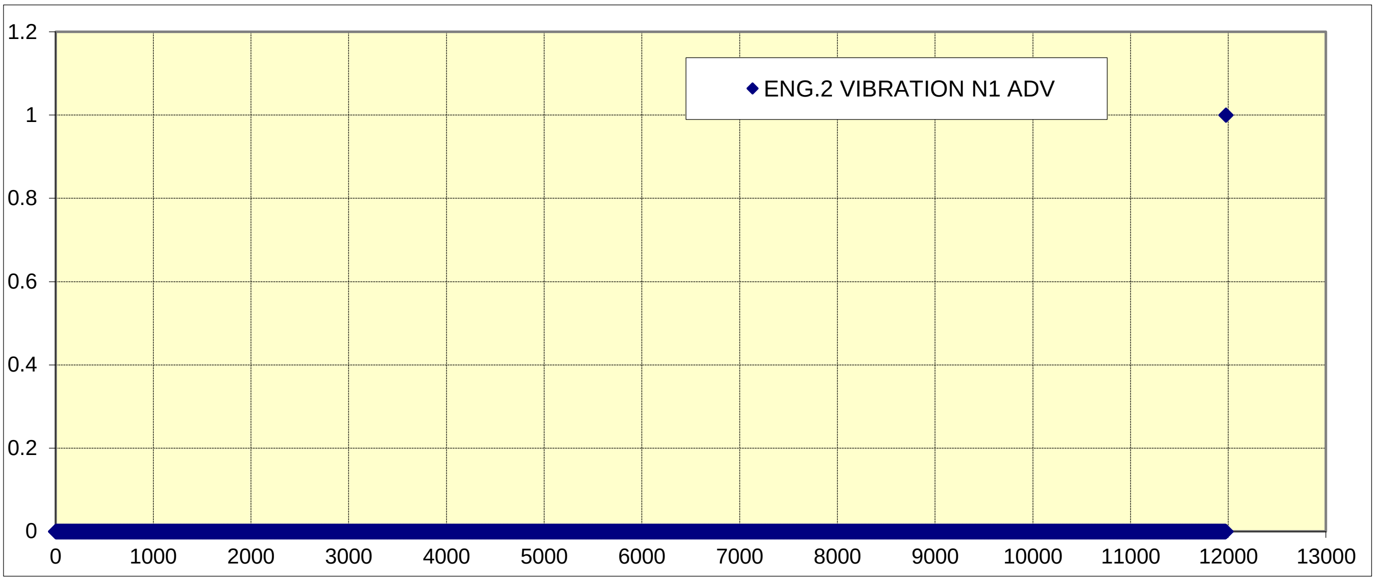


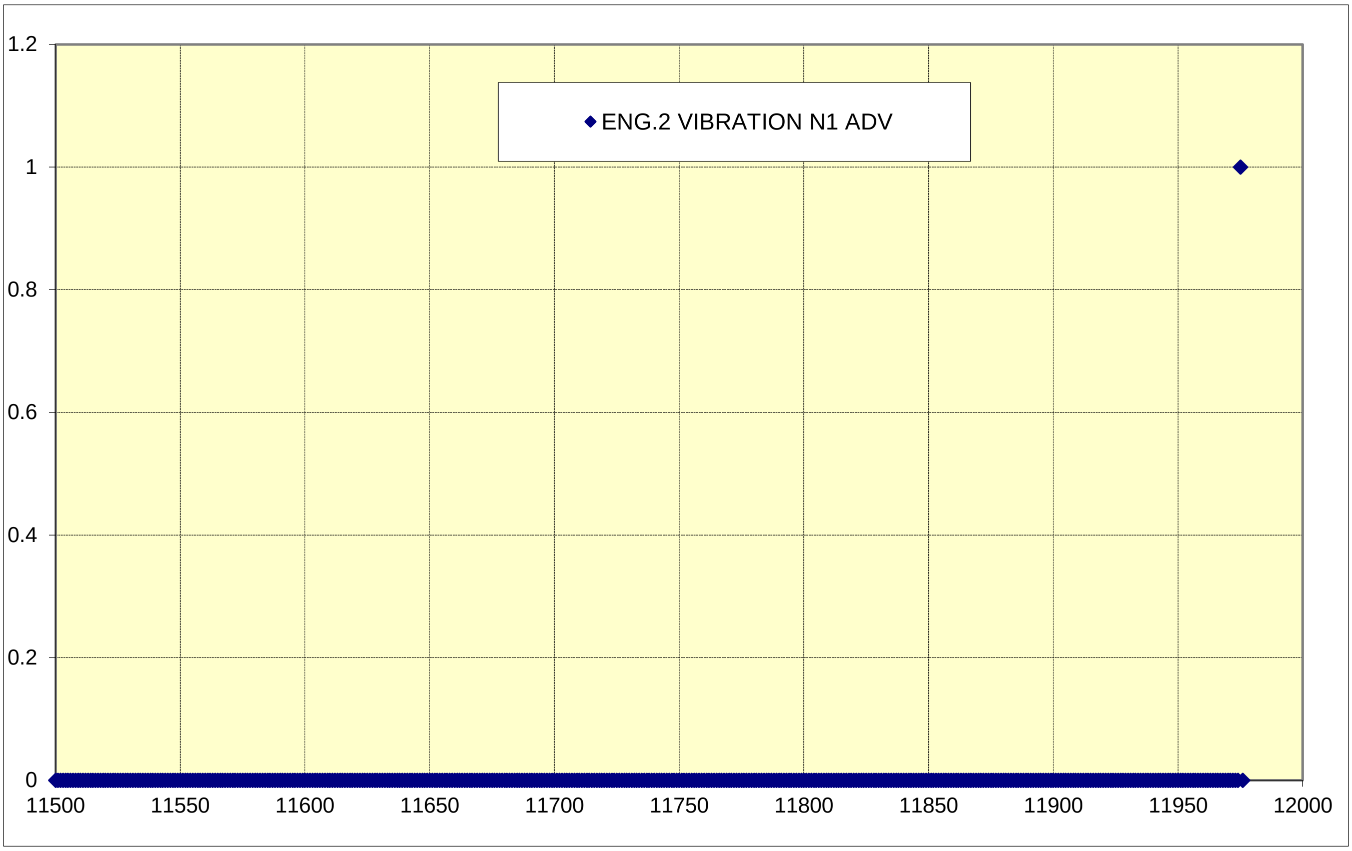
N2 VIBRATION ENG.1 was 0 throughout the whole recording

(7 - N2 VIBRATION ENG.2



(8 ENG 2 VIBRATION N1 ADV

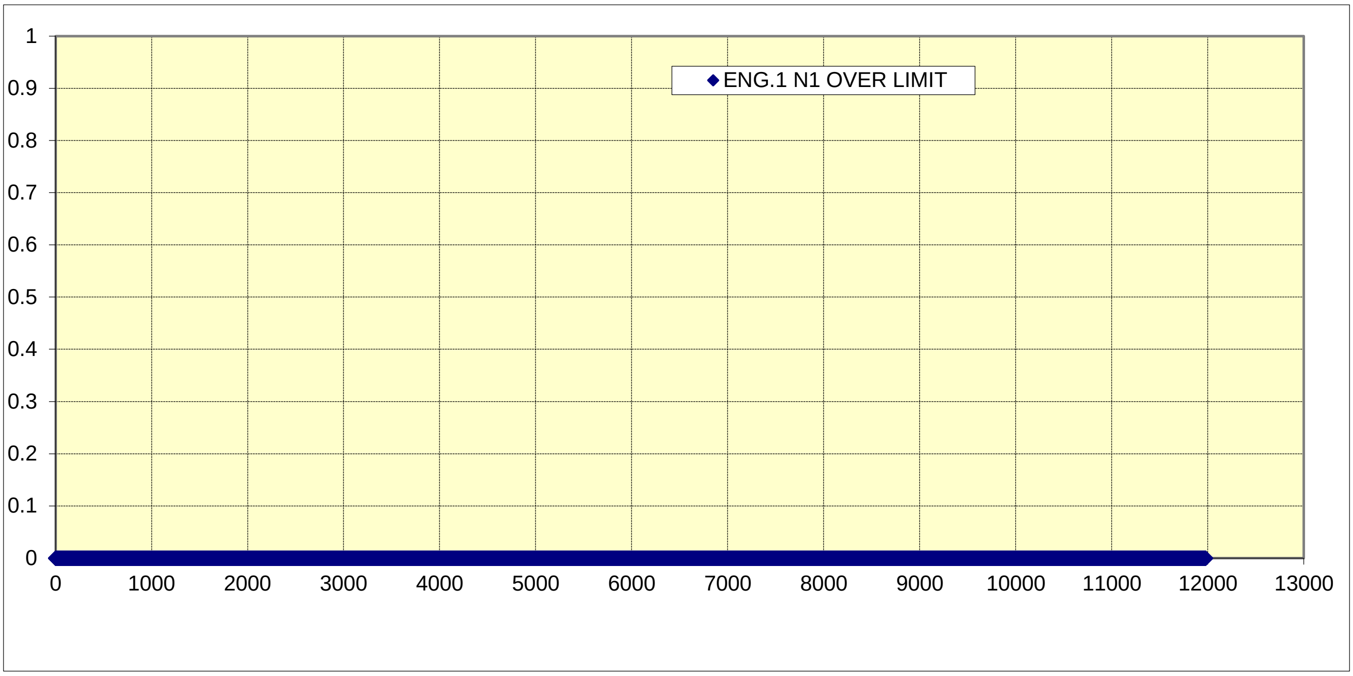




ENG 2 Vibration N1 ADV shown at the end portion of the recording

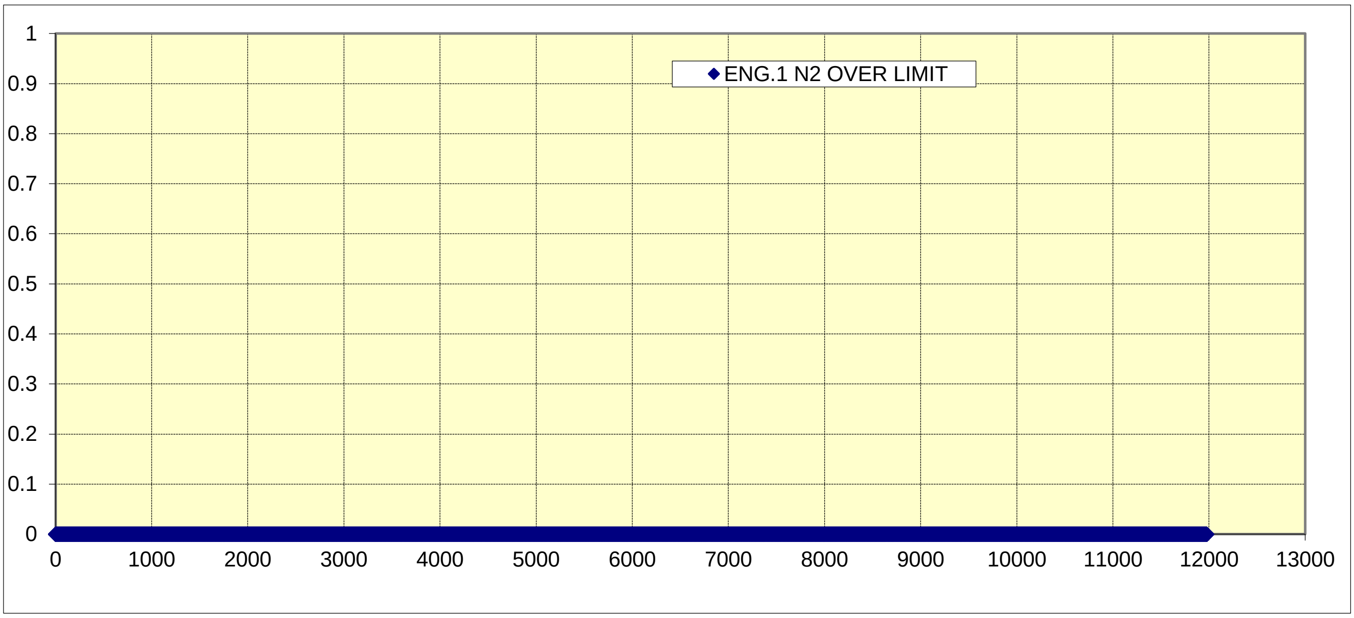
Only at one point 00:29:45 (11975 seconds on the plot) the vibration value changed from 0 to 1

(9 Engine 1 N1 over limit:



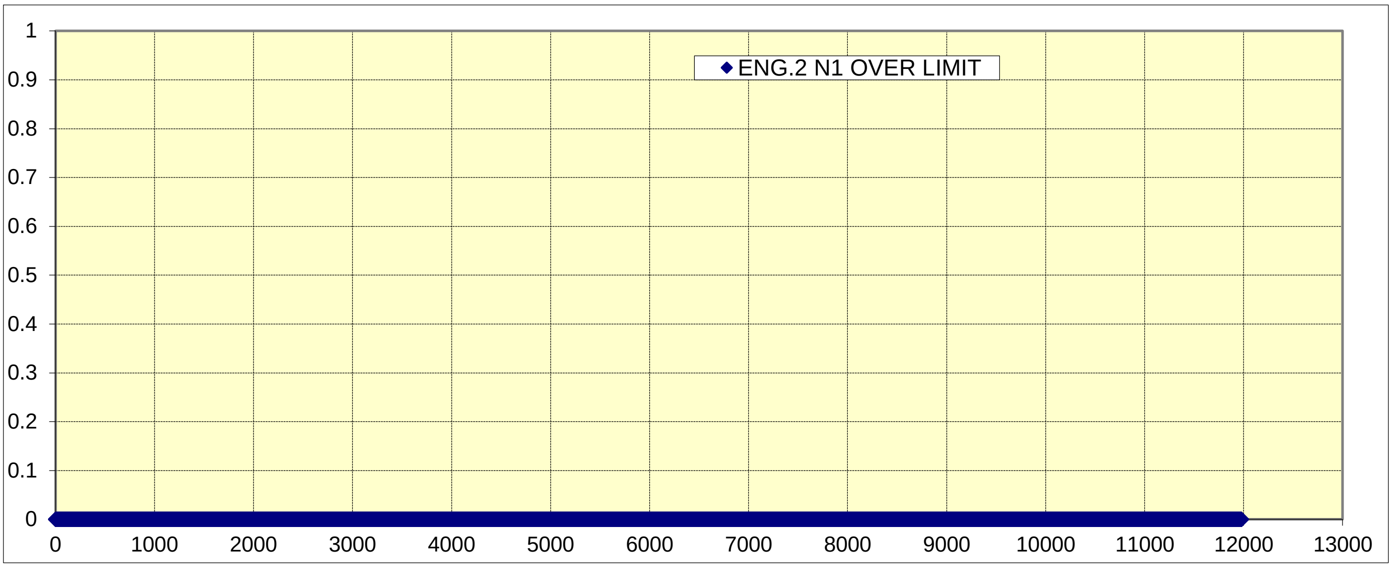
No engine 1 N1 over limit

(10 Engine 1 N2 over limit:

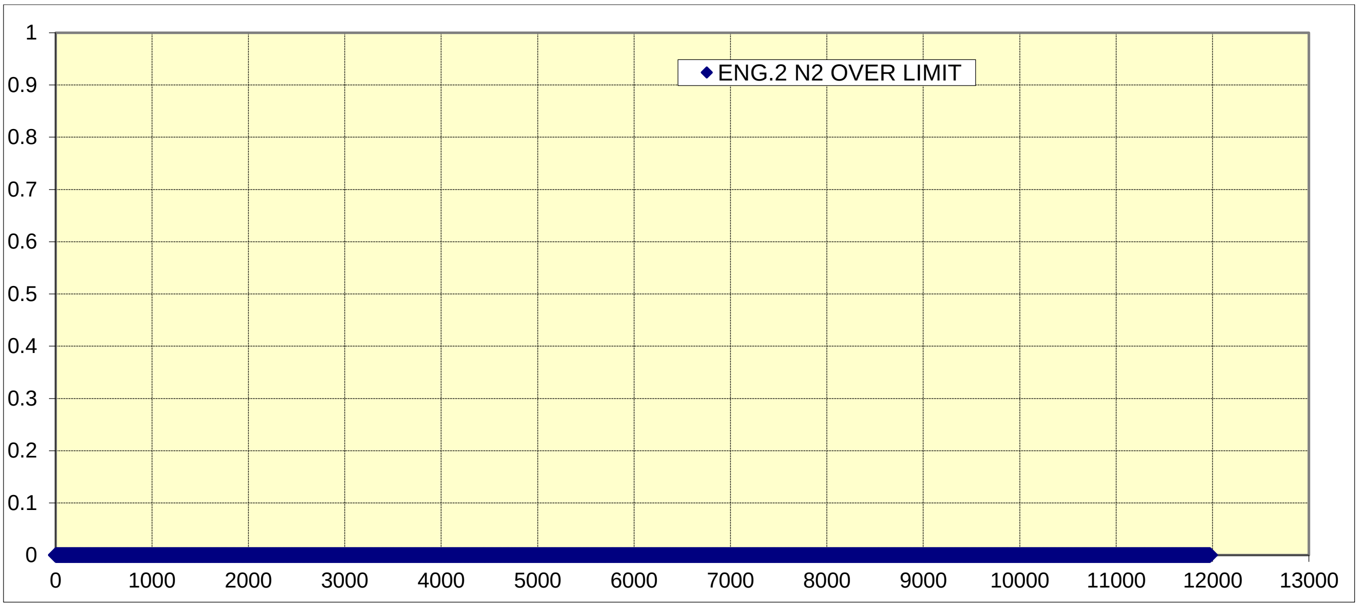


No engine 1 N2 over limit

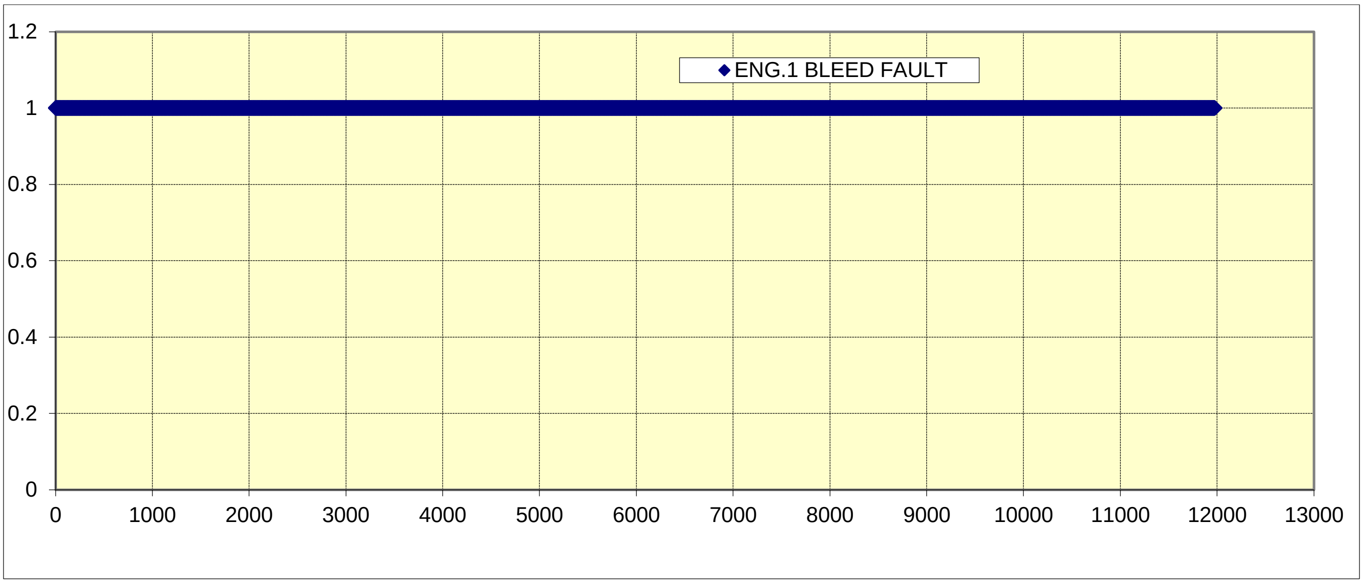
(11 -Engine 2 N1 over limit:



(12 -Engine 2 N2 over limit:

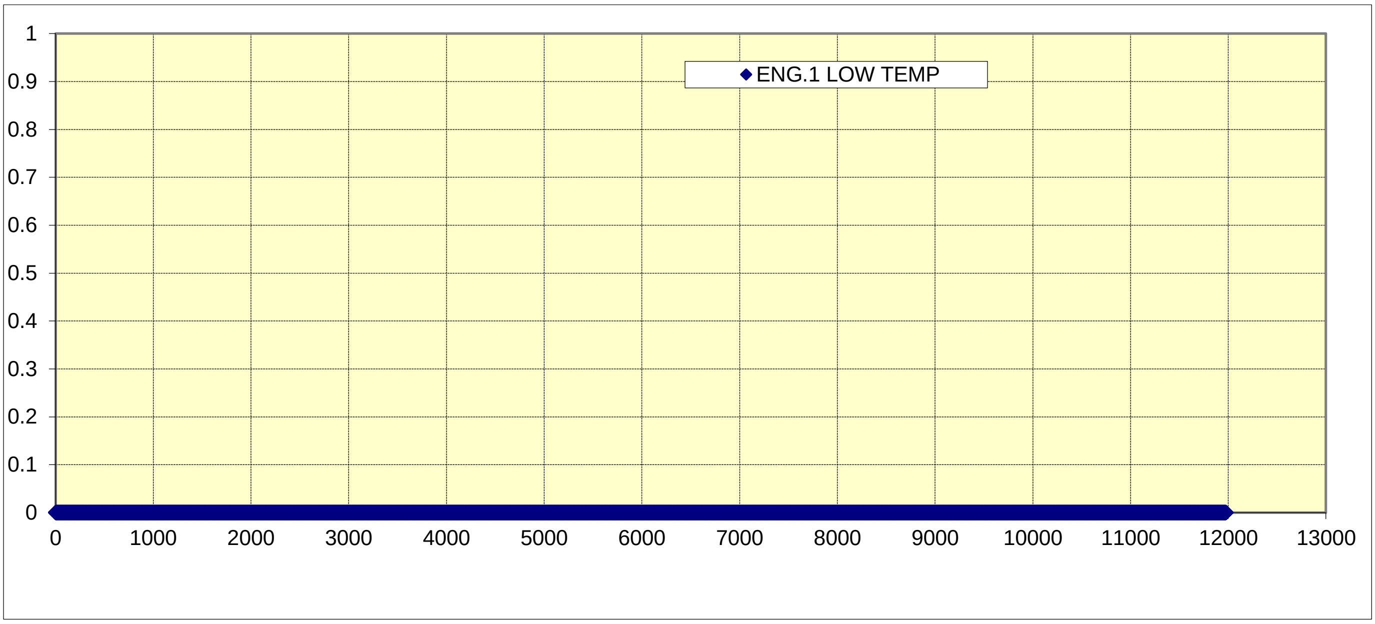


(13 -ENG.1 BLEED FAULT



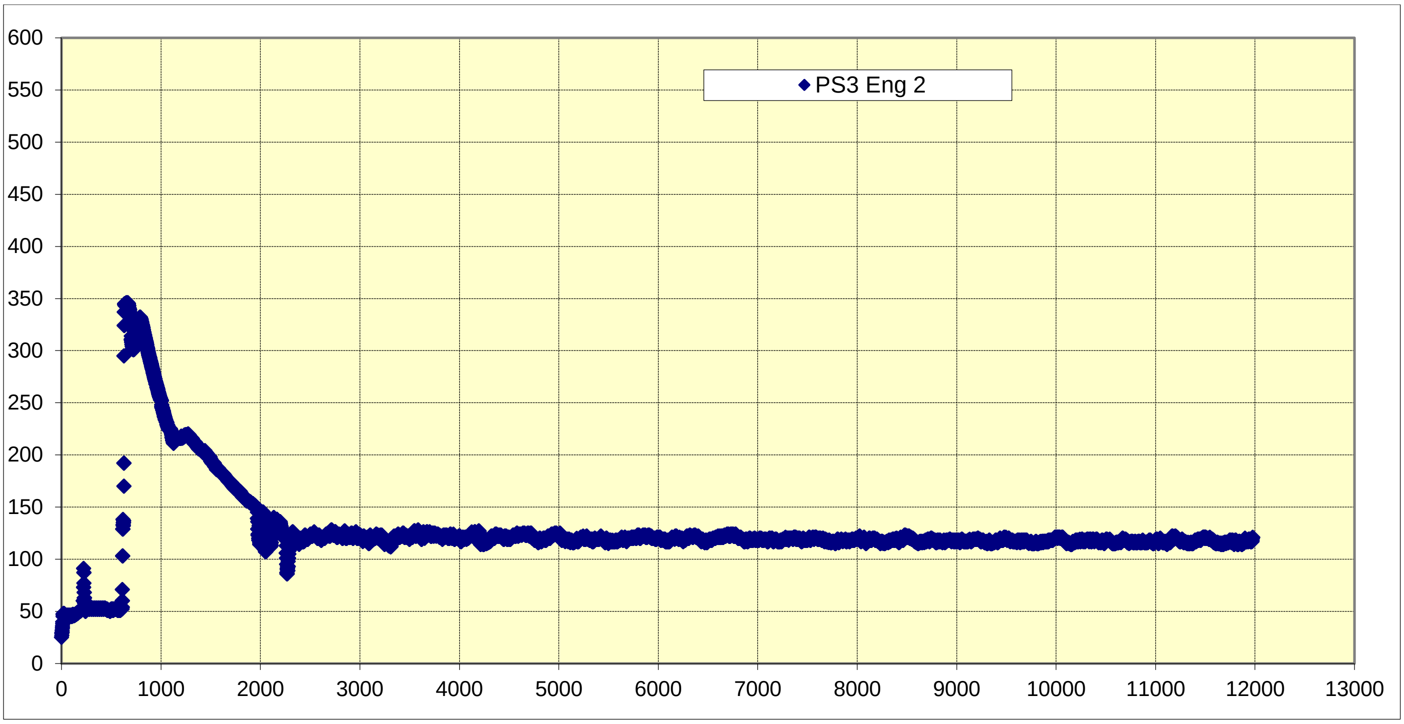
No ENG.1 BLEED FAULT

(14 -ENG.1 LOW TEMP



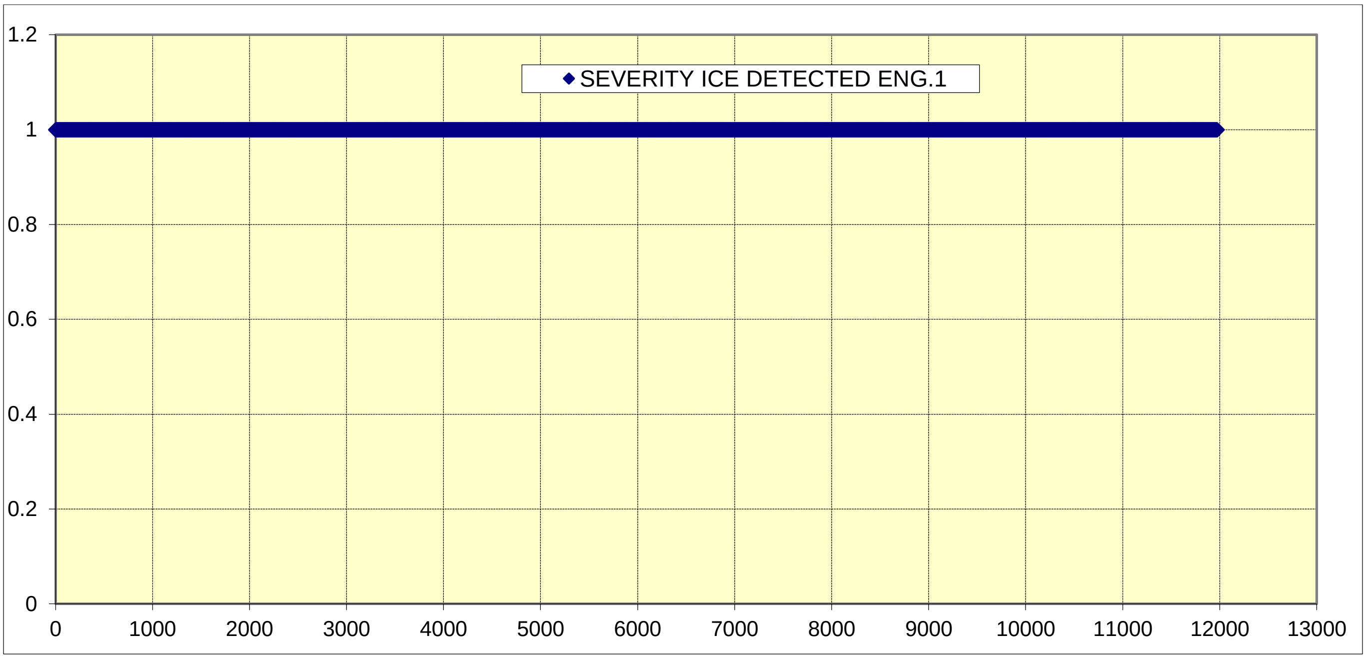
No ENG.1 LOW TEMP

(15 -PS3 Engine 2



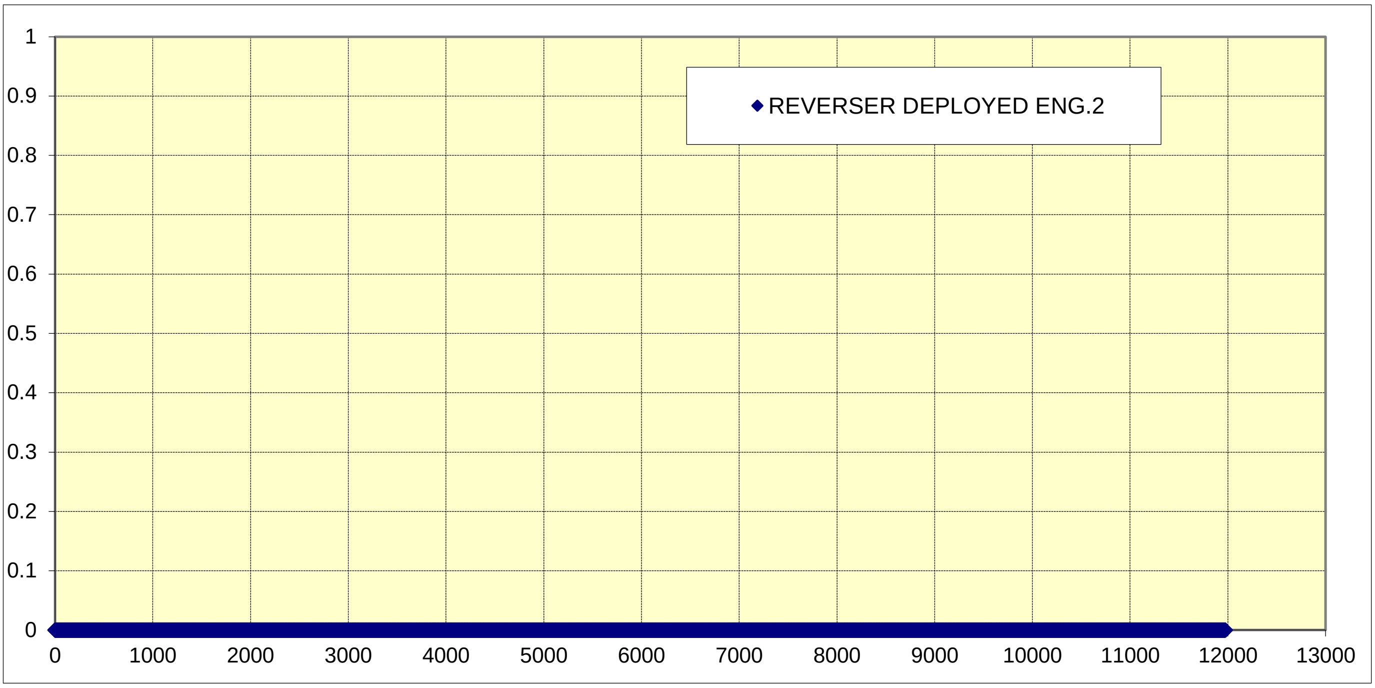
– SEVERITY ICE DETECTED ENG.1

(1 no severity ice detection)



- REVERSER DEPLOYED ENG.2

(1 deployed)



(16 - REVERSER UNLOCK ENG.2

(1 Reverser unlock)

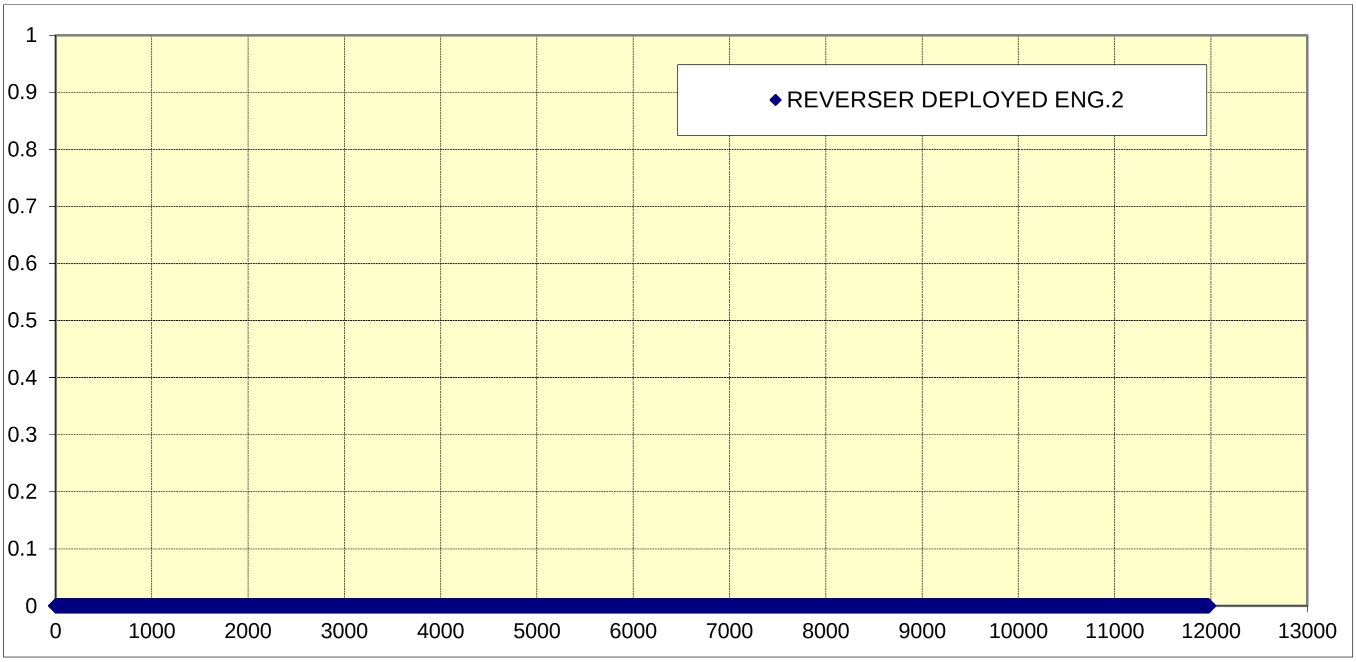


Exhibit B

Cockpit Voice Recorder (CVR) Transcript

CVR Transcript

Aircraft Reg.: SU-GCC | Aircraft Type: A320 | Occurrence Date: 19/05/2016

توقيت عالمي UTC	المتكلم Speaker	المحتوى Content	Translation
23:59:24	F/O	حديث شخصي	Personal conversation
23:59:30	PIC	حديث شخصي	Personal conversation
23:59:37	PIC	حديث شخصي	Personal conversation
23:59:43	342	342 maintain 370 to MADIS	
23:59:44	PIC	حديث شخصي	Personal conversation
23:59:49	PIC	حديث شخصي	Personal conversation
23:59:50	Athena	346 radar contact as cleared	
23:59:51	PIC	حديث شخصي	Personal conversation
23:59:52	PIC	حديث شخصي	Personal conversation
23:59:54	342	Okay	
23:59:57	F/O	حديث شخصي	Personal conversation
00:00:00	PIC	حديث شخصي	Personal conversation
00:00:02	PIC	حديث شخصي	Personal conversation
00:00:08	F/O	حديث شخصي	Personal conversation
00:00:09	PIC	حديث شخصي	Personal conversation
00:00:14	Iberia 3320	Radar good evening, Iberia 3320 flight level 380	
00:00:18	F/O	حديث شخصي	Personal conversation
00:00:20	Athena	Iberia 3320 hello radar contact FL 380	
00:00:26	PIC	حديث شخصي	Personal conversation
00:00:30	Air France 463	Air France 463 Good morning maintain flight level 340	
00:00:31	PIC	حديث شخصي	Personal conversation
00:00:36	Athena	Air France 463 Hello radar contact 340 fly direct to TUMBO squawk 2062	
00:00:39	F/O	حديث شخصي	Personal conversation
00:00:41	PIC	حديث شخصي	Personal conversation
00:00:44	PIC	حديث شخصي	Personal conversation
00:00:49	PIC	حديث شخصي	Personal conversation

CVR Transcript

Aircraft Reg.: SU-GCC | Aircraft Type: A320 | Occurrence Date: 19/05/2016

توقيت عالمي UTC	المتكلم Speaker	المحتـوى Content	Translation
00:00:55	Air France 463	Air France 463 good morning flight level 340	
00:00:59	Athena	Good morning, Air France 463 loud and clear how do you read me	
00:01:04	Air France 463	Loud and clear	
00:01:05	F/O	حديث شخصي	Personal conversation
00:01:06	Athena	Ok radar contact fly to TUMBO and squawk 2062	
00:01:08	PIC	حديث شخصي	Personal conversation
00:01:12	Air France 463	Fly to TUMBO and squawk .... ah 4062 Air France 463	
00:01:17	PIC	حديث شخصي	Personal conversation
00:01:19	Athena	It's 2062	
00:01:21	PIC	حديث شخصي	Personal conversation
00:01:22	Air France 463	2062 Air France	
00:01:23	Athena	Thank you	
00:01:26	PIC	حديث شخصي	Personal conversation
00:01:33	PIC	حديث شخصي	Personal conversation
00:01:37	F/O	حديث شخصي	Personal conversation
00:01:39	PIC	حديث شخصي	Personal conversation
00:01:48	F/O	حديث شخصي	Personal conversation
00:01:55	PIC	حديث شخصي	Personal conversation
00:01:59	PIC	حديث شخصي	Personal conversation
00:02:07	PIC	تصبح على خير	Good night
00:02:09	F/O	يا راجل انت	come on man
00:02:32	F/O	ال Dessert ده شكله حلو مش هتاكله؟	
00:02:37	PIC	ال ايه ؟	What?
00:02:38	F/O	ده الDessert	
00:02:49	F/O	حديث شخصي	Personal conversation
00:03:00		حديث شخصي	Personal conversation

CVR Transcript

Aircraft Reg.: SU-GCC | Aircraft Type: A320 | Occurrence Date: 19/05/2016

توقيت عالمي UTC	المتكلم Speaker	المحتوى Content	Translation
00:03:45	F/O	حديث شخصي	Personal conversation
00:04:10	EL AL 326	Athena EL AL 326 good morning flight level 370	
00:04:15	Athena	Yasso EL AL 326 radar contact as cleared	
00:04:19	EL AL 326	Thank you	
00:04:31		صوت جرس فتح باب كابينة القيادة	Cockpit doorbell opening sound
00:04:35		صوت فتح الباب	Door opening sound
00:04:38	المضيفة (Flight attendant)	لازانيا ؟	Lasagna?
00:04:41	F/O	جاهز	Ready
00:04:45		(صوت فتح الترابيزة)	Sounds like table opening locks sound
00:04:46	Female flight attendant	تاكل ايه ؟	What would you like to eat?
00:04:48	F/O	لا متشكر ما اهى	No, thanks. I have some.
00:04:52	PIC	بس toothpicks عايز	I only want toothpicks
00:04:54	Female flight attendant	حاضر	O.K.
00:05:28	Athena	Willing 7844 contact Nicosia radar 129.550 bye bye	
00:05:34	Willing 7844	Bye bye Willing 7844 have a good day	
00:05:37	Athena	Bye bye	
00:05:43		صوت غلق الباب	Door closing sound
00:06:14	Ethiopian 504	Athena Ethiopian 504 Hello squawk 4005	
00:06:18	Athena	Kalimira Ethiopian 504 identified direct to EVIVI squawk code 1420	
00:06:24	Ethiopian 504	Squawk 1420 direct EVIVI Ethiopian 504	
00:06:31	Athena	Senegal 001 contact AH.... Ankara radar on 128 decimal 625 bye bye	
00:06:41	Senegal 001	Ankara radar 128625 Senegal 001 bye bye	

CVR
Transcript

Aircraft Reg.: SU-GCC | Aircraft Type: A320 | Occurrence Date: 19/05/2016

توقيت عالمي UTC	المتكلم Speaker	المحتوى Content	**Translation**
00:06:45	Athena	Bye now	
00:07:39	Martinair 2033	Ankara (Martinair)2033	
00:07:46	Athena	Martinair 2033 yasso radar contact flight level 360 squawk 2033 and fly direct Olger	
00:07:59	Martinair 2033	Say again the squawk	
00:08:01	Athena	Yeh It is 2033	
00:08:04	Martinair 2033	Squawk 2033	
00:08:53	Athena	Ethiopian five hundred contact Macedonia radar 133.575 good bye	
00:09:00	Ethiopian 500	Macedonia 133.575 radar Ethiopian five zero zero bye bye	
00:10:33	Ethiopian 706	Athena Ethiopian 706 good morning flight level 380	
00:10:39	Athena	Kalimira Ethiopian 706 identified flight level 380 direct to EVIVI squawk 1466	
00:10:48	Ethiopian 706	Direct EVIVI 1466 Ethiopian 706	
00:10:56	Turkey 2744	Athena good morning turkey 2744 flight level 370	
00:11:02	Athena	Turkey 2744...............radar contact to RUGOS	
00:11:07	2744	Direct RUGOS turkey 2744	
00:13:36	Martinair 8322	Athena Kalimira Martinair 8322 flight level 340 approaching (ATBOR)	
00:13:42	Athena	Kalimira Martinair 8322 radar contact squawk 2035 direct RUGOS	
00:13:49	Martinair 8322	Direct Rugas squawking 2035 Martinair 8322	
00:16:43		صوت جرس فتح باب كابينة القيادة	Cockpit doorbell opening sound
00:16:46		صوت فتح الباب	Door opening sound

CVR Transcript

Aircraft Reg.: SU-GCC | Aircraft Type: A320 | Occurrence Date: 19/05/2016

توقيت عالمي UTC	المتكلم Speaker	المحتوى Content	Translation
00:17:21	Athena	Qatary 118 contact Nicosia radar 129,550 Kalimira	
00:17:27	Qatar air 118	129,550 Kalimira Qatary 118 bye bye	
00:18:18	Qatary 8754	Athena Kalimira Qatary 8754	
00:18:23	Athena	Kalimira Qatary 8754 identified flight level 380 fly to TUMBO and squawk 5512	
00:18:32	Qatary 8754	Squawk 5512 and fly to position........ AH say again	
00:18:39	Athena	To TUMBO Tango Uniform Mike Bravo Oscar	
00:18:42	Qatary 8754	To TUMBO Qatary8754 thank you, and request flight level four zero zero	
00:18:48	Athena	Roger that climb now flight level four zero zero	
00:18:52	Qatary 8754	Climb now 400 Qatary8754	
00:20:52	Athena	Sky travel 2512 contact Cairo 127.7 bye bye	
00:20:57	Sky travel 2512	Roger Athena bye bye Athena Sky travel 2512	
00:21:43	Gulf air 006	Radar Gulf air 006 good morning	
00:21:46		صوت غلق الباب	Door closing sound
00:21:47	Athena	Good morning 006 radar contact flight level 410 to MAGIS	
00:21:51	Gulf air 006	Thank you	
00:22:20	Athena	Air France 4320 hello radar contact 370 RUGOS	
00:22:25	Air France 4320	To RUGOS	
00:22:51	PIC	بطانية	I want a blanket
00:22:52	F/O	ايه؟	What?
00:22:53	PIC	لاعايز بطانية , مش قادر	I want a blanket; I Can't stand the cold
00:22:56		حرام عليكوا	Shame on you

توقيت عالمي UTC	المتكلم Speaker	المحتوى Content	Translation
00:22:58	F/O	ليه؟	Why?
00:22:59	PIC	بطانية بقى عايز بطانية اعمل ايه خلاص بردان,,,, يصح	Blanket I want a Blanket, I feel cold
00:23:00	Female flight attendant	عايز بطانية مش كدة	You want a blanket, am I right
00:23:03	F/O	في حاجة انت بتنام ولا ايه	
00:23:03		صوت جرس فتح باب كابينة القيادة	Cockpit doorbell opening sound
00:23:05		صوت فتح الباب	Door opening sound
00:23:06		انت كمان انت قولتلى اني قلقتكم	You too, you told me I disturbed you
00:23:07	F/O	في ايه يا عم؟	What?
00:23:09	PIC	معلش ممكن .... بطانية	A blanket, please
00:23:12	Female flight attendant	بطانية	Blanket?
00:23:13	PIC	اه بعد اذنك	Yes, please
00:23:14	Female flight attendant	ومخدة ؟	And a pillow?
00:23:15	PIC	ماشى مخدة	Ok, and a pillow
00:23:18		صوت غلق الباب	Door closing sound
00:23:40		صوت جرس فتح باب كابينة القيادة	Cockpit doorbell opening sound
00:23:43		صوت فتح الباب	Door opening sound
00:23:49		صوت غلق الباب	Door closing sound
00:23:50	F/O	كلمة غير مفهومة	Undefined word
00:23:52	Female flight attendant	Yes	
00:23:57	F/O	أنتوا أربعة مش كده؟	You are four, right?
		تعالي أقعدى	Have a seat
00:24:34	Female flight attendant	أقعد ؟	Can I sit?
00:24:38		صوت جر و فتح كرسي الـ observer	Observer Chair dragging and opening sound
00:24:50	Athena	Ethiopian 706 continue present heading	

CVR Transcript

Aircraft Reg.: SU-GCC | Aircraft Type: A320 | Occurrence Date: 19/05/2016

توقيت عالمي UTC	المتكلم Speaker	المحتوى Content	Translation
00:24:54	Ethiopian 706	Present heading Ethiopian 706	
00:24:57	Athena	Ethiopian 502 contact Macedonia radar 133 decimal 575 bye bye	
00:25:03	Ethiopian 502	One three three five seven five bye	
00:25:24		1st Hissing sound	
00:25:27		كلمة غير مفهومة	Unidentified word
00:25:29		Pop sound	Pop sound
00:25:29		2nd Hissing sound	
00:25:30	F/O	Fire fire	
00:25:31	Female flight attendant	Fire	
00:25:32	PIC	Fire	
00:25:33	PIC	أوبا!!	Oppaa
00:25:35	PIC	الطفاية الطفاية بسرعة هات الطفاية بسرعة	Extinguisher, extinguisher quickly bring fire extinguisher quickly
00:25:40	PIC	هات الطفاية بسرعة Fire	Bring the extinguisher quickly, Fire!!
00:25:42	PIC	أقفل الباب	Close the door
00:26:02	Athena|	EL AL 388 contact Nicosia radar 125.5 Kali	
00:26:08	EL AL 388	125.5 Kalimira…………	
00:26:15		Master warning	
00:26:48		CRC warning	
00:27:18		CRC warning	
00:27:23	Athena	EgyptAir 804 contact Cairo 124.7 bye bye	
00:27:34	Athena	EgyptAir 804 contact Cairo 124.7	
00:27:50	Athena	EgyptAir 804	
00:28:02		صوت نفس ضعيف	Weak breathing Sound
00:28:16		صوت غير مفهوم (سقوط)	Undefined (Sound of a falling object)

CVR
Transcript

Aircraft Reg.: SU-GCC | Aircraft Type: A320 | Occurrence Date: 19/05/2016

توقيت عالمي UTC	المتكلم Speaker	المحتوى Content	Translation
00:28:21		أستغفر الله ؟	Ask forgiveness of God
00:28:38		صوت نفس ضعيف	Weak breathing Sound
00:28:38	Athena	EgyptAir EgyptAir 804 contact Cairo 124.7	
00:28:42		صوت نفس ضعيف	Weak breathing Sound
00:28:47	Athena	EgyptAir 804 contact Cairo 1247	
00:28:52	Athena	EgyptAir 804 ,1247	
00:29:03	Athena	EgyptAir 804 Cairo 1247	
00:29:09	Athena	EgyptAir 804................ EgyptAir 8780	
00:29:13	Athena	Go ahead	
00:29:23	Another aircraft	يا (اسم المساعد)	Calling the (name of the F/O)
00:29:28	Athena	Ethiopian 706 all navigation EVIVI	
00:29:32	Ethiopian 706	On navigation EVIVI Ethiopian 706	
00:29:36	Athena	Iberia 3320 all navigation SAULIN	
00:29:39		Sound of A/P disconnect (Cavalry charge)	
00:29:42	Iberia 3320	SAULIN 3320	
00:29:44		صوت غير مفهوم (سقوط)	Undefined (Sound of a falling object)

Note:

There was constant background music in the cockpit since the beginning of the recording.
Arabic context has been translated to English, However all English context has been kept as it is.
Operator chief pilot was assigned to assist in recognizing the identity of flight crew(relevant non-discloser and data protection procedures were in effect)

Exhibit C

The recovered debris

EAAID Identification No.25

Part Description: RH forward passenger door

Dive # 1

Debris # D171

Grid square (H; 19)

GPS POS: 33; 28.1966852 N 29; 15.4680133 E

EAAID Identification No. 30 A

Part Description: Electronic box

Dive # 1

Debris # D173

Grid square (I; 20)

GPS POS: 33; 28.1916469N 29; 15.4717301 E

EAAID Identification No. 21

Part of fuselage frame #C20

Dive # 2

Debris # D180

Grid square (G; 20)

GPS POS: 33; 28.1890432 N   29; 15.4413380 E

EAAID Identification No. 37

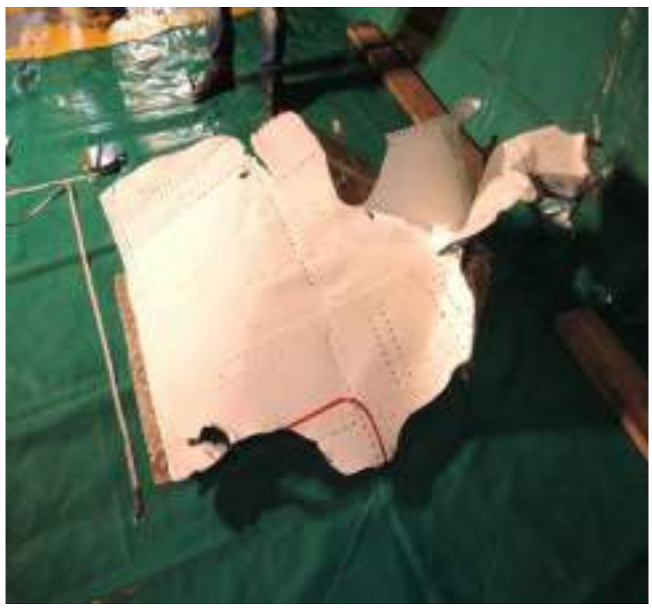
Part Description: Part of RH fuselage with static port

Dive # 2

Debris # D135

Grid square (G; 17)

GPS POS: 33; 28.2281350 N 29; 15.4497250 E



EAAID Identification No. 22

Part Description: Window

Dive # 2

Debris # D136

Grid square (G; 18)

GPS POS: 33; 28.2193894 N 29; 15.4450887 E

EAAID Identification No. 12

Part Description: Safety Valve

Dive # 2

Debris # D46

Grid square (D; 23)

GPS POS: 33; 28.1486459 N   29; 15.3871852 E

EAAID Identification No. 30 B

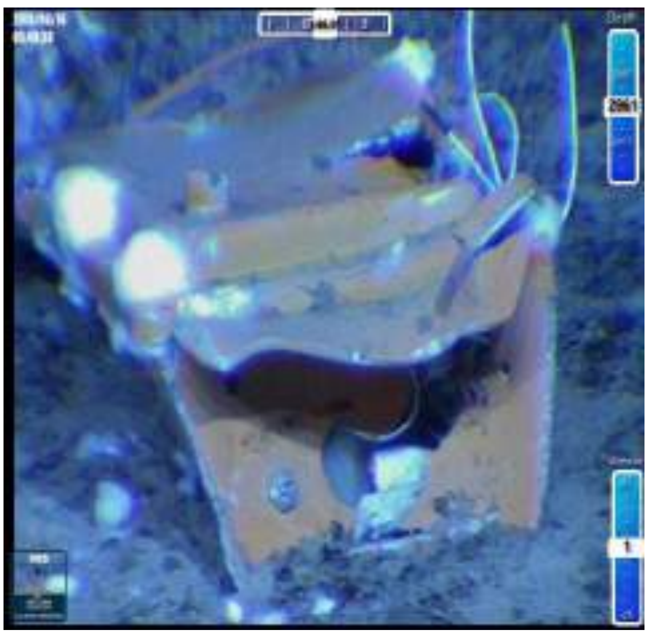
Part Description: ELT

Dive # 2

Debris # D50

Grid square (E; 23)

GPS POS: 33; 28.1526799 N   29; 15.4072885 E



EAAID Identification No. 11

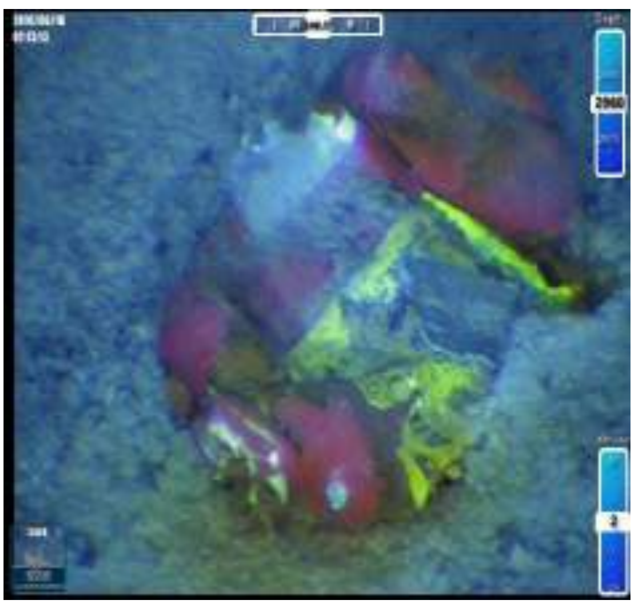
Part Description: Fire extinguisher

Dive # 2

Debris # D35

Grid square (D;22)

GPS POS: 33; 28.1681671 N 29; 15.3977846 E



EAAID Identification No. 13

Part Description: Turbine disk

Dive # 2

Debris # D44

Grid square (D;23)

GPS POS: 33; 28.1512740 N 29; 15.3685858 E

EAAID Identification No. 29

Part Description: Part of side beam - main landing gear bay

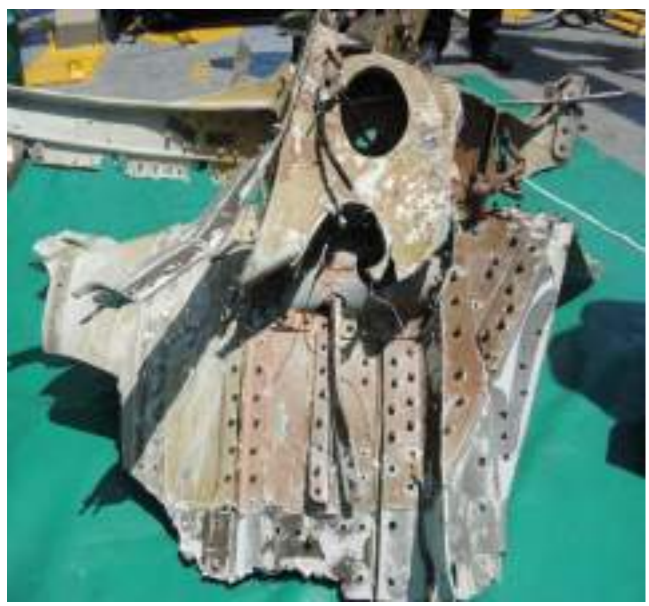
Dive # 3

(RH)

Debris # D203

Grid square (N;25)

GPS POS: 33; 28.1163823 N   29; 15.5488825 E



EAAID Identification No. 19

Part Description: Center wing box rear spar frame 42

Dive # 3

Debris # D178

Grid square (N;19)

GPS POS: 33; 28.1987999 N   29; 15.5614583 E

EAAID Identification No. 31

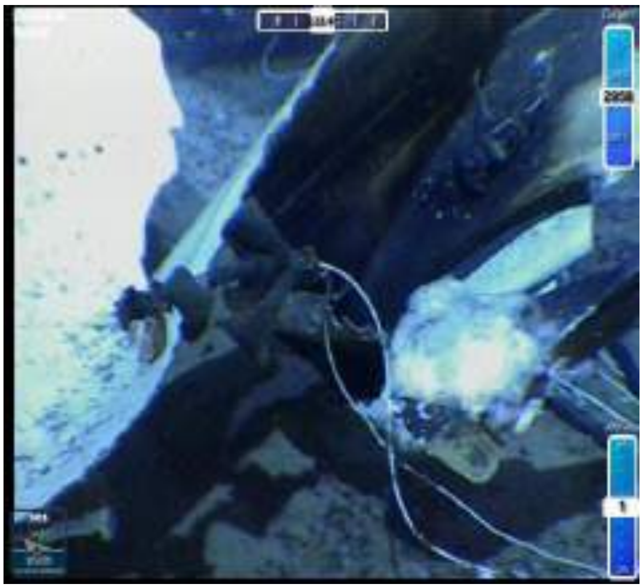
Part Description: Forward fuselage static port (RH) from frame 3 to frame 11

Dive # 4

Debris # D149

Grid square (L;14)

GPS POS: 33; 28.2700431 N   29; 15.5205768 E



EAAID Identification No. 23

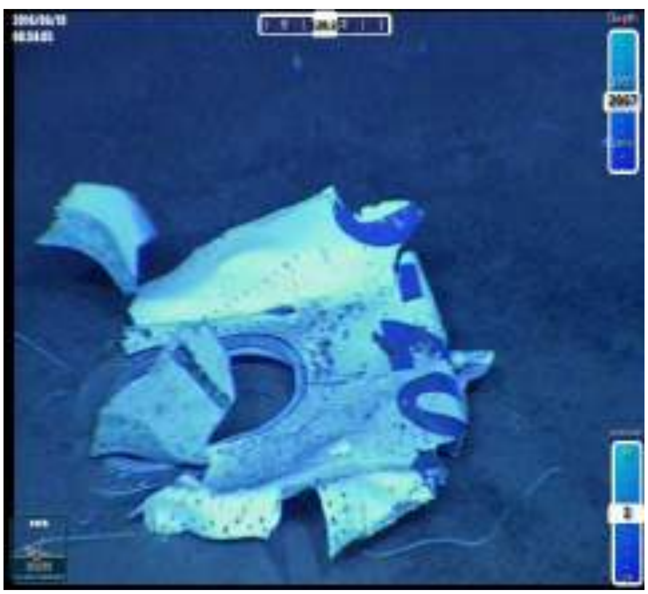
Part Description: Window with aircraft type

Dive # 5

Debris # D159

Grid square (K;12)

GPS POS: 33; 28.2955544 N   29; 15.5168200 E



EAAID Identification No. 20

Part Description: Upper part of frame 42

Dive # 5

Debris # D116

Grid square (J;11)

GPS POS : 33;28.3103246 N   29;15.4918359 E

EAAID Identification No. 14

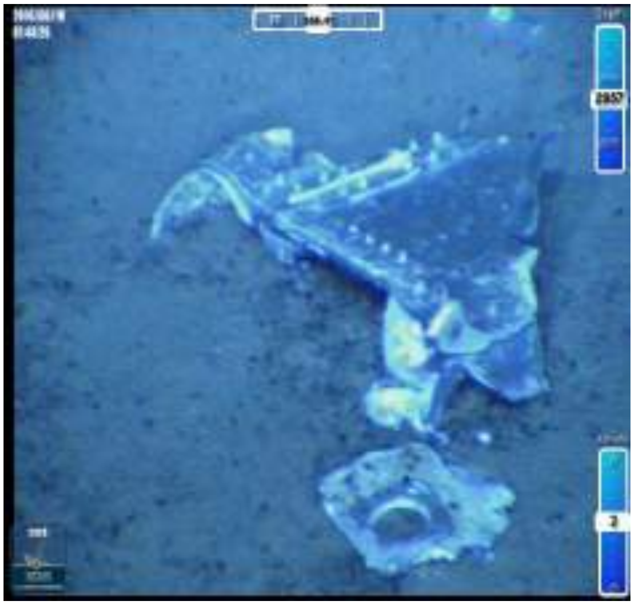
Part Description: Unidentified

Dive # 5

Debris # D152

Grid square (K;14)

GPS POS: 33; 28.2704411 N   29; 15.5131699 E



EAAID Identification No. 24

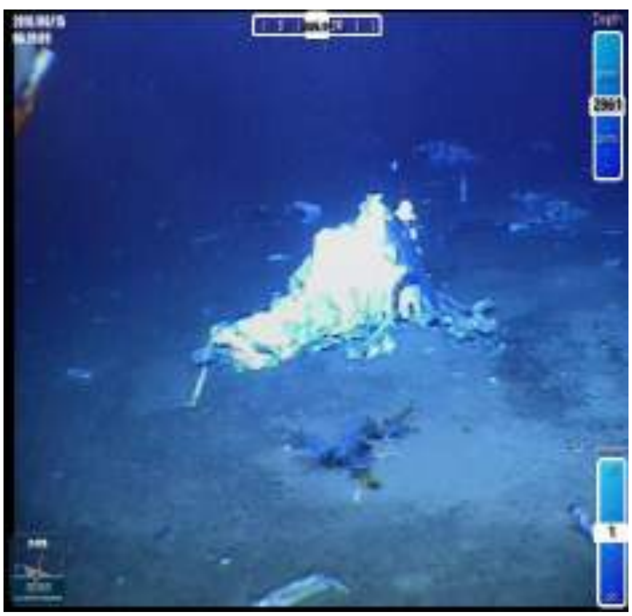
Part Description: Fuselage part with tail number

Dive # 6

Debris # D22

Grid square (C;24)

GPS POS: 33.46893N, 29.256335E



EAAID Identification No. 30 C

Part Description: Pinger from CVR (found inside the fuselage)

Dive # 6

Debris # D22

Grid square (C;24)

GPS POS: 33.46893N, 29.256335E

EAAID Identification No. 15

Part Description: Actuator

Dive # 6

Debris # D65

Grid square (C;29)

GPS POS: 33; 28.0754380 N   29; 15.3753239 E

EAAID Identification No. 16

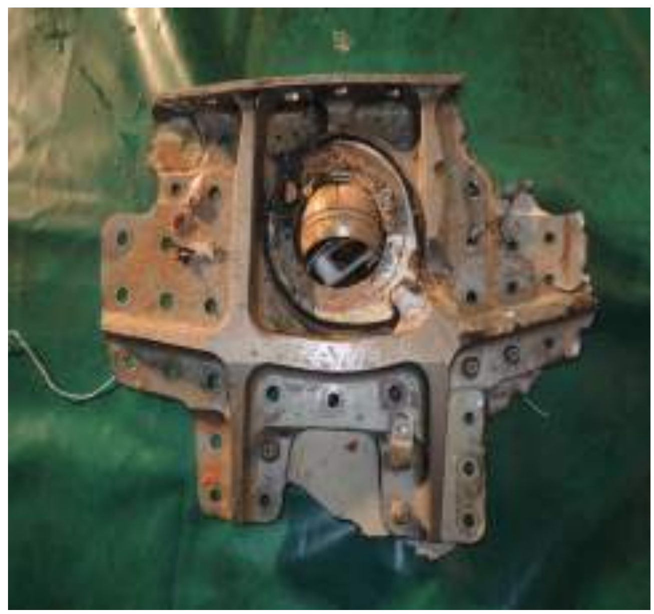
Part Description: RH pintle fitting of main landing gear

Dive # 6

Debris # D52

Grid square (E;26)

GPS POS: 33; 28.1088607 N   29; 15.4048658 E



EAAID Identification No. 18

Part Description: Engine part with shaft

Dive # 6

Debris # D224

Grid square (B; 30)

GPS POS: 33; 28.0574151 N   29; 15.3591488 E

EAAID Identification No. 32

Part Description: Wingtip and aileron

Dive # 7

Debris # D181

Grid square (M;21)

GPS POS: 33; 28.1802594 N   29; 15.5361068 E

Exhibit D

Summary of Forensic Medicine Report

Regarding the victims remains

EgyptAir Accident Flight Number MSR804

On 19/05/2016

- On 22/05/2016 A committee from the "Forensic Department" belonging to the Ministry of Justice, formed of four forensic doctors, under the supervision of chief senior forensic doctor, reviewed the General Prosecution decree of the case number 450/2016, High State Security exclusive, regarding EgyptAir airplane Accident flight number MSR804.
- Visible examination has been carried out on the found parts and victims remains as the result of the accident, to find out the following:
  - Whether these remains are human remains or not,
  - Taking the necessary specimens (samples) for the required emulation, and ensuring emulating with the genetic prints,
  - Taking the necessary photos and making necessary numbering,
  - Showing if these human remains contain any traces of explosive materials.
- The forensic doctor teams made a maritime trip accompanied with a forensic French team on 25/06/2016 to the crash site in the Mediterranean.
- The Egyptian forensic team made also another trip to the airplane crash site on 04/07/2016.

1. Medical forensic examination for the remains submitted to the Medical Forensic Department on 22-05-2016

Serial no.	Specimen no.	Specimen Description	x-Ray Result	Procedure
1	169	Part of a skin tissue and soft tissue and muscles of 75 cm x 60 cm dimensions	Existence of strange metallic and plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
2	170	A part of left upper limb, about 45 cm of length or nails a child	No strange parts were found	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
3	171	Part of a skin tissue and soft tissue and muscles of 60 cm x 70 cm dimensions	Existence of strange metallic and plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists

4	172	Part of a skin or hair tissue and soft tissue and muscles of 45 cm x 25 cm dimensions	Existence of strange metallic and plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
5	173	Upper limb remains skin soft tissue or bone of 15 cm x 12 cm dimensions	Existence of strange metallic and plastic parts and some bones parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
6	174	Part of soft tissue embedded with plastic or fibers of 12 cm x 9 cm dimensions	Existence of strange plastic parts and fibers	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
7	175	Part of soft tissue embedded with plastic or fibers of 20 cm x 5 cm dimensions	Existence of strange plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
8	176	Part of a skin tissue and soft tissue and muscles of 35 cm x 19 cm dimensions	Existence of plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
9	177	Part of a skin tissue and soft tissue and muscles holds some plastic parts of 50 cm x 19 cm dimensions	Existence of strange plastic parts of metallic wire	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
10	178	Skin tissue, soft tissue or muscles of a segment of toe	Black plastic part	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists

11	179	Part of a skin tissue and soft tissue and with hairy skin muscles of 35 cm x 25 cm dimensions	Existence of strange metallic and plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
12	180	A piece of skin with hair of 20 cm x 25 cm dimensions	Nonexistence of metallic parts except for some electric wires and plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
13	181	A piece of hairy skin connected to small part of muscles tissue of 5 cm x 10 cm dimensions	Nonexistence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
14	182	Part of the right upper limb of a child	Nonexistence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
15	183	A piece of skin with a muscles tissue of 6 cm x 11 cm dimensions	Nonexistence of metallic parts except for some plastic parts or glass parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
16	184	A piece of belly skin of 35 cm x 45 cm dimensions	Existence of metallic parts unidentified in shape. And some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
17	185	A piece of face skin of 7 cm x 10 cm dimensions	Existence of small metallic parts and some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
18	186	A part of tissues 5 cm x 10 cm dimensions	Non existence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists

				• Performing DNA Researches by the Medical Lab Specialists
19	187	A part of skin and muscles from the chest area 20 cm x 90 cm dimensions	Non existence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
20	188	A part of tissues 2 cm x 8 cm dimensions	Non existence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
21	189	Two parts of tissues 4 cm x 13 cm dimensions	Non existence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
22	190	Five parts of tissues 1 cm x 12 cm,to 1 cm x 8 cm dimensions	Non existence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
23	191	A part of tissues 8 cm x 10 cm dimensions	Non existence of metallic parts except for some plastic parts	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists

2. Second stage of the shared mission between the Medical Forensic teams, Egyptian and French (moving to the aircraft crash site on 25-06-2016)

– On 25-06-2016 , and based on the general prosecution decree, the members shown hereafter:

- On site Forensic Doctor/ [redacted]
- Lab Forensic Doctor/ [redacted]
- Chemist Expert/ [redacted]
- Technician/ [redacted]

(From Egyptian Forensic Medicine)

- [redacted] Doctor/ [redacted]
- [redacted] Expert/ [redacted]

(From French Forensic Medicine)

Moved from the Egyptian Forensic Medicine General Department to Alexandria, and boarded the vessel John Lightbridge. A plan was established before that with the participation of both partners from the Egyptian and French Forensic Medicine. The plan was made for the complete coordination and for taking all the actions and proper quick procedures. The plan was documented on stages and reviewed so as to be clear for both partners.

The mission was made through several consecutive dives to recover the human remains from the deep water. The dives were numbered by the number of boxes included the recovered specimens (samples) according to the international barcode as follows:

Box #1:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	230	PM-020-0001	A skin part covering the front of the thigh and knee	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
2	231	PM-020-0002	A part of the left foot ankle	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
3	232	PM-020-0003	A part of the left foot	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
4	233	PM-020-0004	A number of 6 Cervical vertebrae	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
5	234	PM-020-0005	A part of the right hand	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists

Box #2:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	235	PM-020-0006	A part of the left hand bone, arm and elbow	Performing DNA Researches by the Medical Lab Specialists
2	236	PM-020-0007	A part of the left hand	Performing DNA Researches by the Medical Lab Specialists
3	237	PM-020-0008	A part of the right elbow	Performing DNA Researches by the Medical Lab Specialists
4	238	PM-020-0009	A number of two parts of two chest ribs	Performing DNA Researches by the Medical Lab Specialists
5	239	PM-020-0010	A part of the left hand bone, surrounded with some tissues	• Searching for any traces of explosive materials by the chemical lab specialists • Performing DNA Researches by the Medical Lab Specialists
6	240	PM-020-0011	A part of the right knee tissue	Performing DNA Researches by the Medical Lab Specialists
7	241	PM-020-0012	A part of the left bone pelvis	Performing DNA Researches by the Medical Lab Specialists
8	242	From PM-020-0013 to PM-020-0023	Group of fractured small bones	Performing DNA Researches by the Medical Lab Specialists

Box #3:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	243	PM-020-0024	A part of a bone from the skull bottom	Performing DNA Researches by the Medical Lab Specialists
2	244	PM-020-0025	A part of the left pelvis bone	Performing DNA Researches by the Medical Lab Specialists
3	245	PM-020-0026	Skin part	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
4	246	PM-020-0027	A part of the right ankle bone	Performing DNA Researches by the Medical Lab Specialists
5	247	PM-020-0028	A part of a hand bone	Performing DNA Researches by the Medical Lab Specialists
6	248	PM-020-0029	A part of the front half of the right foot	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
7	249	PM-020-0030	A part of a skin	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
8	250	PM-020-0031	An upper part of the pelvis bone	Performing DNA Researches by the Medical Lab Specialists
9	251	PM-020-0032	A part of a rib	Performing DNA Researches by the Medical Lab Specialists
10	252	PM-020-0033	Part of vertebrae	Performing DNA Researches by the Medical Lab Specialists
11	253	From PM-020-0034 to PM-020-0036	Group of fractured small bones	Performing DNA Researches by the Medical Lab Specialists

Box #4:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	254	PM-020-0037	A lower part of the radius bone	Performing DNA Researches by the Medical Lab Specialists
2	255	PM-020-0038	Lower part of the middle of Ulna bone	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
3	256	PM-020-0039	Upper part from the shoulder bone	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
4	257	PM-020-0040	Metacarpal bone of finger of the hand fingers	Performing DNA Researches by the Medical Lab Specialists
5	258	PM-020-0041	One hand finger	Performing DNA Researches by the Medical Lab Specialists
6	259	PM-020-0042 to PM-020-0043	A part of a bone from the base of a skull	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists

Box #5:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	260	PM-020-0044	Incomplete hand finger	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
2	261	PM-020-0045	A part of skin	Performing DNA Researches by the Medical Lab Specialists
3	262	PM-020-0046	A part of skin	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
4	263	PM-020-0047	A part of the right hand	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists

Box #6:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	264	PM-020-0048	A part of skin	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
2	265	PM-020-0049	A part of a left hand finger	Performing DNA Researches
3	266	PM-020-0050	An upper part of the bone of the right pelvis	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
4	267	PM-020-0051	A front part of the left foot	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
5	268	PM-020-0052	Right ankle	Performing DNA Researches by the Medical Lab Specialists
6	269	PM-020-0053	A number of Cervical vertebrae	Performing DNA Researches by the Medical Lab Specialists
7	270	PM-020-0054	Fractured part of the pelvis bone body	Performing DNA Researches by the Medical Lab Specialists
8	271	PM-020-0055	Lower part of the right humorous bone	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
9	272	PM-020-0056	A part of skin	Performing DNA Researches by the Medical Lab Specialists
10	273	PM-020-0057	A mashed part of a hand tissue	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
11	274	PM-020-0058	A part of the soft tissue	Performing DNA Researches by the Medical Lab Specialists
12	275	PM-020-0059 PM-020-0060 PM-020-0061 PM-020-0062	Bone parts	Performing DNA Researches by the Medical Lab Specialists

Box #7:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	276	PM-020-0063	an upper part of sternum	Performing DNA Researches by the Medical Lab Specialists
2	277	PM-020-0064	Two fractured parts from two ribs	Performing DNA Researches by the Medical Lab Specialists
3	278	PM-020-0065	Soft decomposed tissues	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
4	279	PM-020-0066	Fragmented part from the left hand	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists

Box #8:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	280	PM-020-0067	A lower part of the radius bone and Ulna	Performing DNA Researches by the Medical Lab Specialists
2	281	PM-020-0068	A complete left foot	Performing DNA Researches by the Medical Lab Specialists
3	282	PM-020-0069	The two bones of the heel and ankle	Performing DNA Researches by the Medical Lab Specialists
4	283	PM-020-0070	Fragmented part from the front of the left foot	Performing DNA Researches by the Medical Lab Specialists
5	284	PM-020-0071	A part of the right elbow	Performing DNA Researches by the Medical Lab Specialists
6	285	PM-020-0072 PM-020-0073	Two part of the radius bone and Ulna	Performing DNA Researches by the Medical Lab Specialists
7	286	PM-020-0074	A part of skin	Performing DNA Researches by the Medical Lab Specialists

Box #9:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	287	PM-020-0075	Upper half of the left elbow bone	Performing DNA Researches by the Medical Lab Specialists
2	288	PM-020-0076	A bone part from the middle of the leg bone	Performing DNA Researches by the Medical Lab Specialists
3	289	PM-020-0077	A bone part of the head of the humerus bone	Performing DNA Researches by the Medical Lab Specialists
4	290	PM-020-0078	Fractured part of the pelvis bone body	Performing DNA Researches by the Medical Lab Specialists
5	291	PM-020-0079	A number of 6 Cervical vertebrae	Performing DNA Researches by the Medical Lab Specialists
6	292	PM-020-0080	A part of abdominal skin	Performing DNA Researches by the Medical Lab Specialists
7	293	PM-020-0081	Canine tooth for an adult person	Performing DNA Researches by the Medical Lab Specialists

Box #10:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	294	PM-020-0082	Upper half of the left humorous bone	Performing DNA Researches by the Medical Lab Specialists
2	295	PM-020-0083	Lower third of the two bones of the radius bone and Ulna	• Searching for any traces of explosive materials by the chemical lab. • Performing DNA Researches by the Medical Lab Specialists
3	296	PM-020-0084	Upper two thirds of the radius	Performing DNA Researches by the Medical Lab Specialists
4	297	PM-020-0085	Upper two thirds of the left humorous	Performing DNA Researches by the Medical Lab Specialists
5	298	PM-020-0086	Fractured part of the pelvis bone	Performing DNA Researches by the Medical Lab Specialists
6	299	PM-020-0087	Rear part of a Cervical vertebrae	Performing DNA Researches by the Medical Lab Specialists
7	300	PM-020-0088	Rear part of a Cervical vertebrae	Performing DNA Researches by the Medical Lab Specialists
8	301	PM-020-0089	A part of a two vertebrae	Performing DNA Researches by the Medical Lab Specialists
9	302	PM-020-0090	Fragmented part from the right hand	Performing DNA Researches by the Medical Lab Specialists
10	303	PM-020-0091	A part of the soft tissue	Performing DNA Researches by the Medical Lab Specialists
11	304	PM-020-0092 PM-020-0093 PM-020-0094 PM-020-0095	Parts from bones	Performing DNA Researches by the Medical Lab Specialists

Box #11:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	305	PM-020-0096	Fractured part of the pelvis bone	Performing DNA Researches by the Medical Lab Specialists
2	306	PM-020-0097	Part of the left shoulder bone	Performing DNA Researches by the Medical Lab Specialists
3	307	PM-020-0098	Part of the elbow joint	Performing DNA Researches by the Medical Lab Specialists
4	308	PM-020-0099	A part of the ankle and heal bone	Performing DNA Researches by the Medical Lab Specialists
5	309	PM-020-0100	Right elbow	Performing DNA Researches by the Medical Lab Specialists
6	310	PM-020-0101	Left hand	Performing DNA Researches by the Medical Lab Specialists
7	311	PM-020-0102	Right elbow joint	Performing DNA Researches by the Medical Lab Specialists
8	312	PM-020-0103	Part of the soft tissues around the knee joint	Performing DNA Researches by the Medical Lab Specialists
9	313	PM-020-0104	Fragmented part from the front pelvis bone	Performing DNA Researches by the Medical Lab Specialists
10	314	PM-020-0105	A part of the shoulder bone	Performing DNA Researches by the Medical Lab Specialists
11	315	PM-020-0106	A part of the bones of the foot and ankle	Performing DNA Researches by the Medical Lab Specialists
12	316	PM-020-0107	A part of the bones of the foot	Performing DNA Researches by the Medical Lab Specialists
13	317	PM-020-0108	parts of the hand bones	Performing DNA Researches by the Medical Lab Specialists
14	318	PM-020-0109	Incomplete part of the ulna bone	Performing DNA Researches by the Medical Lab Specialists
15	319	PM-020-0110	Part from the tissues	Performing DNA Researches by the Medical Lab Specialists
16	320	From PM-020-0111 to PM-020-0119	Parts of bones	Performing DNA Researches by the Medical Lab Specialists

Box #12:

Serial no.	Case no.	Bar code number	Case Description	procedure
1	321	PM-020-0120	Left pelvis bone	Performing DNA Researches by the Medical Lab Specialists
2	322	PM-020-0121	Left elbow for an adult person	Performing DNA Researches by the Medical Lab Specialists
3	323	PM-020-0122	Bone part (Bones for non human)	Performing DNA Researches by the Medical Lab Specialists
4	324	PM-020-0123	Upper two thirds of the left humorous	Performing DNA Researches by the Medical Lab Specialists
5	325	PM-020-0124	Fragmented part from the pelvis bone	Performing DNA Researches by the Medical Lab Specialists
6	326	PM-020-0125	Fragmented part from the pelvis bone	Performing DNA Researches by the Medical Lab Specialists
7	327	PM-020-0126	Fragmented part of the femur of thigh	Performing DNA Researches by the Medical Lab Specialists
8	328	PM-020-0127	Upper part of the humorous bone	Performing DNA Researches by the Medical Lab Specialists
9	329	PM-020-0128	A number of 3 thoracic vertebrae	Performing DNA Researches by the Medical Lab Specialists
10	330	PM-020-0129	Ankle bone	Performing DNA Researches by the Medical Lab Specialists

11	331	PM-020-0130	Fragmented part from the pelvis bone	Performing DNA Researches by the Medical Lab Specialists
12	332	PM-020-0131	Fragmented part from a vertebrae	Performing DNA Researches by the Medical Lab Specialists
13	333	PM-020-0132	Fragmented part from the skull bone	Performing DNA Researches by the Medical Lab Specialists
14	334	PM-020-0133	Fragmented part of sternum bone	Performing DNA Researches by the Medical Lab Specialists

3. **Third stage the transfer of the Egyptian Forensic Medicine team to the aircraft crash site in the sea on 04-07-2016**

– On 04-07-2018, a committee formed of 2 forensic doctors, chemical expert and a technician from the Egyptian Forensic Medicine Department moved to Alexandria sea port and boarded the ship to the airplane crash site.
– The human parts of the airplane victim's human remains were recovered in the period between 04-07-2016 to 16-07-2016. These parts were recovered through several dives through that period.
– These specimens were given forensic medicine numbers as unknowns. Numbers used are from 335 to 429. The total number of recovered parts, where genetic prints were taken from them are 95 human part.

4. **Report of the Medical labs belonging to Forensic medicine department in Cairo**

– Based on the State High Security Prosecutor Decree issued on 21-05-2016 concerning the forensic examinations to the recovered parts and human remains on 21-05-2016 and keeping (reserving) 23 plastic bags and examining them to check their nature and if they are for human remains or not and taking samples from them and from the passengers families to perform required emulation, and ensuring emulating with the genetic prints (DNA). Following had been done:
  - Two teams of the Forensic medical labs Central department doctors moved to the anatomy department to take the required samples from the human remains which had been previously numbered from 169 to 191 by the on-site forensic doctors at Alexandria. The first team took samples from the human remains number 169-179. The second team took samples from the human remains number 180-191.
  - At the second stage during the time between 25-06-2016 to 03-07-2016, 133 samples had been withdrawn from human remains. 95 samples had been withdrawn at the third stage for genetic analysis (DNA) and comparison.
  - A number of samples had been taken from the Egyptian victim's relatives to analyze the DNA Prints and make a comparison.
  - Samples had been acquired from the Canadian, Portuguese, Algerian embassies for the other victim's relatives for the shown citizens. The analysis of the DNA prints from the French victims' relatives had been acquired the French Interpol.
  - The DNA was extracted from all the taken samples, which were taken as follows:

- Human remains samples brought to the Forensic medical labs Central department
- Blood samples that were taken from the accident EgyptAir Airplane victim relatives
- Samples brought from the Canadian and Portuguese embassies.

▪ The DNA was extracted and measured for the samples. The genetic print for the DNA extracted from the samples were shown using the STR Multiplex method. Comparison had been made for the genetic print for all the samples.

▪ As a result. 64 of the airplane victims were identified

5. **The first report of the chemical labs, forensic medical department in Cairo, regarding examination of the samples that had been received in Alexandria seaport.**

– The human remains and the hard part remains numbers from 169 to 191 were examined. The samples taken from them were extracted. The followings were found in the samples extractions numbers 174, 175, 183, 187, 184, 190:

A. Traces of 2, 4, 6 – Tri Nitro Toluene TNT of the explosive compounds that are highly explosives

B. Traces of 3- Nitro phnalic acid (one of the compounds used in making explosives, and has also several other usages)

C. Small traces of the following compounds:

1. Mono Nitro Toluene
2. Mono Nitro Benzene
3. 5.1 Dimethyl – 4. 2 Nitrobenzene
4. 2 Nitro Benzoic acid
5. 4.2 Dichloro – 5 - NitroToluene
6. 2.1 Dimethyl – 4 - Nitrobenzene
7. 2 Amino – P- Toluic Acid

These compounds can be considered as post blast residence of an explosion

D. Small traces of the following compounds:

1. One of the Nitro Methane compounds (one of the compounds that is used in manufacturing explosives plus other uses)
2. Tribytyl phosphate and Dibutyl phenyl phosphate

Several methods were applied using the LC Triple Quad, GC/MS Technique to show and prove these results.

6. The second report of the chemical labs, forensic medical department in Cairo, regarding examination of the samples that had been recovered from the airplane crash site.

- The human remains and the hard part remains collected from the wreckage site in the period from 25-06-2016 to 04-07-2016 with a total number of 40 sample including 20 sample of hard parts from the airplane wreckage and 20 sample of hard parts attached to human remains, from recovered samples were examined.
- The samples visual examination showed existence of burning traces in some of the human remains and some of the hard samples, in addition of dentation(shape change) in the hard samples and small shrapnel (flakes)
- Extraction process has been made to the samples after sorting and taking photos with the codes brought with them during the collection process on the ship. The followings were found with the samples extracts of codes 1S, 4S, 9S, 11S, 17S,18S,20S, MIXT, MIXD:
  - A. Traces of 2, 4, 6 – Tri Nitro Toluene TNT of the explosive compounds that are highly explosives.
  - B. Traces of 4, 6 – Dinitro Toluene (DNT) of the explosive compounds
  - C. Small traces of the following materials:
    1. Mono Nitro Toluene Ions
    2. Mono Nitro Benzene Ions
    3. 2- Nitro- m- Nitro Toluic Acid
    4. 2, 4 Dinitro- diphenylamine
    5. 3, 5 Dinitro – O-Nitrotoluene acid
    6. 2- Fluoro -4- Nitrotoluene
    7. 3, Nitrophythalic acid
    8. 4- Dimemylamino – 3, 5 Dinitro Benzoic acid

  These compounds are considered post blast residues of an explosion products

  Several ways using L C triple quad, GC/MS techniques were used to proof those results.
- A final table that shows the names of the cases after been identified through the DNA Technique and determining the samples that are positive for the explosive materials is shown hereafter:

Serial no.	Deceased Name	Sex (M male, F female)	Nationality	Attached Remains			
				Forensic Medicine No.			Lab Number (Bar Code)
				First Stage	Second stage	Third stage	
65	[redacted]	F	[redacted]			366 379 396	
66	[redacted]	F	[redacted]	177 178 183 positive	268 287 275/1	412	PM-020-0052 PM-020-0075 PM-020-0059
67	[redacted]	M	[redacted]		308 321 304/1 304/3	362 383	PM-020-0099 PM-020-0120 PM-020-0092 PM-020-0094
68	[redacted]	F	[redacted]	176 189/2	244 315 320/5		PM-020-0025 PM-020-0106 PM-020-0115
69	[redacted]	F	[redacted]		295 positive	391 427	PM-020-0083
70	[redacted]	M	[redacted]		300 306 318 320/1 320/3 320/7	363 399 423 425 428	PM-020-0088 PM-020-0097 PM-020-0109 PM-020-0111 PM-020-0113 PM-020-0117
71	[redacted]	M	[redacted]		254 255 positive 257 258		PM-020-0037 PM-020-0038 PM-020-0040 PM-020-0041
72	[redacted]	F	[redacted]		240 242/10	342 357	PM-020-0011 PM-020-0022
73	[redacted]	M	[redacted]		310 266 294 304/2 320/6 320/8	390	PM-020-0101 PM-020-0050 PM-020-0082 PM-020-0093 PM-020-0116 PM-020-0118

74	[redacted]	M	[redacted]			356 406 414	
75	[redacted]	M	[redacted]	172 190/2 positive	301 327		PM-020-0089 PM-020-0126
76	[redacted]	F	[redacted]	170			
77	[redacted]	F	[redacted]		247 270 324	400	PM-020-0028 PM-020-0054 PM-020-0123
78	[redacted]	F	[redacted]	184 Positive	243 280	367	PM-020-0024 PM-020-0067
79	[redacted]	M	[redacted]	187 positive 190/1 positive	230 positive 242/7	348 350	PM-020-0001 PM-020-0019
80	[redacted]	M	[redacted]	190/3 positive	279 positive		PM-020-0066
81	[redacted]	M	[redacted]		298 307	372	PM-020-0086 PM-020-0098
82	[redacted]	M	[redacted]	191			

83	[redacted]	M	[redacted]			413 416	
84	[redacted]	F	[redacted]		332		PM-020-0131
85	[redacted]	M	[redacted]	188	236 237 334 242/1 242/4 242/5 242/6		PM-020-0007 PM-020-0008 PM-020-0133 PM-020-0013 PM-020-0016 PM-020-0017 PM-020-0018
86	[redacted]	F	[redacted]	180			
87	[redacted]	F	[redacted]	171 189/1		385 426 429	
88	[redacted]	M	[redacted]		281 325 333	336 381 382 387	PM-020-0068 PM-020-0124 PM-020-0132
89	[redacted]	M	[redacted]		290		PM-020-0078
90	[redacted]	M	[redacted]		260 positive 263 positive 288 292	370 373	PM-020-0044 PM-020-0047 PM-020-0076 PM-020-0080
91	[redacted]	M	[redacted]	169	274	347 419	PM-020-0058

92	[redacted]	M	[redacted]		273 275/4 296 326	349 375 415	PM-020-0057 PM-020-0062 PM-020-0084 PM-020-0125
93	[redacted]	F	[redacted]			411	
94	[redacted]	M	[redacted]		238 277 305 309 317 328 242/8	360	PM-020-0009 PM-020-0064 PM-020-0096 PM-020-0100 PM-020-0108 PM-020-0127 PM-020-0020
95	[redacted]	M	[redacted]			364	
96	[redacted]	M			265		PM-020-0049
97	[redacted]	M	[redacted]	185		335	
98	[redacted]	F	[redacted]		284 285/1 285/2	368 377	PM-020-0071 PM-020-0072 PM-020-0073
99	[redacted]	F	[redacted]		250		PM-020-0031

100	[redacted]	F	[redacted]		256 positive 331	394 405	PM-020-0039 PM-020-0130
101	[redacted]	M	[redacted]	190/5 positive	312 313 320/2	361	PM-020-0103 PM-020-0104 PM-020-0112
102	[redacted]	M	[redacted]		289		PM-020-0077
103	[redacted]	F	[redacted]		232 positive 253/2		PM-020-0003 PM-020-0035
104	[redacted]	F	[redacted]		231 271 282 275/3	374	PM-020-0002 PM-020-0055 PM-020-0069 PM-020-0061
105	[redacted]	M	[redacted]	186/1	316	424	PM-020-0107
106	[redacted]	F	[redacted]	173			
107	[redacted]	M	[redacted]		262 positive 278 positive 314 320/4		PM-020-0046 PM-020-0065 PM-020-0105 PM-020-0114
108	[redacted]	M	[redacted]		269 276 322	401	PM-020-0053 PM-020-0063 PM-020-0121

109	[redacted]	M	[redacted]			351	
110	[redacted]	M	[redacted]			369 378 407	
111	[redacted]	M	[redacted]	186/2		410	
112	[redacted]	M	[redacted]		267 positive		PM-020-0051
113	[redacted]	M	[redacted]		291		PM-020-0079
114	[redacted]	F	[redacted]	175 positive	246		PM-020-0027
115	[redacted]	M	[redacted]	179		358 365 386	
116	[redacted]	F	[redacted]		320/9		PM-020-0119
117	[redacted]	M	[redacted]	174 positive		402 403 422	

118	[redacted]	M	[redacted]	181	272 283 253/1 275/2		PM-020-0056 PM-020-0070 PM-020-0034 PM-020-0060
119	[redacted]	M	[redacted]		248 positive	418	PM-020-0029
120	[redacted]	M	[redacted]		233 234 positive 239 251 252 297 303 253/3	340 344 397 404	PM-020-0004 PM-020-0005 PM-020-0010 PM-020-0032 PM-020-0033 PM-020-0085 PM-020-0091 PM-020-0036
121	[redacted]	M	[redacted]	190/4 positive	241 319 330 242/9	343 359	PM-020-0012 PM-020-0110 PM-020-0129 PM-020-0021
122	[redacted]	M	[redacted]		302	409 421	PM-020-0090
123	[redacted]	F	[redacted]		329		PM-020-0128
124	[redacted]	M	[redacted]		259/1 259/2	395 384	PM-020-0042 PM-020-0043
125	[redacted]	F	[redacted]	182			

126	[redacted]	M	[redacted]			352 353 354 355 408 420	
127	[redacted]	M	[redacted]			371 376 393	
128	[redacted]	M	[redacted]		235 299 242/2 242/3		PM-020-0006 PM-020-0087 PM-020-0014 PM-020-0015

Conclusion:

- Based on previous and following statements, the forensic medicine experts decide the following:
  1. The examinations to the remains revealed that they are human remains. It was proved, using the technique of DNA and by showing the genetic print and emulating them with the victim families, that they belong to 64 passenger of the total number of passengers which was 66 passengers (including crew).
  2. By using the chemical analysis to the samples taken from the remains and the metallic, plastic materials attached to them and the solid materials that were recovered from the wreckage site, It was proven the existence of traces of the TNT compound. This compound is highly explosive and is not of the normal material of the aircraft structure, and it is not included in the manufacturing of the aircraft nor any of the utilities.
  3. Based on the previous information describing the procedures that were taken for the accident and through the three stages that were previously mentioned, and after taking all the precautions from the Egyptian and the French sides not to pollute the samples , And The appearance of this explosive compound in the samples of the first and the second stages attached to the human remains , the solid , plastic and metallic parts- the forensic medicine experts conclude that this compound was stuck into (attached to) the passengers bodies and the solid bodies included in the aircraft. This indicates that this compound took off at high speed due to the wave blast associated with the explosion, and was come in contact with the passengers bodies and the aircraft body resulting in the aircraft crash and the death of all the passengers.
  4. The cause of the passenger's death is referred to the injuries associated with the explosion and the crash of the aircraft as a result of the explosion with the TNT compound.

Exhibit E

The BEA study concerning the oxygen fires in cockpit

BEA
Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

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SAFETY STUDY

Oxygen fire in cockpit study - Accident to the A320 registered SU_GCC on 19 May 2016

RÉPUBLIQUE FRANÇAISE
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december 2023

BEA2016-0093

PREAMBLE

The BEA is the French Civil Aviation Safety Investigation Authority. Its studies are conducted with the sole objective of improving aviation safety and are not intended to apportion blame or liabilities.

The BEA studies are independent, separate and conducted without prejudice to any judicial or administrative action that may be taken to determine blame or liability.

SPECIAL FOREWORD TO ENGLISH EDITION

This is a courtesy translation by the BEA of the study.

As accurate as the translation may be, the original text in French is the work of reference.

Contents

Glossary

Abbreviation	Definition
A/P	Auto-Pilot
EAAID	Aircraft Accident Investigation Directorate / Egyptian Ministry of Civil Aviation
ACARS	Air Communication Addressing and Reporting System
AIROPS	EU regulation No 965/2012
AMU	Audio Management Unit
APU	Auxiliary Power Unit
ATC	Air Traffic Control
CAM	Cockpit Area Microphone
CFR	Current Flight Report
COPIL	Co-pilot
CRC	Continuous Repetitive Chime
CVR	Cockpit Voice Recorder
EASA	European Aviation Safety Agency
ECAM	Electronic Centralized Aircraft Monitor
EICAS	Engine Indicating and Crew Alerting System
ELT	Emergency Locator Transmitter
FAA	Federal Aviation Authority
FAR	Federal Aviation Regulation
FCOM	Flight Crew Operating Manual
FDR	Flight Data Recorder
FLxxx	Flight Level
PA	Public Address
PBE	Protective Breathing Equipment
PF	Pilot Flying
PM	Pilot Monitoring
QRH	Quick Reference Handbook
UTC	Coordinated Universal Time

SYNOPSIS

Oxygen fire in cockpit study
Accident to the A320 registered SU-GCC

SAFETY INVESTIGATION

Opening of investigation

Following the accident on 19 May 2016 over the Mediterranean Sea, involving an Airbus A320 registered SU-GCC operated by EgyptAir, a safety investigation was opened. In compliance with the international texts in force, and in particular Annex 13 to the Convention on International Civil Aviation, as the accident occurred in international waters, Egypt's Aircraft Accident Investigation Directorate (EAAID), as the State of Registry and State of the Operator of the aeroplane, was charged with the safety investigation.

The BEA appointed an Accredited Representative for France as the State of Design of the aeroplane, assisted by technical advisers from the aircraft manufacturer, Airbus and from the European Aviation Safety Agency (EASA). The American safety investigation authority (NTSB) also appointed an Accredited Representative for the United States as State of Manufacture of the engines.

Organization of investigation

Sea searches located the wreckage and the flight recorders were recovered. In July 2016, the data from the Cockpit Voice Recorder (CVR) and the Flight Data Recorder (FDR) was extracted under the authority of the Egyptian Investigator In Charge, in the BEA laboratory in France.

The EAAID publicly communicated the following information: a fire had broken out on board the aeroplane and was identified by the crew; the flight recorders had stopped while the aeroplane was still in cruise at an altitude of 37,000 ft.

In the scope of the investigation, the BEA shared with the EAAID, information about previous occurrences where there had been fires in the presence of an oxygen leak in the cockpits. In these occurrences, there was a leaking noise comparable to that present on the CVR recording of this occurrence.

In December 2016, the EAAID announced the discovery of traces of explosives on victims and stated that, in accordance with Egyptian legislation, the case was transferred to the Egyptian Attorney General who would from now on be responsible for carrying out the investigation.

The BEA was not able to confirm this finding. Furthermore, no other factual information available to the BEA supported the hypothesis that an explosion had occurred on board the aeroplane.

OXYGEN FIRE STUDY

Initiation of study

The BEA proposed to the EAAID, to continue the work into the accident, using the occurrences identified above. As it was not possible for the EAAID to continue the safety investigation, the BEA carried out a study on oxygenated fires in the cockpit, convinced that a more detailed analysis of the accident to flight MS804 could provide safety lessons to be shared with the international aviation community.

Scope

In the event of depressurisation or smoke, the members of the crew and the passengers may need to use oxygen. For this eventuality, pilots have quick-donning masks at their disposal, stowed in storage boxes on both sides of the cockpit.

	
Fixed breathing equipment (quick-donning)	*Location of fixed breathing equipment in commercial air transport aeroplanes*

The study carried out by the BEA focused on the following subjects:

- the possible mechanisms leading to a fire and a pressurised oxygen leak in or near the oxygen mask storage box;
- the spread of a fire in the presence of a pressurised oxygen leak;
- the possibilities for extinguishing this type of fire;
- the acoustic characterisation of these phenomena.

The fire breakout mechanisms studied included external sources of heat (lithium batteries in electronic devices or glowing cigarettes), internal ignition in the hoses or the ignition of grease and dust in the oxygen-enriched environment.

Fire fed by pressurised oxygen - Test results

Details of the tests and results obtained are summarised in several videos (Video 1 and 2 /4) and confirm that a sound runaway comparable to that produced by a blowtorch is present when the mask assembly catches file when the system is supplied with pressurised oxygen. In this case, the flames are large and the fire spreads rapidly to the surroundings of the storage box.

The results on how the fire spreads in the environment of the oxygen distribution system are also the subject of a video (Video 4/4).

Lastly, a video (Video 3/4) shows the ineffectiveness of using a halon fire extinguisher, present inside the cockpit of flight MS804, on a fire fuelled by a pressurised oxygen leak.

Application of study results to accident to flight MS804

The accident sequence began while the aeroplane was cruising at 37 000 ft (11 277m), with a cabin crew member present in the cockpit, the captain resting in his seat and the co-pilot flying.

The first event of the accident sequence which could be identified was a flow of oxygen for 2.6 s via the co-pilot's mask regulator. This flow had the same characteristics as when the *EMERGENCY* knob of the mask is pressed when the box has not been reset. The investigation was not able to determine if this flow was linked to a human action.

The storage box of the co-pilot's mask was thus highly enriched in oxygen as a result of this flow. A loud transient noise of unknown source occurred at this point in the mask storage box. It has not been possible to determine what generated this loud noise. Less than half a second later, the noise of a continuous oxygen flow appeared again. A fire started in the co-pilot's mask storage box, and was fuelled by the pressurised oxygen leak. It has not been possible to determine which came first: the fire or the oxygen leak. Neither has it been possible to determine the cause of the fire.

Whichever the case, the oxygen-fed fire spread to the outside of the storage box. This type of fire is rapid, large-scale and difficult to control. It produces a characteristic noise comparable to that of a blowtorch. The study has shown that the protection and extinguishing equipment available on board aeroplanes is not sufficient to control this type of fire.

The fire very probably then damaged the computer power supply systems, which led to the disconnection of the autopilot in particular. No crew actions were recorded in the cockpit. It has not been possible to determine whether the crew remained or not in the cockpit, whether they were unconscious in the cockpit or whether they had fled the fire and then returned or remained outside the cockpit. The aeroplane entered an uncontrolled flight path and collided with the sea.

SAFETY RECOMMENDATIONS

In addition to research into the accident scenario, the study has highlighted the safety issues associated with the oxygen systems present on board heavy commercial air transport aeroplanes.

The presence of the oxygen distribution system has a twofold impact:

- the air may become enriched with oxygen in the vicinity of the supply system due to micro-leaks, mask tests or a rupture of a part in the oxygen supply system. The presence of oxygen makes the elements more inflammable and the start of a fire more likely;
- a fire that damages the oxygen systems, if it causes a hose to rupture, becomes an oxygen-enriched fire that is difficult to control.

Certification requires that the occurrence of an uncontrolled oxygen fire is extremely unlikely. Several in-flight and on-ground occurrences gave rise to thought being given not only to the means of preventing these fires, but to their propagation and the means of fighting them.

Further work taking into consideration the effects of overpressure in the oxygen system

The tests carried out by the BEA in the scope of this study were based on the assumption that the pressure in the system was 5 bar. Internal ignition mechanisms such as particle impact, grease oxidation or ignition by electrostatic discharge may depend on the oxygen pressure. Similarly, the fragility created by a nearby external source of ignition could be greater in the event of a high-pressure leak.

EASA, in collaboration with the manufacturers, carry out additional risk analyses to take into account the hypothesis of an overpressure in the distribution system and its consequences in terms of failure mechanisms. The results should be analyzed with regard to the potential factors explaining the scenario of flight MS804. These analyses may require additional testing as part of a research program.

Propagation of a fire fed by an oxygen leak

The events and the tests carried out have highlighted the size of the fire and the speed at which it spreads in the case of a fire fuelled by an oxygen leak. These fires produce a characteristic sound, comparable to that of a blowtorch, and significant heat (recognisable by the whiteness of the flame).

Two on-ground occurrences and the tests showed that halon fire extinguishers are not suitable for treating fires fuelled by an oxygen leak.

In the events on the ground, the crews were unable to control the fires and evacuated the cockpit. In flight, fighting an oxygen-enriched fire requires the oxygen supply to be immediately cut off.

Consequently, the BEA recommends that EASA assess the appropriateness of cockpit fire/smoke procedures incorporating the recognition of an oxygen fire (identifiable by a characteristic noise comparable to that of a blowtorch) and the immediate cutting off of the oxygen supply in this case, and if necessary review the requirements for installing and carrying protective equipment *independent of the oxygen distribution system.*

Risks linked to the use of cigarettes in the cockpit

International regulations are not explicit about banning smoking in the cockpit of commercial air transport aeroplanes. While there are warnings about smoking near oxygen in the passenger compartment, there are no similar warnings with respect to the cockpit. The decision seems to rest with the captain.

No systematic and obvious danger has been established from smoking near an oxygen mask storage box, even with a mask in the EMERGENCY position or when the box has not been reset. However, if a cigarette is introduced into the storage box - unlikely but possible - a fire may start, accompanied by an oxygen leak. In this case, the flames would be large and the fire would spread rapidly to the surroundings of the storage box.

Consequently, the BEA recommends that EASA ensure that the danger represented by a glowing cigarette in the cockpit be taken into account, the associated risks assessed and that certification and operational regulations be amended where applicable.

1. CONTEXT

Following the accident to an Airbus A320 registered SU-GCC and operated by EgyptAir, on 19 May 2016 over the Mediterranean Sea, a safety investigation was opened. In compliance with the international texts in force, as the accident occurred in international waters, the Egyptian safety investigation authority (EAAID), as the State of Registry and State of the Operator of the aeroplane, was in charge of carrying out this investigation.

The BEA appointed an accredited representative, France being the State of Design of the aeroplane, and was assisted by technical advisers from the aircraft manufacturer, Airbus and from EASA. The American safety investigation authority (NTSB) also appointed an accredited representative, the United States being the State of Manufacture of the engine.

Sea searches located the wreckage and the two flight recorders were recovered. The initial work on the flight recorders was carried out under the authority of the Egyptian Investigator In Charge (IIC), in the BEA laboratory. At the beginning of July 2016, the data from the Cockpit Voice Recorder (CVR) and the Flight Data Recorder (FDR) was extracted, read and decoded.

During this work, the EAAID published the following elements about the accident:

- the flight recorders stopped operating while the aircraft was in cruise at an altitude of 37,000 ft;
- the aircraft systems sent ACARS messages indicating the presence of smoke in the toilets and the avionics bay;
- the data from the FDR confirms these messages;
- the playback of the CVR reveals, in particular, that the flight crew mentioned the existence of a fire on board;
- several pieces of debris were retrieved from the accident site. Some of these showed signs of having been subject to high temperatures, and traces of soot.

In December 2016, the EAAID announced the discovery of traces of explosives on human remains and stated that, in accordance with Egyptian legislation, the case was going to be transferred to the Egyptian Attorney General who would from now on be responsible for carrying out the investigation.

The BEA proposed carrying out additional work on the debris and recorded data to the EAAID, to better understand the sequence of events.

In fact, based on the initial observations of the debris and the first analyses of the recorder data, the BEA considered that the most likely hypothesis was that a fire broke out in the cockpit while the aeroplane was flying at its cruise altitude and that the fire spread rapidly resulting in the loss of control of the aeroplane.

The BEA searched for previous occurrences where there had been a fire in the cockpit, particularly focusing on those where it was reported that there had been a loud hissing sound[1] as was the case in the CVR recording of flight MS804.

Three events which occurred on the ground where the CVR recording was available were identified. From a psycho-acoustic view point, the loud hissing that can be heard on the CVR of flight MS804 has

[1] Noise similar to that produced by a pressurised gas leak.

similarities with those recorded during these events. All three correspond to leaks in the oxygen systems in the cockpits (see paragraph 3).

With these events in mind, the BEA was convinced that there were most probably safety lessons to be learned and shared with the international aviation community based on a more detailed safety analysis of the SU-GCC accident. The BEA thus proposed continuing the work to their Egyptian counterpart. As it was not possible for the EAAID to resume the safety investigation, the BEA continued the safety analysis of the event and carried out a study on oxygenated fires in the cockpit.

This work led the BEA to conclude that there were indeed safety lessons to be shared with the international community and safety issues that would lead to safety recommendations. The BEA has drawn up this document to describe the work carried out, the conclusions that can be drawn from it and the resulting recommendations.

The BEA sent this document, in draft form, to the EAAID and the NTSB, inviting them to confirm that they had no objection to its publication.

The EAAID made known its objection to the public release of any information or data relating to flight MS804. EAAID has undertaken to resume the safety investigation and to prepare a draft final accident report in the coming six months.

The BEA, pursuant to standard 6.8 of Annex 13[2] relating to the option given to States participating in the investigation to issue safety recommendations after coordination with the State conducting the investigation, has taken the decision to issue safety recommendations and provide the document supporting these recommendations.

This document has been sent to EASA on a confidential basis. EASA is allowed to share this document, on a confidential basis, solely with the persons who need to be involved in the processing of the safety recommendations.

The BEA, pursuant to standard 6.8 of Annex 13[3] relating to the option given to States participating in the investigation to issue safety recommendations after coordination with the State conducting the investigation, has taken the decision to issue the safety recommendations and the document supporting them.

This document is composed of the following parts.

The first section (paragraph 2) describes the regulatory requirements concerning the oxygen system in the cockpit and the firefighting means.

The second section (paragraph 3) describes four events which occurred on the ground in which there was a fire and oxygen leak.

The third section (paragraph 4) is devoted to describing and understanding the SU-GCC accident sequence.

The fourth section (paragraph 5) describes the examinations carried out to understand:

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[2] Annex 13 to the Convention on International Civil Aviation

[3] Annex 13 to the Convention on International Civil Aviation

- certain fire break-out (ignition) mechanisms likely to affect the cockpit's oxygen system;
- the spread of a fire fed by an oxygen leak;
- the means to extinguish an oxygen-rich fire available in the cockpit.

The fifth section (paragraph 6) sets out partial conclusions with respect to the accident to SU-GCC and enlarges on the resulting safety issues.

Finally, the sixth section (paragraph 7) presents the safety recommendations addressed to EASA and the manufacturers. These recommendations concern the continuation of the work, the procedures for fighting oxygenated fires and the regulations concerning smoking in the cockpit.

2. OXYGEN SYSTEM AND FIREFIGHTING IN THE COCKPIT

In the event of depressurisation or smoke, the members of the crew and the passengers may need to use oxygen.

The large commercial air transport turbo jets are in the majority of cases, equipped with three separate oxygen systems:

- oxygen directly available in the cockpit for the crew’s use;
- oxygen available in the cabin, above each seat, for the passengers and cabin crew;
- portable oxygen equipment for the crew or passengers used in the event of an emergency or when giving first aid.

This chapter is dedicated to the oxygen system in the cockpit to be used by the crew.

2.1 Supplemental oxygen - regulatory requirements

For pressurised aeroplanes operated at pressure altitudes above 25,000 ft, regulatory requirement CAT.IDE.235 of consolidated European regulation (EU) No 965/2012, known as “AIROPS” indicates that the quantity of supplemental oxygen must cover, for all crew members, the flight time with a cabin altitude above 13,000 ft and a flight time of -30 minutes for a cabin altitude between 10,000 and 13,000 ft and in no case less than two flight hours.

Quick-donning type masks must be available for pilots. This type of mask:

(a) can be placed over the face from the pilot's seat, properly secured, sealed and supplying oxygen on demand, with one hand in less than five seconds, and then remain in position with both hands free;

(b) can be donned without interfering with the wearing of glasses and without delaying the pilot in the performance of assigned emergency tasks;

(c) when fitted, does not prevent immediate communication between flight crew members and other crew members via the aircraft's intercom system; and

(d) does not prevent radio communication.

For aircraft weighing more than 5,670 kg, the dedicated supplemental oxygen equipment must meet the certification specifications described mainly in paragraphs CS25.869 and CS25.1441 (or FAR equivalent).

CS25.869 indicates that the system must be installed in such a way that escaping oxygen cannot cause ignition of grease, fluid or vapour accumulations that are present in normal usage conditions or as a result of failure or malfunction of any system.

CS25.1441 adds that the oxygen system must be free from hazards in itself, in its method of operation, and in its effect upon other components.

The means of compliance AMC 25.1441 details the risk analyses that can be carried out to meet these requirements.

With regard to the installation of the oxygen system, in addition to the requirements described in CS25.869, the AMC for CS 25.1441(b) indicates that potential external sources of ignition must be studied and the associated risks minimised.

The compartments in which oxygen systems are installed must provide adequate protection against possible contamination; these compartments must be adequately ventilated and the routing of the system must be insulated.

In addition, the oxygen hazard analysis must show that the oxygen systems and their components are designed in such a way that the occurrence of an uncontrolled oxygen fire in the aircraft is extremely unlikely and does not result from a single failure. This analysis must assess the combustion and ignition mechanisms, and in particular the following aspects:

- equipment failure (excluding failures due to human error during assembly);
- operating conditions;
- components and materials, with particular reference to spontaneous-combustion temperatures in a 100% oxygen-enriched atmosphere;
- ignition mechanisms;
    - the analysis must cover the possible internal ignition mechanisms, taking into consideration as a minimum: particle impact[4], rapid pressurization[5], flow friction[6], resonance[7], mechanical impact[8], galling and friction[9], fresh metal exposure[10], static discharge[11], electric arc[12], chemical reaction[13] and thermal runaway[14],
- kindling chain;
    - the analysis must look into the ability of a fire to propagate and burn through a component. If one of the ignition mechanisms exists, the kindling chain must be analysed.

The following design elements must also be considered: high-pressure shut-off valve, pressure-limiting device, isolation, material of hoses, grounding, joints and recharging systems.

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[4] Heat generated when small particles strike a material with sufficient velocity to ignite the material and/or the particle.

[5] Heat generated during the rapid compression of a gas (usually less than one second) from a low pressure to a high pressure.

[6] Heat generated by the flow of oxygen along a polymer and the appearance of erosion, friction and/or vibration.

[7] Heat generated by acoustic oscillations within resonant cavities which cause a rapid rise in temperature.

[8] Heat generated by one or more impacts on a material with sufficient energy to ignite it.

[9] Heat generated by two parts rubbing against each other.

[10] Heat generated by the oxidation of a non-oxidised metal in an oxidising atmosphere.

[11] Heat generated by the discharge of accumulated electrostatic charges, with sufficient energy to ignite the material.

[12] Heat generated by an electric current sufficient to create an arc from a source of electricity and capable of igniting materials.

[13] Heat generated by the combination of chemical compounds capable of igniting surrounding materials.

[14] Heat generated by the accumulation of liquid or solid materials that can undergo self-sustaining exothermic reactions.

To sum up, the oxygen system must be installed in such a way that:

1. The impacts of an external source of ignition are minimised.

2. The immediate environment is preserved, i.e. an oxygen leak cannot cause the ignition of substances close by.

3. And the system's design is such that a single failure of one of its components does not lead to an uncontrolled fire in the aeroplane and that in all cases, such a fire is extremely improbable.

To meet these requirements, the risk analysis of the oxygen system must look at the failures of the various components, the most unfavourable uses, the properties of the materials and the internal ignition mechanisms. If an internal ignition mechanism exists, the associated fire kindling chain must be analysed.

In the remainder of this document, the term ignition will be used. The term external ignition mechanism will be used when talking about elements located outside the oxygen system, i.e. elements that were originally outside the mask stowage boxes, for example the runaway of a lithium battery of a device in a nearby document storage compartment.

The term internal ignition mechanism will be used when talking about sources inside the oxygen system, for example the heat released when a metal particle collides with a wall.

2.2 Description of cockpit oxygen system on a commercial air transport aeroplane

On the majority of large commercial air transport jets, there is a supply of oxygen stored in one or more bottles (capacity of 1,400 to 3,200 l), pressurised to more than 100 bar, under the cockpit floor. A distribution system allows pressurised oxygen (around 5 bar) to flow from the cylinder, via a regulator, to the masks located on each side of the cockpit. These masks are positioned for use, if required, by the two pilots and two people which may be on the jump seats in the cockpit.

On some aeroplanes, the crew can control the arrival of the oxygen in the system via a control panel located in the cockpit to open or close a solenoid valve. The crew have information screens indicating the oxygen pressure in the cylinder.

The masks are stowed in metal boxes by the side of the seats and can be easily accessed by the crew. It must be possible to remove the mask from the box with one hand and in a single movement, inflate the harness, place the mask on the face and tighten the harness.

The masks are composed of a visor and a regulator to supply oxygen at a pressure close to the ambient pressure each time the pilot breathes in. An *EMERGENCY* knob on the mask regulator can be used to produce a continuous overpressure of a few millibars in the oronasal cavity and a continuous flow of a few litres of oxygen in the ocular cavity and thus prevent the ingress of contamination (smoke).

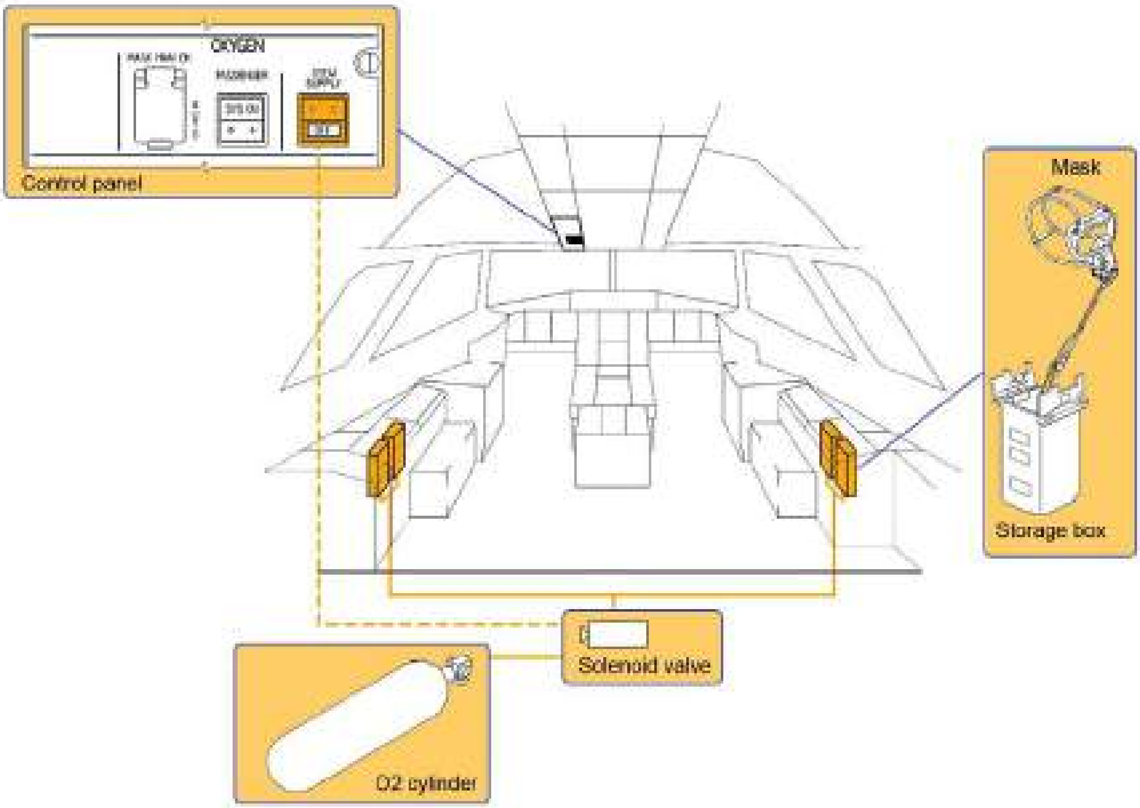


Figure 1: description of cockpit oxygen system of a commercial air transport aeroplane

Some aeroplanes are equipped with flow fuses in the oxygen system, located close to each mask storage box. These flow fuses close and cut off or limit the oxygen flow to the associated mask when a leak is detected downline.

2.3 Firefighting means

2.3.1 Fire extinguishing equipment

The fire protection and fire-fighting systems on most large commercial air transport aeroplanes include:

- fire and overheating detection and extinguishing systems for the engines and APU;
- smoke detection and extinguishing systems for baggage compartments and lavatories;
- smoke detection for the avionics bay(s);
- portable fire extinguishers for the cockpit and passenger cabin.

Regulation CAT.IDE.A.250 indicates that the type and quantity of extinguishing agent for the required fire extinguishers shall be suitable for the type of fire likely to occur in the cockpitand AMC.CAT.IDE.A.250 specifies that at least one fire extinguisher must be present in the cockpit, and that it must be suitable for fighting liquid fires and electrical equipment fires.

Historically, halon 1211[15][16] was the most common agent used in portable fire extinguishers on aircraft. Minimum Performance Standards (MPS) for extinguishing agents are defined in Appendix A of DOT/FAA/AR-01/37 dated August 2002, while acceptable criteria for selecting extinguishers containing these agents are defined in FAA Advisory Circular AC 20-42C.

Halon is due to disappear from cockpits in the near future (by the end of 2025), as the use of this gas will soon be banned for environmental reasons.

Three alternatives to halon are currently known and comply with the MPS:
- HFC-227ea;
- HFC-236fa;
- HFC Blend B.

2.3.2 Protective breathing equipment

The AIROPS European regulatory requirement CAT.IDE.A.245 specifies that all pressurised aeroplanes must be equipped with Protective Breathing Equipment (PBE) to protect the eyes, nose and mouth and to provide for a period of at least 15 minutes, oxygen for each flight crew member.

AMC1 CAT.IDE.A.245 specifies that this function can be provided by quick-donning masks.

Figure 2: fixed breathing equipment (quick-donning)

In part CAT of the AIROPS, it is also indicated that aeroplanes must be equipped with an additional portable PBE installed adjacent to the hand fire extinguisher. Some operators have not adopted the installation of a portable PBE next to the hand fire extinguisher. In particular, certain companies have recently modified their configuration by installing a fire extinguisher behind the captain and a hood behind the co-pilot.

[15] CF2ClBr - Bromochlorodifluoromethane
[16] AMC 25.851 (c)

Figure 3: portable breathing equipment

Airbus A320 Boeing 777

Figure 4: examples of a PBE installation on a commercial air transport aeroplane (source: BEA)

2.3.3 Smoking in a cockpit

Smoking has been banned on domestic and international flights in most countries since the 1990s. China is cited as being the last country to authorise pilots to smoke in the cockpit (up to 2019).

For commercial air transport aircraft, the European certification specification CS25.853 indicates: "*Smoking is not allowed in lavatories. If smoking is allowed in any area occupied by the crew or passengers, an adequate number of self-contained, removable ashtrays must be provided in designated smoking sections for all seated occupants*."

In Europe, the AIROPS regulatory requirement CAT.OP.MPA.240 specifies that the captain shall not allow smoking on board:

“*(a) whenever considered necessary in the interest of safety;*
(b) during refuelling and defuelling of the aircraft;
(c) while the aircraft is on the surface unless the operator has determined procedures to mitigate the risks during ground operations;
(d) outside designated smoking areas, in the aisle(s) and lavatory(ies);
(e) in cargo compartments and/or other areas where cargo is carried that is not stored in flame resistant containers or covered by flame-resistant canvas; and
(f) in those areas of the passenger compartment where oxygen is being supplied.”

Manufacturers still provide ashtrays. In the toilets, this corresponds to a type certification requirement. In the cockpit, the installation of ashtrays is an option that can be requested by the customer company.

Figure 5: example of an ashtray in an Airbus A330 cockpit (source: BEA)

Figure 6: example of an ashtray in a Boeing 777 cockpit (source: BEA)

3. ACCIDENTS PRIOR TO THE ACCIDENT TO SU-GCC, INVOLVING A FIRE AND THE OXYGEN SYSTEM IN THE COCKPIT

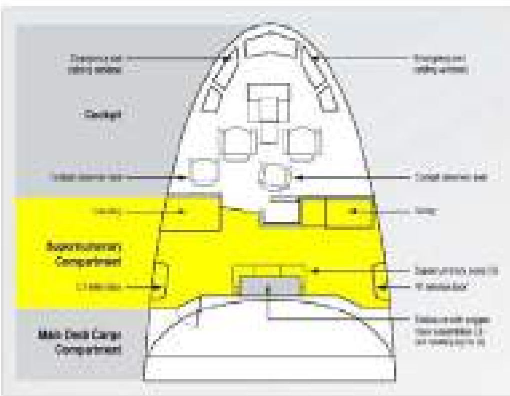
The following events were selected on the basis of the following criteria:

- an oxygen leak and a fire were identified and the intensity of the fire was aggravated by the oxygen leak;
- for all of them, the authorities in charge of the investigation indicated a hissing sound corresponding to a leak under pressure;
- for three of them, sound recordings were available;
- the sounds recorded during the events show very close similarities with the recording of the flight MS804.

The events described below occurred on the ground. No particularity linked to this specificity has been identified. In other words, the accident scenarios are transposable to flight and can be compared with the accident of flight MS804 which occurred in flight.

3.1 Accident to the Boeing 767 cargo registered N799AX in 2008

The accident occurred on 28 June 2008 on the ground at San Francisco. The NTSB investigation report contains recommendations on the design of the oxygen hoses.



a. location of compartment

b. oxygen distribution system

c. oxygen supply hose

d. damage following fire

Figure 7: images from investigation report (source: NTSB)

The fire broke out during flight preparation, in the compartment between the cockpit and the cargo area (see Figure 7a).

The captain and co-pilot evacuated the aeroplane through the cockpit windows after closing the cockpit door and calling in the aircraft rescue and firefighting service. The aeroplane was considered destroyed due to the extent of the damage (see Figure 7d).

The compartment where the fire occurred contained three oxygen masks supplied by an oxygen cylinder independent of the cockpit oxygen supply.

The investigation showed that a short-circuit energised the spring in the oxygen hoses, which became a source of ignition; the hose caught fire and the oxygen promoted combustion. The fire spread to adjacent materials.

The pilots reported that, while performing the engine start-up checklist, they heard loud "pop" and "hissing" sounds. This was confirmed by the spectral analysis of the CVR recording that shows that the event begins with a transient noise (pop), immediately followed by a loud hiss. The hissing sound was recorded for about 1minute, until the CVR was switched off. The popping and hissing sounds were consistent with the ignition of an oxygen hose by an internal rather than external heat source.

From a psycho-acoustic point of view, this recording shows similarities with the CVR of the MS804.

Lessons learnt - Intermediate conclusion

The mechanism involved in the accident to N799AX was an internal ignition in the system (linked to the design of the hoses) which caused a rupture in the oxygen hose and consequently a fire fuelled by an oxygen leak which led to the destruction of the aeroplane. The crew evacuated the aeroplane without trying to put out the fire.

3.2 Accident to the CRJ 200 registered N830AS in 2009

The accident occurred on the ground at Tallahassee on 28 February 2009.

The NTSB investigation report indicated that the fire broke out in the cockpit. A flight attendant and the captain of the aeroplane perceived an unusual hissing sound quickly followed by smoke and signs of a fire. They evacuated the aeroplane.

The investigation determined that the fire initiated in the top portion of a junction box which contained components associated with the distribution of electrical power from the APU or an external AC power supply.

The fire ignited combustible materials and spread upwards toward an oxygen hose mounted above the junction box. The oxygen mask of the third crew member was installed in the top forward portion of the wardrobe unit.

The oxygen hose ignited when exposed to the fire, and the fire burned through the aeroplane's fuselage.

After the event, it was observed that the pressure indicator of the oxygen cylinder supplying the cockpit indicated 0 psi (showing that it had emptied during the event) and that the oxygen mask hoses of the third crew member had been damaged.

Hissing is audible on the CVR for around ten seconds, after which the CVR was switched off.

Lessons learnt - Intermediate conclusion.
The mechanism involved in the accident to N830AS was damage to the oxygen system by a fire which had broken out nearby. The fire caused a rupture in the oxygen hose, resulting in a fire fuelled by an oxygen leak. The crew evacuated the aeroplane without trying to put out the fire.

3.3 Accident to the Boeing 777- 200 registered SU-GBP in 2011

The accident occurred on the ground at Cairo on 29 July 2011. The EAAID investigation report indicates that fire and smoke appeared on the right side of the co-pilot following a pop and hissing sound.

The captain asked the co-pilot to exit the cockpit and to warn the crew of the fire. The captain used the cockpit fire extinguisher, situated behind his seat, to fight the fire. This attempt was unsuccessful, and the fire continued to spread in the cockpit.

	
Damage inside the cockpit	Exterior damage

Figure 8: photos from investigation report (source: EAAID)

The evidence gathered during the investigation did not make it possible to determine whether the oxygen system ruptured first, creating a flammable environment, or whether the oxygen system ruptured as a result of the aeroplane fire.

The report indicated that the accident could be linked to the following probable causes.
1. An electrical fault or short circuit resulted in electrical heating of flexible hoses in the flight crew oxygen system (electrical short circuits; contact between aircraft wiring and oxygen system components may be possible if multiple wire clamps are missing or fractured or if wires are incorrectly installed).
2. Exposure to electrical current.

Lessons learnt - Intermediate conclusion.
The mechanism involved in the accident to SU-GBP has not been determined: it is possible that the oxygen system was damaged by a fire that broke out nearby, or that a hose ruptured, creating a flammable environment. The crew used a halon fire extinguisher, which did not put out the fire.

3.4 Accident to a Boeing 737 in 2012

The accident occurred on the ground during the push-back. The authority in charge of the safety investigation who has not yet published a rapport gave the following information to the BEA.

An oxygen leak and fire broke out in the cockpit on the captain's side. It is said that two seconds after the start of the leak, the co-pilot reported the problem and called out "cologne". The captain asked the pilots to leave the cockpit and asked for a fire extinguisher. A fire extinguisher was activated one minute later. The passengers were evacuated and the aircraft rescue and firefighting service intervened to being the fire under control. The fire caused substantial damage in the cockpit as well as in the electronic and avionics bays along with heat damage to the outer skin.

Image of General Cockpit Damage

Figure 9: photo from draft investigation report (source: safety investigation authority)

It is believed that the crew reported seeing a ball of sparks heading towards the captain's oxygen mask and that the mask and its surroundings burst into flames accompanied by the noise of escaping oxygen. The fire was out of control and the flames very high within approximately five seconds. Thick black smoke escaped from the cockpit.

The captain tried to stop the leak by squeezing the hose of the mask and to put out the fire using a halon fire extinguisher. He then indicated that this fire was not a fire to be put out with these fire extinguishers.

The investigation authority reported the following findings:

- after the event, the captain's oxygen mask was found on the floor, on the right side of the flight control lever;
- the mask had been left in the *EMERGENCY* position;
- the captain lit up a cigarette 2 min 21 s before the start of the leak.

Questions remain about the scenario of the event.

It is thought that the event began with an initial continuous leak of pure oxygen, this oxygen leak then spreading into the cockpit. The fire started as a result of a perfume and a burning cigarette meeting. The fire then spread inside the cockpit after the captain opened the mask storage box in order to fight the fire.

According to the information provided by the investigation authority, the CVR recorded an initial hissing sound lasting 3.5 s. The hissing sound stopped for less than two seconds. A new hissing sound was perceptible for less than one second which then increased in volume. The total duration is thought to be 5 min 17 s. A slow decrease in the strength of the hissing could be heard until the CVR stopped. This could be explained by the progressive damage to the cockpit microphone.

Lessons learnt - Intermediate conclusion.

The mechanism involved in the accident has not been determined with certainty: it is thought that there was an initial leak which, on contact with an external heat source, caused a fire which was then fuelled by a flow of oxygen from a mask in the *EMERGENCY* position, which had been removed from its box. The crew were said to have emphasised the speed and extent of the fire. It is thought that the crew used a halon fire extinguisher, which did not put out the fire before the evacuation of the aeroplane.

3.5 Conclusion with respect to prior events involving a fire and the oxygen system in the cockpit

These events, and in particular the content of the sound recordings when available, were used to characterize the noise caused by an oxygen-fed fire.

These events cannot be considered as precursors for the start of the MS804 accident sequence. The equipment was different and the causes of the fire may differ. For those events where the design of the hoses was considered a contributory factor, the faults identified have been corrected.

However, these events have the following features in common:

- the fire was rapid and large-scale;
- damage was extensive;
- all the crews had to evacuate the aircraft;
- the sounds recorded during the events show very strong similarities with the recording of the flight MS804.

In two of these events, the crews attempted to extinguish the fire, but were unable to do so.

4. ACCIDENT TO THE AIRBUS A320 REGISTERED SU-GCC OPERATED BY EGYPTAIR ON 19 MAY 2016

The following information is based on the information which came to the knowledge of the BEA.

4.1 History of the flight

On 18 May 2016, the crew aboard the A320, registered SU-GCC, took off at 21:21[17] from Paris - Charles-de-Gaulle airport (France) bound for Cairo (Egypt). The co-pilot was the PF[18] and the captain was the PM[19].

The aeroplane reached its cruising altitude of 37,000 ft shortly after 21:43. At 23:48, the crew exchanged for the last time with the Greek air traffic control.

At around 00:30, the aeroplane disappeared from the Greek secondary surveillance radar.

The data from the primary radar showed that the aircraft successively turned left and then right in descent.

A signal from the aeroplane's Emergency Locator Transmitter (ELT) was transmitted at 00:36:59.

4.2 Injuries to persons

	Injuries		
	Fatal	Serious	Minor/None
Crew	10		
Passengers	56		
Others			

All the crew members and passengers were fatally injured.

Note: The ten crew members included three security agents.

4.3 Aircraft information

4.3.1 Airframe

Aeroplane type	Airbus A320
MSN	2088
Registration	SU-GCC
Date of delivery	3 November 2003

[17] Except where otherwise indicated, the times in this report are in Coordinated Universal Time (UTC).
[18] Pilot Flying.
[19] Pilot Monitoring.

Cycles	Approx. 20,687 cycles
Flight Hours	Approx. 47,866 hours
Engines	IAE V2500-A5

4.3.2 Maintenance

On 16 May 2016, a maintenance operation carried out on the aeroplane at Cairo led to the replacement of the storage box for the co-pilot's oxygen mask.

After this maintenance action, the aircraft performed 10 flight cycles, for a total time of 32 flight hours and total elapsed time of 72 hours.

4.3.3 Oxygen supply system in cockpit

4.3.3.1 Description of system

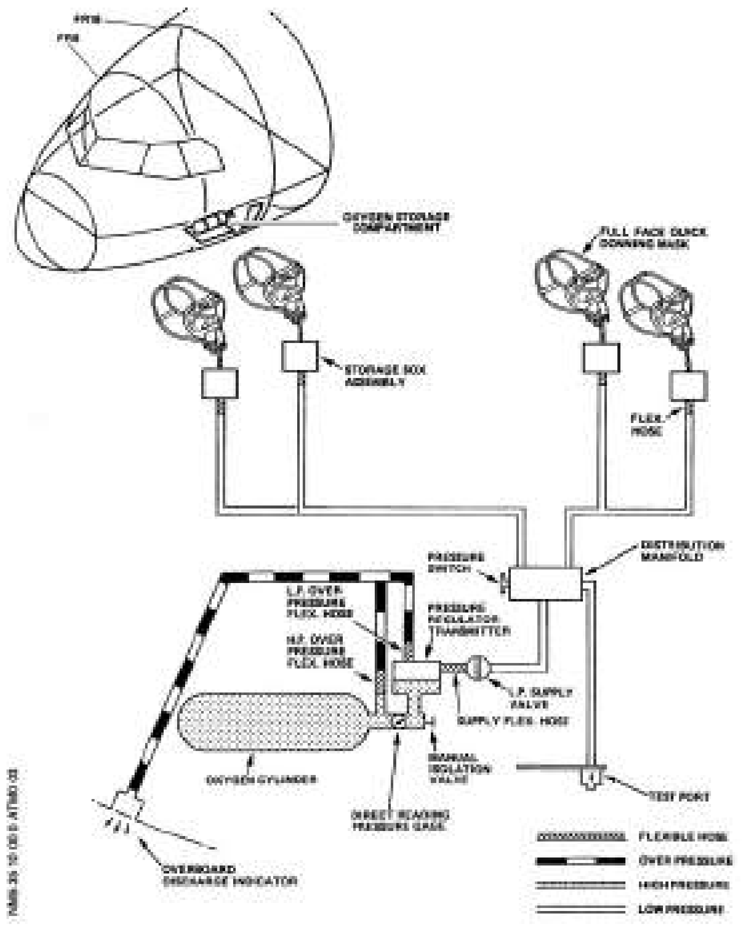


Figure 10: diagram of Airbus A320 oxygen system layout (source: Airbus AMM)

Oxygen is stored in an oxygen cylinder under the cockpit.

A regulator located on the head of the cylinder reduces the pressure to 5 bar in the downstream system.

In the event of overpressure, a valve evacuates oxygen to the outside of the aircraft.

A solenoid valve, called DVE on the Airbus A320, or LP SUPPLY valve on the diagram above, controlled from the cockpit by a *CREW SUPPLY* pushbutton located on the overhead panel, cuts off or authorises the flow of oxygen (at a pressure of 5 bar) to the masks.

The oxygen then travels from the regulator, under the cockpit floor through rigid stainless steel lines to four mask storage boxes located on the left and right side of the cockpit (two on each side). The boxes are connected to the rigid line by flexible hoses (soft hoses protected by a metal braid tube). This connection is in the cockpit's side compartments where the boxes are housed.

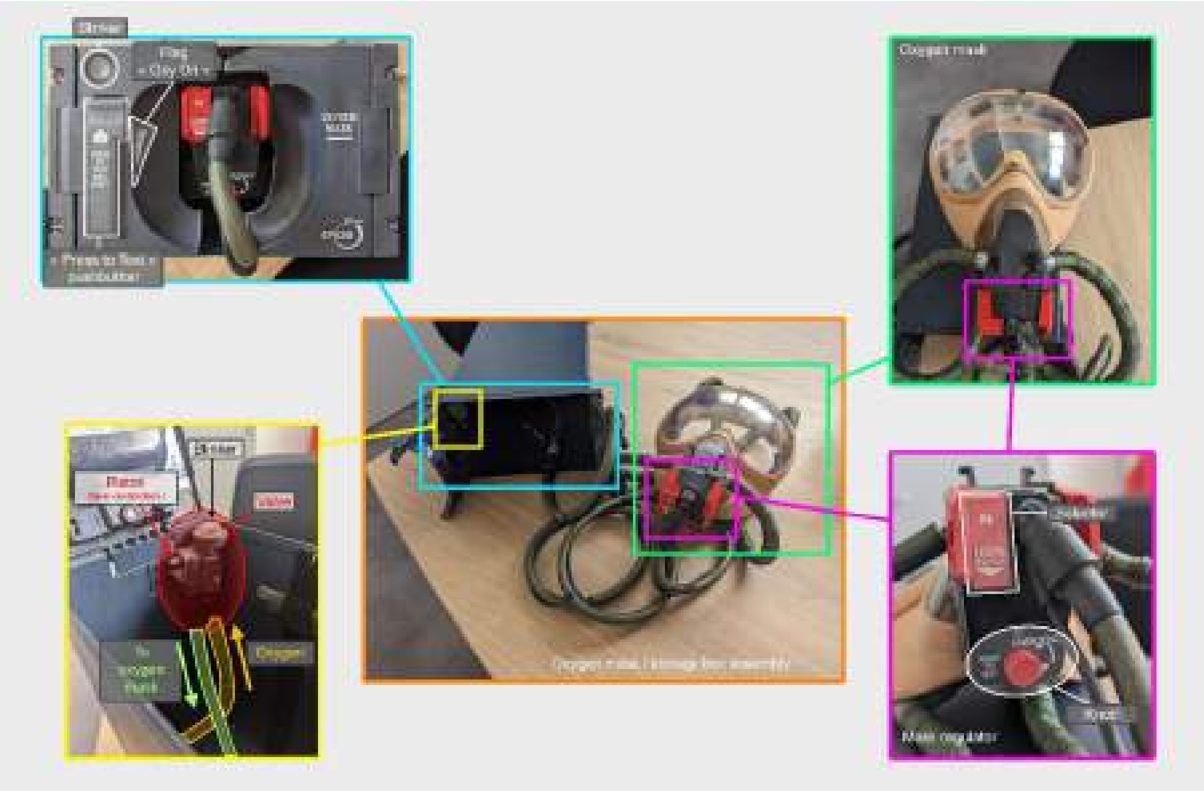


Figure 11: storage box and oxygen mask

In the mask storage box, a first hose (Dekabon - aluminium tubing in a nylon sheath) connects the box inlet to a valve. Inside the valve, a piston is mechanically held in the closed position. It prevents the flow of pressurised oxygen (5 bar) to the mask.

When the *PRESS TO TEST* pushbutton is pressed or the box door is opened, the mechanical stop is moved. The piston slides and oxygen flows through the lines to the mask. In the same way, this piston presses a microswitch which activates the mask microphone.

When the piston is not in its closed position and the left-hand box door is folded down, the piston comes to a stop on a plastic element and an *OXY ON* flag is moved, indicating that the mask is supplied with oxygen.

Similarly, the flow of oxygen through this valve activates a 'pop-out' (*blinker*) membrane to confirm the flow of gas when the pilot breathes.

A green hose connects the valve to a quick-release union with a check valve, enabling the mask to be disconnected and replaced without oxygen leaking.

Another hose (grey) connects the union to the mask regulator. These hoses are made up of silicone tubes surrounded by a braided tube made of Nomex (a type of Kevlar), which has no elastic properties and prevents the hose from swelling.

The regulator sends oxygen (or a mixture of air and oxygen, depending on the position of the selector) to the pilot each time he breathes in, at a pressure close to the atmospheric pressure. A system of chambers, diaphragms and pressure differentials regulates this pressure.

On the regulator, a selector can be used to choose the 'N' position, which sends a mixture of air and oxygen[20] adapted to the cabin's pressure altitude, or the "100%" position, which sends only pure oxygen (used in the case of cabin smoke, for example).

In addition, a knob can be used to select the *NORMAL* or *EMERGENCY* position. In the *NORMAL* position, the flow of oxygen is triggered by the person wearing the mask breathing in. With each breath in, the mask delivers a mixture of air and oxygen ("N" position) or pure oxygen ("100%" position). In the *EMERGENCY* position, the mask delivers oxygen with a continuous overpressure.

Some of the oxygen is used in the mask to defog the visor and keep a positive pressure under the mask to prevent the ingress of smoke.

The EMERGENCY knob can be both turned and pressed. Pressing the *EMERGENCY* knob performs the *PUSH-TO-TEST* function and triggers a flow of oxygen into the mask (flow equivalent to the *EMERGENCY* position) for as long as the knob is pressed and there are no obstacles preventing the overpressure from building up.

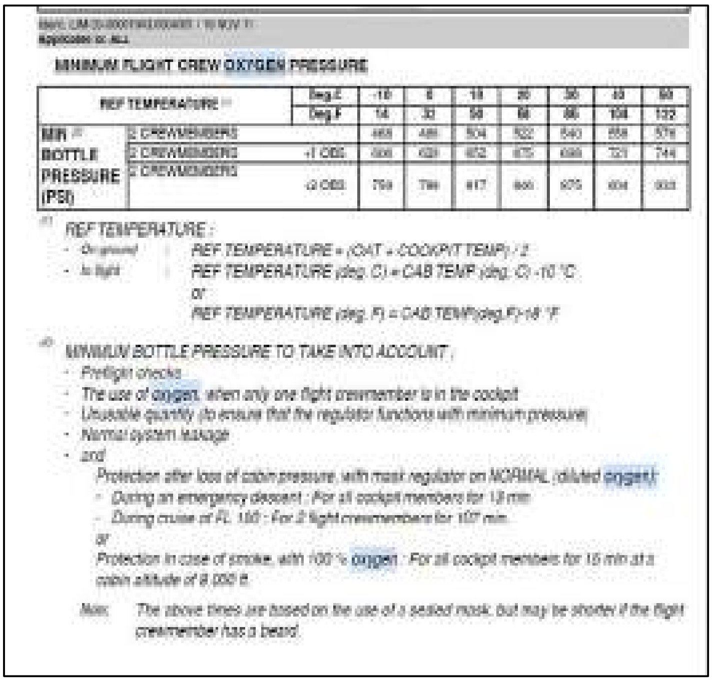
The cockpit oxygen system on SU-GCC was equipped with a high-pressure oxygen cylinder with a capacity of 3,256 l (115 cubic feet) (NTPD[21]) at a pressure of 127.5 bar (1,850 psig).

4.3.3.2 Associated procedures

The FCOM specifies the minimum quantity to be carried.

[20] The air in the mixture is taken from the ambient air in the cockpit.

[21] Normal Temperature Pressure Dry.



MINIMUM FLIGHT CREW OXYGEN PRESSURE

REF TEMPERATURE (1)		Deg.C	-10	0	10	20	30	40	50
		Deg.F	14	32	50	68	86	104	122
MIN (2) BOTTLE PRESSURE (PSI)	2 CREWMEMBERS		468	486	504	522	540	558	576
	2 CREWMEMBERS	+1 OBS	606	629	652	675	698	721	744
	2 CREWMEMBERS	+2 OBS	759	788	817	846	875	904	933

(1) REF TEMPERATURE :
- On ground : REF TEMPERATURE = (OAT + COCKPIT TEMP) / 2
- In flight : REF TEMPERATURE (deg. C) = CAB TEMP (deg. C) -10 °C
  or
  REF TEMPERATURE (deg. F) = CAB TEMP(deg.F)-18 °F

(2) MINIMUM BOTTLE PRESSURE TO TAKE INTO ACCOUNT :
- Preflight checks
- The use of oxygen, when only one flight crewmember is in the cockpit
- Unusable quantity (to ensure that the regulator functions with minimum pressure)
- Normal system leakage
- and
  Protection after loss of cabin pressure, with mask regulator on NORMAL (diluted oxygen):
  - During an emergency descent : For all cockpit members for 13 min
  - During cruise at FL 100 : For 2 flight crewmembers for 107 min.
  or
  Protection in case of smoke, with 100 % oxygen : For all cockpit members for 15 min at a cabin altitude of 8 000 ft.

Note: The above times are based on the use of a sealed mask, but may be shorter if the flight crewmember has a beard.

Figure 12: minimum oxygen to be carried for flight (source: Egyptair A320 FCOM)

Check of quantity of oxygen available

The crew check the quantity of oxygen available before the flight. During the flight, if the cylinder pressure drops to below 400 psi, the corresponding page (DOOR/OXY) is displayed on the ECAM.

Oxygen system operating procedures

When preparing the cockpit, the crew check that there is no pushbutton with a white light illuminated on the overhead panel and set the cockpit oxygen to ON if this has not been done beforehand.

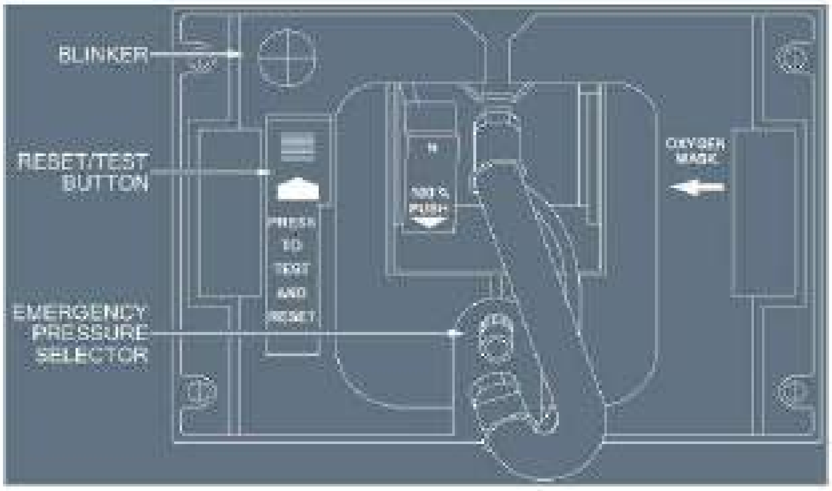
Each oxygen mask is then checked.

Figure 13: view of actions of oxygen mask test procedure (source: BEA)

The oxygen mask test procedure described in the FCOM is the following:

Ident.: PRO-NOR-SOP-06-[illegible] / 25 JUN 15
Applicable to: ALL

OXYGEN MASK TEST



WARNING	To prevent hearing damage to ground mechanics connected to the intercom system, inform them that a loud noise may be heard in the headset when performing this test.

On the OXYGEN panel:

CREW SUPPLY pb...CHECK ON

On the glareshield:

LOUDSPEAKERS...ON

On the audio control panel:

INT reception knob...PRESS OUT-ADJUST
INT/RAD sw...INT

On the mask stowage box:

- Press and hold the reset/test button in the direction of the arrow.
  - Check that the blinker turns yellow for a short time, and then goes black.
- Hold the reset/test button down, and press the emergency pressure selector.
  - Check that the blinker turns yellow and remains yellow, as long as the emergency pressure selector is pressed.
  - Listen for oxygen flow through the loudspeakers. Warn any engineer, whose headset may be connected to the nose intercom, that a loud noise may be heard when performing this check.
- Check that the reset/test button returns to the up position and the N 100 % selector is in the 100 % position.
- Press the emergency pressure selector again, and check that the blinker does not turn yellow. This ensures that the mask is not supplied.

On the ECAM DOOR/OXY page:

REGUL LO PR message...CHECK OFF

The crew must perform this check after having checked all masks. It ensures that the LP valve is open, (due to residual pressure between the LP valve and the oxygen masks, an LP valve failed in the closed position may not be detected during the oxygen mask test).

Figure 14: oxygen mask test procedure PRO-NOR-SOP-06 P14 and P15/16 (source: Egyptair A320 FCOM)

The oxygen mask test procedure is designed to check:

- That the oxygen mask storage box is supplied with oxygen; when the test pushbutton is pressed, oxygen is admitted into the hose up to the mask and the pressure is balanced at 5 bar in the box hoses upstream of the oxygen mask regulator. The visual indicator (called a *blinker* in the procedure) opens and a yellow dot appears when the pressure is balanced, then closes and turns black when the pressure is the same everywhere.

  While the test pushbutton is being pressed, the piston that allows oxygen to flow to the pilot's mask moves and, via an electrical contactor, activates the link between the microphone and the audio system. During this basic test, there is no continuous noise of an oxygen flow.

- That the box is supplied with oxygen and that the mask and microphone are functional.

  By simultaneously pressing the *PUSH TO TEST* pushbutton on the box and the *EMERGENCY* knob on the mask, a continuous flow of oxygen is established from the oxygen supply to the nose cup via the regulator. Oxygen is then released into the box. The microphone picks up the noise produced by this flow of oxygen and the sound can be heard on the cockpit loudspeaker.

- That the box is effectively in the reset position (i.e. the piston that allows oxygen to flow to the mask is in the closed position, preventing oxygen from being delivered to the mask). Just pressing the mask's *EMERGENCY* knob does not release any oxygen and the blinker fed by the flow downstream of the piston does not change colour (from black to yellow).

4.3.4 Fire-smoke in cockpit procedures

4.3.4.1 Smoke/Fumes/Avionics smoke procedure

The philosophy of the procedure described in the FCOM is as follows: in the event of fire/smoke, a diversion must be considered as soon as smoke is detected. The aim is then to identify the source of the smoke/fire and to combat it. If the source is not identified, is not visible or not accessible, and cannot be extinguished, the diversion must be started immediately. If the smoke is detected by the crew and there is no procedure displayed on the ECAM, the crew must refer to the QRH.

The immediate actions are to:

- protect the crew, in particular by the wearing of oxygen masks;
- prevent further contamination (spread);
- communicate with the cabin crew.

At all times, the elimination of smoke, the compliance with the ELEC EMER procedure and the immediate landing must be considered.

4.3.4.2 Specific procedure for lithium battery fires

For lithium battery fires, the actions are specified in the FCOM as follows: the PF dons his oxygen mask while the PM dons the PBE/hood and if there is a flame, uses the halon extinguisher.

It is indicated that halon extinguishers are effective on flames but cannot stop a thermal runaway. It is also indicated that if necessary, the control of the aeroplane should be transferred to the pilot on the opposite side of the fire.

4.3.4.3 Protective breathing equipment

A hood is located on the right-hand side of the cockpit, at the rear.
Another hood is located on the left-hand side of the cockpit.

The FCOM states that this system protects a crew member's eyes and respiratory system when fighting a fire, in the event of smoke, harmful gas emissions or depressurisation.

4.4 Wreckage and debris information

A sonar search located the wreckage and defined the limits of the field of debris. The debris was scattered in a rectangle measuring 1.2 km by 525 m. The debris was then identified, mapped and some pieces recovered. All the extremities of the aeroplane were within the identified rectangle: the cockpit, the wings and the tail. These observations, together with the small size of the debris, made it possible to conclude that the aeroplane had collided with the surface of the water under high energy and ruled out the scenario of the aeroplane having broken up in flight.

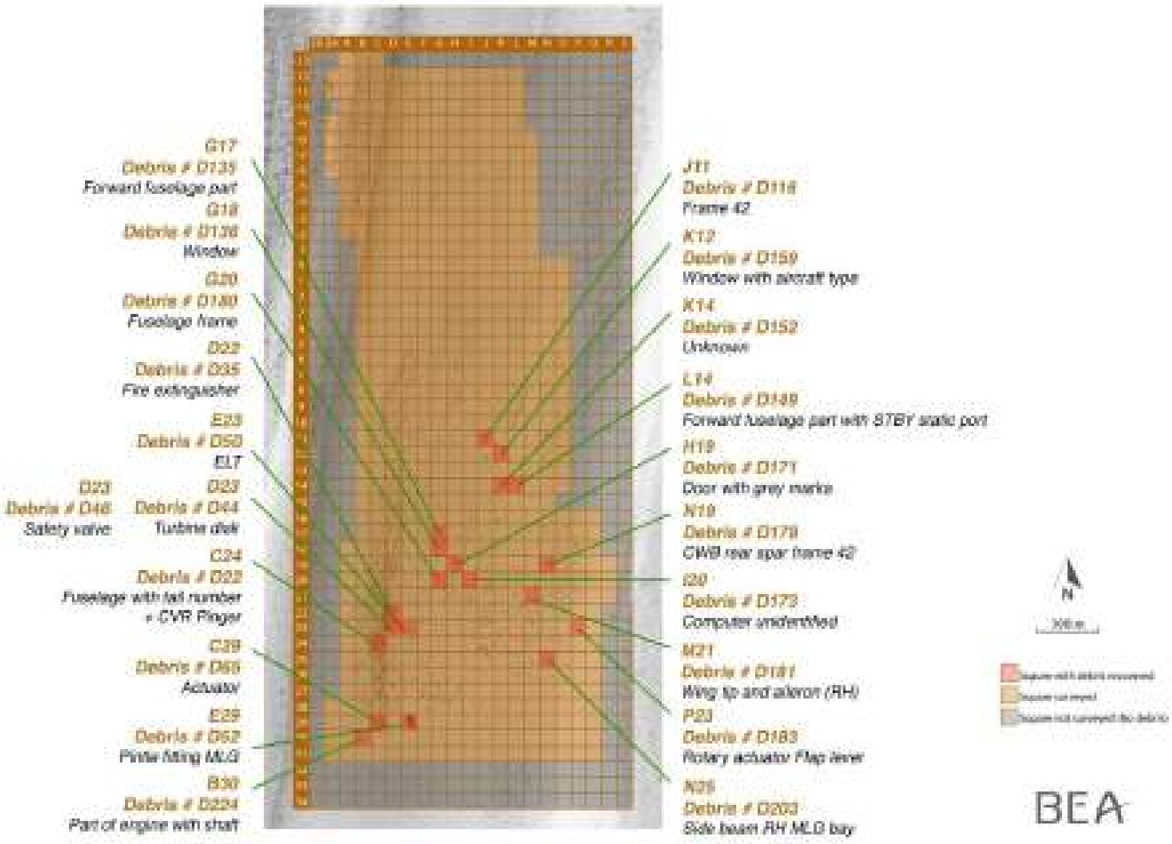


Figure 15: field of debris (source: BEA/EAAID)

Some debris showed signs of having been subject to high temperatures, and traces of soot. In particular, soot was visible on the side of the cockpit between frames 4 and 8 as illustrated in the image below.

Figure 16: cockpit debris showing black deposits (source: BEA/EAAID)

The figure below roughly shows the corresponding area.

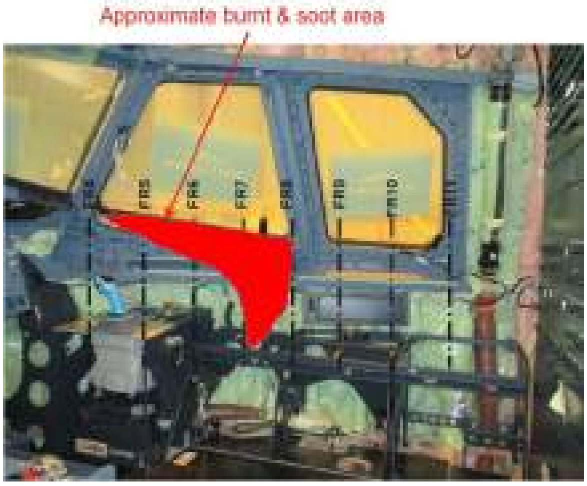


Figure 17: corresponding area on an A320 (source: BEA/EAAID)

4.5 CFR and FDR recording

4.5.1 Current Flight Reports (CFR)

The CFR is generated by the aeroplane's systems. It records the failures or malfunctions of the systems, including the ECAM alerts and maintenance messages. The CFR is used for maintenance purposes and allows the operator to anticipate any maintenance action before the aircraft lands.

The CFR from the flight was recovered by the aeroplane manufacturer and the operator.

It contained the following data regarding the failure/alerts during the cruise phase of the flight.

Time	Message	Message type
00:26	ANTI ICE R WINDOW	ECAM alert
00:26	R SLIDING WINDOW SENSOR	Maintenance message
00:28	R FIXED WINDOW SENSOR	Maintenance message
00:26	SMOKE LAVATORY SMOKE	ECAM alert
00:27	AVIONICS SMOKE	ECAM alert
00:29	AUTO FLT FCU 2 FAULT	ECAM alert
00:29	F/ CTL SEC 3 FAULT	ECAM alert

4.5.2 Flight Data Recorder (FDR)

The FDR ceased operating when the aeroplane was in cruise at FL370. Around seven minutes of flight were not recorded between the FDR ceasing operation and the estimated impact with the water (estimated from the ELT transmission time).

At 00:26:14, the "*LAVATORY SMOKE*" warning was activated. This warning remained active until the end of the FDR recording. In the cockpit, a CRC-type warning (Continuous Repetitive Chime) and the *Master warning* light were activated on the captain's and co-pilot's sides.

The *AVIONICS SMOKE* alert was triggered 46 s later. No specific sound or warning light was associated with this alert.

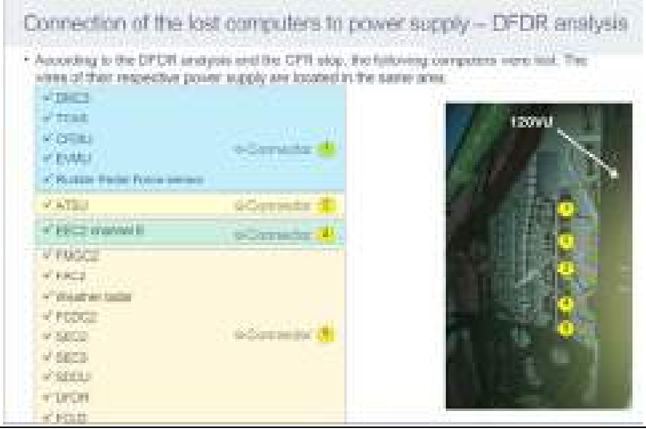
At 00:29:39, the on-board systems disconnected the autopilot. The CRC warning associated with the *LAVATORY SMOKE* warning stopped and the aural warning (*Cavalry charge*) associated with the disconnection of the autopilot sounded twice in the cockpit[22].

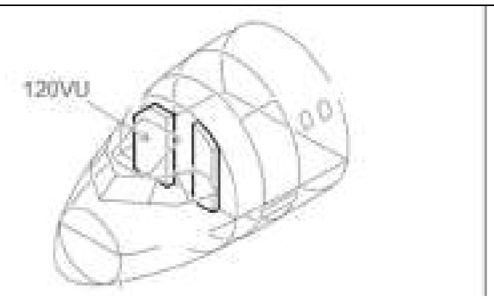
The read-out of the FDR showed that several on-board computers failed successively from 00:29:26 within an interval of 30 s.

The loss of these computers alone does not immediately affect the aeroplane's ability to fly, navigate or send information. At the end of the recording, the aeroplane's flight path and speed were stable.

These computers are located at various points on the aeroplane. However, the power supply cables for these computers are all connected in the same place, in an area at the rear right of the cockpit.

[22] The procedures ask pilots to cancel the warning by pressing the *MASTER WARN* pushbutton or the *Take over pb* on the sidestick.





The area which all the power supply cables run through is located between the cockpit floor and the electrical panel marked “120VU”.

Note: The ECAM “ANTI ICE R WINDOWS” alert present in the CFR is not part of the parameters recorded by the FDR.

4.6 Cockpit Voice Recorder (CVR)

4.6.1 Contents

As for the FDR, the CVR ceased operating when the aeroplane was in cruise at FL370. Around seven minutes of flight were not recorded between the CVR ceasing operation and the estimated impact with the water.

The CVR recording is of a total time of 02 h 05 min 26 s. The CVR model equipping SU-GCC stores information from the four input channels in five memory spaces:

- CVR channel 1 (CDB) file: it contains the left-hand pilot’s audio signal (radio and interphones) and the signal from his microphones*. The duration of this file is 30 min 30 s.
- CVR channel 2 (COPIL) file: it contains the right-hand pilot’s audio signal (radio and interphones) and the signal from his microphones*. The duration of this file is 30 min 30 s.
- CVR channel 3 (3rd/PA) file: it contains the audio signal from the third person (sat on the jump seat behind the co-pilot’s seat) (radio and interphones) and the signal from his microphones*. It also contains the exchanges between the cockpit and the cabin (cabin crew) via the cabin interphone. The duration of this file is 30 min 30 s.
- CVR Mix file (MIX): it contains the CVR channel 1 to 3 inputs for a duration of 2 h 05 min 26 s.
- CVR channel 4 file (CAM): it contains the signal from the cockpit area mike. The duration of this file is 2 h 01 min 03 s.

*: headset mike, hand-held mike and oxygen mask mike when the latter is active.

4.6.2 Pick-up sources

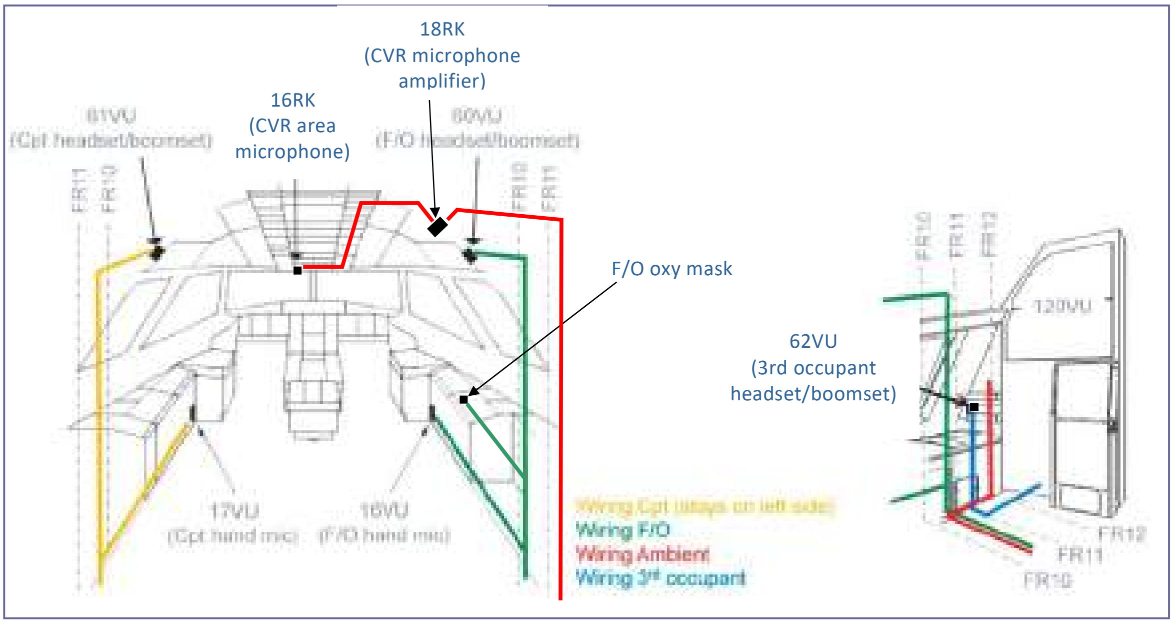
The playback of the CVR and the analysis of the waveforms revealed, shortly after the crew first started mentioning the fire[23], the successive loss of the various pick-up sources supplying the audio-CVR systems.

[23] See paragraph 4.6.5.

UTC	Cumulated time	Events
00:25:30	0	“*Fire!*” call-out by crew
	+4 s	The signal from the co-pilot’s oxygen mask microphone no longer reaches the audio-CVR system
	+17.5 s	The signal from the co-pilot’s headset microphone (boom mike) no longer reaches the audio-CVR system
	+1 min 11 s	The signal from the third person’s headset microphone (boom mike) no longer reaches the audio-CVR system
	+2 min 03 s	The audio signal from the CAM/microphone and/or CU channel starts to degrade
	+3 min 30 s	The signal from the CAM/microphone and/or CU channel no longer reaches the CVR
	+4 min 24 s	End of CVR recording

Note: the captain’s boom mike continued to operate without any noticeable degradation in its audio pick-up and thus picked up part of the background noise up to the end of the CVR recording.

The view below shows the routing of the electrical harnesses that carry the audio signals in the cockpit to their respective systems (AMU and CVR):



(Source: BEA based on AIRBUS

Figure 18: route of electrical harnesses associated with CVR on an A320

4.6.3 Use of headsets and ATC communications

Each pilot has the necessary set of equipment for his/her exchanges. This consists of several microphones along with interface and selection units. Refer to the appended Functional description of the Audio-CVR system.

In commercial air transport operations, the operational procedures recommend that pilots wear their headsets and use the headset boom microphone when the aircraft is below FL100. During cruise, radio and interphone activities (exchanges with the cabin) are monitored by the PM by listening to his loudspeaker; voice messages are generally transmitted using the hand-held microphone.

A detailed analysis of the audio content of the two CVR channels allocated to each of the pilots revealed that the pilots of flight MS804 had not been wearing their headsets since the start of the CVR recording. During the last two hours of the recording, radio communications were mainly made by the captain via the hand-held microphone; two were probably made by the co-pilot via the hand-held microphone.

The audio analysis of the co-pilot's CVR channel revealed a "cavernous" background noise characteristic of the pick-up by the oxygen mask's internal microphone from the beginning of the CVR recording. This microphone is located inside the oxygen mask, in the visor support, at the base of the regulator which delivers the ambient air and oxygen mixture to the pilot.

The sound picked up by the oxygen mask microphone had an acoustic signature consisting of the emergence of five characteristic noise bumps The appendix Sound pick-up by the oxygen mask microphone presents the comparison made with a series of audio samples taken from the BEA's audio database. The spectral view below shows the comparison between the signal recorded by the captain's CVR channel and that recorded by the co-pilot's CVR channel.

The low-frequency noise bump (from 100 to 500 Hz) and the four broadband bumps (780 Hz, 1300 Hz, 2090 Hz and 2640 Hz) confirmed that the microphone of the co-pilot's oxygen mask was active.

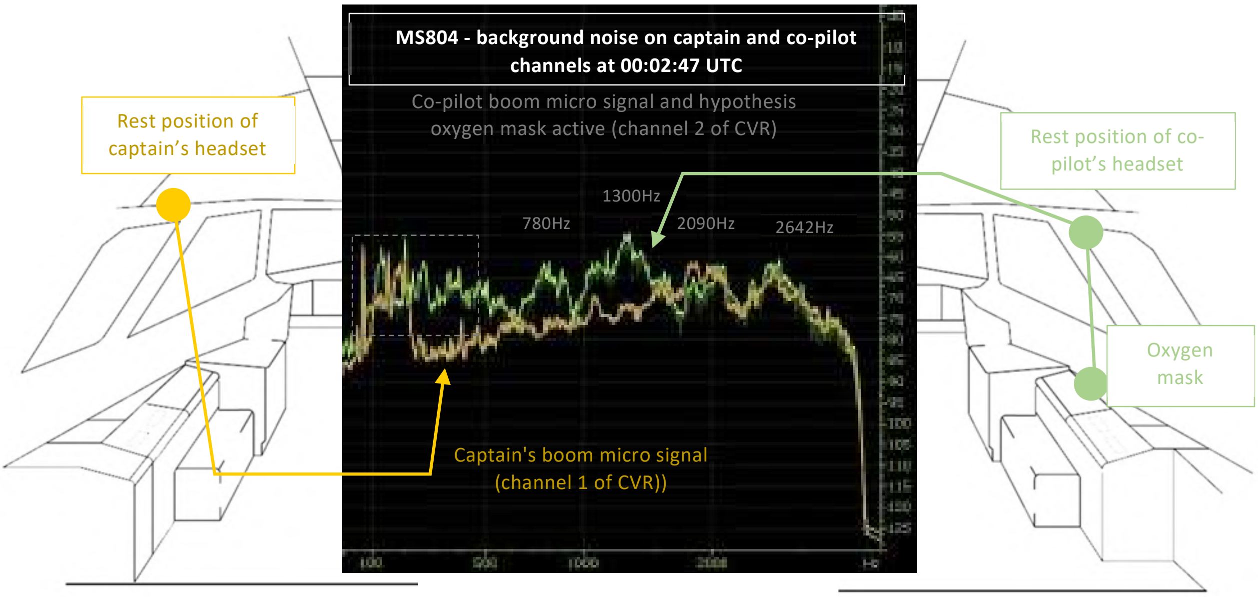


Figure 19: comparison of noise spectrum picked up by captain's and co-pilot's boom mikes

Findings-Intermediate conclusion

The co-pilot's oxygen mask microphone was active during the last 30 min of the CVR recording, and most likely from the start of the CVR recording.

The CVR input channels, which are dedicated to recording conversations, radio communications and the pilots' audio signals, receive a composite signal that is the result of mixing by the on-board audio source management system. The appendix, Functional description of audio-CVR system sets out the on-board audio system.

The audio system routes the signals picked up by the various microphones to the transmission source(s) (i.e. the selected radio, the intercom, the loudspeaker, etc.). This routing is based on priority rules. One of these rules defines the following priority for the "radio" function:

- hand-held microphone;
- oxygen mask;
- pilot’s headset microphone (boom mike).

In this case, the continuous activation of the co-pilot's oxygen mask microphone meant that he could not use his boom mike to transmit radio messages. The aircraft was in cruise from the start of the CVR recording; the pilots were no longer using their respective boom mikes.

Findings- Intermediate conclusion
The co-pilot's boom mike could not be used to transmit radio communications for the last thirty minutes, and most probably for the last two hours. The co-pilot, as PF on the flight, did not need to use his boom mike before reaching FL100 and used his hand-held microphone when needed during the cruise. Therefore, the co-pilot had no opportunity to detect that his boom mike was inoperative. This explains why the activation of the mask’s microphone might not have been detected.

With a normal operating pressure in the system, the activation of the oxygen mask microphone may have been due to:

- the oxygen mask storage box having been manipulated. The mask storage box might have been opened and not reset. The reset is a normal part of the test procedure before every first flight of the day;
- a faulty or incorrectly set microphone activation switch.

The manufacturer of the mask and oxygen box indicated that it was also possible that overpressure in the supply system could place and maintain the storage box in the unreset position. However, the manufacturer pointed out that the overpressure required to move the piston is greater than the overpressure which would lead to an uncontrolled flow through the mask regulator.

4.6.4 Analysis of CVR conversations

The voice recording (area microphone and headset boom microphones) by the CVR only gives a partial view of the activity in the cockpit, of communications with the exterior (traffic control or operations) and of communications between the flight and cabin crew members. This must be taken into account when drawing conclusions based on the interpretation and translation of the audible speech on the CVR recordings.

4.6.4.1 Context prior to the accident sequence

The CVR recording of flight MS804 contains the 02 h 01 min 04 s of the last exchanges in the cockpit. The discussions between the crew members (between cabin crew and/or between cabin crew and flight crew) were in Egyptian Arabic. At the start of the recording, the aircraft was in cruise. ATC communications were mainly from the captain. There was constant background music in the cockpit. The cabin crew were looking after a sick passenger whose state of health was deteriorating (faintness). In the first hour of the recording, this event led to the cabin crew going in and out of the cockpit a large number of times in order to inform the captain of the evolution of the passenger's state of health. In the second hour of the recording, a cabin crew member took a seat in the cockpit and the conversations no longer concerned the management of the flight. Forty minutes before the end of the recording, the crew had a meal.

In the last ten minutes of the CVR recording, the captain asked a cabin crew member for a blanket and a pillow. Once these items had been provided, this cabin crew member left. At this point, the two pilots and the first cabin crew member were present in the cockpit.

4.6.4.2 Elements relating to smoking in the cockpit

On 26 April 2022, an Italian media[24] published information presented as a summary of a confidential report drawn up by experts appointed by the French courts. The report stated that there had been the sound of an oxygen leak in a pilot's oxygen mask and that "a spark or flame had started a fire", adding that a lit cigarette could have been the cause of the fire. The Italian article noted that the report mentioned that cigarettes were frequently used on this aeroplane, since the ashtrays had recently been replaced.

The preliminary CVR playback work carried out by the BEA mentioned the presence of a phrase initially translated from Arabic as follows: "blow smoke on me"; this phrase could potentially reflect the action of smoking by one of the crew members.

Additional work involving seven Arabic-speaking linguists - two of them native Egyptians - was carried out in order to have an in-depth analysis of the content of the recorded conversations. The aforementioned phrase was corrected and its translation modified as follows: "he fainted" or "he felt unwell", probably referring to the ill passenger. This phrase precedes a discussion between the two pilots about the possibility of diverting to Athens or Albania.

A second phrase later on could potentially refer to the smoking habits of one of the two pilots: "Have you stopped smoking [or what/not], I can't smell [the smoke/smell]?”

In conclusion, none of the speech components heard in the conversations recorded by the CVR clearly mentioned the crew's intention to smoke or that they were smoking.

Findings- Intermediate conclusion
No evidence from the cockpit voice recording confirms or refutes the hypothesis that people were smoking in the cockpit.

4.6.5 Audio description of accident sequence

Conversations/voices/speech during the accident sequence

At 00:25:23, a loud hissing lasting 2.6 s could be heard on the CVR recording. This noise is considered to be the start of the accident sequence (referred to as "*T0*").

At this point, the captain called out to the co-pilot just before a loud transient noise was heard,

[24] https://www.corriere.it/cronache/22_aprile_26/volo-egyptair-incendio-piloti-fumo-fb725f4c-c4d3-11ec-8db2-dfe15c68e9dd.shtml

immediately followed by a hissing sound, a sound runaway phenomenon[25] and a continuous leaking noise[26].

The crew mentioned the words "fire" and "extinguisher" several times. Short coughing fits and voiced sounds (unintelligible words or phrases) were emitted shortly afterwards. The noise level of the continuous leak gradually decreased, making it possible to perceive crackling noises and to detect the ambient music again.

A succession of aural warnings were audible on the CVR recording; these consist mainly of the MASTER WARNING, SMOKE DETECTOR and CAVALRY CHARGE warnings 15 s before the end of the CVR recording.

Waveforms and key events

The appendix Waveforms of the CVR recording graphically presents the CVR content and chronologically describes the succession of different sound events during the last five minutes of the CVR recording.

The view below shows an extract lasting one minute, of the beginning of the accident sequence. The various events (noises, sounds, crew call-outs, etc.) are called EVT1 to EVT9 For the most part, the events are in the 18 s that followed the first flow noise (EVT2).

[25] Presence of noise bumps - broadband energy bumps - where the frequency increases rapidly to concentrate around 1.2 and 2 kHz (the phenomenon could be described in psychoacoustic terms as a "hissing sound increasing in pitch"). The sound runaway is accompanied by an increase in the overall noise level.

[26] Broadband noise over the entire bandwidth of the microphone picking up the sound.

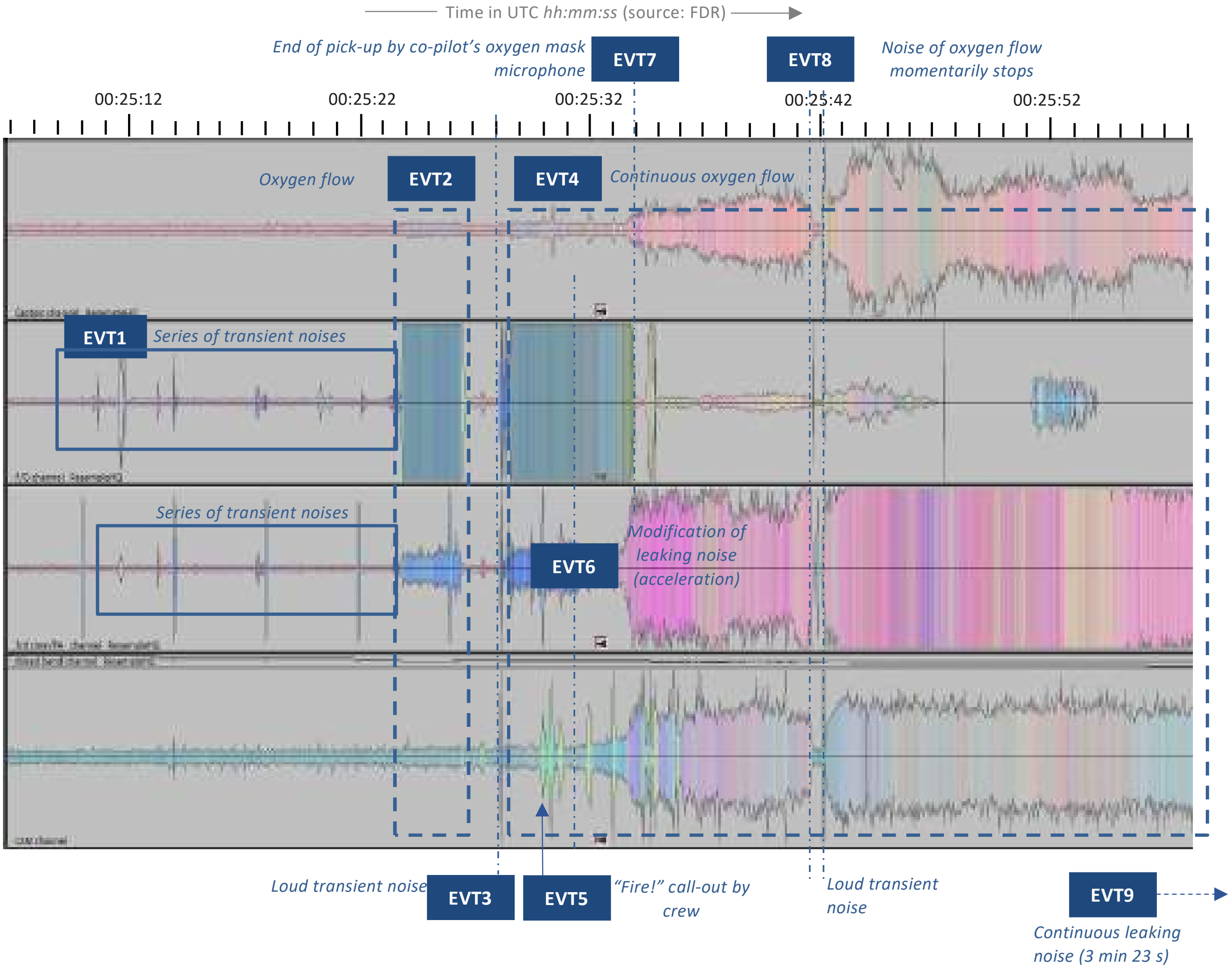


Figure 20: sequence of aural events - chronological detail (view of waveform – source: BEA)

The nine sound events in question are the following:

- EVT1 Numerous transient noises were present on the co-pilot CVR audio channel and to a lesser extent, on the third person/PA channel;
- EVT 2 A very loud, short (2.6 s) leaking noise is recorded on the co-pilot's CVR audio channel. The start of the leaking noise constitutes T0 of the event sequence;
- EVT 3 A loud transient noise is heard at T0 + 4.3 s;
- EVT 4 A continuous leaking noise starts (and will last more than 3 min) at T0 + 4.7 s;
- EVT 5 First "fire" call-out at T0 + 6.1 s;
- EVT 6 Modification of continuous leaking noise at T0 + 7.6 s;
- EVT 7 Loss of signal from co-pilot's oxygen mask microphone at T0 + 9.6 s;
- EVT 8 Leaking noise stops for a short time at T0 + 17.9 s (duration: 0.5 s);
- EVT 9 End of leaking noise at T0 + 3 min 23 s: the noise level of the leak continues to decrease until it disappears into the background noise of the cockpit.

4.7 Tests and research

4.7.1 Description of tests and research

Tests and research were carried out to identify the nine isolated sound events in the accident sequence.

These tests were carried out on the BEA's premises and on the premises of the manufacturer of the oxygen system. The principal test resources were:

- a mobile CVR system to record the audio pick-up by a CAM and two boom microphones;
- a cockpit oxygen distribution system.

4.7.2 EVT1: Transient noises on the co-pilot's audio channel

The series of transient noises recorded on the co-pilot's channel corresponds to the mix of the pick-up by the mask microphone and the co-pilot's headset.

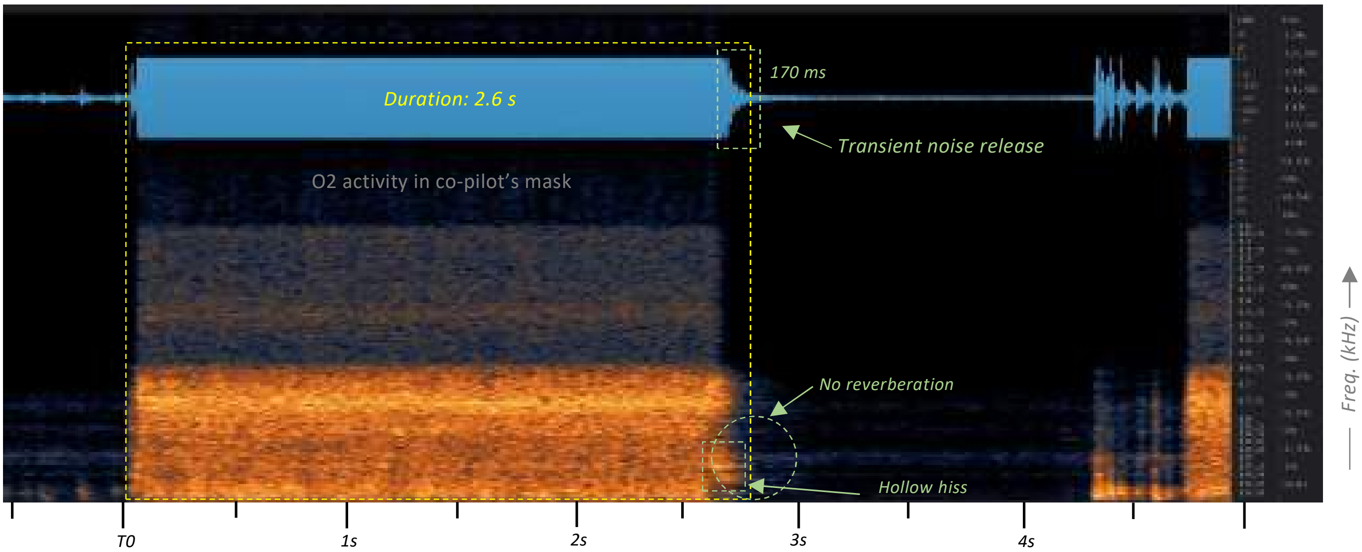
Some of these transient noises are present with a lower amplitude on the 3rd person's channel. They are barely detectable on the CAM channel. Based on the measurements carried out in a cockpit (see appendix EVT1), these transient noises correspond to elements being moved close to the document storage compartment.

Tests in the cockpit also showed that the noise of elements being moved were broadcast by the co-pilot's loudspeaker and that they were perceptible from the co-pilot's seat. However, these same events were picked up to a small extent or not at all by the CAM microphone (with the exception of the loud events).

Findings - Intermediate conclusion
For the duration of the CVR recording, the co-pilot's oxygen mask microphone picked up low sound transient noises of elements being moved close to the document storage compartment. This pick-up could be heard on the co-pilot's loudspeaker (depending on the volume selected).

4.7.3 EVT2: A very loud, short (2.6 s) leaking noise recorded on the co-pilot's CVR audio channel

The following figure shows the analysis of the EVT2 from an acoustic point of view. In blue, the waveform represents the amplitude of the noise as a function of time. The band in shades of orange represents the distribution of the frequency as a function of time.



T0 = 00:25:22 UTC (ref. FDR data)

Figure 21: first oxygen flow activity in co-pilot's mask (spectral view – source: BEA)

This sequence was compared with various sound recordings made during the handling of oxygen masks and mask storage boxes (see appendix EVT2).

The duration of the transient noise release (170 ms) corresponds to the end of pressurisation to 5 bar of all the hoses upstream of the regulator:

- this is the case when the mask is not in the *EMERGENCY* configuration and the test pushbutton on the door of the oxygen mask storage box is pressed;
- or when the box is not reset after pressing the *EMERGENCY* knob.

The absence of a reverberation indicates that there is no bleed and corresponds to a box with identical pressure in all the hoses, and therefore not reset.

The leaking noise lasts much longer than that created by pressing the test pushbutton on the mask storage box door (observed between 700 and 900 ms during tests carried out in the laboratory and on aeroplanes in service).

The leaking noise lasting 2.6 s which starts at t0 corresponds to an oxygen flow via the oxygen mask regulator; it is comparable to that produced by pressing the mask *EMERGENCY* knob when the box has not been reset.

In addition, the hollow hiss indicates that the dilution control on the co-pilot's mask was in the 100% oxygen position.

Findings - Intermediate conclusion
The co-pilot's oxygen mask was not in the permanent *EMERGENCY* position before t0, start of the oxygen flow sound. The dilution control on the co-pilot's oxygen mask was in the 100% position. The storage box for the co-pilot's oxygen mask was not in the reset position. A flow of oxygen via the co-pilot's mask lasting 2.6 s began at 00:25:30 (t0). The flow is equivalent to that caused by pressing the *EMERGENCY* knob on the mask.

The information available in the scope of the investigation does not make it possible to determine if the oxygen flow was the result of a human action on the *EMERGENCY* knob, whether it be unintentional or intentional.

- Unintentional action

  It seems unlikely that there was an unintentional action on the knob, partly because the knob was pushed for 2.6 s, and partly because of the relative difficulty of accessing the knob (the knob is protected by the hose which passes over it). Moreover, in flight, the cover is normally closed on the mask storage boxes[27].
- Intentional action

  One possible explanation is that the co-pilot was alerted by the noises emitted on the loudspeaker from the moving of elements nearby, picked up by the microphone of the oxygen mask. At this time, the noise level in the cockpit was low compared with the previous period. In addition, the captain wished to rest and although the CVR contained no mention of a transfer, he might have passed communications to the co-pilot, who might have increased the volume of the loudspeaker. It is possible that the co-pilot then performed actions corresponding to the mask test procedure. In the darkness of the night flight, with the seat forward in the PF’s position, this action may have simply been to press the *EMERGENCY* knob on the mask; pressing the pushbutton on the box being more difficult to do. No mention of a coordination for such an action is present on the CVR.

No "oxygen" activity was recorded by the CVR before t0 - i.e. no intentional handling of the personal oxygen device, or noise characteristic of a leak. No pilot "oxygen" activity (donning and normal use of a cockpit oxygen mask) was recorded by the CVR after t0. The only element linked to the cockpit oxygen system is the continuous leak mentioned above.

Findings-Intermediate conclusion
There was no mention of any intention or action on the part of either of the pilots to use the personal oxygen devices.

4.7.4 EVT3: Loud transient noise

A loud transient noise occurred at t0 + 4.3 s. It was clearly picked up by the co-pilot channel, to a lesser extent by the 3rd person channel and to an even lesser extent by the CAM. These differences indicate that the co-pilot’s mask was in the storage box. The source was not identified.

[27] There was no evidence to determine whether or not this was the case for flight MS804.

Findings-Intermediate conclusion
An event leading to a loud transient noise of unknown source occurred in the co-pilot's mask storage box 4.3 s after the start of the first flow of oxygen in the mask (t0 + 4.3 s).

4.7.5 EVT4 and EVT9: continuous leak

A cockpit oxygen cylinder was completely emptied in a laboratory several times by creating a continuous oxygen leak (see Appendices EVT4 and EVT9).

The oxygen leak produced by the rupture of a hose, either upstream of the mask storage box or at the hose connecting the mask to the box, generated a broadband noise lasting several minutes, the sound level of which decreased progressively when a remaining pressure of less than 20 bar in the oxygen bottle was reached.

The tests confirmed that the long gas flow noise present on the CVR recording of flight MS804 corresponded to a continuous leak from the cockpit oxygen system. The acoustic signatures recorded during these tests seem to attribute the leak to a rupture in the oxygen supply in the box, upstream of a mask, as being more likely than a leak upstream of the mask storage box.

The continuous leaking noise did not give rise to a sound runaway as is the case on the recording of flight MS804 (EVT6).

The time taken for the O2 cylinder to completely empty on flight MS804 is well below the theoretical value calculated by the equipment manufacturer (11 min). Several hypotheses can be envisaged:

- either the theoretical value is overestimated;
- or the flow rate in the event is greater than that obtained with a pressure of 5 bar[28];
- or the cylinder was not very full.

Findings-Intermediate conclusion
There was a continuous uncontrolled leak lasting 3 min 23 s in the co-pilot's mask storage box corresponding to the complete emptying of the oxygen cylinder (start at t0 + 4.7 s).

4.7.6 EVT8: interruption of leaking noise

The leaking noise was observed to stop for 0.6 s at t0 + 17.9 s. Tests were carried out to try and reproduce this break by twice pressing the CREW SUPPLY ON pushbutton on the overhead panel.

Tests on a reproduction of the A320 oxygen system and on several aeroplane of the same type showed that the controlled cut-off using this pushbutton lasted a minimum of 0.9 s. Details of the tests are given in appendix EVT8.

Pressing this pushbutton is the only way for the crew to cut off the oxygen supply. The observed break in the leak was not linked to a crew action.

[28] In the event of overpressure upstream of the oxygen bottle pressure regulator (or in the oxygen bottle) and with a pressure regulator operating as per design, a valve evacuates the oxygen to the outside of the aircraft. In the time taken in such a scenario, the mask storage box can be activated, resulting in the mask having a continuous or temporary leak.

Findings-Intermediate conclusion

The break in the oxygen leaking noise (at t0 + 17.9 s) lasting 0.6 s was not linked to a crew action.

4.7.7 Cockpit door open or closed

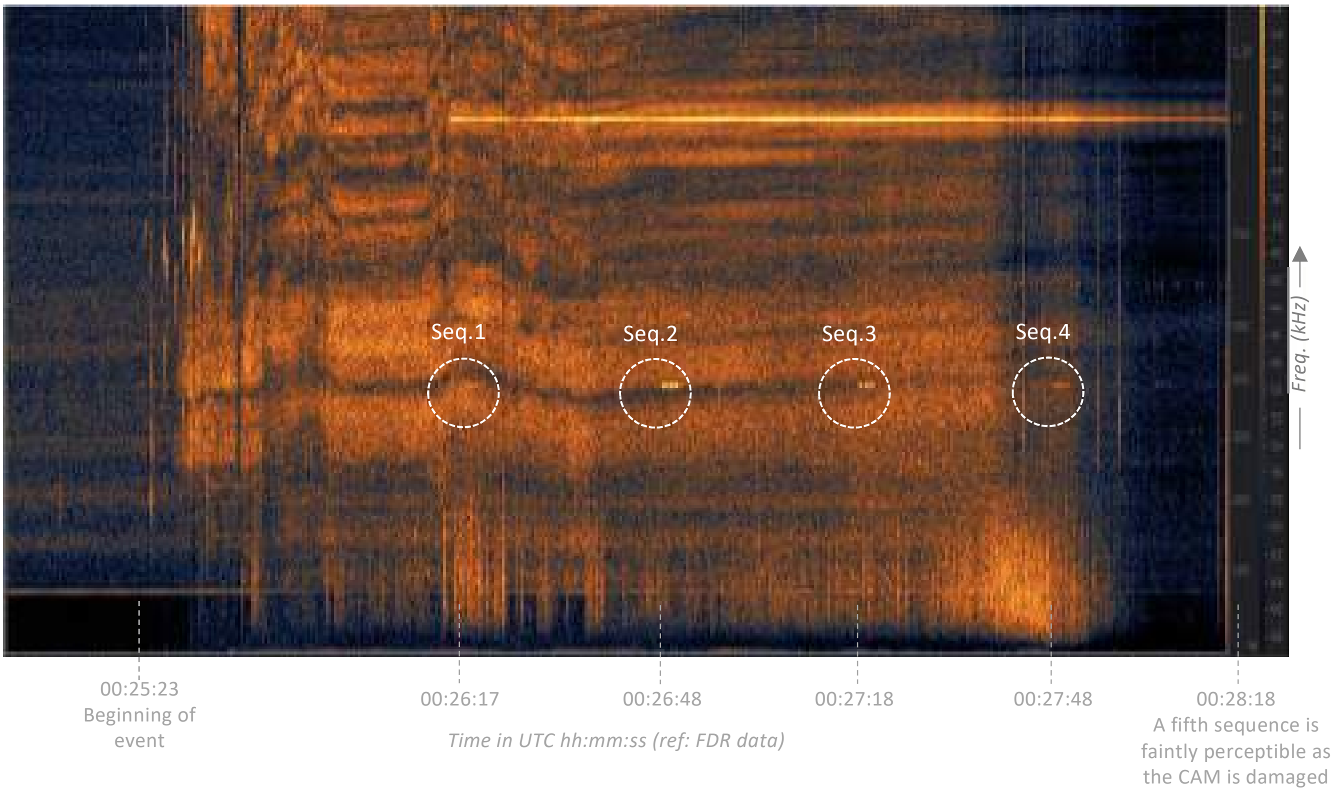


Figure 22: Lavatory Smoke warning sequences (*triple low chime*) - (spectral view)

The "triple low chime" corresponding to the "Lavatory Smoke" warning can be perceived on the CVR (first transmission at 00:26:17 i.e. t0 + 47 s) via the CAM channel. This signal was generated on the cabin loudspeakers every thirty seconds. The next three transmissions are also perceptible; the CAM was then too damaged to pick them up.

A 10 dB increase in the "triple low chime" signal was measured for sequences 2 and 3. This increase was compatible with the warning being picked up when the cockpit door was open (see appendix, Lavatory for details). Sequences 1 and 4 were therefore very likely picked up with the door closed.

In addition, a noise that could correspond to the cockpit door being used could be heard at 00:26:46.

Findings-Intermediate conclusion

When the "Lavatory Smoke" warning first sounded, i.e. 47 s after the start of the event at 00:26:17, the cockpit door was closed. It was then in the open position (at 00:26:48 and 00:27:18, potentially continuously over this period) before being closed again.

When the continuous leaking noise ceased - or reached such a low level that it disappeared into the cockpit background noise - the background music in the cockpit reappeared, the CRC aural warning ceased and the autopilot disengagement aural alert was triggered. A that time, no movement or door opening noise are perceptible on the CVR. The cockpit door appeared to be closed at this point.

Findings-Intermediate conclusion
The cockpit door was most likely closed when the autopilot was disengaged and the CVR stopped operating at 00:29:54, i.e. t0 + 4 min 24 s.

4.7.8 Disconnection of autopilot

At 00:29:39, the aural warning (Cavalry charge) associated with the disconnection of the A/P sounded twice in the cockpit.

The procedures ask pilots to cancel the warning by pressing the *MASTER WARN* pushbutton or the *Take over pb* on the sidestick.

Findings-Intermediate conclusion
The data recorder did not record any change in parameters that could result from an action by the crew after the autopilot was disconnected.

5. OXYGEN FIRE STUDY

Note: The aim of the study is twofold: to study certain phenomena, and in particular to record the noise produced, in order to validate or invalidate hypotheses concerning the accident scenario for flight MS804, and to learn more about fires in the presence of oxygen in the cockpit. For this reason, the scope of the study covers wider accident scenarios than the potential ones of the SU_GCC accident. The fact that batteries and cigarettes, for example, were chosen as external ignition sources does not mean that they are considered the most likely ignition sources. In the same way, the effects of halon are studied without the conclusions being directly transposed to flight MS804. Conclusions specific to flight MS804 are set out in chapter 5.6.

5.1 Introduction

A fire is defined as the combustion of a fuel by oxygen and occurs when oxygen, fuel and heat combine to create a self-sustaining chemical reaction.

The chemical reaction is an oxidation of hydrocarbons. When wood, paper, oil or gas burn, for example, it is the hydrocarbons making up the materials that oxidise during combustion.

The oxidation reaction has to be initiated by the addition of heat. Since oxidation releases heat, the reaction sustains itself over time.

The pressure and concentration of oxygen affect the flammability of a material. The greater the quantity of oxygen present, the easier it is for the material to ignite, the faster and more extensive the combustion and the higher the temperatures.

The presence of the oxygen distribution system has a twofold impact:
(1) the air may become enriched with oxygen in the vicinity of the supply system; the presence of oxygen makes the elements more flammable and the start of a fire more likely;
(2) a fire that damages the oxygen systems, if it causes a hose to rupture, becomes an oxygen-enriched fire that is difficult to control.

The cockpit oxygen system is therefore particularly critical and must be resistant to various ignition mechanisms (both internal to the system and external) to prevent it contributing to a fire in the cockpit.

Full-scale tests were carried out to study:

- certain ignition mechanisms likely to affect the cockpit oxygen system;
- the spread of an oxygen-fed fire;
- the means to extinguish an oxygen-fed fire available in the cockpit.

The tests were organised with the help of the oxygen equipment manufacturer, using equipment from dismantled aircraft, on the INERIS's[29] premises.

[29] Institut national de l'environnement industriel et des risques (French National Institute for industrial and environmental risks).

5.2 Starting a fire affecting the oxygen system

The following ignition mechanisms were studied:

- impact of an external heat source;
- internal ignition of the hoses by:
    - creation of a spark,
    - particle impacts,
    - electrostatic discharge;
- ignition of grease and dust in the vicinity of the device, which may be enriched with oxygen.

5.2.1 External heat source

The certification requires the oxygen system to be designed and installed in such a way that the impact of an external ignition source is minimised. Note, by convention in this document, external ignition mechanisms are defined as elements outside the oxygen system, i.e. elements originally outside the mask storage boxes.

Two potential external sources of heat were selected and tested:

- a lithium battery from an electronic device (smartphone, tablet, electronic cigarette);
- a glowing cigarette.

5.2.1.1 Lithium battery tests

The aim of the tests was to study the thermal runaway of lithium batteries, used in electronic equipment, and their capacity to damage the oxygen system.

In flight, electronic equipment such as smartphones, tablets and electronic cigarettes may be placed on the cockpit structure or in the document storage compartments on the sides of the cockpit, close to the oxygen masks.

Figure 23: aeroplane document storage compartment (here Airbus A320)

During the tests, the smartphones, electronic cigarettes and tablets were placed on a hot plate that could reach a temperature of 400°C, causing a thermal runaway in the internal batteries. The equipment was tested either in a free field (on a block of cellular concrete) or in an aeroplane document storage compartment. The temperature of the hot plate was gradually increased until there was thermal runaway in the equipment's battery.

Eight tests were carried out in total:

	Tested equipment	Position
Lithium battery_01[30]	Smartphone	Free field
Lithium battery_02	Smartphone	Free field
Lithium battery_03	Smartphone	Document storage compartment
Lithium battery_04	Tablet	Free field
Lithium battery_05	Tablet	Document storage compartment
Lithium battery_06	Electronic cigarette	Free field
Lithium battery_07	Electronic cigarette	Free field
Lithium battery_08	Electronic cigarette	Document storage compartment

During the tests, the thermal runaway of the batteries was visually characterised by a sudden release of thick white smoke. No sudden loud sound (snapping, detonation) was produced; only a whooshing sound or hiss could be heard during the ejection of gases. The ejection of incandescent particles was often observed during these tests, but the combustion of these particles proved to be very rapid and insufficient to spread the fire to the environment. The runaways were all preceded by the release of smoke over several minutes.

Figure 24: example of release of smoke during thermal runaway of battery (Lithium_Battery_04 test)

[30] The videos of these tests are provided with the document.

Figure 25: ejection of incandescent particles during thermal runaway of battery (Lithium_Battery_02 test)

The appearance of flames was observed only once, during a test carried out on an electronic cigarette in the free field (Lithium battery_07 test). It is likely that the fire broke out due to the presence of adhesive tape affixed[31] to the body of the cigarette, which burst into flames during the test.

Figure 26: visible flames during Lithium_Battery_07 test

In the conditions of the tests, only one element external to the electronic cigarette (adhesive tape) probably contributed to the outbreak of fire after the thermal runaway of the battery.

[31] This adhesive tape had been affixed by the BEA for the needs of the test.

It is possible that some of the electronic equipment items tested were fitted with batteries protected by a system of pressure relief valves that release the gases if the battery swells; this system prevents spontaneous combustion of the gases.

Tablets are generally equipped with high-capacity batteries. Their internal architecture is often made up of several small battery modules (three in the case of the tablets tested). As a result, the thermal runaway of a tablet is no more violent than that of a smartphone or electronic cigarette; the event is broken down into a succession of thermal runaways corresponding to each of the battery modules.

During the tests carried out on the equipment placed in the document storage compartments, no outbreak of fire was observed. Only the release of dense white smoke was seen.

Figure 27: release of smoke during Lithium_Battery_05 test

Several thermocouples were installed to measure the temperature of the hot plate, the temperature of the battery[32] and the temperature at various points in the volume surrounding the electronic equipment.

The temperature curves are shown in the graphs below.

[32] A single thermocouple was placed on the battery. The temperature value measured does not necessarily represent the maximum temperature of the battery.

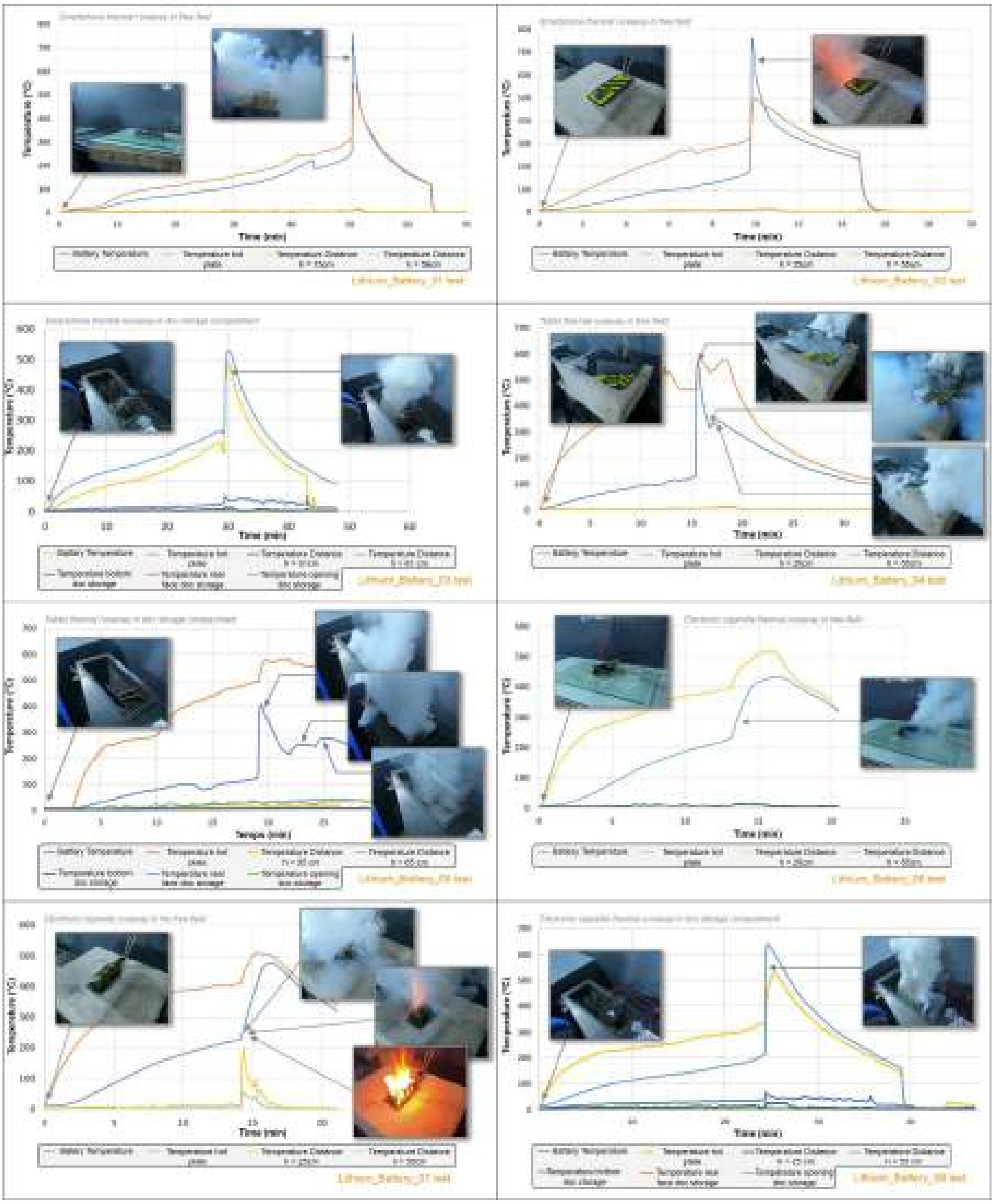


Figure 28: temperature curves - Lithium battery tests (source: BEA - INERIS)

Thermal runaway occurred at battery temperatures of between 100°C (tablets) and 250°C (smartphones), depending on the device. The battery temperature then rose almost instantaneously to an average of 550°C, with values as high as 750°C (in the case of smartphones). No significant rise in temperature in the air surrounding the batteries was measured. During tests carried out in the document storage compartment, the temperature inside the compartment rose without exceeding 50°C.

Only one rise in temperature was observed in the environment (approx. 200°C at a distance of 25 cm and approx. 50°C at a distance of 55 cm), during the Lithium battery_07 test when the tape on the electronic cigarette caught fire.

From a psychoacoustic point of view, the sound produced by the thermal runaway of a lithium battery was similar to a medium to low level whooshing sound. The whooshing sound lasted between 1.5 and 4 s according to the equipment tested. Its tonality varied over time and the whooshing sound was sometimes associated with light hissing.

CONCLUSION

In the conditions used for testing the lithium batteries in electronic equipment, the thermal runaway of a battery resulted in the sudden release of dense white smoke with a sharp and rapid rise in its temperature, without any significant transfer of heat to the surrounding environment. The incandescent particles ejected did not have sufficient thermal energy to ignite the materials. The only outbreak of fire observed was caused by the adhesive tape affixed to an electronic cigarette igniting.

5.2.1.2 Handling a glowing cigarette

5.2.1.2.1 Test on box without presence of external oxygen

The aim of the test was to study the resistance of an oxygen mask hose to a glowing cigarette. The test corresponded to the scenario of a glowing cigarette falling into the oxygen maskstorage box.

Test sequence:
A glowing cigarette was brought into contact with the hose of an oxygen mask. The oxygen pressure in the hose was 5 bar and the whole system was placed in ambient air.

The cigarette went out after about ten seconds. The braided outer protection of the hose and its core (a flexible silicone tube) were not damaged or impaired.

Thus, in the test conditions, a glowing cigarette placed in an open-air enclosure in contact with a pressurised oxygen hose did not damage the system or start a fire. The absence of damage is consistent with the certification, which requires equipment manufacturers to use fire-resistant materials to limit the outbreak and spread of fires.

Figure 29: open-air test (source: BEA)

5.2.1.2.2 Tests on oxygen-enriched boxes

There are several sources of occasional oxygen enrichment of the mask storage box when in service. An oxygen leak from the oxygen mask and storage box assembly is tolerated by the manufacturer (a few millilitres per minute and accumulation of oxygen in the oxygen mask storage box). In addition, the crew must test the oxygen supply to the masks when preparing the flight.

It is therefore possible for the mask storage box to be accidentally or occasionally enriched in oxygen. Oxygen is heavier than air, which is mainly composed of nitrogen, and concentrates in the bottom of the box, which is relatively airtight.

Tests involving the handling of glowing cigarettes were carried out in boxes enriched by oxygen on pressing the *EMERGENCY* knob on the mask regulator. When the *EMERGENCY* knob was pressed, an increase in oxygen concentration of 2 to 3 % per second was measured in the mask storage box.

For each of the tests, a mask storage box with a glass panel was used; the glass surface made the inside of the box visible so that the sequence of events produced by potential damage to the oxygen mask and storage box assembly could be observed.

An oxygen mask and its hose holding oxygen under a pressure of 5 bar were placed in the box. A glowing cigarette attached to the end of a pole was handled near the box and then the cigarette was dropped inside.

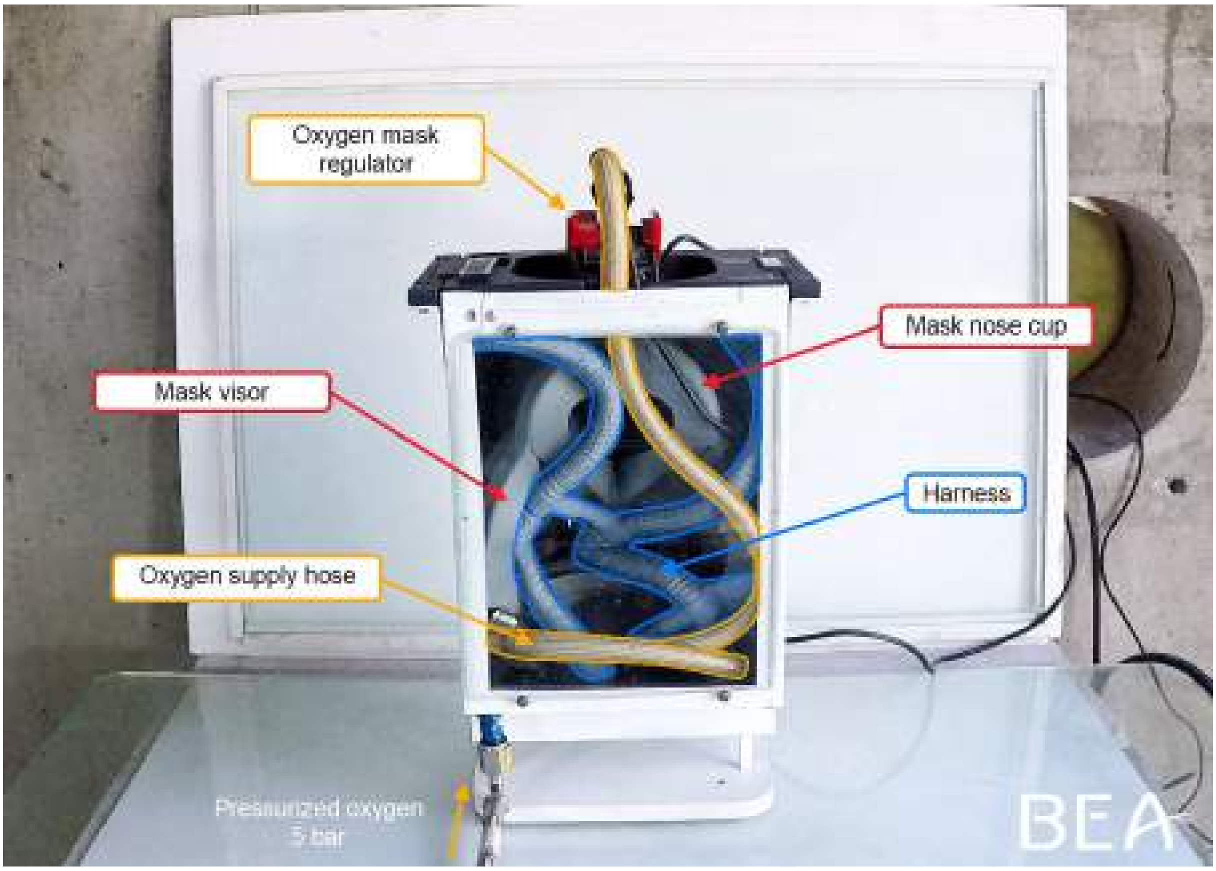


Figure 30: mask storage box with glass panel (source: BEA)

Each test was subdivided into several sequences:

- handling of cigarette near the box;
- handling of cigarette at the box opening, level with the mask regulator;
- introduction of ash into the mask storage box;
- introduction of a whole cigarette into the box.

These tests were carried out three times with different oxygen concentrations in the box.

	Duration of oxygen enrichment
Cigarette_01	15 s via the system solenoid valve with the mask knob in the *EMERGENCY* position
Cigarette_02	20 s by pressing the *EMERGENCY* knob
Cigarette_03	20 s by pressing the *EMERGENCY* knob
Cigarette_04	7 s by pressing the *EMERGENCY* knob

Sequences 1 & 2: Handling of cigarette near the box

When the glowing cigarette was handled close to the box, no variation in the intensity of combustion was observed. Each time, the cigarette burned at the same rate as in the open air. As oxygen is heavier than air, although the box was enriched with oxygen, outside the box or in the direct vicinity of the regulator, the composition of the atmosphere remained close to the normal composition of ambient air.

Sequences 3: Introduction of ash
No ignition occurred when ash was introduced into the box. The mass of the ash was probably too small to retain the heat needed to produce a flame. The ash burnt instantly.

Sequences 4: Introduction of a cigarette
When a glowing cigarette was placed in the box, there was a sudden increase in its rate of burning. Combustion was more intense and whiter. Flames were visible and black smoke was produced.

During the first test (Cigarette_01), the cigarette landed on the mask's harness and perforated it. The fire did not spread to other parts of the mask and extinguished.

Figure 31: cigarette_01 test - video sequence (source: BEA)

During the second test (cigarette_02), the cigarette landed on the silicone envelope of the oxygen mask nose cup and began to consume this part of the mask. When the oxygen contained in the box was consumed, the intensity of the fire decreased and the fire went out.

Figure 32: cigarette_02 test - video sequence (source: BEA)

In the next two tests, the cigarette was placed in contact with the mask's oxygen supply hose. The flames damaged the casing of the hose and after a few seconds, its core (silicone tube) was pierced; a leak at a pressure of 5 bar was caused and the fire rapidly developed in the box, producing flames which escaped from the mask storage box. Cutting off the oxygen supply extinguished the fire after a few seconds.

Audio analysis

Cigarette_03 test: crackling noises for 28 s were audible on the recording, corresponding to the combustion of the hose casing. The subsequent piercing of the hose produced a broadband noise. 1 s later, the mask ignited, causing a sound runaway. The mask microphone stopped working 6 s after the mask ignited.

Cigarette_04 test: crackling noises for 22 s were audible, corresponding to the combustion of the hose casing. The subsequent piercing of the hose produced a broadband noise. The mask ignited 0.5 s later, causing a sound runaway. The oxygen supply was cut off before the mask microphone was damaged.

Figure 33: cigarette_03 test - video sequence (source: BEA)

Figure 34: cigarette_04 test - video sequence (source: BEA)

CONCLUSION

In the tests carried out, the handling of a cigarette in the immediate vicinity of an oxygen mask storage box, even if the box had been enriched with oxygen, did not lead to any variation in the combustion of the cigarette and did not cause a fire. The introduction of hot ashes into the storage box did not start a fire.

In each test, placing a cigarette in a mask storage box that had been enriched with oxygen accelerated its burning rate and produced a more intense flame. When the cigarette came into contact with an oxygen supply hose, the fire attacked the hose, pierced the internal silicone tube and created an oxygen leak under pressure. The leak intensified the fire, allowing it to spread rapidly.

5.2.2 Internal ignition mechanisms

The certification indicates that the system must be intrinsically safe. In particular, the system's design must be such that a single failure of one of its components does not lead to an uncontrolled fire in the aeroplane and that in all cases, such a fire is extremely improbable.

The risk analysis of the oxygen system must look at the failures of the various components, the properties of the materials and the internal ignition mechanisms. If an internal ignition mechanism exists, the associated fire kindling chain must be analysed.

5.2.2.1 A heat source causing ignition inside the device

The aim was to describe the sequence that would arise from internal damage from an acoustic point of view (appearance of transient noise phenomena, noises, whooshing sounds, etc.), to determine the level of damage produced on the individual oxygen equipment (mask storage box and mask) placed under a pressure of 5 bar, and to specify the chronology of this damage (propagation time).

To artificially cause internal damage to the oxygen distribution system - and more specifically to the oxygen mask hose - a spark-trigger device[33] was introduced into the hose.

Figure 35: spark production device (source: BEA)

[33] A two-wire connection that provides a continuous low-voltage supply to a filament; the filament becomes incandescent when it is connected via a pushbutton to a voltage source.

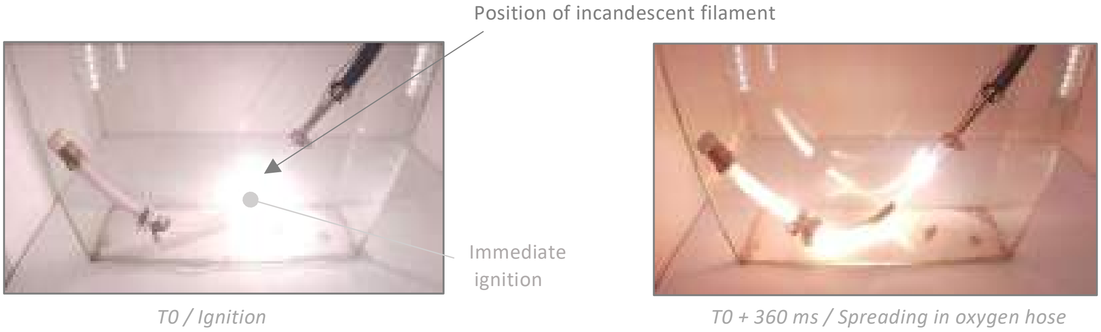


Figure 36: fire in oxygen flow (source: BEA)

An initial test carried out in a transparent tube confirmed that ignition at the point where the spark is created was immediate.

Three tests were carried out using a mask storage box with a front glass panel, with the spark-production device inserted halfway along the mask hose.

Figure 37: insertion of device in hose of oxygen mask (source: BEA)

Note: During these tests, the combustible material represented by the visor support (silicone) and the visor (polycarbonate) were removed.

Tests: the volume of the mask storage box was first enriched with oxygen by pressing the *EMERGENCY* knob on the oxygen mask regulator for a few seconds.

Figure 38: internal damage to mask oxygen hose (source: BEA)

During the first test, immediate damage occurred inside the hose (appearance of a moving glow in the tube); the hose was punctured and the fire spread to the surrounding area 42 s after the spark was created.

In the second test, no immediate internal damage was detected; the hose was punctured and the fire spread to the surrounding area 30 s after the spark was created.

The last test did not produce any ignition of the box[34]. The puncture occurred 18 s after the spark was created.

The production of a spark in the oxygen supply hose of the mask sometimes created a puncture in the hose after 20 to 40 s. In some cases, the puncture was accompanied by a fire that spread rapidly to the surrounding area when the flow of oxygen was maintained.

CONCLUSION

In the three tests, the creation of a spark in one of the mask's oxygen supply hoses produced instant ignition.

The ignition did not have a detonating effect. It led to the hose being punctured after 20 to 40 s. In some cases, the puncture was accompanied by a fire that spread rapidly to the surrounding materials when the flow of oxygen was maintained.

5.2.2.2 Metal particle impacts in the oxygen system

Particle impacts are one of the internal ignition mechanisms to be considered in the hazard analyses. This hazard relates in particular to particles that could be introduced into the system during maintenance operations.

[34] The puncture occurred two seconds after the oxygen supply to the mask storage box and mask was cut off.

During the maintenance of oxygen systems on commercial air transport aeroplanes, particular care is taken not to contaminate the oxygen distribution system.

However, it is possible for particles to be accidentally introduced into the lines carrying the oxygen. For example, operations to replace one or more sub-assemblies of the individual oxygen equipment (storage box, mask, etc.) may produce metal residues during connection operations when the components are screwed together (e.g. partial breakage of screw threads, metal seals or unions).

These metal particles could present a risk of ignition of the oxygen system when there is a pressurised gas flow. When the gas is set in motion, the particle accidentally introduced advances through the system, accelerating. The various changes in direction of the hoses or rigid pipes can potentially cause the particle to collide with other metal components (filter, elbow, etc.) that make up the oxygen distribution system. This impact can be accompanied by a high, localised rise in temperature (linked to the transfer of kinetic energy) which, in an oxygen-rich environment, can lead to the start of a fire. This is referred to as “particle impact ignition”.

According to the literature[35], the scenario of a fire starting as a result of the impact of a metal particle in the oxygen system of a commercial aircraft is possible. The necessary criteria for this outbreak are:

- particles circulating in a flow of oxygen;
- gases travelling at more than 30 m/s; and
- an impact plane between 45° and 90° to the path of the particle.

Tests were carried out in a laboratory environment to try and reproduce this phenomenon. A test bench was set up to project particles at high speed against a component to be tested.

[35] NASA doc

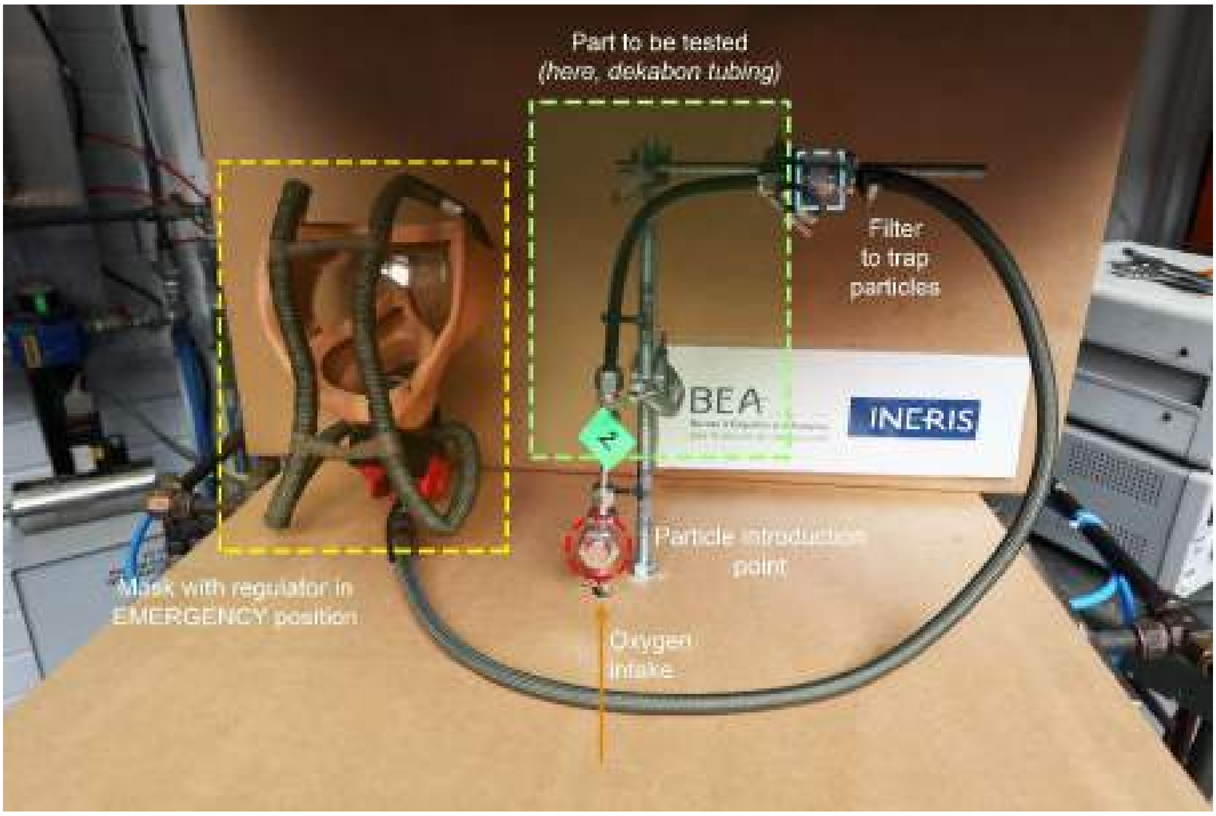


Figure 39: test set-up (source: BEA)

Description of installation: the test system was supplied with oxygen at a pressure of 5 bar. A mask positioned at the end of the line with the knob in the EMERGENCY position was used to create a pressure drop consistent with that in an aircraft oxygen system.

The oxygen passed through a filter on which metal particles had been deposited. The flow of oxygen and particles travelled through the system to the component to be tested. The particles were then collected on a filter to avoid saturating the oxygen mask placed at the end of the line.

Each part of the system was tested with particles of different sizes from different materials. The aim was to identify the "part/particle" pairing most likely to create the sought for particle impact ignition phenomenon.

A total of five parts of the oxygen system, located in the mask storage box or regulator, were considered:

	Parts to be tested
1	90° inlet elbow
2	Dekabon tubing
3	Box valve piston - in this part of the system, the oxygen flow takes a 180° bend
4	135° inlet union of mask regulator
5	Oxygen mask inlet filter

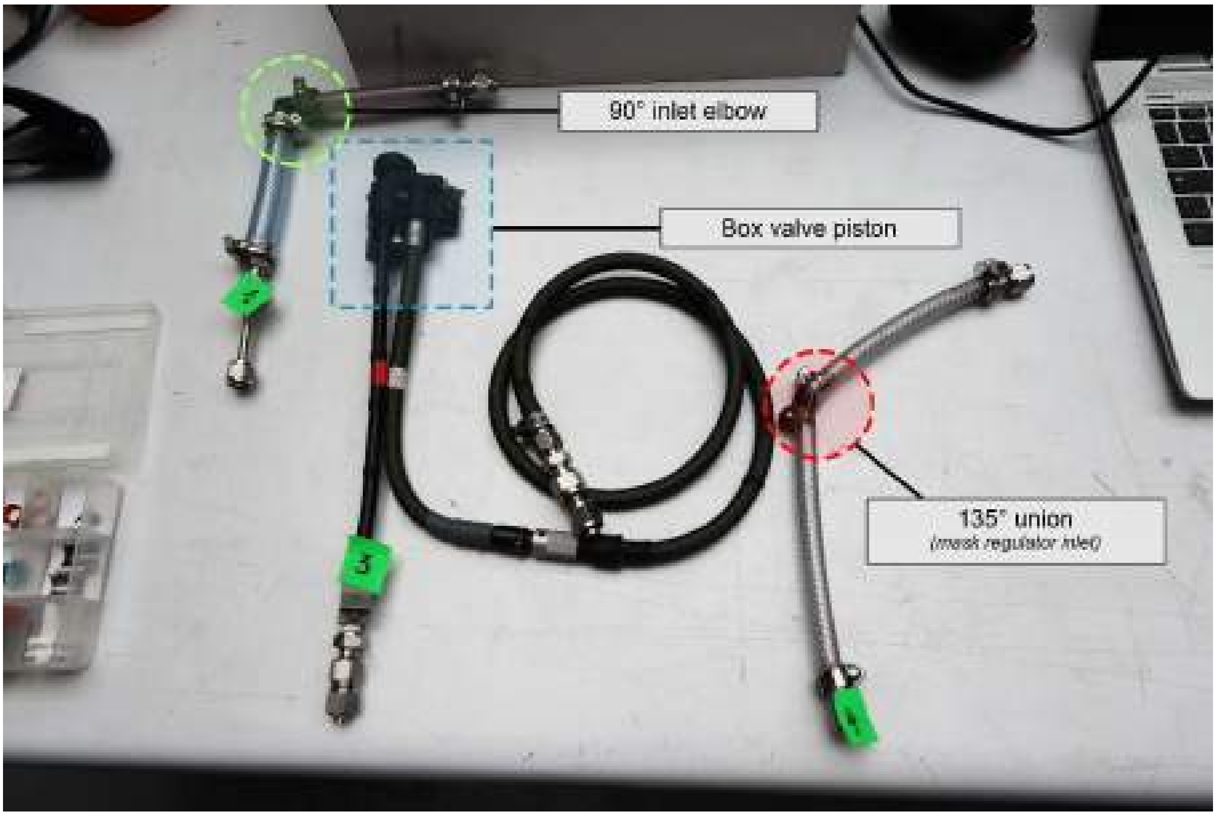


Figure 40: mask parts tested during particle tests (source: BEA)

The particles were created from parts of the oxygen system:

	Particles
A	Aluminium from the inlet elbow of the mask storage box
B	Copper from crush seals in the distribution circuit
C	Aluminium from Dekabon tubing
D	Stainless steel from oxygen supply hoses

Particles of two sizes were produced from each material:

- around 300 µm in size;
- around one millimetre in size.

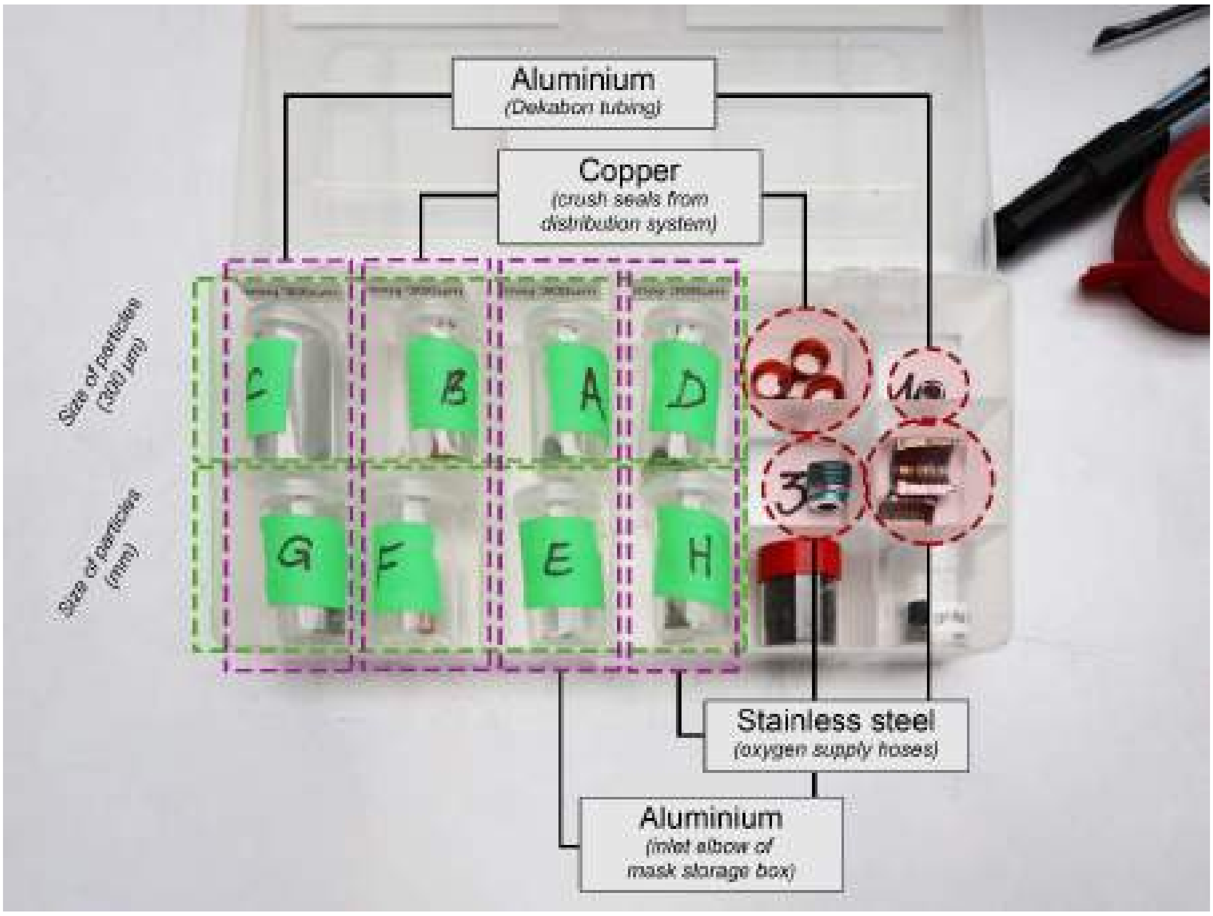


Figure 41: particles used (source: BEA)

For each test, several oxygen bursts at an average pressure of 5 bar and a constant flow rate of 200 l/min were sent through the system (this corresponded to an estimated gas travel speed of more than 50 m/s). A thermal camera directed towards the part to be tested, monitored the potential rise in local temperature at the time of the “particle impact ignition”.

The tests for each "part/particle" pair were carried out between three and five times with different quantities of particles.

A total of 76 tests were carried out. No particle impact ignition or increase in temperature were observed during the tests.

Note: Due to the architecture of the test bench, some particles may have been trapped in the filter and not set in motion at each pressurisation (three to five successive pressurisations per "part/particle" pair). The chances of particles colliding with a part were therefore lower than the number of tests.

The particle impact ignition phenomenon is random in nature. New tests could be carried out by modifying the test conditions to increase the quantity of the sample and the probability of reproducing a particle impact ignition.

Figure 42: overall view of particle test equipment (source: BEA)

CONCLUSION

The "particle impact ignition" phenomenon described in the literature was not reproduced in the test conditions adopted.

5.2.2.3 Ignition due to electrostatic discharge

The discharge of electrostatic charges accumulated by friction or flow can in some cases release sufficient energy to ignite materials, particularly when the environment is rich in oxygen. This can happen when materials used in the systems exhibit differences in electrical potential.

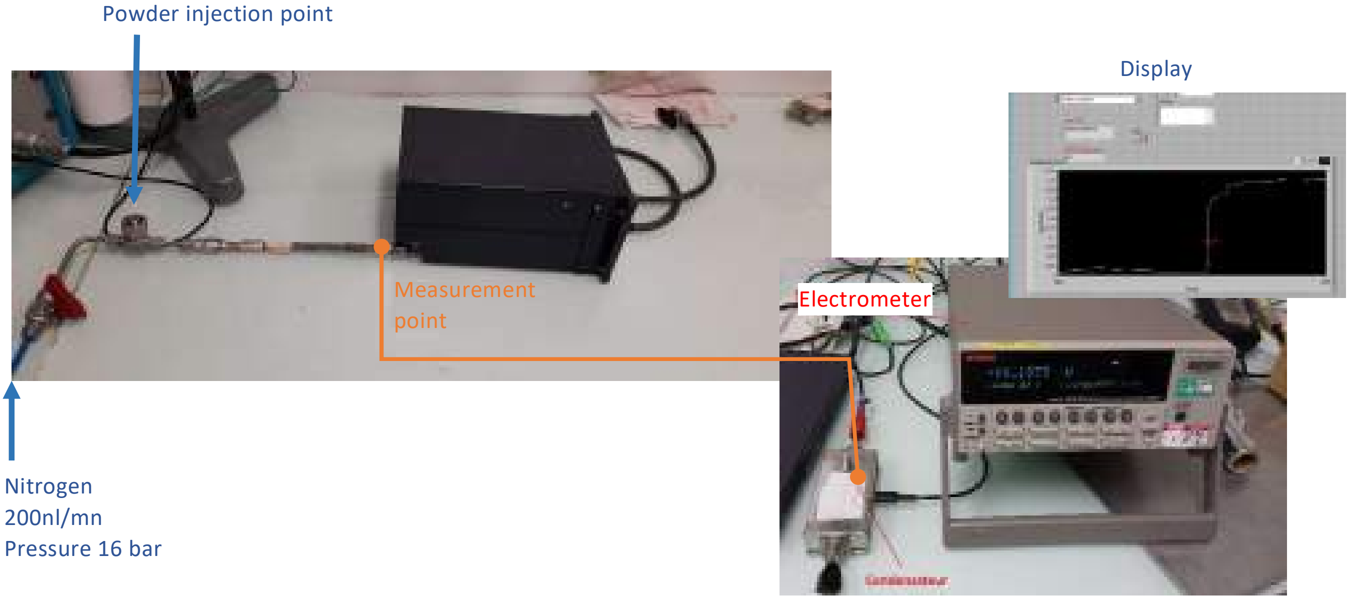
The aim was to determine whether the electrostatic charges generated by the dynamics of the passage of oxygen, combined with the movement of particles in the system, could create an arc likely to generate the start of a fire.

Electrostatic charge measurements were carried out at various points on a complete oxygen system (supply hose, storage box, mask) in which nitrogen at 6 bar and a flow rate of 200 l/min was travelling. Two types of powder were used for these tests:

- conductive metal powder (400 µm aluminium);
- insulating polystyrene powder (600 µm).

For these tests, the mask was stored in its box, where the accumulation of charges was thought be the greatest. Three measurements were carried out:

- at the threaded connection at the storage box inlet;
- at the inlet hose of the mask regulator;
- at the filter in the mask regulator.



*Note: the charge is determined by Q=C*U with Q in nC, C in Farad, and U in Volt.*

Figure 43: measurement method of electrostatic charge (in compliance with technical specification CEI/TS 60079-32-1) (source: INERIS)

Measurement principle:
The electric potential (instantaneous voltage measurement) taken at the inlet union of the mask storage box was accumulated over a defined period by a capacitor whose average charge is measured by an electrometer. This charge, expressed in nanoCoulomb (nC), expresses the level of electrostatic charge accumulated at the measurement point.

The charges measured in nC during these tests were as follows:

	Aluminium	Polystyrene
Box inlet union	2 nC	1 nC
Regulator inlet hose	16 nC	2 nC
Mask filter	22 nC	4 nC

These values were too low to create a spark capable of igniting a part in the oxygen system. By way of comparison, in an explosive atmosphere, electrostatic charges present a risk at values above 200 nC.

The electrostatic fields were also measured on a mask stored in a box containing polyester fabric lint. It is not uncommon to find an accumulation of dust in the bottom of mask storage boxes after several weeks or months in service. The measurements were taken after nitrogen had been injected into the system.

Polyester lint placed in bottom of box

Figure 44: measurement of electrostatic fields created on accumulated synthetic debris at bottom of storage box (source: INERIS)

The maximum voltage observed was 255 V; this voltage was too low to generate an electrostatic charge likely to produce sparks capable of igniting dust or metal particles. In an explosive environment, the formation of dangerous sparks is considered for a value greater than 2 kV.

CONCLUSION

The measurements carried out on the oxygen system of a commercial air transport aeroplane seemed to indicate that the accumulated electrostatic charges were too low to create sparks capable of igniting elements of the system itself or organic or synthetic debris present in the storage box.

5.2.3 Ignition of substances in an oxygen-enriched environment

5.2.3.1 Oxidation of grease

The scientific article entitled "*Fire and Explosion Hazards Due to Medical Oxygen Handling During Coronavirus Pandemic*" describes in detail the chemical oxidation reactions likely to produce temperatures reaching the spontaneous combustion temperatures of certain materials. This document refers to the known risk associated with the use of greases in an oxygen-enriched environment.

According to a summary provided by INERIS, in the scope of the study:

It is generally accepted that grease can react with oxygen by oxidation (decomposition of the grease molecules) leading to the production of radicals (peroxides), an increase in temperature and then possibly combustion if sufficient energy is supplied (heating by friction or creation of an electrostatic charge, for example).

Normally, this oxidation does not produce enough heat to lead to combustion, except in special conditions such as:

- large exchange surfaces between grease and oxygen;
- poor air circulation (conducive to heat build-up);
- adiabatic compression following rapid injection of pressurised oxygen into a non-pressurised system. However, a pressure of 5 bar seems too low to ensure a sufficient production of energy.

All materials ignite in the presence of oxygen at temperatures lower than their ignition temperature in ambient air.

When analysing events that had occurred on cockpit oxygen systems, the possibility that the start of the fire was related to the presence of grease could not immediately be ruled out, particularly if the grease traces in question were hydrocarbon-based. However, it is more difficult, if not impossible, for a fire to start if the greases used are "non-reactive" (e.g. fluorinated greases). The aging condition of a grease must also be taken into account, as it increases the risk.

This risk was not the subject of any specific experiments in the scope of this "Oxygen fire" study. The only test carried out consisted of the deliberate introduction of grease during a propagation test (see paragraph 5.4) into an oxygen mask storage box union; no fire was triggered when oxygen was admitted and circulated in the system under a pressure of 5 bar.

This test illustrated that the spontaneous combustion of grease in an oxygen-rich environment is not systematic and that it occurs under specific conditions (type of grease, oxygen pressure, flow rate, etc.).

The variables to be controlled, such as trigger conditions, type of grease and oxygen pressure, would require the definition of a dedicated protocol and multiple tests, which could not be carried out as part of the study.

The main supplier of oxygen systems[36] for commercial aviation, and the reference organization[37] for the risk analysis of oxygen and hydrogen systems, have produced a summary which is presented in the appendix, Grease and hydrocarbon ignition. The analysis indicates that the mere presence of grease exposed to a pressure of less than 10 bar - which is much higher than the operating pressure of a mask storage box and associated mask - cannot generate a fire.

[36] SAFRAN Oxygen Systems

[37] WHA International Inc / https://wha-international.com/about/

CONCLUSION

Greases are hydrocarbons that react with oxygen in the air to form peroxides. This oxidation reaction releases heat. Heat can be sufficient to undergo grease combustion.

The risk represented by the presence of grease in an oxygen-rich environment is commonly accepted and taken into account in procedures. However, the conditions under which spontaneous combustion occurs are poorly documented in the aeronautical field.

The only test carried out highlighted the fact that the ignition of grease in an oxygen-enriched environment is not systematic.

5.2.3.2 Ignition of dust

Mask storage boxes may contain dust that has accumulated over time.

The aim of the tests was to determine whether the addition of heat could cause the dust to ignite, and whether this would be sufficient to damage the oxygen system.

To reproduce the accidental ignition of dust, a device producing an electric arc[38] was introduced into an oxygen-saturated enclosure.

Figure 45: spark produced by the piezoelectric system (source: BEA)

A first test was carried out on domestic dust. Several attempts were made to ignite the dust by producing a spark in the middle of the pile of dust. No incipient ignition was observed.

[38] The head of a friction piezoelectric igniter was remotely controlled by a two-wire line.

Figure 46: domestic dust (source: BEA)

A second test was carried out on dust taken from the bottom of oxygen mask storage boxes in three aircraft. Several attempts were made to ignite the dust by producing a spark in the middle of the pile of dust. No incipient ignition was observed.

Figure 47: aeroplane dust (source: BEA)

CONCLUSION
The production of a spark (electric arc) in a pile of dust placed in an environment previously saturated in oxygen did not, under our test conditions, produce immediate ignition.

5.3 Extinguishing a fire in the presence of an oxygen leak: use of halon extinguishers

The cockpits of commercial air transport aeroplanes are equipped with portable halon fire extinguishers, also known as halogenated hydrocarbon extinguishers.

These extinguishers contain halon 1211 expelled by the pressure of an auxiliary gas (nitrogen). It acts by inhibiting the combustion reaction by combining with the oxygen in the atmosphere, thus depriving the combustion of comburant.

The action of a halon extinguisher is faster than that of a carbon dioxide extinguisher and requires less product. This makes it a smaller and lighter extinguisher.

Halon presents little risk when cold. On the other hand, in the presence of high temperatures, which can occur in prolonged and extensive fires, its pyrolysis products can be highly toxic and corrosive. Halon has no cooling effect, unlike carbon dioxide.

Halon extinguishers should be used at a distance of about 1 m from the flames, attacking the fire at its base as soon as flames are visible. The maximum angle of use for this type of extinguisher is 45° in order to keep the dip tube in the liquid extinguishing agent and not to expel just the auxiliary propellant gas.

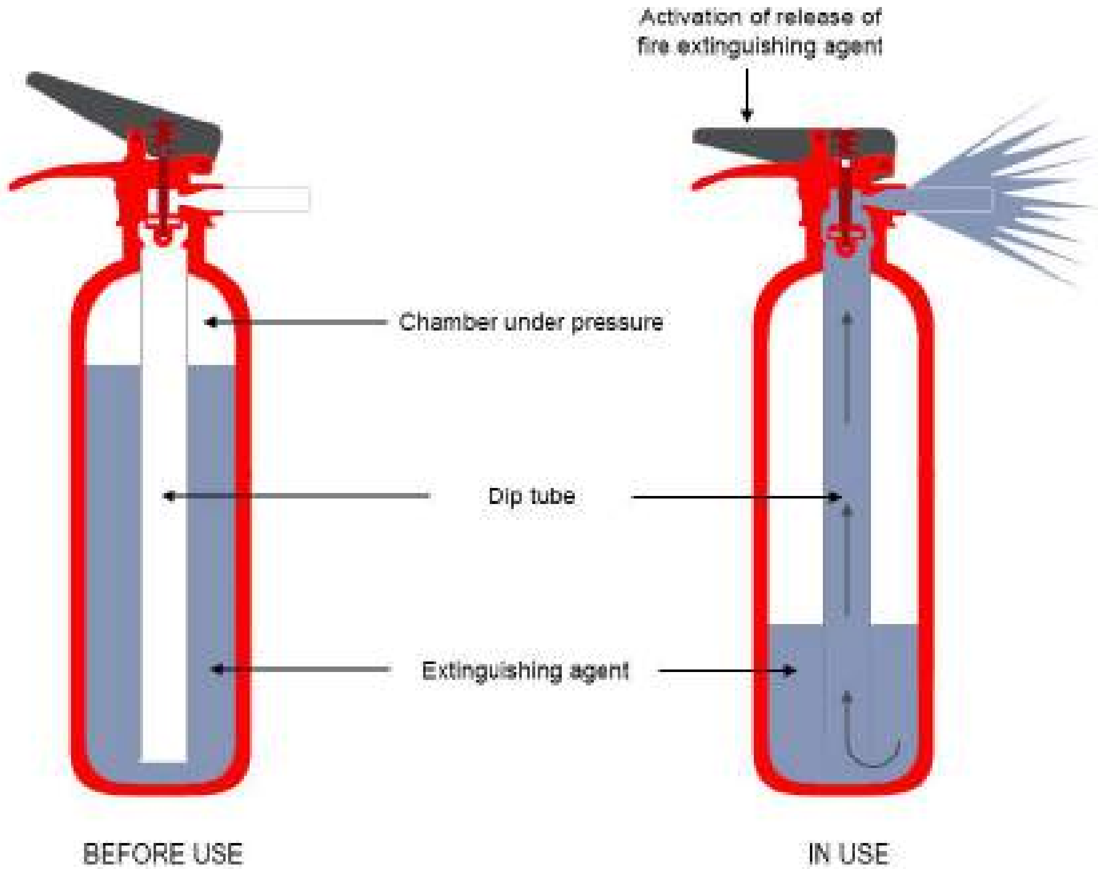


Figure 48: halon extinguisher operating principle (source: *L'avionnaire*)

The study looked at the effectiveness of the fire extinguishers available in the cockpit for extinguishing a fire in the presence of an oxygen leak.

Three tests using halon extinguishers were carried out on a fire contained in a metal firebox into which oxygen was introduced via a hose located at the bottom of the box to simulate an oxygen leak. A flame was supplied with fuel in the centre of the firebox (a Hessian wick placed in an oil bath).

The model of extinguisher used for these tests was the Air Total 74-20.

Extinguisher_01	Fire extinguisher used on non-oxygen enriched firebox
Extinguisher_02	Fire extinguisher used on firebox with oxygen leak
Extinguisher_03	Fire extinguisher used on firebox with oxygen leak

The measurements showed that an extinguisher was completely discharged in 14 to 18 s.

A first test was carried out without the addition of oxygen (Extinguisher_01 test); the flames disappeared as soon as the extinguisher was activated. The fire did not restart again. There was no change in visibility in the room.

Figure 49: extinguisher_01 test - video sequence (source: BEA)

During the fire extinguisher_02 test, the fire was enriched with oxygen. The halon extinguisher was unable to extinguish the fire. No effect on the flames was observed. On activation of the extinguisher, thick smoke appeared, significantly reducing visibility.

Figure 50: extinguisher_02 test - video sequence (source: BEA)

The protocol followed for the fire extinguisher_03 test was identical to the previous one, except that there was practically no oil in the oil bath. The flames were extinguished as soon as the extinguisher was activated[39]. The oxygen leak was present throughout the test. There was a detonation 12 s after the extinguisher had been emptied, and the flames reappeared.

Figure 51: extinguisher_03 test - video sequence (source: BEA)

The tests showed that the use of a halon fire extinguisher is not suitable for extinguishing an oxygen-enriched fire.

Halon acts on oxygen to inhibit the combustion reaction. The continuous oxygen leak prevented the extinguishing agent from overcoming the accumulation of oxygen in the environment. Thus, either the fire was not extinguished because there was enough oxygen to support combustion, or the fire was extinguished but the sustained supply of oxygen and the high combustion temperatures reached allowed the fire to start again. As halon has no cooling effect on the elements, the residual embers recreated flames in the presence of oxygen.

CONCLUSION

During the tests, a fire fuelled by an oxygen leak could not be extinguished using halon extinguishers. This result is consistent with the chemical mechanism by which halon gas acts on a fire. The halon acted on the oxygen, but the leak continued to supply oxygen to the fire.

During the three tests, the presence of an unpleasant odour, and acidic, irritating emanations was noted. The video and sound recording equipment was damaged by the acid vapours released when the fire extinguishers were used (particularly during the "Extinguisher_02 test").

The identification of the gases produced during each of the three tests[40] gave rise to the following list and level of gases resulting from the combustion and degradation of halon:

- carbon gases: COF2 - carbonyl fluoride and CF4 - carbon tetrachloride;
- acids: HF - hydrogen fluoride, HCl - hydrogen chloride, and HBr - hydrogen bromide;
- halon (extinguishing agent): halon.

The tables in the appendix, Halon gas give details of the gas levels produced during three separate tests, which were carried out under different conditions:

- the first test consisted of using a halon fire extinguisher to put out a fire without oxygen enrichment (example of the "*Extinguisher_01 test*") and without ventilation;
- the second consisted of attempting to put out an oxygen-enriched fire (example of the "*Extinguisher_02 test*") with ventilation of the test space[41];
- the last test involved extinguishing a fire enriched with oxygen but rapidly deprived of fuel (example of the "*extinguisher_03 test*"), again with ventilation of the test area.

[40] Ambient air samples were taken from the test chamber suction system.

[41] The air extraction volume was much higher (5000 m3/h) than that of an airliner cockpit ventilation system (between 0.13 and 0.15 m3/s).

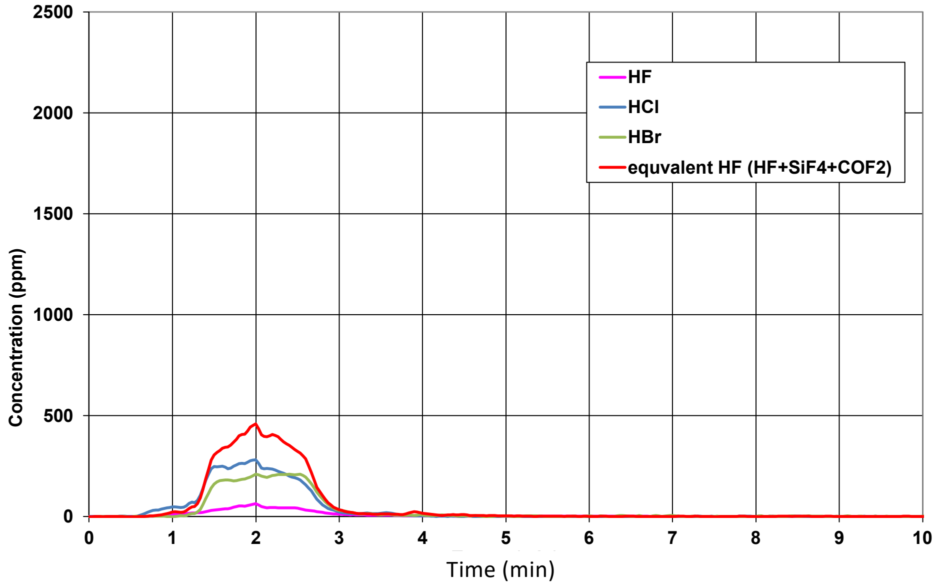


Figure 52: example of a table giving acid gas measurements (source: INERIS report)

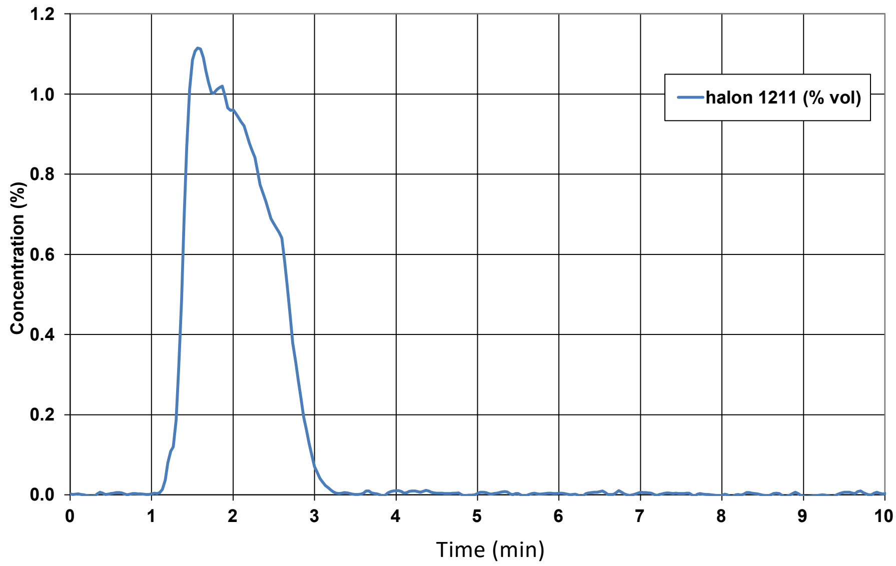


Figure 53: example of a table giving halon measurements (source: INERIS report)

All the measurements were compared with the gas toxicity thresholds for a 10-minute exposure of personnel (see appendix, Halon gas for details).

It appeared that during the three tests, the COF2 concentration exceeded the irreversible effect threshold. During the test carried out without ventilation, the concentration of HF and HCl largely exceeded the irreversible effect threshold. Lastly, INERIS indicated that during the "Extinguisher test_02", exposure to the cumulative gases generated reached the irreversible effect threshold, and probably the first lethal effects (see concept of *toxic dose* described in the appendix, Halon gas).

The INRS toxicological data sheet for Bromochlorodifluoromethane (CFC2ClBr, halon 1211) states: When using this product in a portable fire extinguisher, take care not to expose people to pyrolysis products. HF, HCl and HBr acid gases are toxic and corrosive pyrolysis products.

The acid gases identified during the tests (HF, HCl and HBr) correspond to these pyrolysis products. They are toxic and corrosive.

CONCLUSION

During the tests, using a halon fire extinguisher on an oxygen fire produced opaque smoke that rapidly invaded the environment. Visibility became almost zero. The pyrolysis of the halon created acid gases in quantities that were harmful to people in the vicinity of where the fire was being put out.

5.4 Propagation (and extinction) of a fire in the presence of an oxygen leak

Three tests involved the propagation of a fire started in an oxygen mask storage box.

The tests were carried out using structural elements (lateral storage compartments) taken from an A318 and an A319 that were being torn down. A mask storage box and the associated oxygen mask were placed in this lateral compartment. The fire was started in the storage box using a remote-controlled flame. A fire extinguisher, operable from the outside for safety reasons, was placed on a fixed support and aimed at the storage box.

The three tests carried out differed in terms of the means used to create the oxygen leak and the subsequent fire extinguishing sequence. The table below shows the different configurations adopted.

	Propagation_01	Propagation_02	Propagation_03
Test Environment	10 m3 chamber: Lateral compartment + storage box with oxygen mask		
Start of fire	Caused by a flame in the storage box		
Start of oxygen leak	Mask set to EMERGENCY (controlled by a solenoid valve)	By propagation of fire	
Activation of fire extinguisher	No	Yes	After oxygen cut off*

*The tests carried out with the fire box in the presence of oxygen showed the relative ineffectiveness of halon on an oxygen-rich fire. The propagation_03 test was designed to incorporate this result by adding the cutting off of the oxygen prior to using the fire extinguisher.

Propagation_01 test:

The fire was started by a flame created in the storage box (at 00:48 in the video[42]). The oxygen leak was started from outside the test chamber via the solenoid valve in the oxygen supply system, after the fire had had time to develop to a small extent inside the box[43].

High flames appeared rapidly; the fire was intense. In the seconds that followed, the fire seemed to diminish until it disappeared. The sound of leaking oxygen seemed to die down. Only black smoke remained visible, slightly obscuring the room. After several dozen seconds, flames were again visible in the mask storage box. The sound of oxygen leaking stopped for half a second, then a detonation was heard (at 01:39), accompanied by sparks and a reddish glow in the environment of the lateral storage compartment. More and more black smoke escaped.

The fire was hidden and contained in the lateral storage compartment; it was barely visible in the shots. Its intensity seemed to increase progressively until flames escaped again through the oxygen mask storage box where the fire was initially started (at 01:56). As soon as the flames emerged, they spread to the rest of the lateral compartment, in particular to the second oxygen mask. The fire intensified. The room was filled with increasingly opaque smoke. Incandescent material was projected at 02:28, then the lateral compartment cover closed over the mask storage boxes. Flames next escaped from around the edges of the storage box.

The oxygen supply was cut off and the fire extinguished using water-spray fire extinguishers.

Audio elements: when the mask hose was pierced 18 s after the fire broke out, a broadband noise (leaking noise) was heard, immediately followed by a sound runaway. The leaking noise stopped 0.5 s - without any action by the test operators - 50 s after the mask hose was pierced. The interruption was followed by a detonation, the resumption of the leak and the enrichment of the fire.

[42] The timing indicated corresponds to that of the raw file of the camera recording.
[43] The mask regulator knob was set to *EMERGENCY* to obtain a continuous flow of oxygen.

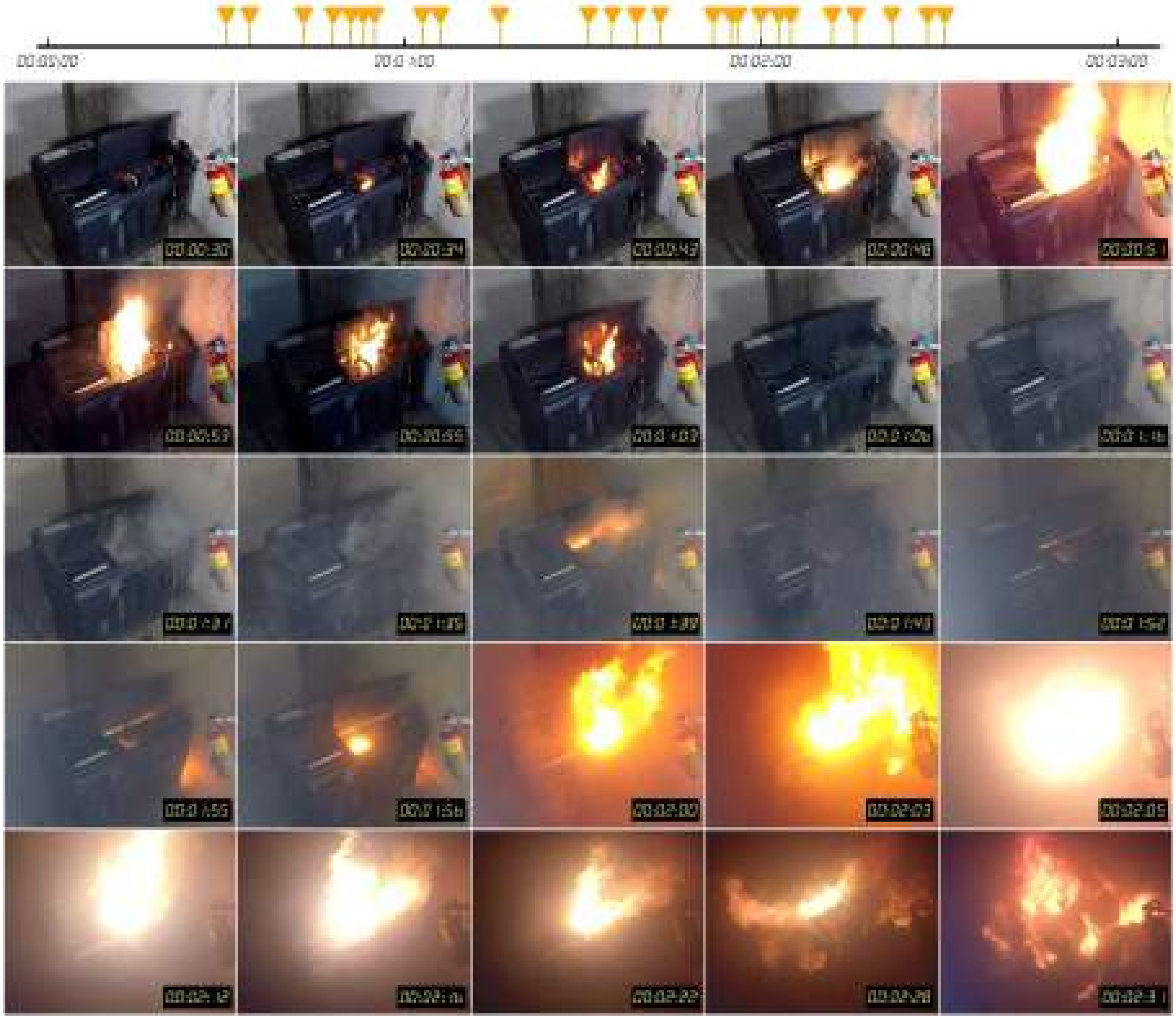


Figure 54: Propagation_01 test - video sequence (source: BEA)

Propagation_02 test:

The fire was started by a flame created in the mask storage box (at 10:52 on the video[44]). The flame was positioned close to the mask's oxygen supply hose to damage it and create an oxygen leak (at 10:58). The mask storage box had been previously enriched with oxygen to encourage the fire to start.

After the fire was established in the presence of the oxygen leak, the fire extinguisher was activated (at 11:22). The flames were quickly smothered and thick, opaque smoke filled the room. About 20 s after the fire extinguisher was activated, despite the smoke, glowing flames were visible in the oxygen mask storage box. The fire continued to intensify in the following seconds until the oxygen supply to the test chamber was deliberately cut off. The fire was extinguished using water-spray fire extinguishers.

Note: this test was carried out in February 2023 in an uninsulated room that had not been heated beforehand.

[44] The timing indicated corresponds to that of the raw file of the camera recording.

Audio elements: the piercing of the mask hose 13 s after the reactivation of the fire was preceded by crackling noises (picked up by the microphone on the oxygen mask). The piercing of the hose produced a broadband noise (leaking noise). The mask microphone stopped working 5 s after the hose of the oxygen mask was pierced.

The fire that followed the piercing of the hose spread rapidly to the surrounding components. No sound runaway or interruption in the leaking sound was observed.

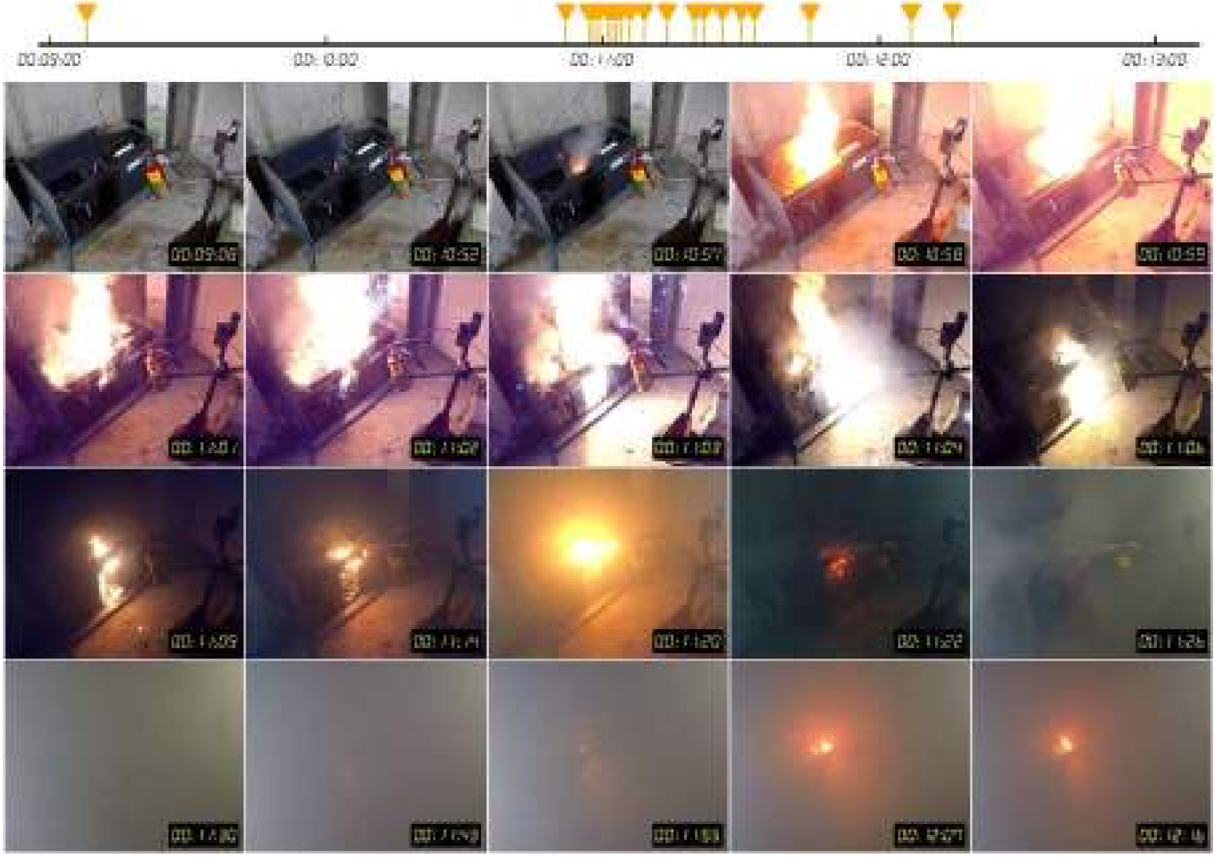


Figure 55: Propagation_02 test - video sequence (source: BEA)

Propagation_03 test:

The propagation_03 test was carried out under the same conditions as the previous test.

After the oxygen supply hose was damaged (at 06:25 on the video[45]), the fire remained hidden inside the lateral compartment. Flames and a reddish glow were visible on several occasions at the rear of the structure (for example at 06:36 and 06:44), and appeared to vary in intensity thereafter. The flow of oxygen was audible throughout the test. Sparks were intermittently visible through the lateral compartment. Thick black smoke gradually invaded the test chamber.

At 06:57, the oxygen supply solenoid valve was closed. The sound of the leak disappeared and the intensity of the flames seemed to diminish instantly (the red glow radiated by the wall behind the lateral compartment diminished). The extinguisher was activated and thick, opaque smoke quickly filled the test chamber, making visibility almost nil. Visibility gradually returned after a few

[45] The timing indicated corresponds to that of the raw file of the Gopro camera recording.

minutes (at 10:50). No flames or red glow were visible; crackling noises were present and smoke escaped from the mask storage box. Flames reappeared in the vicinity of the mask storage box four minutes after the activation of the fire extinguisher.

Audio elements: the piercing of the mask hose 14 s after the fire was started was preceded by crackling noises (picked up by the microphone of the oxygen mask). When the hose was pierced, there was a broadband noise (leaking noise) followed 0.5 s later by a sound runaway. Cutting off the oxygen supply - which preceded the use of the extinguisher - interrupted the leaking noise.

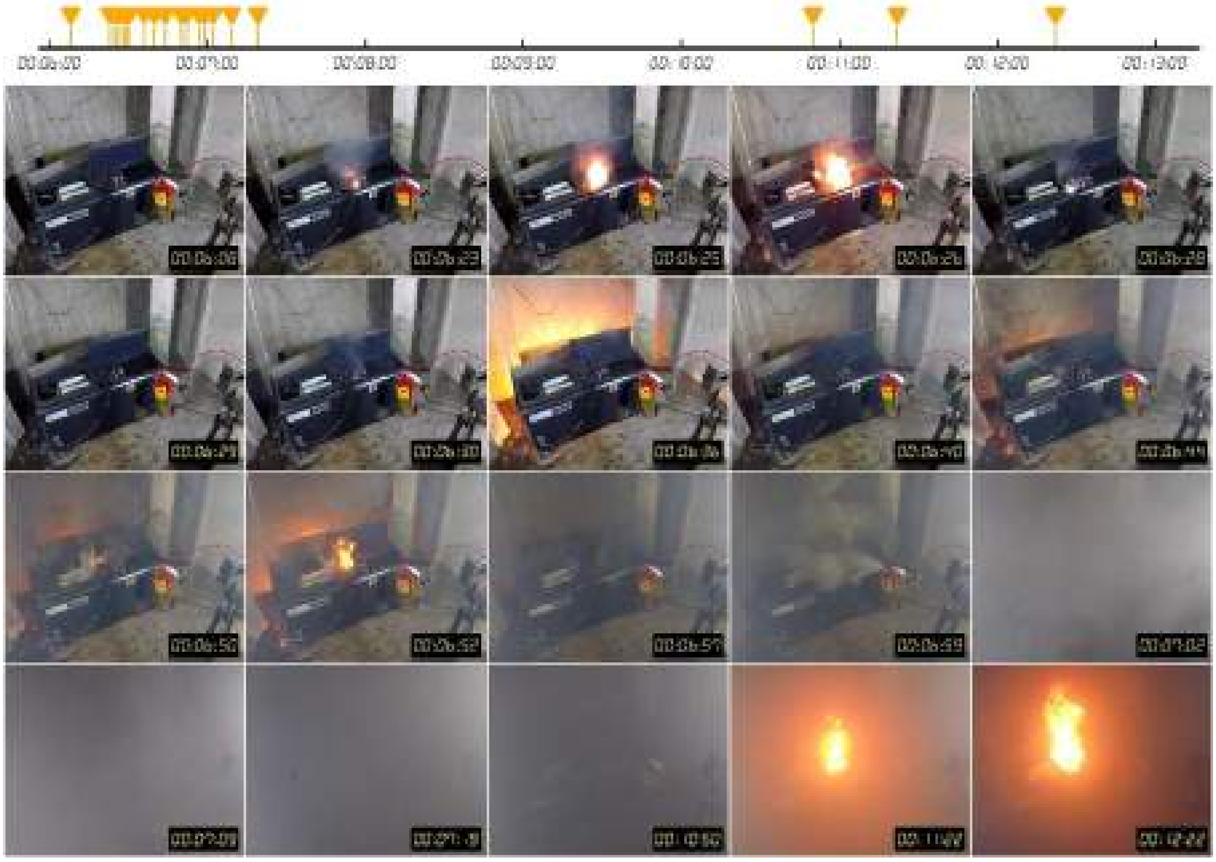


Figure 56: Propagation 03 test - video sequence (source: BEA)

During the test, the fire was concealed in the lateral compartment. The technique of fighting the fire with a halon fire extinguisher could not be applied. It is recommended to aim at the base of the flames, and if necessary, when the flames are inaccessible, to perforate the vertical wall of the compartment and slide the nozzle of the extinguisher into it before activating it. As the extinguisher was activated from the outside, it was not possible to accurately direct the extinguishing jet onto the flames, which may explain why the fire started up again after several minutes.

5.5 Summary of fire propagation with the addition of oxygen

The addition of oxygen to a flame (whatever its origin) makes the latter physically change. Introducing a lit cigarette into an oxygen-rich environment instantly ignites the glowing part and the cigarette burns completely in a few seconds.

The flow of oxygen-enriched gas directs the flame in the same way as a torch flame. In tests using a fire box, the flames were contained within the box and did not appear to emerge (the oxygen supply pipe sent a horizontal jet parallel to the bottom of the box). During large-scale tests carried out in mask storage boxes placed inside or outside lateral storage compartments, the flames were visible and emerged from the mask storage box in which the leak had been created.

In a fire fuelled by an oxygen leak, the colour of the flames is whiter because the combustion is richer in oxygen. This colouration reflects the high temperature of the fire. This characteristic variation in flame colour was observed in all the tests carried out as soon as an oxygen leak - controlled or uncontrolled - occurred. The flames were more intense and larger as soon as oxygen was added.

From a sound point of view, the oxygen leak was audible and the noise masked any other crackling noises heard when the fire was not supplied with oxygen. These crackling noises reappeared as soon as the oxygen leak was cut off.

The materials used in the cockpit comply with requirement CS25.853, which specifies that these materials must be self-extinguishing. However, in the case of an oxygen-fed fire, these materials are subjected to more demanding conditions than those of the certification tests.

In the tests, in the case of a "classic" fire, before the presence of an oxygen leak, the fire remained confined to the mask storage box where it started. It did not spread to the rest of the lateral compartment.

However, as soon as there was an oxygen leak, the fire spread rapidly:

- inside the lateral compartment, causing a concealed fire, which, with time, could emerge to spread to the rest of the lateral compartment;
- outside the lateral compartment, to the other oxygen mask storage box, to the document storage compartment that may contain flammable materials (documents etc.).

CONCLUSION

In the tests carried out in the presence of oxygen, fire spread rapidly from where it initially started, even to fire-resistant materials. Flames were whiter in colour, indicating a hotter fire. Thick black smoke was emitted from the fire. The sound of leaking oxygen was audible until the oxygen supply was cut off, and masked crackling noises. The sound of a fire fuelled by leaking oxygen was characteristic, comparable to that of a blowtorch.

5.6 Results of Oxygen fire study in connection with accident to the A320 registered SU-GCC

The audio analysis of the tests carried out as part of the Oxygen fire study gave the following results:

- the introduction of an external, glowing or ignited object into an oxygen mask storage box enriched with oxygen can cause slow combustion of the protective elements of the oxygen distribution hoses; the hose can be pierced between 13 and 28 s after the introduction of the exogenous element. The slow combustion prior to piercing is accompanied by characteristic crackling noises;

- when the entire mask caught fire, a sound runaway comparable to that produced by a blowtorch is present;
- a screeching noise may precede the loss of signal from the oxygen mask microphone;
- the degradation mechanism produced by the propagation of the fire to the storage box environment (lateral storage compartment) can show uncontrolled, random variations in terms of the level and timbre of the sound. During these tests, there was an interruption in the leaking noise for half a second followed by a detonation.

Comparison with the CVR recording of flight MS804 (see following figure):

- no crackling noise was present in the mask microphone recording;
- a sound runaway could be heard on the co-pilot mask microphone and CAM channels at 00:25:31 (EVT6);
- a screeching noise preceded the loss of the co-pilot mask microphone signal at 00:25:33 (EVT7);
- a momentary interruption (510 ms) in the oxygen leaking noise occurred at 00:25 :42 (EVT8).

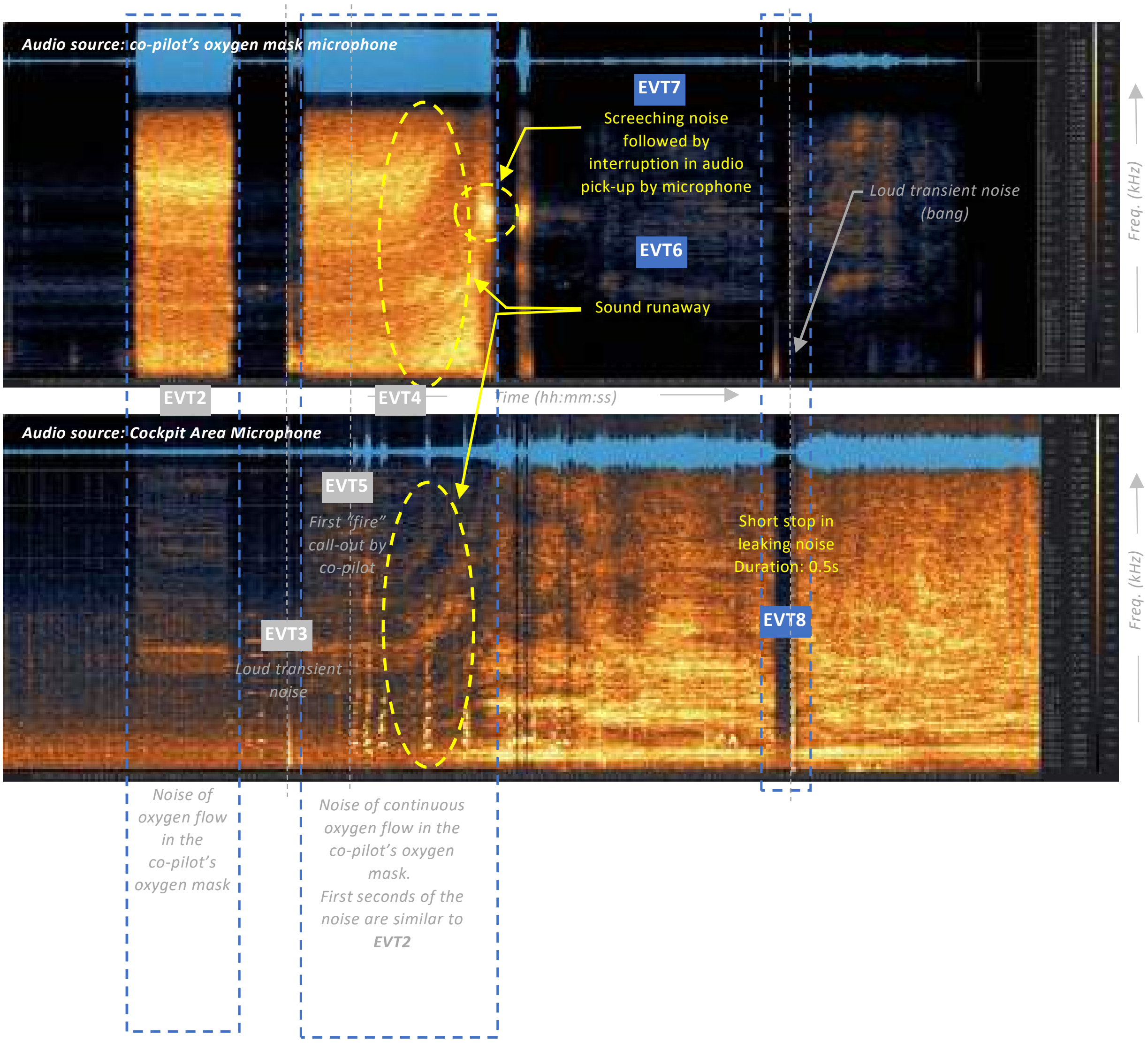


Figure 57: part of spectrum - waveform - flight MS804 (source: BEA)

5.6.1 EVT3: loud transient noise (t0 + 4.3 s)

None of the tests produced a sound similar to that corresponding to EVT3.

In the test conditions, the sound corresponding to the runaway of a lithium battery did not correspond to event 3; moreover, the dynamics of the event (presence of fire in the mask storage box immediately after the transient noise) does not support this hypothesis.

In the hypothesis of a “particle impact ignition” linked to the acceleration of a particle under the first flow of oxygen, there would be an interval of five seconds between the acceleration of the particle and the loud transient noise. The transient noise would not directly be the noise corresponding to the impact of the particle, but to a subsequent detonation or damage. The "particle impact ignition" and therefore its consequences were not reproduced.

A spark was used to create a controlled ignition in the device; this did not generate a detonating effect and the rupture of the hose that followed a few seconds later did not produce a loud transient noise.

In none of the next three candidate events was it possible to measure a noise with the same acoustic properties as the transient noise corresponding to EVT3:

- lithium battery runaway;
- rupture of an oxygen hose of the storage box and oxygen mask assembly;
- damage following particle impact.

Findings-Intermediate conclusion
The loud transient noise picked up by the oxygen mask microphone (at t0 + 4.3 s) probably does not correspond to the sound of a lithium battery runaway, nor to that of the rupture of a hose carrying oxygen pressurised to 5 bars.

5.6.2 EVT5: The co-pilot indicated the presence of a fire (t0 + 6.1 s)

The introduction of an external, glowing or ignited object into an oxygen mask storage box enriched with oxygen caused slow combustion of the protective elements of the oxygen distribution hoses of the assembly. The slow combustion was accompanied by characteristic crackling sounds that can only be perceived on the oxygen mask microphone signal. The hose was pierced between 13 and 28 s after introducing the external element (flame or cigarette).

No crackling noise was present in the co-pilot’s oxygen mask microphone recording.

Findings-Intermediate conclusion
The absence of crackling prior to the ignition does not support the hypothesis that a burning element was introduced into the oxygen box, i.e. an element outside the oxygen hose such as a glowing cigarette.

The various tests carried out to damage the oxygen assembly (either by dropping a cigarette or by placing a flame in direct contact with the elements contained in the mask storage box) showed that the hoses that carry the oxygen in the box had to be exposed for between 15 s to more than 50 s before there was irreversible damage and the flexible hose was pierced.

The suddenness of the phenomenon (EVT3__see paragraph 3.7.2) which preceded the start of the continuous leak (EVT4 and EVT9) and the rapidity of the sequence (sound events versus crew call-outs) seem to favour the hypothesis of the occurrence of internal damage to one or more of the components carrying the oxygen in the box (box, hoses, mask regulator, etc.) or to one or more of the sub-assemblies that make them up (connectors, filters, elbows, etc.).

Findings-Intermediate conclusion

The rapidity of the sequence (6 s between the first sound of the oxygen flow and the first fire call-out by the crew) supports the scenario of internal damage to the co-pilot's oxygen system, in which the appearance of an oxygen leak and the start of a fire fuelled by this leak would be almost simultaneous.

5.6.3 EVT6 and EVT7: modification of the continuous leaking noise: sound runaway and loss of signal from the co-pilot's oxygen mask microphone (t0 + 7.6 s and t0 + 9.6 s)

The sound runaway was reproduced during cigarette tests and fire propagation tests in the lateral storage compartment. During the cigarette tests, the use of a mask storage box with a glass panel made it possible to identify that the sound runaway corresponded to the ignition of the contents of the storage box (mask and hoses).

The screeching noise prior to the loss of the signal from the mask microphone was reproduced during a cigarette test.

Findings-Intermediate conclusion

The contents of the storage box for the co-pilot's oxygen mask caught fire at 00:25:31 i.e. att0 + 7.6 s (causing a sound runaway).
The microphone on the co-pilot's oxygen mask was destroyed by the flames at 00:25:33 i.e. at t0 + 9.6 s.

5.6.4 EVT8: interruption in oxygen leaking noise (t0 + 17.9 s)

The fire tests in the lateral storage compartments showed that the degradation mechanism produced by the propagation of the fire to the environment of the mask storage box presented significant and uncontrolled variations in terms of the differences in the audio phenomena picked up with random variations in the level and timbre of the sound. During these tests, an unexplained interruption in the leaking noise followed by a detonation was reproduced.

Findings-Intermediate conclusion

The momentary interruption in the leaking noise may be linked to damage to the oxygen assembly located in or under the lateral storage compartment.

5.6.5 EXT EVT: activation of a fire extinguisher

The noise generated by the activation of a fire extinguisher (see appendix, Air Formation) was recorded and compared with the audio recording of the CVR of flight MS804. This comparison did not make it possible to isolate a noise lasting 12 to 17 s characteristic of the use of a fire extinguisher.

Findings-Intermediate conclusion

There is no audio evidence to confirm or not that a fire extinguisher was used in the cockpit.

6. CONCLUSIONS CONCERNING ACCIDENT TO AIRBUS A320, REGISTERED SU-GCC, OPERATED BY EGYPTAIR ON 19 MAY 2016

6.1 Findings

Only the facts relating to the oxygen leak and fire in the cockpit are set out below.

The co-pilot's oxygen mask microphone was active during the last 30 min of the CVR recording, and most likely from the start of the CVR recording.

The co-pilot's boom mike could not be used to transmit radio communications for the last thirty minutes, and most probably for the last two hours. The co-pilot, as PF on the flight, did not need to use his boom mike before reaching FL100 and used his hand-held microphone when needed during the cruise. Therefore, the co-pilot had no opportunity to detect that his boom mike was inoperative. This explains why the activation of the mask's microphone might not have been detected.

For the duration of the CVR recording, the co-pilot's oxygen mask microphone picked up low transient noises of elements being moved close to the document storage compartment. This pick-up could be heard on the co-pilot's loudspeaker (depending on the volume selected).

No evidence from the cockpit voice recordings confirms or refutes the hypothesis that people were smoking in the cockpit.

There was no mention of any intention or action on the part of either of the pilots to use the personal oxygen equipment.

The co-pilot's oxygen mask was not in the permanent *EMERGENCY* position before t0, start of the oxygen flow sound.
The dilution control on the co-pilot's oxygen mask was in the 100% position.
The storage box for the co-pilot's oxygen mask was not in the reset position.
A flow of oxygen via the co-pilot's mask lasting 2.6 s began at 00:25:30 (t0).
The flow is equivalent to that caused by pressing the *EMERGENCY* knob on the mask.

An event leading to a loud transient noise of unknown source occurred in the co-pilot's mask storage box 4.3 s after the start of the first flow of oxygen in the mask (t0 + 4.3 s).

The loud transient noise picked up by the oxygen mask microphone (at t0 + 4.3 s) probably does not correspond to the sound of a lithium battery runaway, nor to that of the rupture of a hose carrying oxygen pressurised to 5 bars.

There was a continuous uncontrolled leak lasting 3 min 23 s in the co-pilot's mask storage box corresponding to the complete emptying of the oxygen cylinder (start: t0 + 4.7s).

A fire was present in the cockpit at t0 + 6 s.

The contents of the storage box for the co-pilot's oxygen mask caught fire at 00:25:31 i.e. t0 + 7.6 s (causing a sound runaway)

The microphone on the co-pilot's oxygen mask was destroyed by the flames at 00:25:33 t0 + 9.6 s

The absence of a crackling sound prior to the ignition does not support the hypothesis that a burning element was introduced into the oxygen box (i.e. an element outside the oxygen hose).

The rapidity of the sequence (6 s between the first sound of the oxygen flow and the first fire call-out by the crew) supports the scenario of internal damage to the co-pilot's oxygen system, in which the appearance of an oxygen leak and the start of a fire fuelled by this leak would be almost simultaneous.

The interruption in the oxygen leaking noise (at t0 + 17.9 s) lasting 0.6 s was not linked to a crew action.

The momentary interruption in the leaking noise may be linked to damage to the oxygen assembly, located in or under the lateral storage compartment.

There is no audio evidence to confirm or not that a fire extinguisher was used in the cockpit.

When the "Lavatory Smoke" warning first sounded, i.e. 47 s after the start of the event at 00:26:17, the cockpit door was closed. It was then in the open position (at 00:26:48 and 00:27:18, potentially continuously over this period) before being closed again.

The cockpit door was likely closed when the autopilot was disengaged and the CVR stopped operating at 00:29:54, i.e. t0 + 4 min 24 s.

The data recorder did not record any change in parameters that could result from an action by the crew after the autopilot was disconnected.

6.2 Scenario

Context of flight

The Airbus A320 registered SU-GCC, took off from Paris-Charles de Gaulle bound for Cairo at 21:21. The event occurred when the aeroplane was cruising at FL370 with the autopilot engaged, after three flight hours. The co-pilot was the Pilot Flying (PF) and the captain, the Pilot Monitoring (PM).

Previously, there had been a lot of back and forth activity in the cockpit to deal with a sick passenger. After a moment's discussion between crew members, the captain had just announced that he wanted to rest and had asked for a blanket and pillow. Initially PM, he had probably passed communications to the co-pilot. Before that, the co-pilot had already made some communications with his hand mike. As usual above FL 100, neither of the pilots were wearing their headsets.

At this point, the two flight crew members and a cabin crew member were present in the cockpit. Music could be heard in the cockpit (the music was present throughout the recording by the cockpit area microphone).

Storage box for co-pilot’s mask not reset and mask microphone active

Noises of elements being moved close to the co-pilot's document storage compartment were also recorded on the CVR. They might have been heard on the co-pilot’s loudspeaker, as the co-pilot’s oxygen mask microphone was active.

The fact that the co-pilot’s oxygen mask microphone was active might have been due to:

- the storage box being in the non-reset position;
- a faulty component in the storage box.

First oxygen flow

The first event of the accident sequence that could be identified was a flow of oxygen for 2.6 s via the co-pilot’s mask regulator. This flow had the same characteristics as when the *EMERGENCY* knob of the mask is pressed when the box is not reset. The investigation was not able to determine if this flow was linked to a human action.

The noise of this oxygen flow could be heard in the cockpit. At this moment, the captain, possibly on hearing this noise, questioned the co-pilot.

The storage box of the co-pilot’s mask was thus highly enriched in oxygen as a result of this flow.

Start of leak

An event leading to a loud transient noise of unknown source occurred at this point in the mask storage box. It has not been possible to determine what generated this loud noise.

Less than half a second later, the noise of an oxygen flow, as when the *EMERGENCY* knob is pressed, appeared again. The noise evolved into a continuous leaking noise in the co-pilot's mask storage box.

Fire break-out and spread of fire

The co-pilot's call-outs indicated that a fire was present less than two seconds after the start of the continuous leak. The sound runaway indicates that the fire was present in the co-pilot's mask storage box. The fire spread to the exterior of the mask storage box.

The captain asked for a fire extinguisher to be brought to him. It has not been possible to determine whether the extinguisher was used. None of the pilots were wearing masks. As one of the two hoods and the halon fire extinguisher were on the co-pilot's side in the immediate vicinity of the fire, it is likely that these two items of equipment quickly became inaccessible to the crew.

Coughing sounds were heard. It was not possible to determine the level of breathability of the air or the level of visibility in the cockpit at the time. It is possible that the smoke made the air difficult to breathe and reduced visibility from that point onwards.

Smoke spread into the toilets and the avionics bay.

The cockpit door was opened and closed several times.

The leaking noise stopped for 0.5 s. This interruption was not due to any deliberate action to cut off the oxygen, but probably to the fire having damaged various components. The leak stopped after 3 min 23 s.

The fire continued to spread, shown by the crackling sounds on the audio recordings.

The cables powering several computers were damaged and several redundancies were lost. The on-board systems disconnected the autopilot.

No crew actions were recorded in the cockpit. It has not been possible to determine whether the crew remained in the cockpit, whether they were unconscious or whether they fled the fire and then returned or remained outside the cockpit.

The recorders stopped operating when the aeroplane was in cruise at FL370. The aircraft turned successively to the left and right in a descending turn and then collided with the sea.

6.3 Scenario based on presence of explosives

In December 2016, the EAAID announced the discovery of traces of explosives on human remains. This lead the BEA to study this hypothetical scenario.

The mapping of the accident site on the sea bottom found that all the extremities of the aeroplane were within the identified rectangle: the cockpit, the wings and the tail. These observations, together with the small size of the debris, lead to the conclusion that the aeroplane had collided with the surface of the water under high energy, and ruled out the scenario of the aeroplane having broken up in flight.

The BEA audio database contains some audio samples from on-ground and in-flight explosions produced by explosive material or missile strikes. The sound produced by the explosion picked up by the cockpit microphones was very different to the sounds recorded on the CVR of the event.

The BEA audio database contains audio samples from in-flight accidental depressurizations. These include loss of windshield in the cockpit, activation of explosive charge on a passenger, loss of cargo door and activation of an explosive in the cargo hold. The associated noises are different: total saturation of all the microphones for a long time or explosion followed by a blast or loud noise with a release noise or loud noise and the CVR stopping. All these sounds are very different to those on the CVR of the MS804. Sudden aircraft depressurization produces a very different sound to the one recorded on the CVR of the event where there was a long audio phenomenon (3 min) associated with a decrease in its level and timbre. Furthermore there was no depressurization warning.

No explanation related to the presence of an explosive could explain the first event of the accident sequence that could be identified, i.e. a flow of oxygen for 2.6 s via the co-pilot's mask regulator.

Regarding the event leading to a loud transient noise that occurred later, the comparison of the transient noise level on the four audio sources recorded by the CVR showed that the sound was louder (and longer) on the co-pilot CVR channel compared to the 3rd Crew and CAM channels. This leads to the conclusion that the transient noise originated inside the co-pilot's oxygen mask box or in the near vicinity of it and that this noise was not loud enough to be attributed to explosives.

In conclusion,

The possible discovery of traces of explosives on the aeroplane's occupants, even in several places, does not in itself make it possible to conclude that there was an explosion on board, when all the other physical evidence is incompatible with the scenario of an explosion that damaged the plane's structure or systems to the point of rendering it uncontrollable.

6.4 Safety issues

The certification requirements stipulate that the oxygen system shall be free from hazards in itself, in its method of operation, and in its effect upon other components. It is also stipulated that the impacts of an external source of ignition shall be minimised and that the immediate environment shall be preserved, i.e. an oxygen leak cannot cause the ignition of substances close by.

During flight MS804, the presence of emergency oxygen in the cockpit clearly contributed, if not to the outbreak, at least to the speed and the extent to which the fire spread in the cockpit.

This was also the case for several events on the ground. In all these events, which could be described as precursors, a fire fuelled by an oxygen leak occurred on the ground, the aeroplane was evacuated and only the fire-fighting services were able to bring the fire under control.

Based on the data available for the analysis of the accident to flight MS804 and the tests carried out as part of the Oxygen fire study, the following safety issues need to be considered:

- external heat sources in the vicinity of the oxygen which might have been the cause of the outbreak of a fire affecting the oxygen system components;
- the impact of contamination and internal ignition processes. The replacement of the storage box of the co-pilot's mask a few flights before flight MS804 led to the examination of the hypothesis of contamination of the mask supply hose during the maintenance operation;
- the failure of one of the system's components that might have caused a leak;
- the spread of a fire fed by an oxygen leak;
- the protection means available to the crew;
- the means to put out a fire fed by an oxygen leak.

6.4.1 External ignition sources to oxygen system

The data available for flight MS804 did not make it possible to determine the source of ignition of the fire in the co-pilot's mask storage box.

During the investigation, two potential ignition sources external to the oxygen system were mentioned: thermal runaway of a lithium battery and a lit cigarette.

6.4.1.1 Thermal runaway

As detailed in paragraph 5.2.1.1 Lithium battery tests, the document storage compartments located on the sides of the cockpit, near the oxygen masks, can be used to store electronic devices containing lithium batteries (smartphones, tablets or electronic cigarettes). There are specific procedures for fires involving the thermal runaway of lithium batteries. In the case of flight MS804, these detailed, in particular, the role of the PF and the PM, the use of protective equipment (mask and hood) and the fire extinguishing equipment (halon fire extinguisher if there are flames).

Following the event, a study carried out at Airbus revealed a potential fragility in the heat resistance of the glue used to assemble the panels of certain document storage compartments, raising concerns with respect to a fire propagation scenario initiated by the runaway of a lithium battery, followed by the collapse of the document storage compartments and the ignition of the oxygen distribution system. Following the identification of this risk, Airbus created a modification which consists in changing the material of the lateral stowage boxes from honeycomb to aluminium. This modification was subject to a monitored retrofit campaign.

In the scope of the Oxygen fire study, the BEA tested a number of electronic devices: the thermal runaway of their lithium battery(ies) was induced by the addition of heat; the sound and thermal effects were analysed.

The tests produced the following results. Firstly, the acoustic signature of the lithium battery runaways did not match the noise recorded on the CVR of flight MS804. Secondly, in the test conditions used in the study, the rise in temperature of the lithium batteries used in electronic tablets, electronic cigarettes and smartphones was not transferred to the surrounding environment and the incandescent particles did not ignite the materials. There was one outbreak of fire, linked to the presence of highly flammable material (adhesive tape) in the immediate vicinity of the battery.

In recent decades, lithium battery runaway has become a new risk to be taken into account, particularly in the cockpit, due to the use of electronic tablets.
The tests carried out did not reveal any particular fragility likely to correspond to an accident scenario for flight MS804 (based on the available data).
In other words, it is highly unlikely that a lithium battery runaway constitutes an element in the accident scenario for flight MS804.

6.4.1.2 Glowing cigarette

International regulations are not explicit about banning smoking in the cockpit of commercial air transport aeroplanes. While there are warnings about smoking near oxygen in the passenger compartments, there are no similar warnings with respect to the cockpit. The decision seems to rest with the captain.

In the case of flight MS804, the press reported information said to be taken from the judicial investigation suggesting that a member of the crew might have been smoking in the cockpit. No evidence from the cockpit voice recordings confirms or refutes the hypothesis that people were smoking in the cockpit.

With regard to the Boeing 737 accident that occurred on the ground before the accident to SU-GCC, the investigation showed that the captain had lit a cigarette two minutes before the fire broke out and the oxygen leak. The findings of the investigation highlighted a possible fragility created by smoking near a mask left in the *EMERGENCY* position.

During the tests carried out, handling a cigarette in the immediate vicinity of an oxygen-enriched mask storage box did not cause a fire to start. The same was true when hot ashes were introduced into the box. On the other hand, the introduction of a cigarette into an oxygen-enriched box accelerated its combustion, and if the cigarette was in contact with an oxygen supply hose, the fire could perforate the hose, causing pressurised oxygen to leak and create an oxygen-enriched fire that could rapidly spread.

No immediate, systematic and obvious danger has been established from smoking near an oxygen mask storage box, even with a mask in the EMERGENCY position or when the box has not been reset.

However, if a cigarette is introduced into the storage box – unlikely but possible - a fire may start, accompanied by an oxygen leak. In this case, the flames would be large and the fire would spread rapidly to the surroundings of the storage box.

6.4.2 Internal ignition sources

During flight MS804, the contents of the co-pilot's oxygen mask storage box caught fire. The absence of any prior crackling sound makes it unlikely that a burning object was introduced into the box. The rapidity of the sequence favours the scenario of internal damage to the co-pilot's oxygen system.

Tests have shown that in the event of an ignition inside the system, after an interval of a few seconds, the hose is ruptured, potentially resulting in a fire fuelled by the oxygen leak created by this same rupture.

The replacement of the storage box of the co-pilot's mask a few flights beforehand led to the examination of the hypothesis of contamination of the mask supply hose during the maintenance operation, which could have played a role in an internal ignition mechanism.

The particle impact ignition phenomenon described in literature i.e. the release of heat linked to the collision of a particle on a metal element, was not reproduced on the test bench used. However, given the limitations of the test conditions, this hypothesis cannot be ruled out.

The results of the electrostatic measurements carried out on the system make it highly unlikely that the ignition of system components or organic or synthetic debris in the storage box could be linked to electrostatic charges.

Moreover, the simple introduction of grease is not synonymous with an outbreak of fire. In other words, a fire will not systematically break out when grease and oxygen are brought together. However, this does not rule out the hypothesis.

In conclusion, although the hypothesis of internal damage to the system is favoured, the available data and the tests carried out have not made it possible to determine which internal ignition mechanism is likely to have occurred during flight MS804.

The tests carried out by the BEA were based on the assumption that the pressure in the system was 5 bar. Internal ignition mechanisms such as particle impact, grease oxidation or ignition by electrostatic discharge may depend on the oxygen pressure.

Additional tests could make it possible to:
- determine the conditions for spontaneous combustion of grease;
- determine the conditions for producing particle impact ignition and the resulting effects.

6.4.3 Propagation of oxygen-fed fire

The analysis of oxygen system hazards must look into the ability of a fire to propagate and burn through a component.

In the case of the fire on flight MS804, the analysis of the audio recording and those made during the tests showed the speed of the leak, along with the size of the fire and the speed at which it spread. The fact that no action by the crew was recorded subsequently also seems to testify to the extent and to the speed of the phenomenon.

This was also the case for events that occurred on the ground. In three of the events studied (see paragraph 3), the rupture of a hose under the action of the fire created an oxygen leak which fed the fire. These three events led to the evacuation of the cockpit.

In the presence of oxygen, the whiter flames are the sign of a hotter fire, and the materials are more inflammable. In an oxygen-enriched environment, a fire will spread rapidly despite the fire resistance of the materials in the immediate environment where it started.

6.4.4 Protective breathing equipment

When smoke or fire breaks out in the cockpit, one of the immediate actions is to protect the crew.

In the four accidents reviewed in this study, as the fire occurred on the ground, the crew members were able to evacuate the cockpit and the aeroplane.

In the case of the fire on flight MS804, the co-pilot could not use his oxygen mask and most likely could not remain in his seat. It is possible that the intensity and speed of the fire also made it impossible to use the hood (PBE) located on the right side of the cockpit.

In the case of SU-GCC, a second hood was available on the captain's side. However, this configuration is not systematic, and the possibility of a fire spreading in the environment of an oxygen mask on the same side as the hood seems not to have been considered when defining the fire procedures and determining the crew's means of protection.

6.4.5 Fire extinguishing equipment

At least one fire extinguisher must be present in the cockpit, and it must be suitable for fighting liquid fires and electrical equipment fires. Halon 1211 is one of the most frequently used agents. SU-CGC was equipped with halon fire extinguishers in the passenger cabin and cockpit.

During flight MS804, when the fire broke out, the captain asked for a fire extinguisher to be brought to him. As the cockpit fire extinguisher was in the immediate vicinity of where the fire broke out, it is not possible to know whether the captain was referring to this extinguisher or to an extinguisher in the cabin. From an acoustic point of view, it was not possible to isolate a sequence corresponding to the activation of a fire extinguisher.

In the four events that occurred on the ground, the fire required the intervention of the firefighting services. In two of the events, the crew members tried to extinguish the fire with the means at their disposal, but found that it was difficult to gain access to the cockpit (black smoke) and that the halon was ineffective.

During the tests carried out by the BEA (see paragraph 5.3 Extinguishing a fire in the presence of an oxygen leak: use of halon extinguishers), halon fire extinguishers were not effective in putting out a fire fuelled by a continuous oxygen leak. In order to stop the fire, halon combines with oxygen to reduce the latter's amplifying effect on the fire; however, a leak will constantly supply the fire with oxygen. In the test conditions, opaque smoke rapidly invaded the environment as soon as the fire extinguisher was used on an oxygen-enriched fire, considerably impairing visibility. In addition, the halon pyrolysis creates acid gases (HF, HCl, HBr) in harmful quantities for people nearby.

Halon fire extinguishers are therefore not suitable for treating fires fuelled by oxygen leaks. In many cockpits, however, these types of extinguishers are the only ones available.

In one of the tests carried out, the oxygen supply was deliberately cut off before the fire extinguisher was used. The idea was to act on the oxygen leak and therefore on the source of the fire's enrichment before attempting to extinguish it with a halon fire extinguisher. The sound of the leak disappeared instantly, the flames diminished and the spread of the fire slowed down.

6.5 Conclusion

The accident sequence began while the aeroplane was cruising at FL370, with a cabin crew member present in the cockpit, the captain resting in his seat and the co-pilot flying.

It has not been possible to precisely explain the start of the accident sequence. It is likely to have been an oxygen flow resulting either from pressing the *EMERGENCY* knob on the co-pilot's oxygen mask or from a component failure. A fire then started in the mask storage box, and was fuelled by a leak of pressurised oxygen. It has not been possible to determine which came first: the fire or the oxygen leak.

Whichever the case, the oxygen-fed fire spread to the outside of the storage box. This type of fire is rapid, large-scale and difficult to control. It produces a characteristic noise comparable to that of a blowtorch. The protective and extinguishing equipment items in the cockpit were not sufficient to bring the fire under control.

The fire damaged the computer power supply systems, which led to the disconnection of the autopilot in particular.

No crew actions were recorded in the cockpit. It has not been possible to determine whether the crew remained in the cockpit, whether they were unconscious or whether they fled the fire and then returned or remained outside the cockpit.

The aeroplane’s flight path was uncontrolled and the aircraft collided with the sea.

7. SAFETY RECOMMENDATIONS

Note: in accordance with the provisions of Article 17.3 of Regulation No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation in no case creates a presumption of fault or liability in an accident, serious incident or incident. The recipients of safety recommendations shall report to the safety investigation authority which issued them, on the measures taken or being studied for their implementation, as provided for in Article 18 of the aforementioned regulation.

7.1 Further work taking into consideration the effects of overpressure in the oxygen system

The manufacturer of the oxygen equipment informed the BEA that there had been three recent occurrences of in-flight oxygen leaks. The tests as part of this Oxygen fire study had been completed when the BEA became aware of this.

These occurrences were classified as incidents and did not give rise to the opening of an investigation. The main elements of the three occurrences are as follows:

- Occurrence 1 In cruise at FL380 on an A321 on 29 March 2022

ECAM advice - crew oxygen 500 psi and dropping
The crew were alerted by the ECAM of a drop in oxygen pressure. The blinker on the captain's oxygen mask storage box indicated that there was an oxygen flow. The crew tried to reset the box. The oxygen flow suddenly increased and became noisy. The pilot took out the oxygen mask to try to solve the problem. A rapid and simultaneous flow occurred in all the other oxygen masks in the cockpit. The flow could not be stopped.

It seemed that at least one mask microphone was activated, but could not be reset. The crew's oxygen was switched off to stop the loud noise.

The rest of the flight was carried out at FL100, with two portable oxygen cylinders brought into the cockpit as a precaution.

A preliminary analysis indicated that an error in adjusting the oxygen bottle pressure regulator may have been the cause of the leak.

- Occurrence 2 In cruise on an A319 in January 2023

The crew noticed the sound of a leak and cut off the supply line. However, the leak continued until the cylinder was empty. After replacing the cylinder, the leak occurred again on the next flight.

- Occurrence 3 In descent from FL370 on an A319 on 28 May 2023

The captain's oxygen mask began to lose oxygen even though it had not been touched and was stowed in its box. The oxygen pressure in the cylinder dropped from 1300 psi to 150 psi in 5 s.

Following an initial analysis, it appears that a faulty installation or adjustment of the regulator installed on an oxygen cylinder supplying the cockpit could lead to overpressure in the entire system. In the event of overpressure (from 13 bar), the box status could change to “not reset”, the mask regulator could fail and a high-pressure leak could occur in one or all of the cockpit masks.

Further analysis is necessary to consider whether these events could lead to the examination of new hypotheses to try to explain the accident of flight MS804.

In particular,

An overpressure in the distribution systems is an additional hypothesis to consider in explaining why the mask microphone was active.

The first flow of oxygen present on the recording of flight MS804 is that of a flow via the mask regulator. An initial hypothesis was that the mask knob had been pressed, but overpressure in the system could be another explanation.

A few flights before the accident flight, the storage box of the co-pilot's oxygen mask had been replaced. A faulty regulator could be the common explanation for two unusual events: - the replacement of the storage box and the leak in the cockpit.

The overpressure is also a hypothesis to be considered to explain the short time in which the cylinder drained compared with the theoretical values.

The tests carried out by the BEA in the scope of this study were based on the assumption that the pressure in the system was 5 bar. Internal ignition mechanisms such as particle impact, grease oxidation or ignition by electrostatic discharge may depend on the oxygen pressure. Similarly, the fragility created by a nearby external source of ignition could be greater in the event of a high-pressure leak.

The general architecture of oxygen distribution systems - a high-pressure cylinder, a regulator, storage boxes, masks with regulators - can be found on most large commercial air transport aeroplanes.

Consequently, the BEA recommends that:

EASA, in collaboration with the manufacturers, carry out additional risk analyses to take into account the hypothesis of an overpressure in the distribution system and its consequences in terms of failure mechanisms. The results should be analyzed with regard to the potential factors explaining the scenario of flight MS804. These analyses may require additional testing as part of a research program.

[Recommendation FRAN 2023-024]

7.2 Propagation of a fire fed by an oxygen leak

The presence of the oxygen distribution system has a twofold impact: (1) The air may become enriched with oxygen in the vicinity of the supply system due to micro-leaks, mask tests or a rupture of a part in the oxygen supply system; the presence of oxygen makes the elements more inflammable and the start of a fire more likely. (2) A fire that damages the oxygen systems, if it causes a hose to rupture, becomes an oxygen-enriched fire that is difficult to control.

Certification requires that the occurrence of an uncontrolled oxygen fire is extremely unlikely. The accident to flight MS804 and previous similar events (on the ground) requires consideration to be given, not only to the means of preventing these fires, but to their propagation and the means of fighting them.

These events and the tests carried out have highlighted the size of the fire and the speed at which it spreads in the case of a fire fuelled by an oxygen leak. These fires produce a characteristic sound, comparable to that of a blowtorch, and significant heat (recognisable by the whiteness of the flame).

During flight MS804, when the fire broke out, the captain asked for a fire extinguisher to be brought to him. The aeroplane was equipped with a halon fire extinguisher in the cockpit. As this fire extinguisher was in the immediate vicinity of where the fire broke out, it is not possible to know whether the captain was referring to this extinguisher or to an extinguisher in the cabin. From an acoustic point of view, it was not possible to isolate with any certainty, a sequence corresponding to the activation of a fire extinguisher.

In the four events that occurred on the ground, the fire required the intervention of the firefighting services. In two of the events, the crew members tried to extinguish the fire with the means at their disposal, but found that it was difficult to gain access to the cockpit (black smoke) and that the halon was ineffective.

During the tests, halon fire extinguishers were not effective in putting out a fire fuelled by a continuous oxygen leak. In order to stop the fire, halon combines with oxygen to reduce the latter's amplifying effect on the fire; however, a leak will constantly supply the fire with oxygen. In the test conditions, opaque smoke rapidly invaded the environment as soon as the fire extinguisher was used on an oxygen-enriched fire, considerably impairing visibility. In addition, the halon pyrolysis created acid gases (HF, HCl, HBr) in harmful quantities.

Halon fire extinguishers are therefore not suitable for treating fires fuelled by oxygen leaks. In many cockpits, however, these types of extinguishers are the only ones available.

The existing fire-fighting procedures have not been designed to deal with the specific case of an oxygen fire. The tests carried out by the BEA show that these procedures are ineffective and even counter-productive in the case of an oxygen fire.

In events on the ground, the crews were unable to control the fires and evacuated the cockpit. In flight, fighting an oxygen-enriched fire requires the oxygen supply to be immediately cut off.

Consequently, the BEA recommends that:

- *whereas the occurrence of ground events and one in-flight event in which there was an uncontrolled oxygen fire;*
- *whereas a fire fuelled by an oxygen leak spreads rapidly and is large in size;*
- *whereas such a fire presents identifiable characteristics such as a noise comparable to that of a blowtorch and the colour of the flames;*
- *whereas fighting a fire of this type requires first and foremost the cutting off of the supply of oxygen;*
- *whereas the oxygen mask is one of the protective breathing devices;*

❍ ***EASA assess the appropriateness of cockpit fire/smoke procedures incorporating the recognition of an oxygen fire (identifiable by a characteristic noise comparable to that of a blowtorch) and the need for the immediate cutting off of the oxygen supply in this case, and if applicable, review the requirements for installing and carrying protective equipment independent of the oxygen distribution system.***
[Recommendation FRAN 2023-025]

7.3 Risks linked to the use of cigarettes in the cockpit

International regulations are not explicit about banning smoking in the cockpit of commercial air transport aeroplanes. While there are warnings about smoking near oxygen in the passenger compartment, there are no similar warnings with respect to the cockpit. The decision seems to rest with the captain.

In the case of flight MS804, the press reported information said to be taken from the French judicial investigation suggesting that a member of the crew might have been smoking in the cockpit. No evidence from the cockpit voice recordings confirms or refutes the hypothesis that people were smoking in the cockpit. The results of the tests carried out do not suggest that a lit cigarette contributed to the accident sequence.

With regard to the event that occurred on the ground four years previously on a Boeing 737, the investigation showed that the captain had lit a cigarette two minutes before the start of the fire and the oxygen leak. The investigation highlighted a possible fragility created by smoking near a mask left in the *EMERGENCY* position.

During the tests carried out in the scope of this study, it was found that handling a cigarette in the immediate vicinity of a mask storage box did not cause a fire to start even if this box was rich in oxygen. The same was true when hot ashes were introduced into the box. On the other hand, the introduction of a cigarette into an oxygen-enriched box accelerated its combustion, and if the cigarette was in contact with an oxygen supply hose, the fire could perforate the hose, causing pressurised oxygen to leak and create an oxygen-enriched fire that could rapidly spread.

No systematic and obvious danger has been established from smoking near an oxygen mask storage box, even with a mask in the EMERGENCY position or when the box has not been reset. However, if a cigarette is introduced into the storage box - unlikely but possible - a fire may start, accompanied by an oxygen leak. In this case, the flames would be large and the fire would spread rapidly to the surroundings of the storage box.

Consequently, the BEA recommends that:

- ***EASA ensure that:***
    - ***the danger represented by a glowing cigarette in the cockpit be taken into account and the associated risks assessed;***
    - ***certification and operational regulations be amended where applicable.***

[Recommendation FRAN 2023-026]

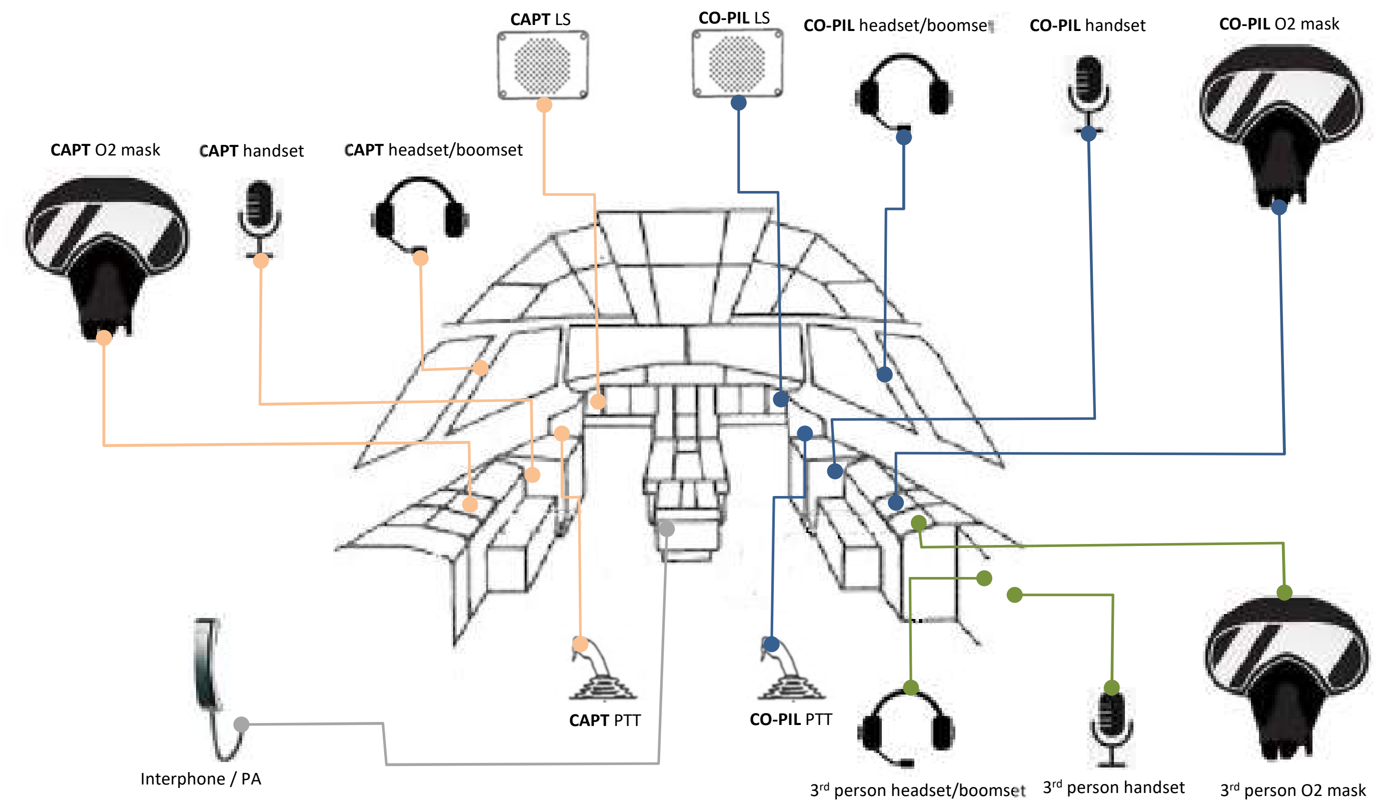
APPENDICES

Functional description of CVR audio system
Audio pick-up by oxygen mask microphone
Waveforms from CVR recording
EVT1
EVT2
EVT4 and 9
EVT8
Lavatory
Air Formation
Halon gas
Comparative audio analysis for EVTS 6 7 8
Grease and hydrocarbon ignition

Videos 1,2,3&4

Functional description of MS804 audio/CVR system

Various audio pick-up sources and their position in the cockpit:



Each pilot (captain, co-pilot) has:

- A headset fitted with a mouth microphone (BOOMSET)
- A hand-held microphone (HANDSET)
- An oxygen mask fitted with an internal microphone (O2 MASK)
- A microphone activation command (PTT (Push To Transmit))
- A LoudSpeaker (LS)

The third person position does not have a PTT or loudspeaker.

Audio Management Unit (AMU)

All these audio pick-up sources (microphones) and associated peripheral equipment (loudspeakers and PTT) are managed by the Audio Management Unit (AMU). This computer receives all the audio signals, amplifies and conditions (filters) them, and then sends them to the processing, broadcasting[1] and recording units (CVR).

The AMU has three distinct functions for managing the pick-up sources:

- Microphone signal used for radio transmission
- Microphone signal used for interphone exchanges (cockpit and/or cabin)
- Microphone signal sent to the various CVR input channels

Each pilot selects the transmission and reception sources from his Audio Control Panel (ACP).

[1] Cockpit interphone function, radio transceivers, link with cabin interphone, passenger announcements, etc.

1/ Radio transmission function

When a radio is active and selected for reception and/or transmission, there are three ways for each pilot to send a message:

- Either by using the boomset microphone after pressing and holding the PTT button on the side stick (or the RAD switch on the audio selection box).
- Or by using the hand-held microphone after pressing and holding the PTT built into this microphone.
- Or by using the oxygen mask microphone - when removed from the oxygen box and placed over the face - after pressing and holding the PTT on the side stick (or the RAD switch on the audio selection box).

In the unlikely event of all three microphones being used simultaneously, the hand-held microphone has priority over the other two for radio transmission.

2/ Interphone function

This function is activated when the pilots set the INT/RAD switch on their respective ACP to INT. The two pilots converse via the boomset microphone and the radio transmission is only activated on pressing the PTT on the side stick or temporarily switching the INT/RAD switch to RAD.

> Note: the wearing of a headset and the use of the boomset are recommended by operational procedures when the aircraft is climbing (or descending) up to (down from) FL100. On climbing through FL100, both pilots set their INT/RAD switch to the middle (neutral) position and remove their headsets; the latter are generally placed in their rest position, on a support on the side windshield post.
> In cruise flight, radio and interphone activities (exchanges with the cabin) are generally followed by the pilot monitoring by means of his loudspeaker; voice messages are generally transmitted using the hand-held microphone.

3/ Signal distribution to CVR function

As mentioned above, the AMU receives all the audio pick-ups from the sources used by the flight crew. For each cockpit position[2] - regardless of the selections made on their ACP[3] - it sums the signals received as follows:

- Continuous "hot mike" pick-up[4] from boomset microphone.
- Pick-up of the oxygen mask microphone when the mask is active (i.e. when the oxygen box has been opened and until it is reset).
- Pick-up of the hand-held microphone when the PTT button on the hand-held microphone is pressed.

The signal obtained is then mixed with what the pilot receives in his headset, ensuring relative proportionality between the sources[5]; it is then adapted (filtering, control of signal dynamics and impedance adaptation) for presentation at the CVR input.

> Note: It should be noted that on the Airbus *Single Aisle* family (A318 to A321), the various aural warnings generated by the flight system are not sent in the signal to the pilot's headset[6] and are de facto not mixed on the corresponding CVR channels.

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[2] Pilot, co-pilot, third person

[3] There are three ACPs, one for each cockpit position.

[4] This function is required by EASA and CAA regulations. It was optional under FAA regulations.

[5] Regulatory specifications require that the pilot's voice be given priority over reception sources, radio, interphone and warnings (when recorded on the CVR channel).

The summed signal produced for the third person is supplemented by the CVR data time-stamp signal (FSK[7]) and the "Passenger Address" (PA) reception signal.

Cockpit Voice Recorder system

It consists of the voice recorder (CVR), the cockpit area microphone (CAM) and a pre-amplification unit (CU (Control Unit)).

The CVR installed on MS804 had a recording capacity of two hours on average. It received the signal on four input channels as follows:

- Channel 1 input: captain's audio mix (microphones and reception equipment) delivered by the AMU
- Channel 2 input: co-pilot's audio mix (microphones and reception equipment) delivered by the AMU
- Channel 3 input: third persons audio mix (microphones, reception equipment, coded time and PA) delivered by the AMU
- Channel 4 input: CAM signal delivered by the CU).

The four input channels have different characteristics in terms of input dynamics and bandwidth. Channels 1 to 3, commonly referred to as "pilot channels", come from the AMU. They do not benefit from a global dynamic control, so audio signals can be presented in a state of saturation at the input of the CVR, which offers a lower permissible dynamic range on the "pilot channels" (0.5 Vrms) than on the channel dedicated to the signal coming from the CAM (2.5 Vrms). Channels 1 to 3 are dedicated to recording conversations (speech signal) and their bandwidth is limited to 150 Hz-3500 Hz.

Channel 4, on the other hand, which is assigned to the CAM signal, receives a signal that is pre-filtered and dynamically controlled by a compressor-limiter stage integrated into the CU; the function of this stage is to instantly crush any high-level signal received by the CAM microphone itself, and gradually restore the dynamic range once the loud sound event has disappeared. Channel 4 is dedicated to recording the background noise in the cockpit and has a slightly wider bandwidth, but remains limited to 150 Hz-6000 Hz.

The CVR recorder is located in the tail of the aircraft, in the non-pressurised area below the vertical fin.

The CAM is located at the bottom of the overhead panel, in the upper right-hand corner of the captain's windshield. As previously mentioned, its function is to pick up the background noise in the cockpit, voice exchanges between crew members when they are not wearing their headsets, and as far as possible conversations between the flight crew and third parties (cabin crew, ground crew, others, etc.) present in the cockpit.

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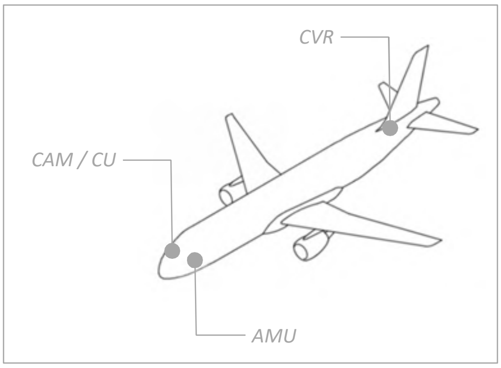
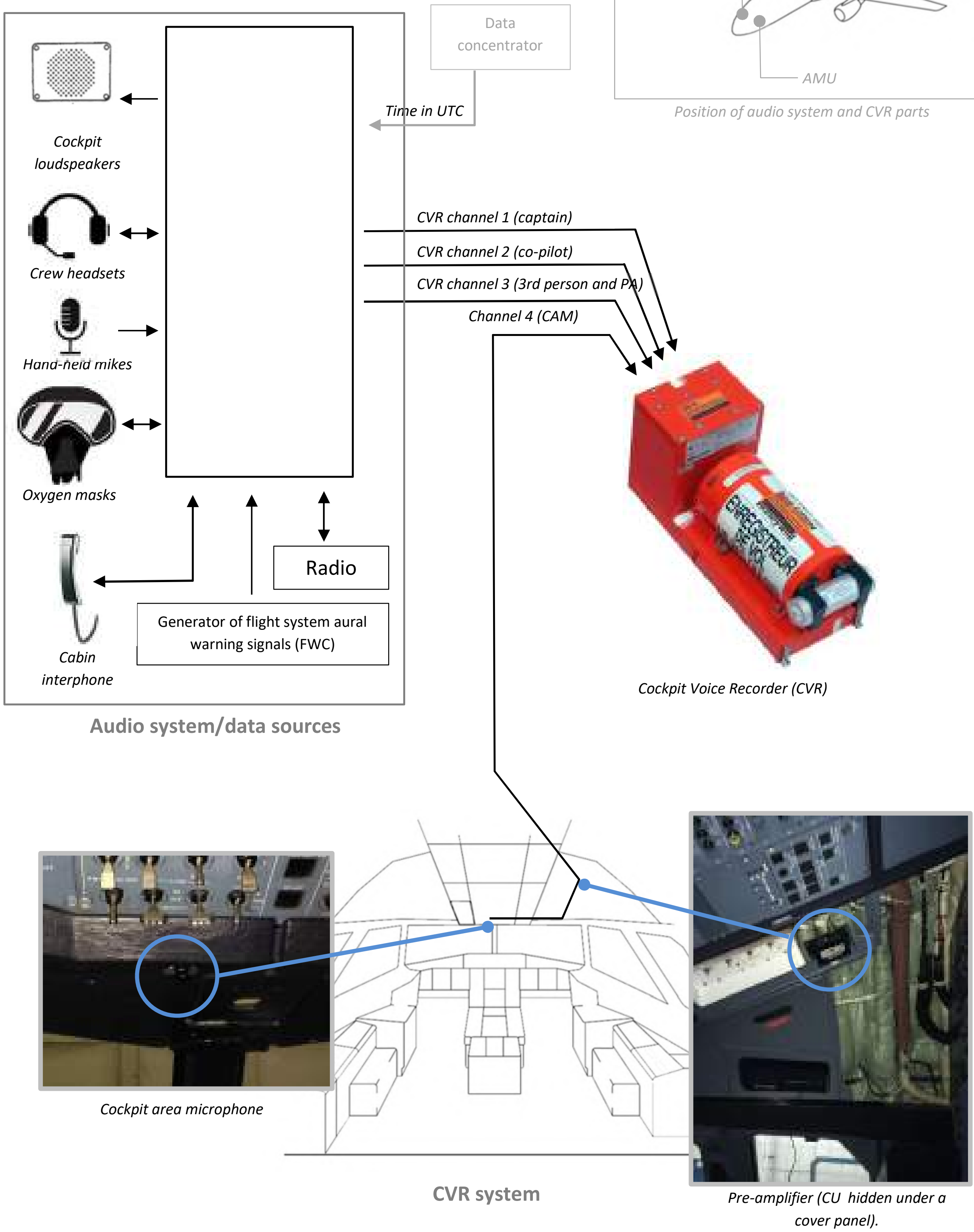
[6] They are sent directly to the loudspeakers of the two pilots (their sound level cannot be adjusted by the crew). However, they are more or less perceptible in the reception signal because they are picked up in the background noise by the boomset microphones.

[7] This is an audible "blip" emitted every four seconds. It contains a (32 bit) digital code which converts UTC time into analogue by means of Frequency-Shift Keying (FSK). This time reference is transmitted by the data concentrator (FDIU) to the two flight recorders (CVR and FDR).

Schematic description of CVR and its connections with the audio system



Position of audio system and CVR parts

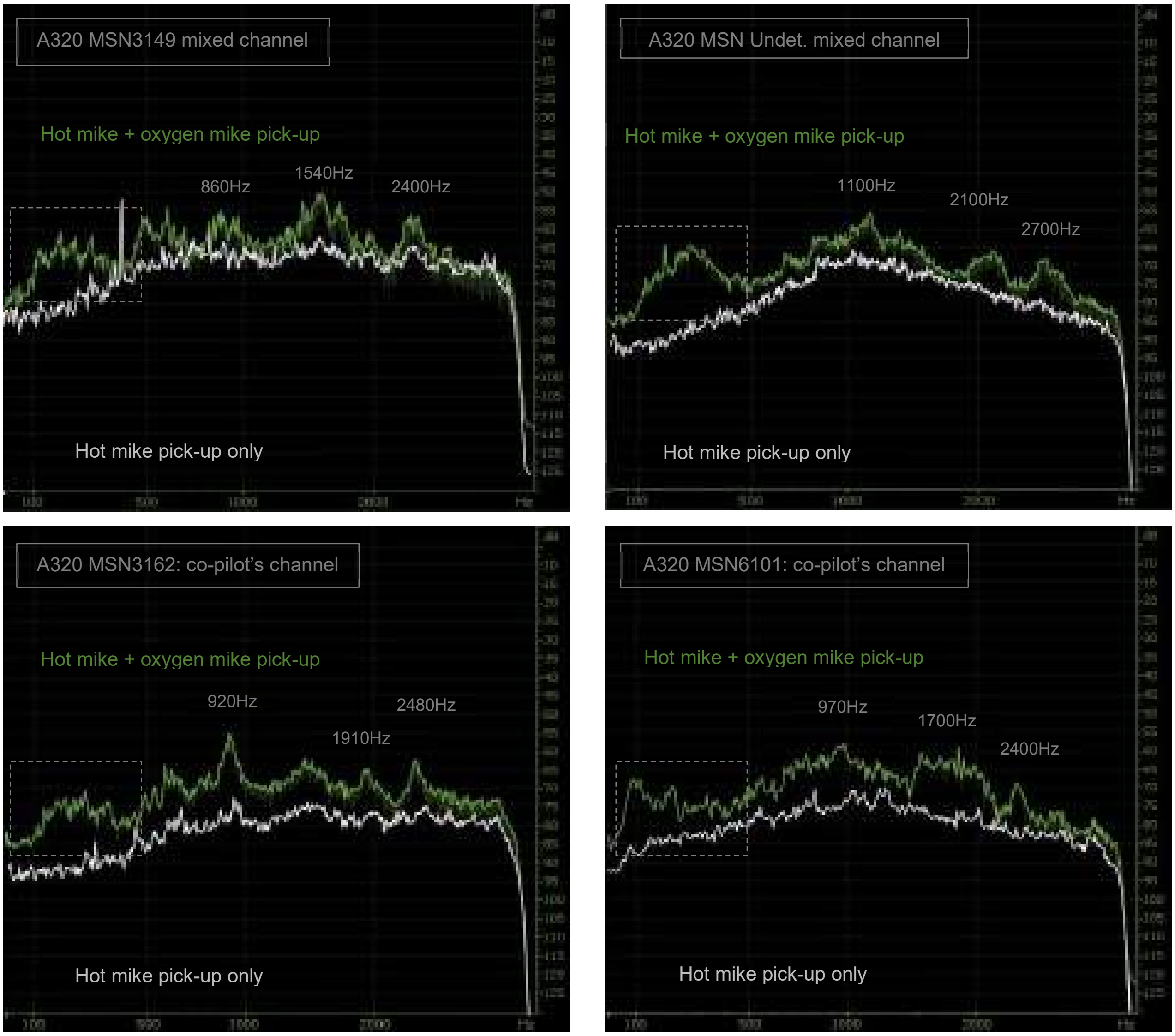


Audio pick-up by oxygen mask microphone

Listening to samples of audio recordings of oxygen mask activity on the A320 (and on other models, A330, A350, A380) makes it possible to describe, from a psychoacoustic point of view, the pick-up by the oxygen mask microphone as muffled and hollow.

The analysis of the frequency spectrum shows that the sound picked up by the oxygen mask microphone has the following acoustic signature on the A320:

- A LF energy bump from 100 to 500 Hz on average
- A pseudo sawtooth PSD spectrum
- A few (3 or 4) energy bumps distributed between 900 and 2400 Hz

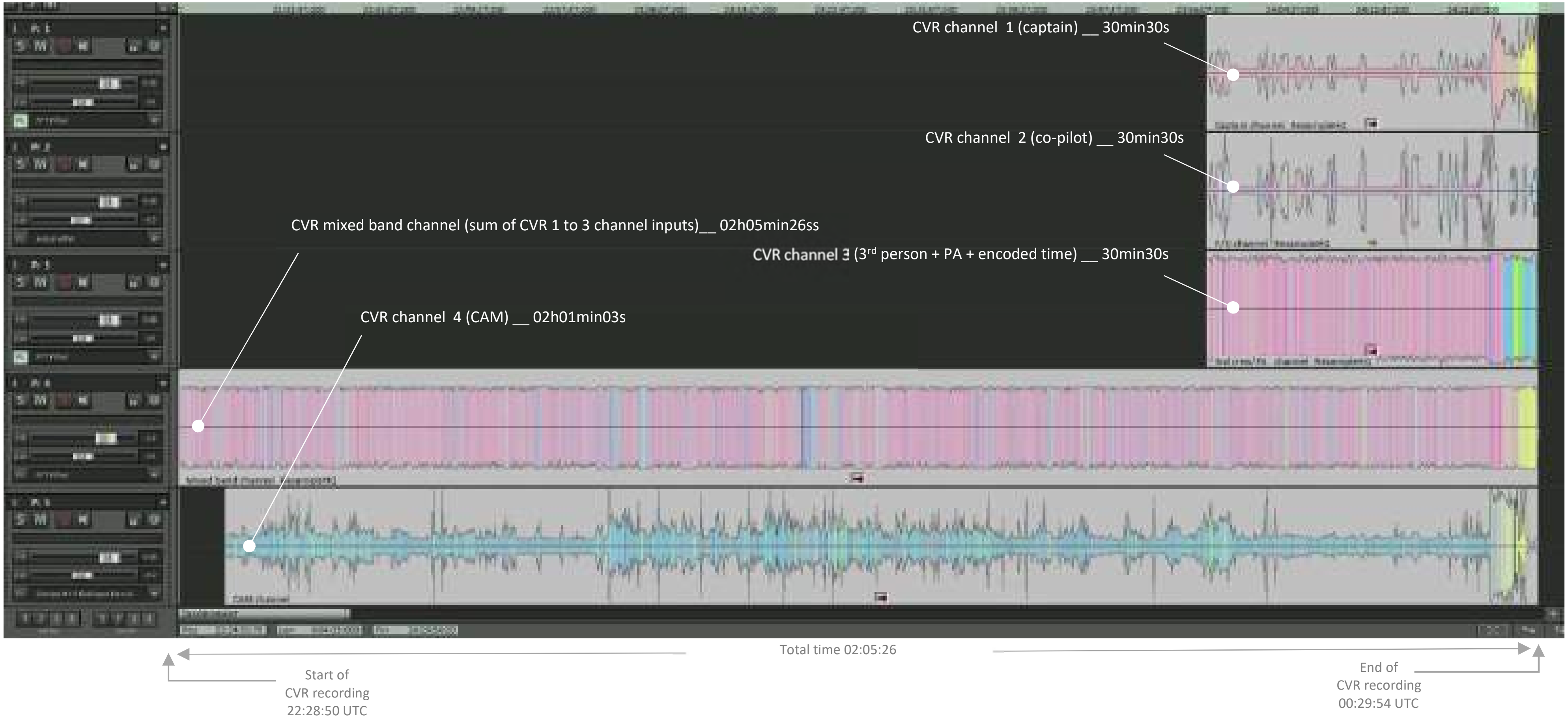


Acoustic signature of audio pick-up by the oxygen mask microphone - Detailed PSD views of samples from pilot channels (with and without active oxygen microphone).

A similar acoustic signature was observed on the noise spectrum of the MS804 CVR.

Waveforms from CVR recording

View of multi-track audio based on the CVR data:

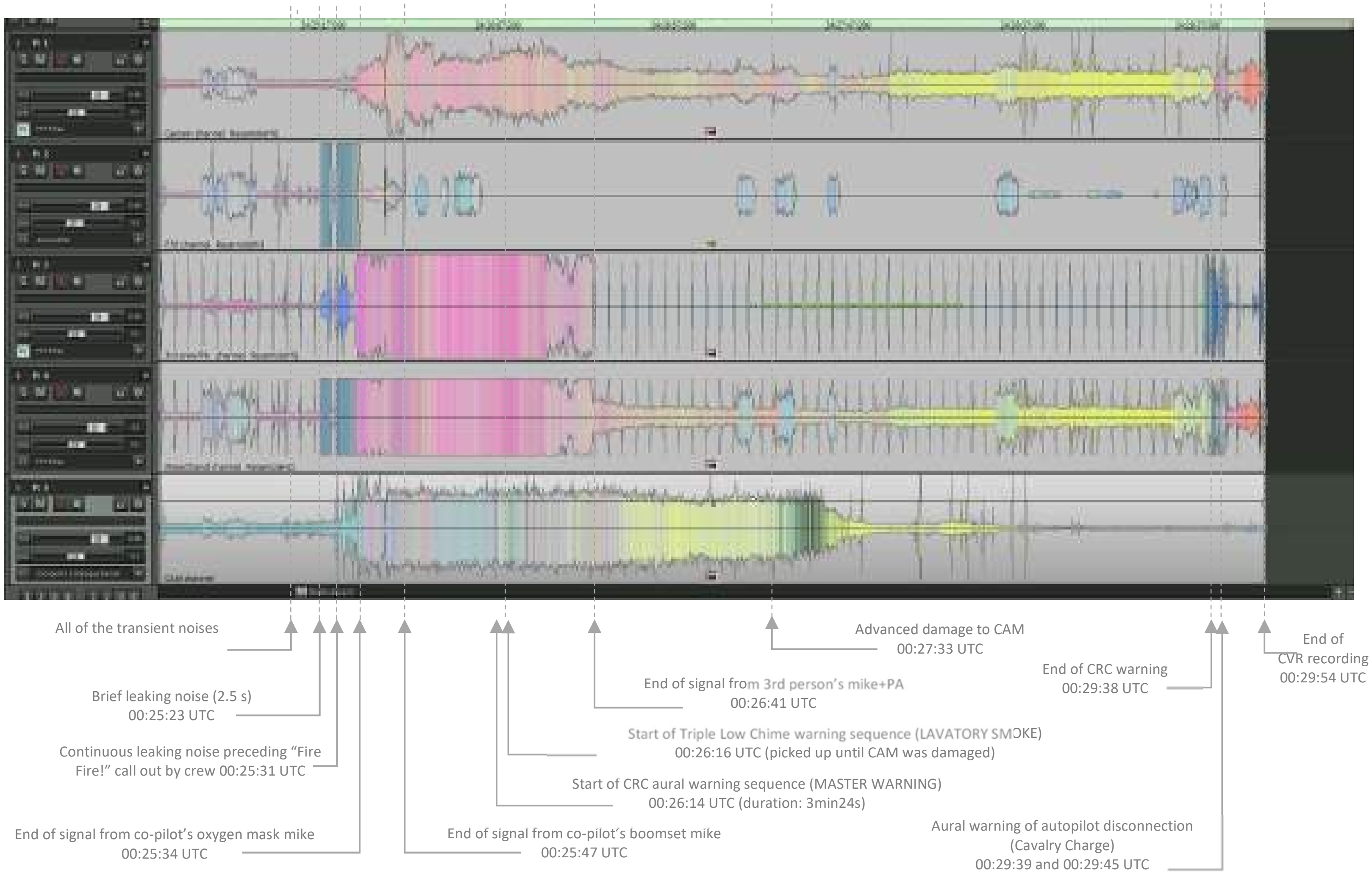


Note: the CVR data was synchronised (using the UTC time of the FDR) based on the information triggering the various warnings and the radio communication times recorded by the control services (ATC).

Appendix 3 - Waveforms from CVR recording

Audio sequence of interest:

The view below shows the waveform of the last 5 minutes of the audio recording:



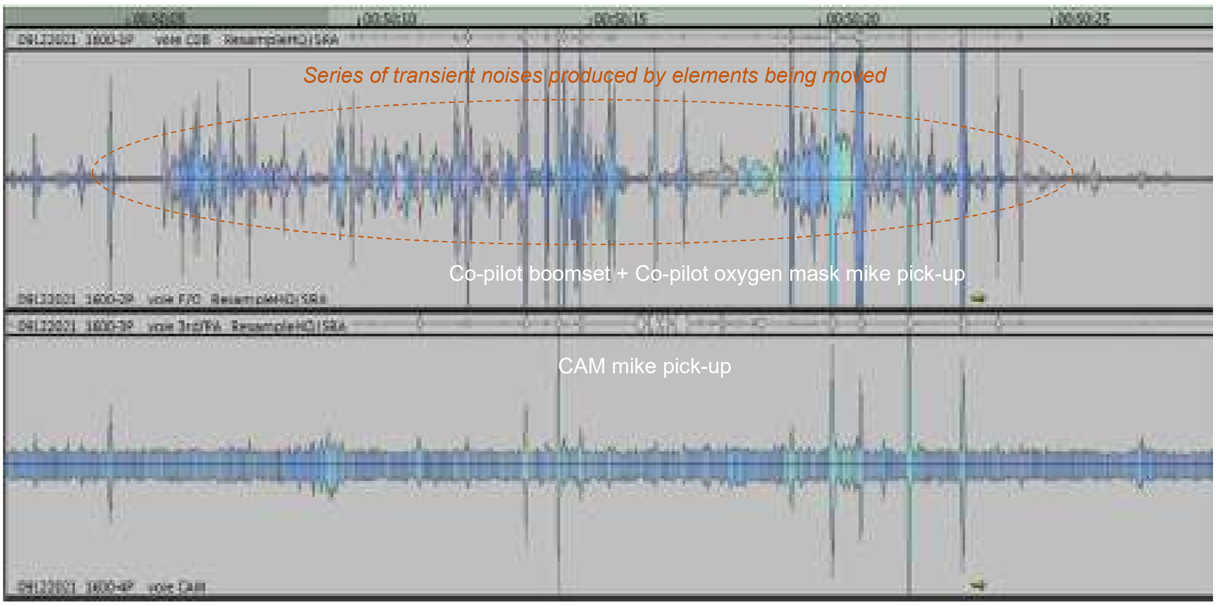
Appendix 3 - Waveforms from CVR recording

Perception of sound events broadcast by the co-pilot's loudspeaker when the co-pilot's oxygen mask microphone was active

Note: the door of the co-pilot's oxygen mask storage box was opened and then closed again (with no reset) to activate the pick-up by the oxygen mask microphone.

The volume of the co-pilot's loudspeaker was set to maximum, and actions were carried out near the mask storage box (object thrown into the doc storage compartment, document removed, box door moved, oxygen mask knob touched, etc.).

The waveform below shows, for the audio signal of the co-pilot channel, the predominance of transient noises produced by these different actions.



Findings:

The noise from elements being moved (transient noises) were broadcast on the co-pilot's LS and were perceptible by an operator sat in the co-pilot's seat. They were picked up to a small extent or not at all by the CAM microphone (with the exception of those which were loud). This phenomenon can possibly be explained by the position of the CAM at the base of the overhead panel, set back from the vertical of the instrument panel (i.e. the FCU console masks the sound cone of the loudspeakers).

Similar events were detected on the CVR co-pilot channel of flight MS804.

Sequences/scenarios of actions on oxygen mask and mask storage box

An MXP801 oxygen mask storage box equipped with an MF20-534 mask was supplied with 5-bar compressed air. The following actions were carried out:

- Seq.0 / Reproduction of the before flight oxygen system test procedure.
- Seq.1 / The mask EMERGENCY knob was pressed (2.6 s) after door was opened.
- Seq.2 / The mask EMERGENCY knob and the PRESS TO TEST pushbutton on the box door were simultaneously pressed (2.6 s).
- Seq.3 / The PRESS TO TEST pushbutton on the box door was pressed (2.6 s) with the mask knob in the EMERGENCY position.
- Seq.4 / With the mask knob in the EMERGENCY position, the door of the oxygen mask storage box was opened (2.6 s).
- Seq.5 / With the mask knob in the EMERGENCY position, the door of the oxygen mask storage box was opened and supplied with air for 2.6 s.

Each of these sequences was carried out with the oxygen dilution set to Normal (Test 8a). The sequences were then repeated with the dilution set to 100% (Test 8b).

Result: from an audio point of view - and in these test conditions - the actions on the oxygen assembly, whether it be pressing the EMERGENCY knob to carry out a mask test or pressing the PRESS TO TEST pushbutton on the box, or both, produce an audio event which differs in terms of the duration of the transient noise at the end of the oxygen flow (transient noise release) and the noise of bleeding of the system (reverberation). The acoustic signature of the leak produced during sequences 2, 3 and 4 was identical.

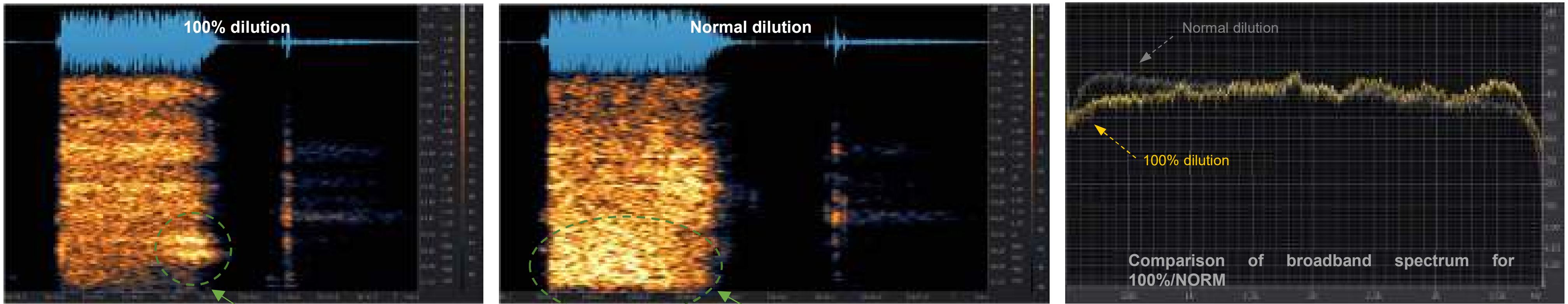
Comparison_____Signature differences - Mask dilution set to 100% then normal

Mask dilution / N (Normal) or 100%

Box test control

Door Press To Test PB / pushbutton to obtain a temporary oxygen flow and to RESET after opening the oxygen box

Test procedure: The Press To Test pushbutton on the left door of the oxygen mask storage box was pressed and held, and then released.



Short presence of two noise bumps (average 600 and 900 Hz) which appeared during the transient noise release, producing a hollow hiss. This signature was observed in all the tests carried out with the dilution set to 100%.

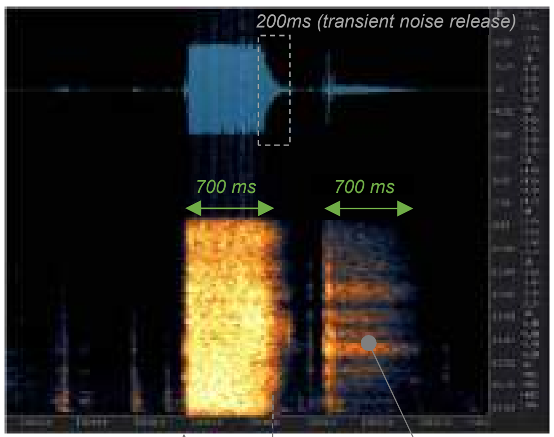
Low-frequency contribution to the spectrum. This contribution was observed in all the tests carried out with the dilution set to Normal.

Comparison_____Spectrum of oxygen mask and storage box handling sequences

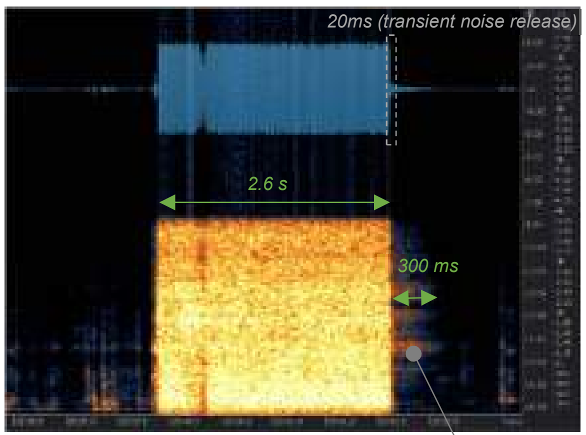
Test conditions: the test sequences were carried out on an assembly composed of an MXP801 box and an MF20-534 mask. The assembly was supplied with air at 5 bar (an additional test on another model of box and mask gave different duration values).

Note: tests 8a (regulator set to NORMAL) and 8b (regulator set to 100 %) produced the same data in terms of the duration of the transient noise and reverberation (bleeding noise).

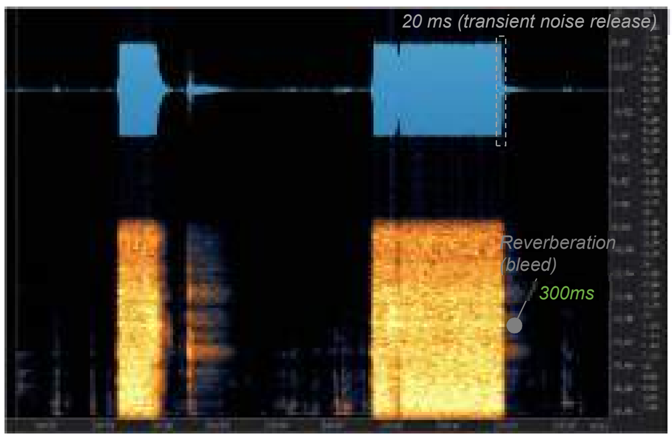
Box Press To Test PB pressed and held / Mask set to Normal



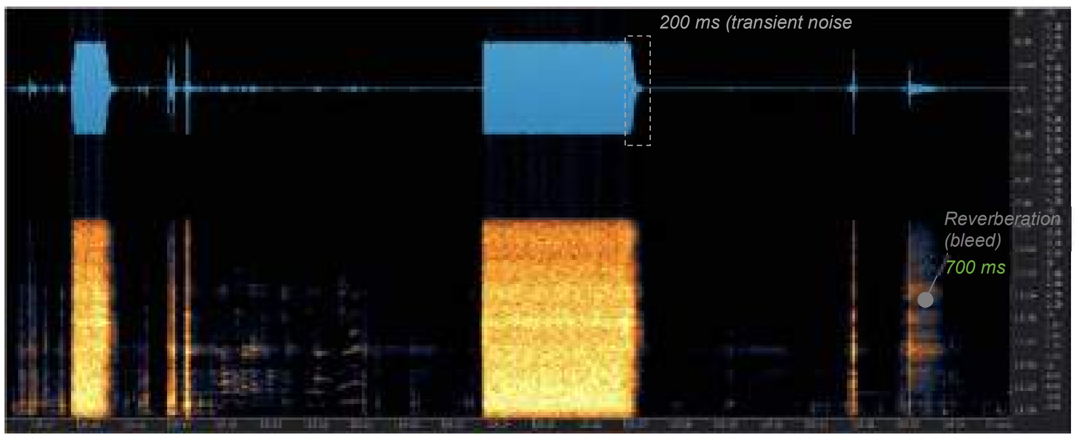
Simultaneous pressing of box Press To Test PB and mask knob (EMERGENCY)



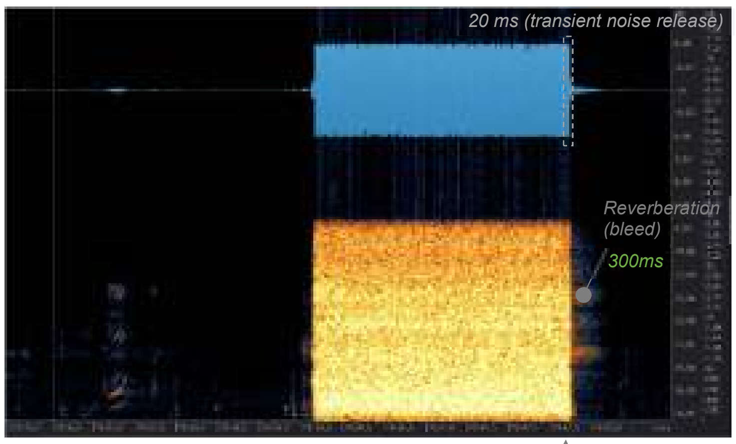
Seq.0/ SOPS / Door Press To Test PB and mask knob pressed / released simultaneously



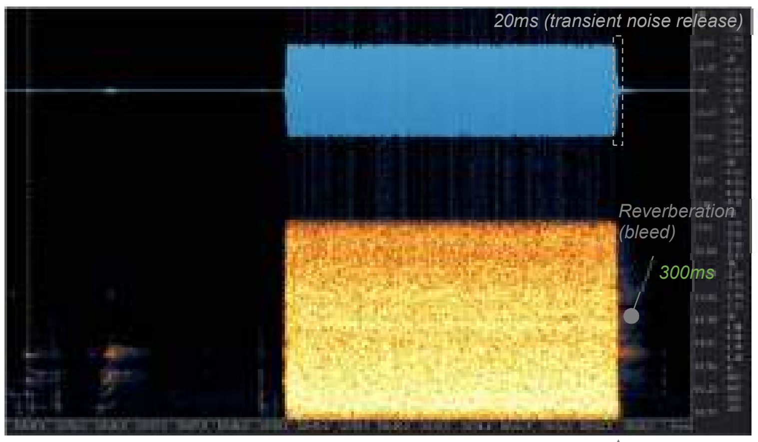
Seq.1/ **Door o**pened and then closed / Mask knob pressed (3s) then oxygen box reset



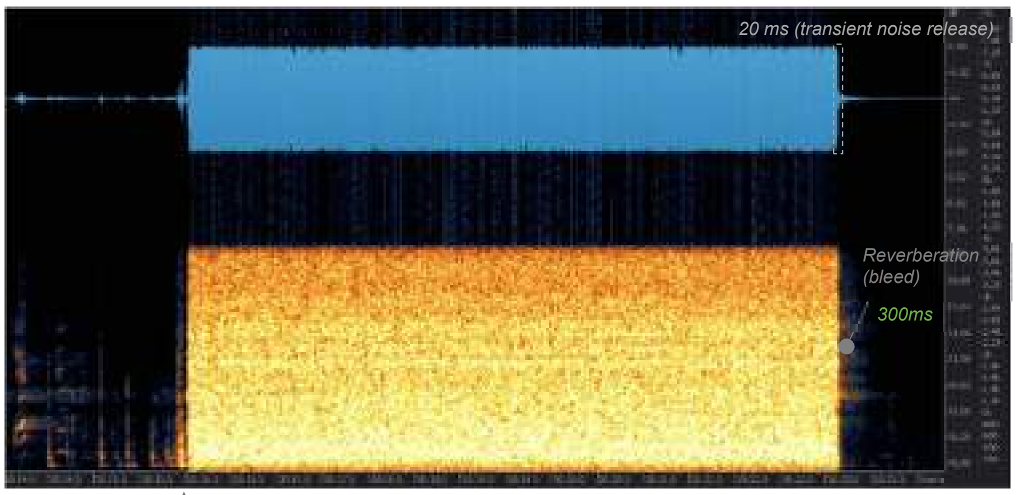
Seq.2/ Door Press To Test PB and mask knob simultaneously pressed for 2.6 s



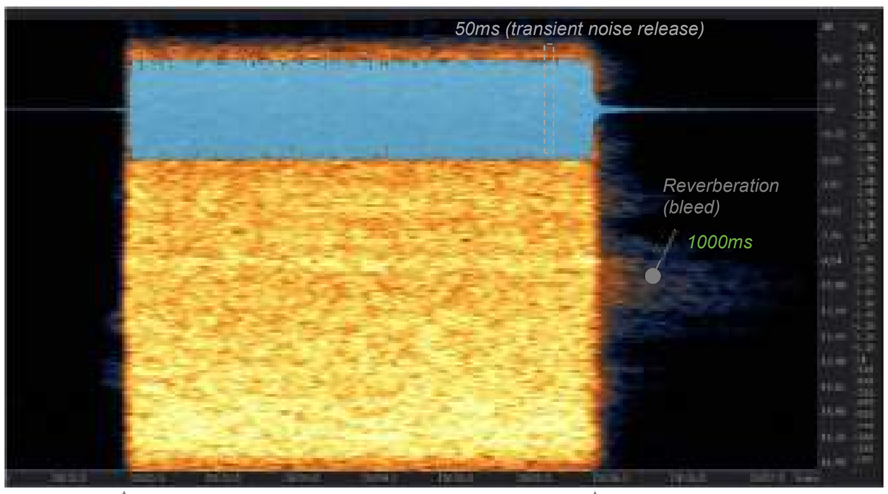
Seq.3/ Door Press To Test PB pressed for 2.6 s with mask in EMER



Seq.4/ Door of mask storage box opened with mask in EMERGENCY position



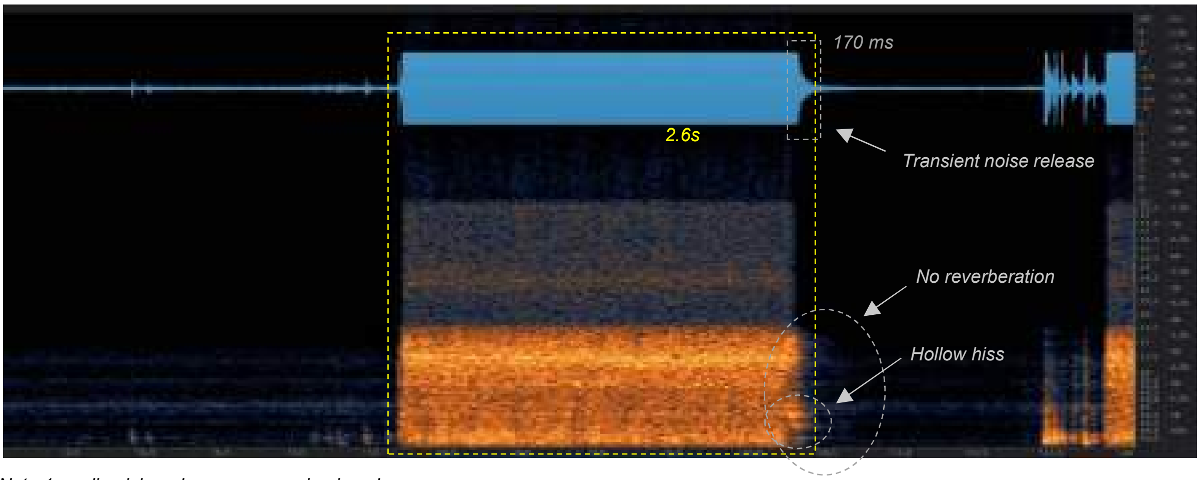
Seq.5/ Temporary oxygen supply (2.6 s via solenoid control*) with door of mask storage box open and mask in EMERGENCY position



* general cockpit oxygen supply solenoid valve

SU-GCC – CVR event sequence (first oxygen activity noise / co-pilot’s mask)

Oxygen flow in co-pilot’s mask



Note 1: audio pick-up by oxygen mask microphone

Note 2: the co-pilot’s fixed oxygen equipment on flight MS804 was composed of an MF20 oxygen mask and an MXP801 mask storage box.

Synthesis

The flow time of 2.6 s indicates that oxygen was being expelled from the mask (via the regulator).

The duration of the transient noise release (200 ms) corresponds to the end of pressurisation to 5 bar of all the hoses upstream of the regulator:

- This is the case when the mask knob is not in the *EMERGENCY* position and the test pushbutton on the door of the oxygen mask storage box is pressed once.
- Or when the box is not reset after pressing the *EMERGENCY* knob of the mask.

The reverberation (bleed) corresponds to the evacuation of excess pressure.

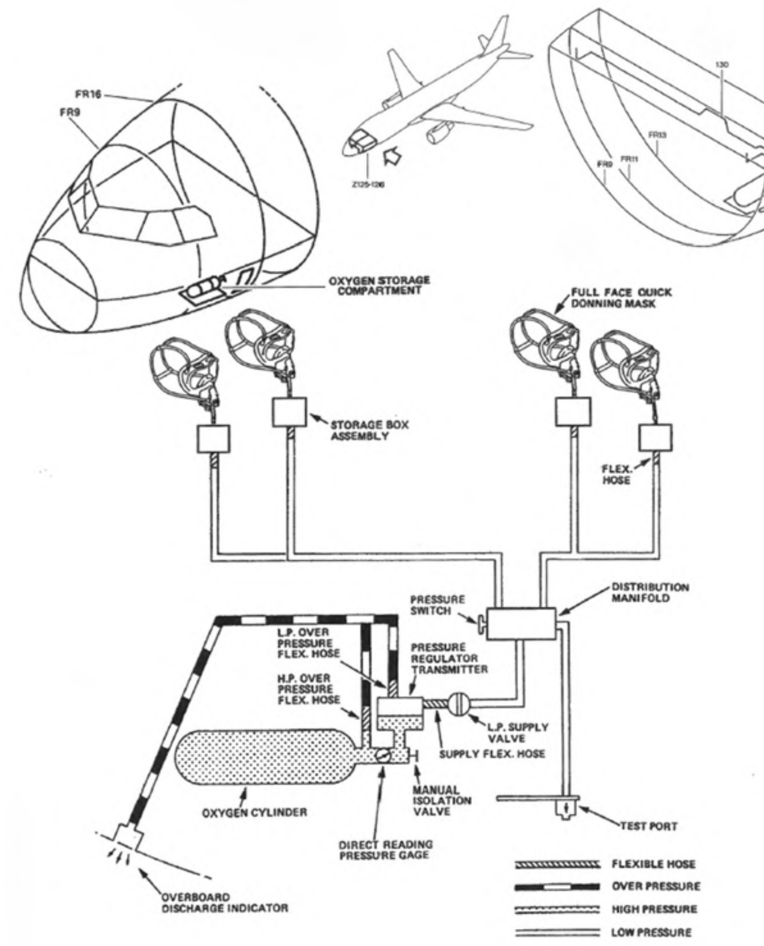
- When the Press To Test button on the door of the storage box is released without the flow being evacuated via the mask regulator (700 ms).
- Or when the Press To Test button on the door of the storage box is released with evacuation via the mask regulator (300 ms).

The hollow hiss indicated that the co-pilot's mask was in the 100% oxygen position.

Appendix: EVT4 and EVT9

Configuration

The tests were carried out on an installation that reproduced an A320 oxygen system, consisting of the elements below:



An original A320 cockpit oxygen system was taken from an aeroplane and set up in the laboratory at SAFRAN's.

The audio pick-up was performed by a "mobile CVR" system composed of original equipment (microphones, preamplifiers, mounting rack, etc.) taken from an A320. A signal conditioning unit sent signals to the microphones on the co-pilot's mask and on the two flight crew boomsets.

Purpose

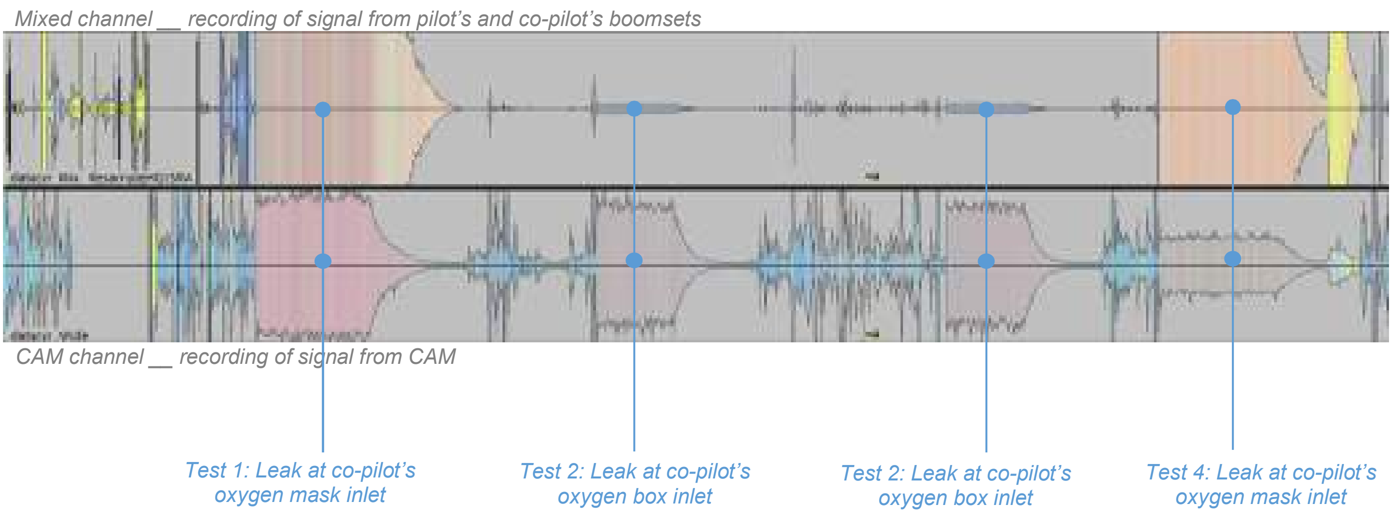
The purpose of this test was to produce the complete emptying of a cockpit oxygen cylinder by creating a continuous oxygen leak either upstream of the personal installation of a crew member (before an oxygen box) or in a crew member's oxygen box (before the oxygen mask). The oxygen cylinder was emptied of its contents and recharged to its maximum capacity[1] with ambient air before each test. The CVR recorded the noise picked up by the various microphones of the installation.

Four test sequences were carried out:

- Two leaks were simulated at the inlet of the oxygen box (the supply hose was unscrewed).
- Two leaks were simulated in the oxygen box (the mask's oxygen supply hose was disconnected and replaced by an open tube connected to the oxygen box outlet valve).

Results

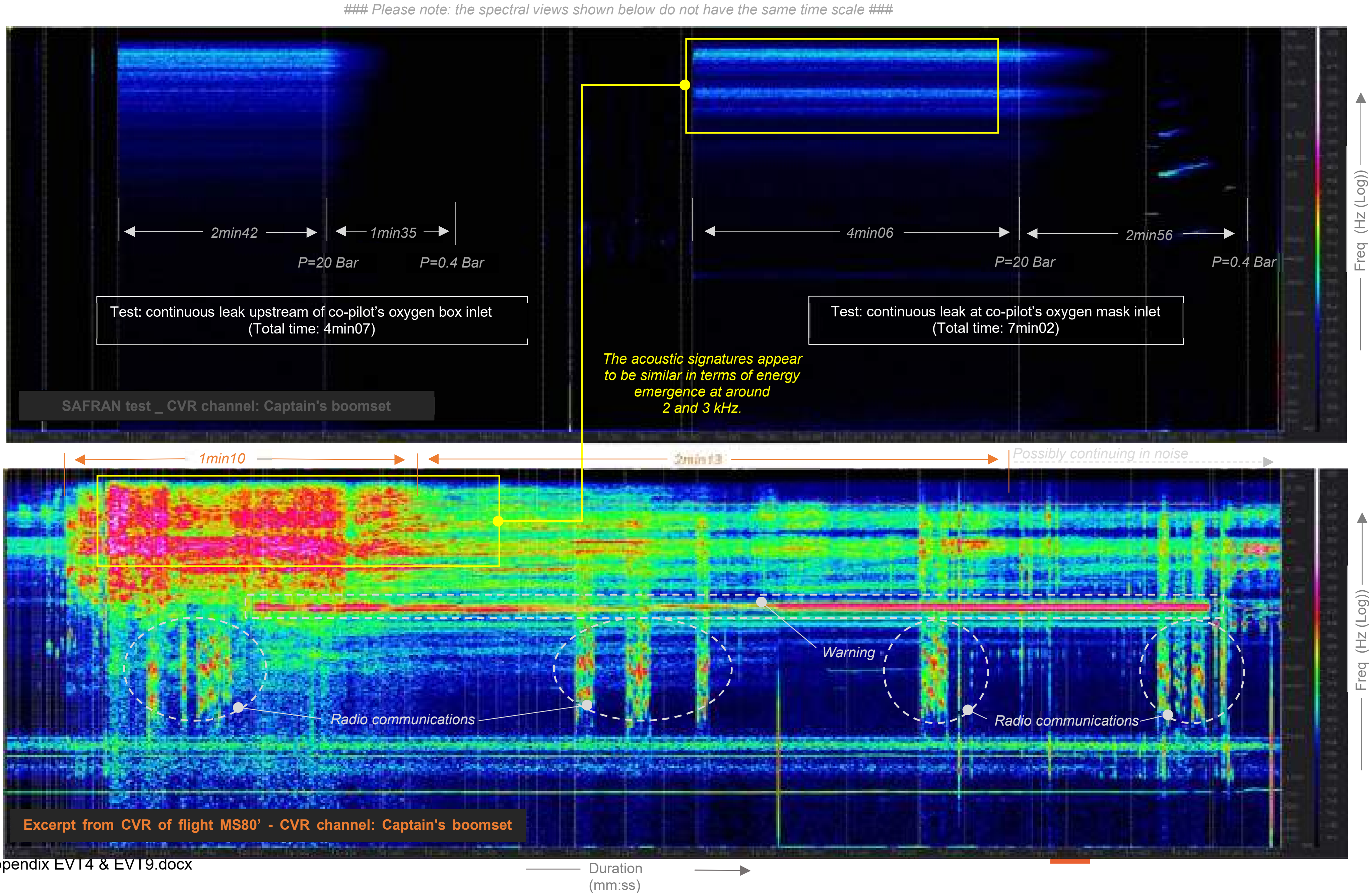
The waveform below shows the chronology of the test sequences:



The waveforms and spectral content of the audio signals collected during the four test sequences were analysed and compared with those obtained from the recording of flight MS804.

[1] The oxygen cylinder in the event was a 3250 L (115 cubic ft) cylinder. The BEA, unable to acquire a similar cylinder, acquired a 1420 L (50 cubic ft) cylinder to carry out the test.

The metrics (duration, acoustic signature, etc.) observed on the signals are illustrated in the example below:



The following information was observed:

Continuous leak sequence	Source of leak	Total leak time	Noise bumps	Leak time before 20 bar threshold	Leak time after 20 bar threshold
Test 1	In oxygen box	6min53s	Reinforced between 2 and 3 kHz	3min53s	3min
Test 2	Outside oxygen box	4min16s	Several swathes distributed from 1 to 2.8kHz	2min42s	1min34s
Test 3	Outside oxygen box	4min17s	Several swathes distributed from 1 to 2.8kHz	2min42s	1min35s
Test 4	In oxygen box	7min02	Reinforced between 2 and 3 kHz	4min06s	2min56s
Flight MS804	Undetermined	Estimated at 3min23s	Reinforced between 2 and 3 kHz	Estimated at 1min10s	Possibly 2min13s (difficult to determine due to background noise in cockpit).

Note 1: the capacity of the cylinder used for the tests was half that of the cylinder that was a priori on board the A320 registered SU-GCC.

Note 2: the equipment manufacturer of the oxygen system on board the AIRBUS indicated that it would take 17min1 for a 3250 L cylinder filled to its maximum capacity to be completely emptied in the event of a leak upstream of the oxygen box.

An oxygen leak produced by the rupture of a hose, either upstream of the oxygen box or upstream of the mask generated a broadband noise lasting <u>several minutes</u>, the <u>sound level of which decreased progressively</u> when a remaining pressure of less than 20 bar was reached.

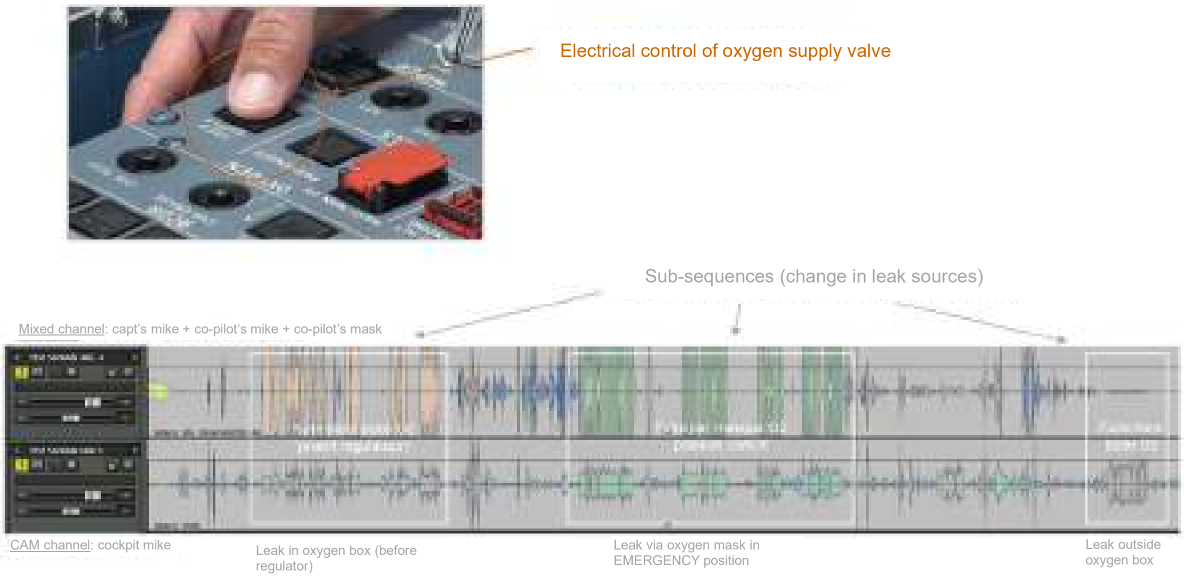
Interruption of oxygen flow

First set of tests carried out on a reproduction of the oxygen assembly

The complete A320 cockpit oxygen system assembly was taken from an aeroplane and set up in the laboratory.

The audio pick-up was performed by a "mobile CVR" system. A signal conditioning unit sent signals to the microphones on the co-pilot's mask and on the two flight crew boomsets.

The "CREW OXY SUPPLY" pushbutton on the A320's dedicated control panel was pressed several times to control the oxygen distribution solenoid valve, with variations in the frequency and hold time (random pressing of pushbutton and time pushbutton held pushed in) in an attempt to simulate a short interruption in the flow of oxygen.



Pressing the pushbutton twice in quick succession generated in all the cases, **a minimum interruption of 0.9 s** in the leaking noise to within the accuracy of the measurement.

Second set of tests on an aeroplane

The sound sequences produced by pressing the CREW SUPPLY pushbutton (to control the oxygen distribution solenoid valve) were recorded on three aeroplane types, the A318, the A319 and the A321.

For the three aeroplanes, rapid double presses on the pushbutton activated the solenoid valve (click heard under the floor) with a **constant time delay of 0.9 s**.

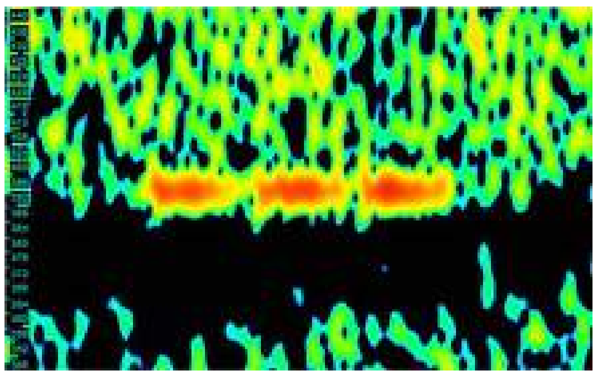
Synthesis

The tests of the CREW SUPPLY control carried out on the three aeroplanes - in addition to the previous tests carried out in the SAFRAN laboratory and at the BEA - confirmed that however quickly two consecutive inputs are made to control the cockpit oxygen supply valve, a time delay of 0.9 s is applied. Thus, no intentional action - even very rapid - on the oxygen supply control can produce the 0.5 s micro-interruption observed on the CVR of the occurrence.

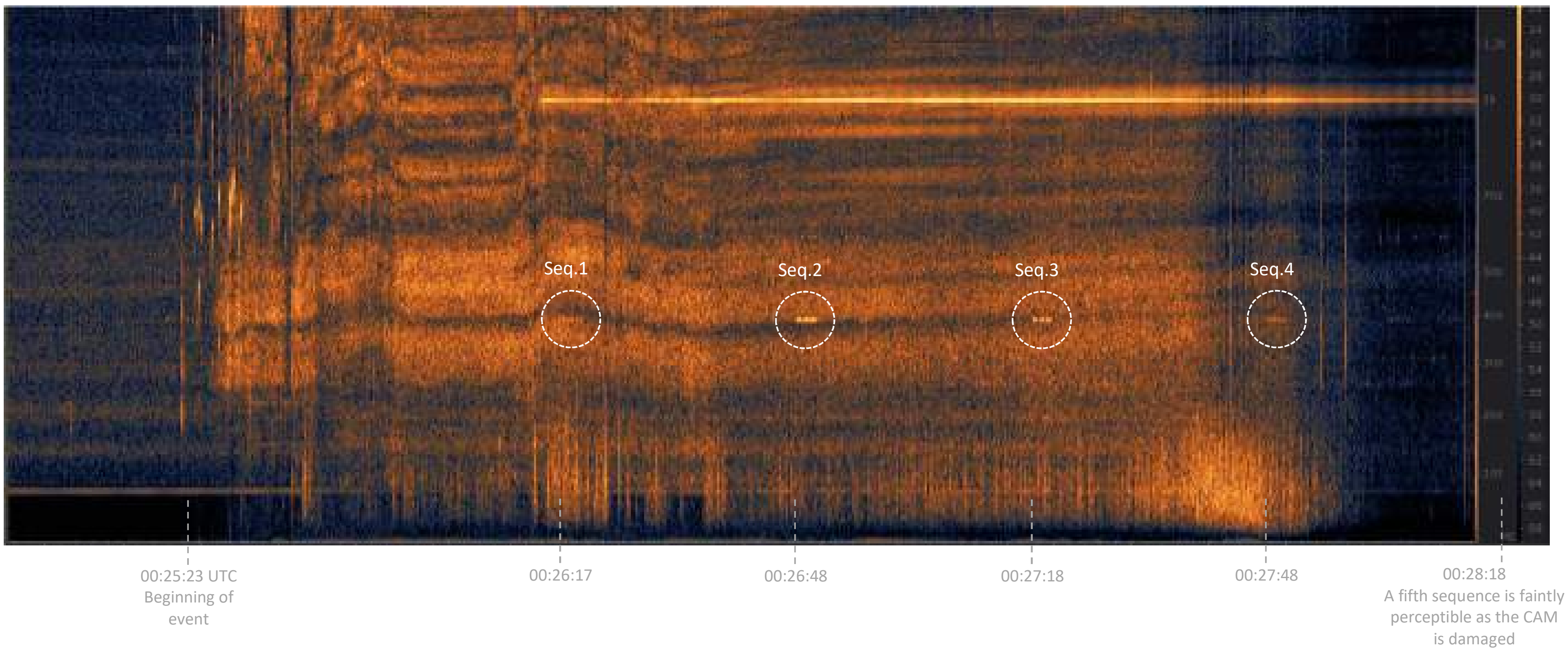
Comparison of noise level of Lavatory smoke warning

As a reminder, the LAVATORY SMOKE warning sounds in the cabin. It consists of an audible signal of a pure frequency of 392 Hz emitted for 440 ms, followed by a silence for the same period (440ms); this sound is repeated three times. It is called a "triple low chime" in the Airbus glossary.

The triple low chime is generated on the cabin loudspeakers every thirty seconds.



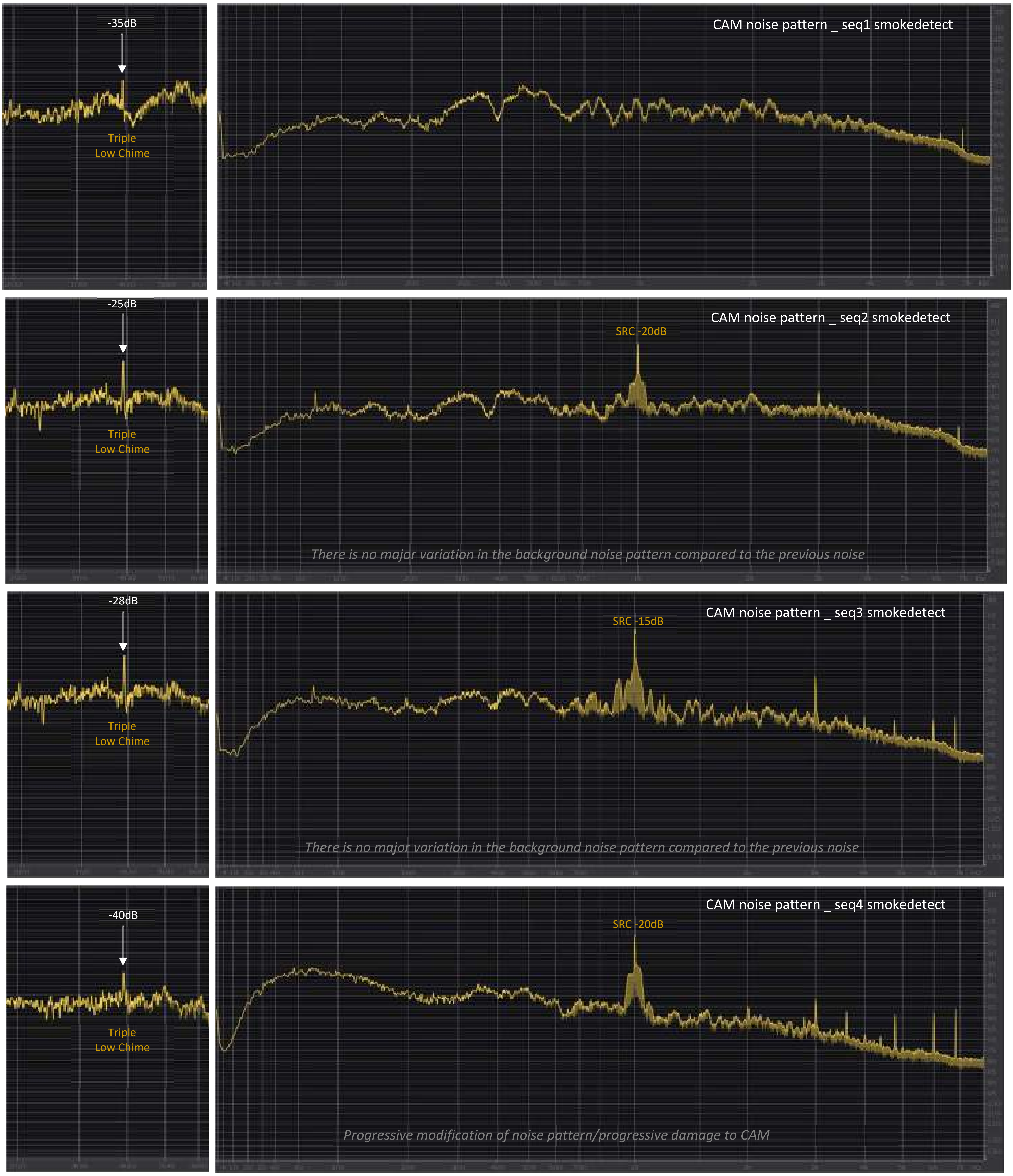
View of the Lavatory Smoke warning sequence picked up during the event:



Comparison of the overall noise pattern before and after the event

Note: There is an average dynamic loss of -15 to -20 dB over all of the CAM's bandwidth.

Chronology and pick-up level of “triple low chime” signal via the CAM in the cockpit



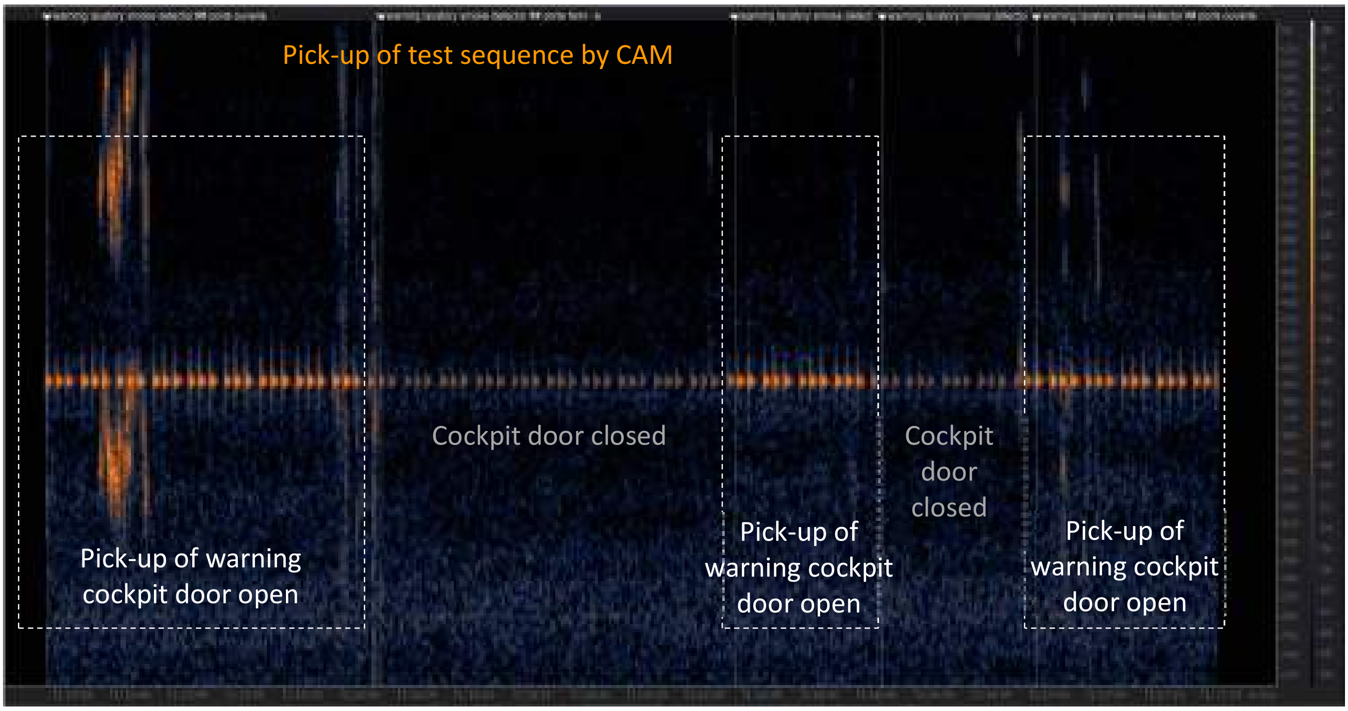
Conclusion:

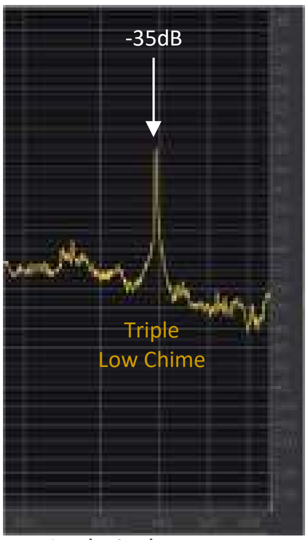
A 10 dB increase in the "triple low chime" signal was measured for sequences 2 and 3 (perceived at 00:26:48 and 00:27:18 UTC). This increase was compatible with the warning being picked up when the cockpit door was open.

De facto, sequences 1 and 4 were probably recorded with the door closed.

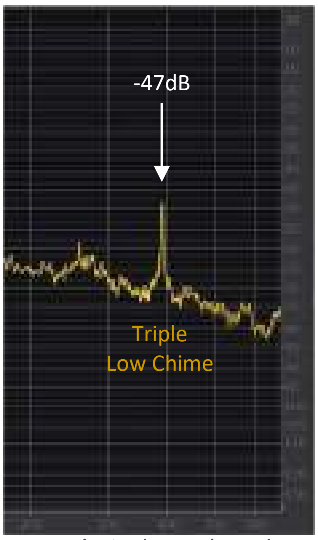
Lavatory Smoke Detector warning emission test carried out on the ground on an Airbus A319

Note: The Lavatory Smoke Detector warning test was activated via the CDIS test page. The "triple low chime" sequence was emitted continuously for the duration of the test.





Cockpit door open



Cockpit door closed

Findings:

The cockpit door masked the warning shown by a reduction in the signal level of the “triple low chime” of -10 to -12 dB.

8 Appendix Lavatory

Training in the use of halon cockpit extinguishers

Air Formation, a company specialising in firefighting and evacuation training for aircraft crews, provided the BEA with an A340 cockpit in which it carries out recurrent training for flight crews.

Fire attack procedure:

The fire is attacked at the base of the flames, on the nearest outbreak, by spraying the product at a low angle, at a distance of about 1 m from the centre. If possible, the fire extinguisher should be kept in a vertical position; if not, it should not be tilted more than 45°[1].

Activation of a cockpit fire extinguisher in the cockpit of Air Formation's A340

[1] If this is not the case (i.e. steep angle) the propellant - pressurised neutral gas - is expelled instead of the extinguishing agent, halon.

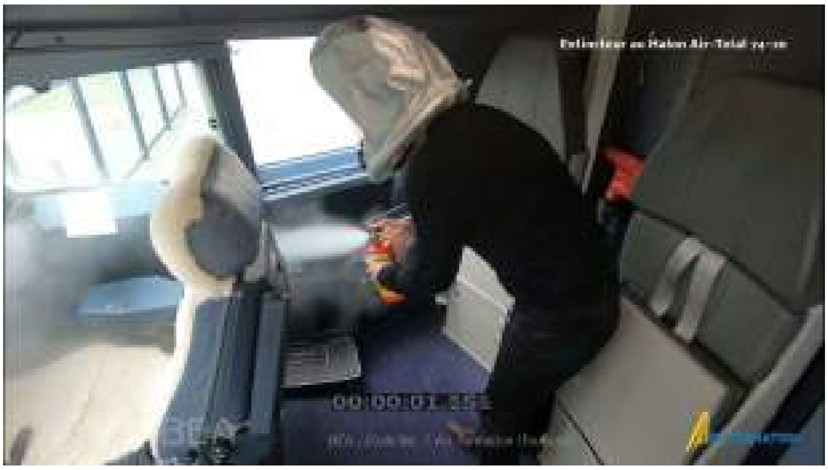
Recording noise produced by the activation of a cockpit fire extinguisher
Two fire extinguishers were activated in the cockpit and the cylinders completely emptied. The Cockpit Area Microphone (CAM) was used to pick up the background noise. A crew headset was placed in the rest position (on the side windshield post) to pick-up the noise detected by the boomset mike of a crew member. It should be noted that no environmental noise was emitted in the cockpit (ventilation, aerodynamic noise, engine noise, etc.).

<u>Model H3R Aviation C352TS</u> (extinguisher widely used on commercial transport aircraft and in business aviation):

Note: the extinguisher emptied in 19.4s of uninterrupted spraying.

<u>Model Air Total 74-20</u> (extinguisher in the cockpit of the SU-GCC):

Note: the extinguisher emptied in 15 s of uninterrupted spraying.



The following two pages show the spectral content of the noise produced by the activation and emptying of each of the two fire extinguishers.

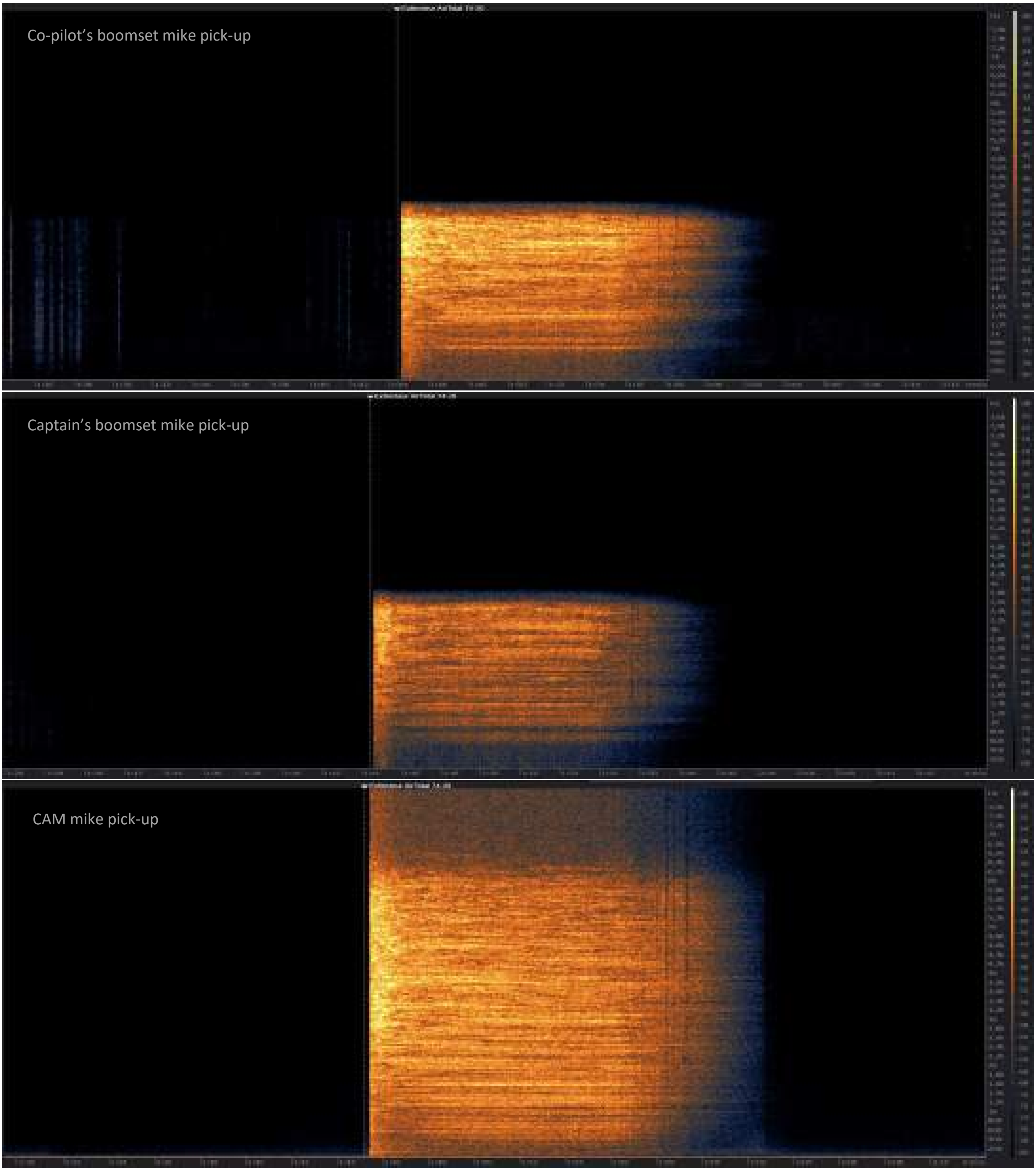
Visible and olfactory effects observed
In a training situation - without a fire - the halon gas spray is odourless and colourless.

Synthesis / audio analysis
The emptying of a halon fire extinguisher produced a broadband noise that occupied the entire bandwidth offered by the recording channel. The sound event was long (measured duration varying from 13 to 19 s over all the tests carried out (Air Formation and INERIS), and its level was average. No event with an acoustic signature similar to that of the fire extinguisher emptying, recorded during these tests, was identified on the CVR recording of flight MS804.

Appendix 9 Air Formation

Activation and emptying of an Air Total 74-20 halon fire extinguisher

(A340 cockpit - fire extinguisher directed towards the co-pilot's doc storage compartment)

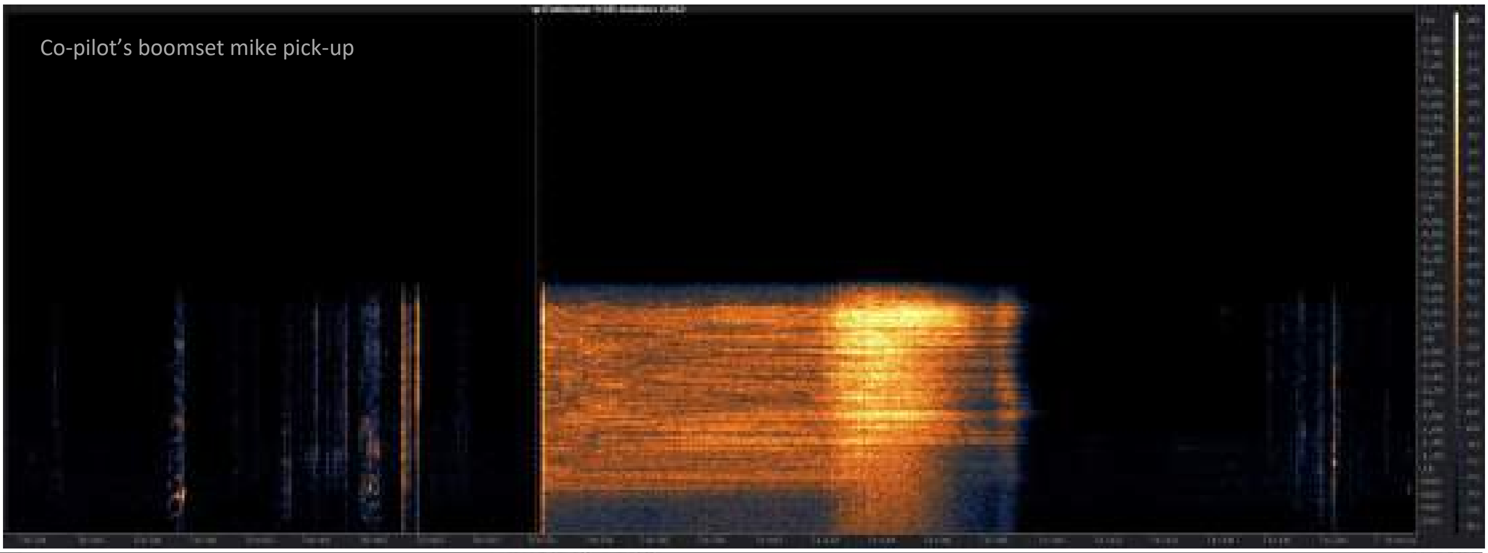


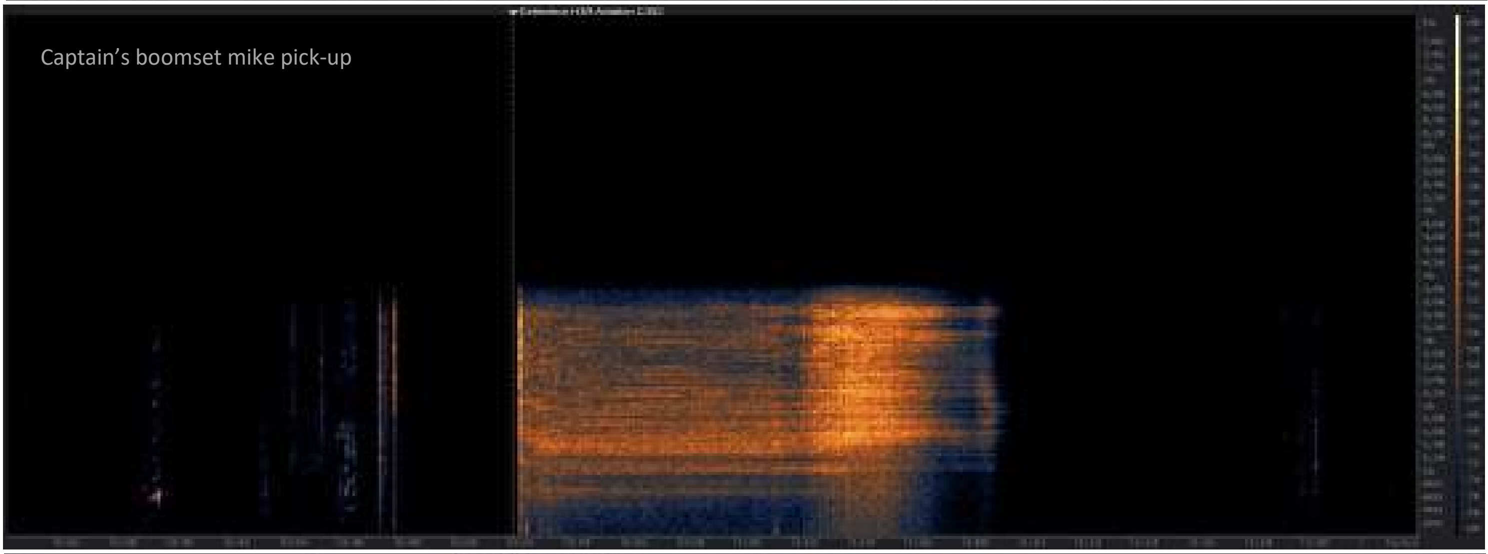
Summary Total time = 15 s

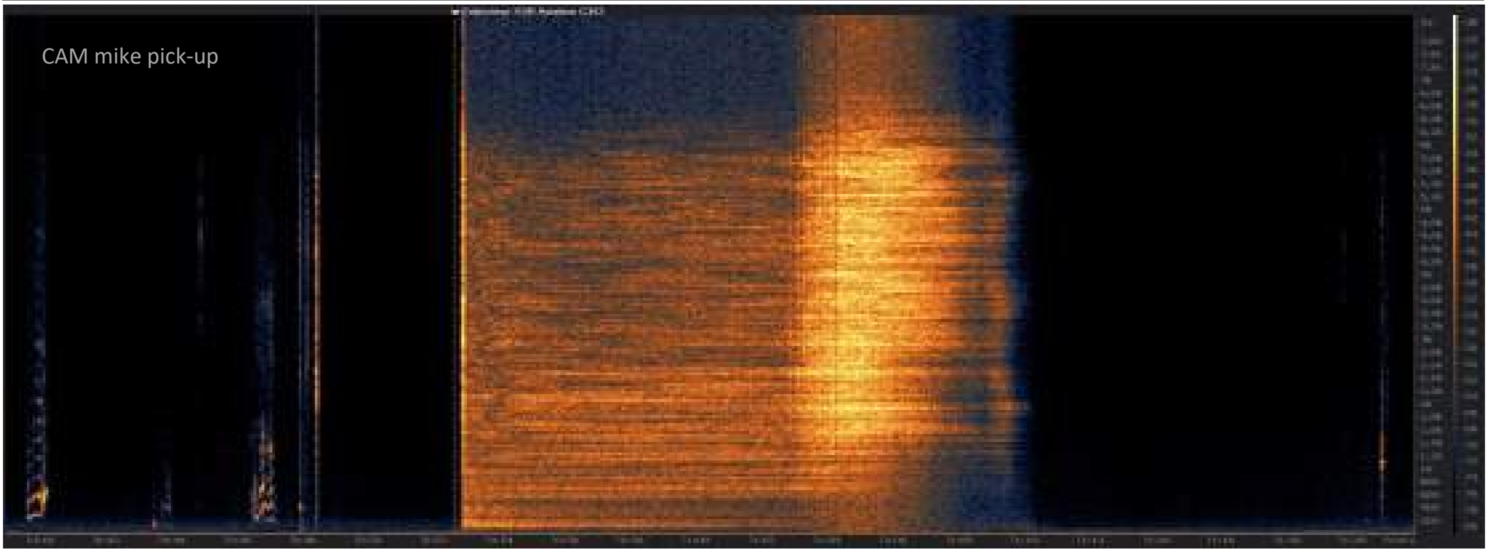
- <u>Flight crew boomset channels</u>: broadband noise from 800 Hz to 3.8 kHz, fairly pronounced between 2 and 3.8 kHz
- <u>CAM channels</u>: broadband noise over the entire bandwidth of the CVR CAM channel

Activation and emptying of an H3R Aviation C352TS halon fire extinguisher

(A340 cockpit - fire extinguisher directed towards the co-pilot's doc storage compartment)







Summary Total time = 19.4 s

- Flight crew boomset channels: broadband noise from 800 Hz to 3.8 kHz. Noise reinforcing between 1.4 and 3.8 kHz when cylinder emptied of two-thirds of the content.
- CAM channels: diffuse broadband noise over the entire bandwidth of the CVR CAM channel. Noise reinforcing between 1.4 and 3.8 kHz when cylinder emptied of two-thirds of the content.

Analysis of combustion gases generated during tests to extinguish an oxygen fire with a halon fire extinguisher

Synthesis of INERIS test report (document: Ineris – 205964 – 2740277 – v0.1)

Test B4-1__Remote activation of an Air Total 74-20 halon fire extinguisher on a fire not enriched with oxygen – 10m3 test chamber.
Carried out on 8 March 2022.

The fire extinguisher was installed on a mount and activated by an operator outside the 10m3 chamber. The fire was fuelled by a piece of Hessian soaked in a cup of oil and placed in a metal enclosure.

Test conditions: the fire was not enriched by a flow of oxygen. The test chamber was not ventilated. The fire extinguisher was activated once and kept in operation until it was completely empty (approximately 15 s).

Test B4-2__Remote activation of an Air Total 74-20 halon fire extinguisher on a fire enriched with oxygen – 10m3 test chamber.
Carried out on 8 March 2022.

The equipment for extinguishing and activating the fire and the source of the fire were identical to the previous test.

Test conditions: the fire was enriched by a continuous flow of oxygen. The test chamber was ventilated (5000m3/h) after the activation of the fire extinguisher which occurred once and was kept in operation until it was completely empty (approximately 13 s).

Test B6__ Remote activation of an Air Total 74-20 halon fire extinguisher on a fire enriched with oxygen – 10m3 test chamber. Carried out on 8 March 2022.

The equipment for extinguishing and activating the fire and the source of the fire were identical to the previous test.

Test conditions: the fire was enriched by a continuous flow of oxygen. The test chamber was ventilated (5000m3/h) throughout the test. The fire extinguisher was activated once and kept in operation until it was completely empty (approximately 20 s).

The concentrations of COF2 and CF4 gases and of HF, HCl and HBr acids were measured during the three tests. The values are presented in the tables below:

Summary of toxic effects

Threshold limits

The toxicity thresholds for the various gases in terms of VSTAF[1] and AEGL[2] for 10 minutes of exposure are given in Table 1. The definitions of AEGL-2 and AEGL-3 correspond to those of the irreversible effects threshold and lethal effects threshold respectively, the AEGL values being safer. The VSTAF was chosen as a priority when it existed.

For 10 minutes of exposure				
Gaz	SEI (irreversible effects threshold) [ppm]	AEGL-2 [ppm]	SEL (lethal effects threshold) [ppm]	AEGL-3 [ppm]
HF	600	95	1 123	170
HCl	240	100	1 300	620
HBr	366	100	4 108	740
COF2	ND	0.35	ND	1
CO	2 600	420	7 000	1 700
CF4	ND	ND	ND	ND
COCl2	3	0.6	10	3.6

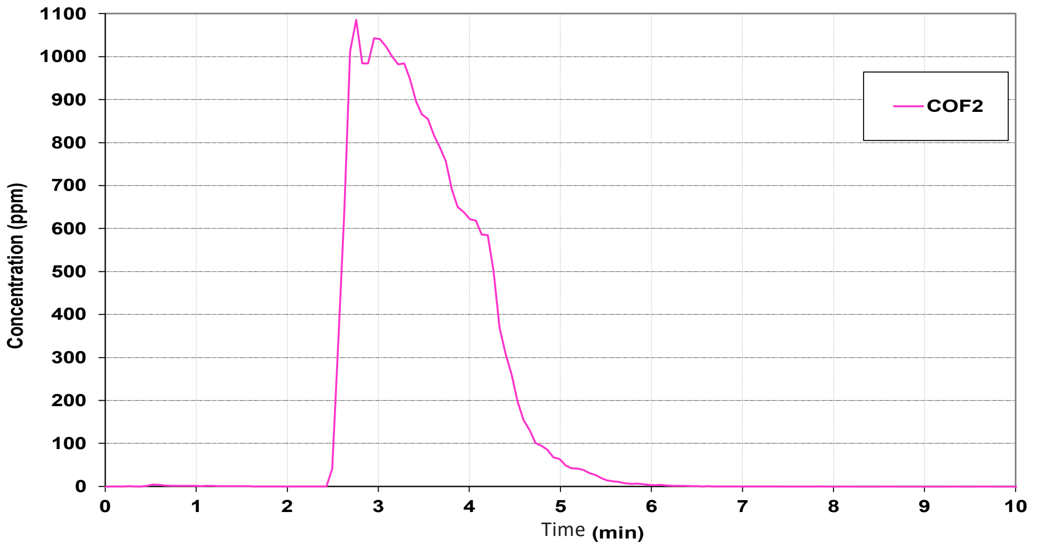
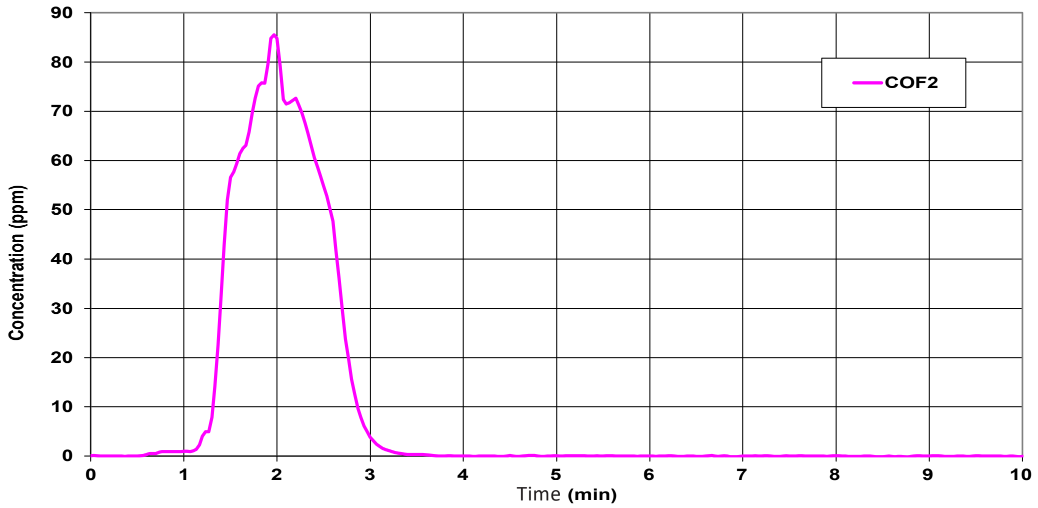
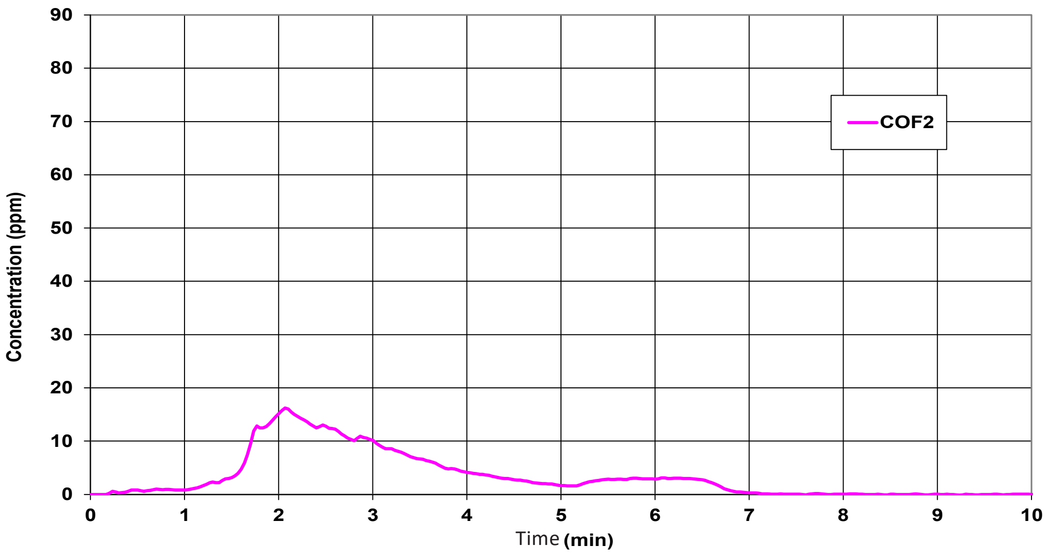
AEGL thresholds of gases measured during the test

For halon, the INRS[3] gives a threshold value for 1 min of exposure of 4%.

[1] French acute toxicity threshold value
[2] Acute Exposure Guideline Level
[3] Toxicological data sheet No 165

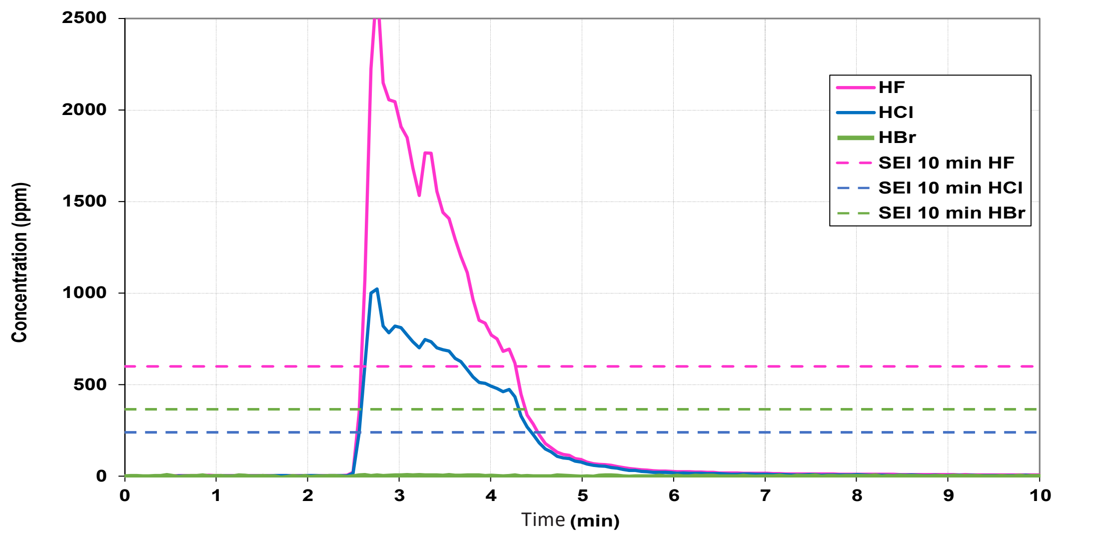
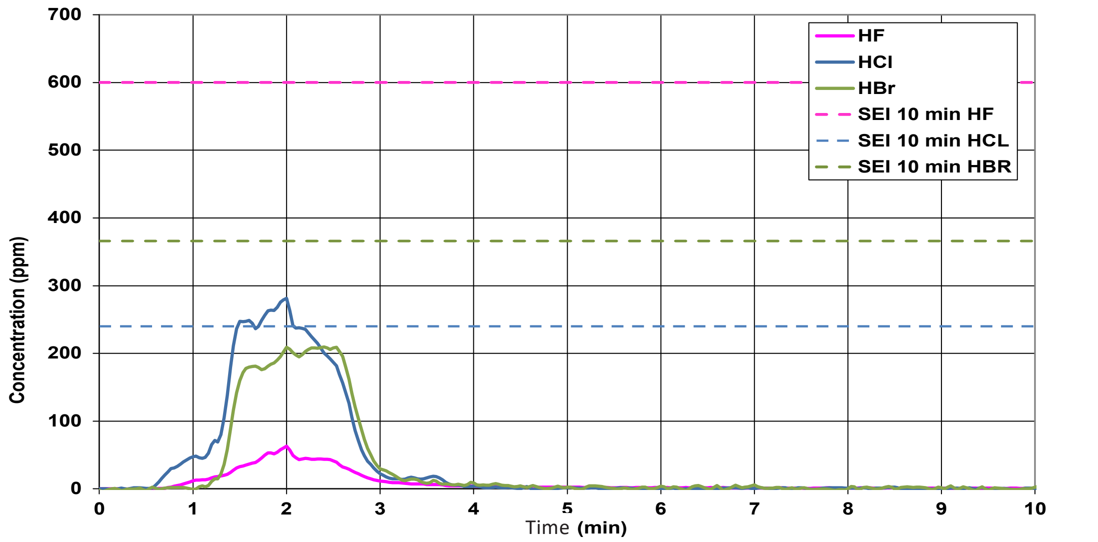
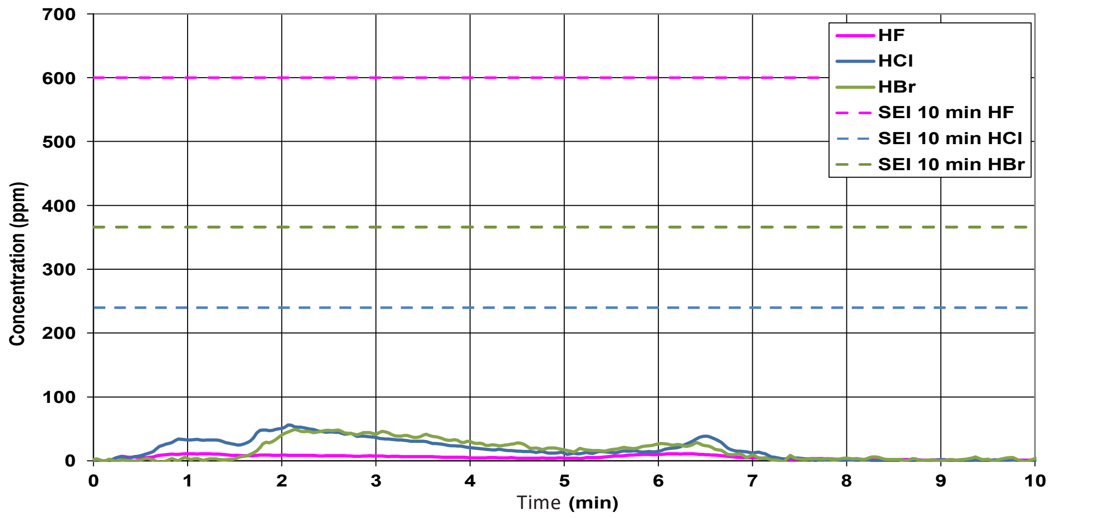
Comparison of concentrations observed and risk thresholds

COF2

B4-2 test	
B5 test	
B6 test	

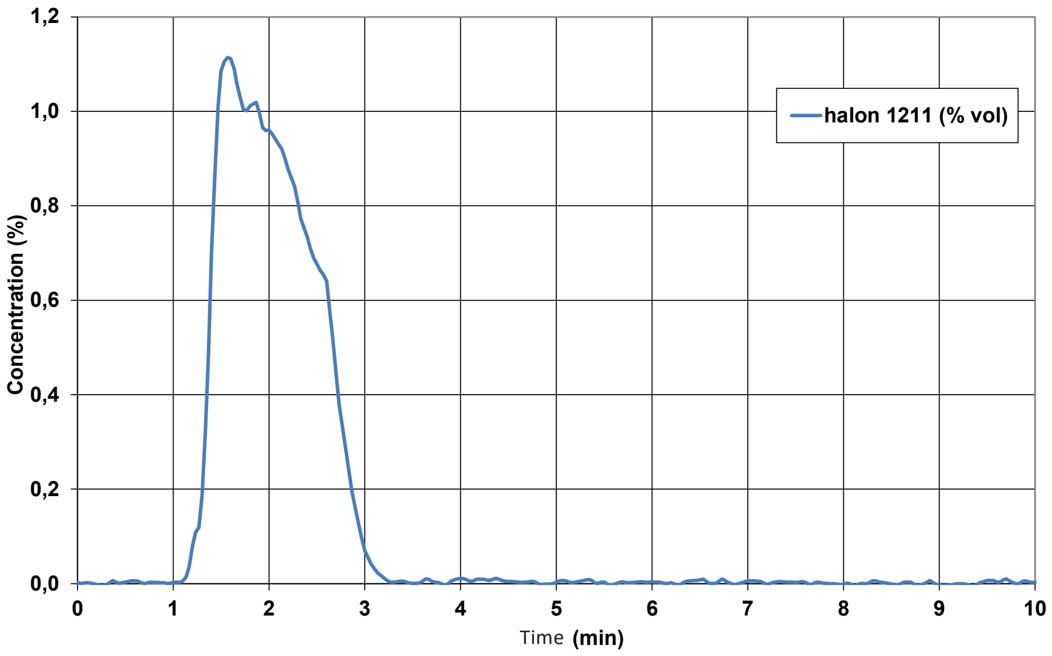
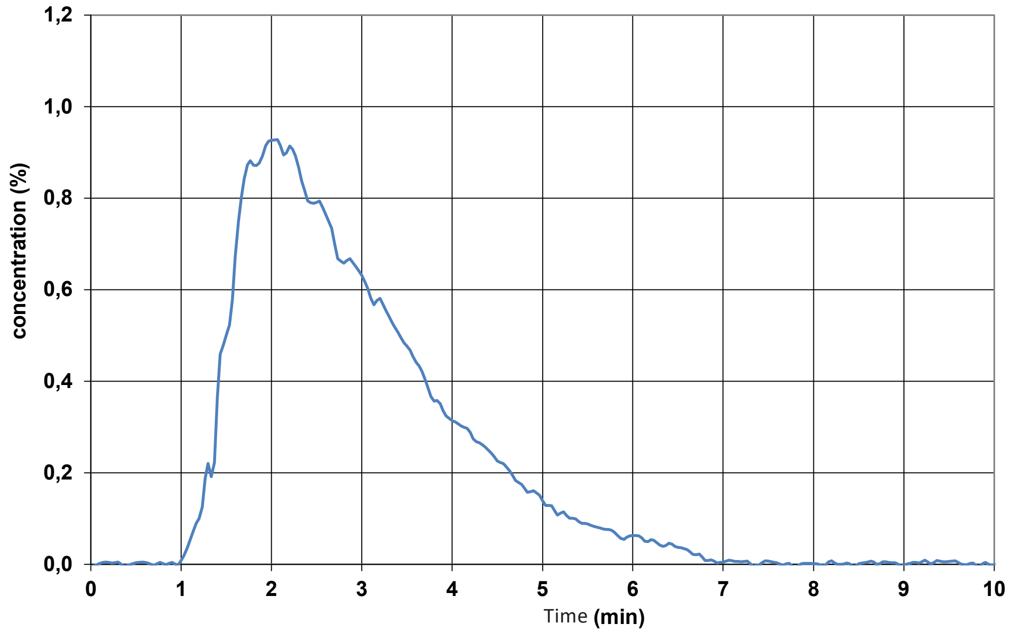
Concentration of COF2 measured during the three tests

Acids

B4-2 test	
B5 test	
B6 test	

Concentration of acids measured during the three tests (SEI = irreversible effects threshold)

Halon

B4-2 test	Measurement not made
B5 test	
B6 test	

Concentration of halon measured during the two tests

Findings:

- The concentration of COF2 exceeded the AEGL-2 threshold (equivalent to the irreversible effects threshold) in all three tests, B4-2, B5 and B6.
- The concentration of HF and HCL acids largely exceeded the irreversible effects threshold during test B4-2, mainly due to the absence of ventilation. The irreversible effects threshold for HCl was also exceeded during test B5.
- The 4% halon concentration limit was not reached during tests B5 and B6 (not measured during B4-2).

The chapter below describes the method for qualitatively comparing the gases measured against the toxicity thresholds.

Calculation of toxic dose

A toxic dose approach provides a quantitative assessment of the toxic effects caused by the fire and the action of halon, taking into account the duration of the exposure. A toxic dose is calculated using the following formula:

$$D_i = \int_{t1}^{t2} C_i(t)^{n_i}.\,dt$$

Where:

D_i	=	Toxic dose for gas i [-]
n_i	=	Regression parameter specific to gas i
$C_i(t)$	=	Concentration of gas i as a function of time [ppm]
dt	=	No time [min]
t1	=	Start of exposure [min]
t2	=	End of exposure [min]

In addition, in order to add up the respective toxicity of each gas, the law of additivity is applied. To do this, the sum of the doses associated with each gas is calculated as follows:

$$S_{SEI} = \sum_i \frac{D_i}{D_{SEI\_i}}$$

Where

D_{SEI_i}	=	Toxic dose at irreversible effects threshold for gas i [-]

If the sum S exceeds 1, the irreversible effect threshold is likely to be reached.

The results obtained for test B5 are presented in Table 2. The method is also used for the lethal effects.

	CO	CO2	HF	HBr	HCl	COF2	Halon	
n SEI	1,99	ND	1	2	1	1	ND	
n SEL	2,27		1	2	1,07	0,8		
D_{SEI} limite	62400000	ND	6000	1330000	2410	30	ND	
D_{SEL} limite	5090000000	ND	11100	108000000	21200	55		
Remarque						*Note: No known value for COF2. COCL2 level is considered.*	*Note: No value for Halon. Not considered into the computation.*	
	CO	CO2	HF	HBr	HCl	COF2	Halon	∑
D/D_{SEI}	0,01	ND	0,01	0,04	0,15	3,02	ND	>3.24
D/D_{SEL}	0,001	ND	0,007	0,000	0,025	0,746	ND	>0.78

Calculation of toxic dose

CONCLUSION

The results show, taking into account both the less penalising thresholds for COF_2 and omitting the halon effects, that the irreversible effects were reached given that coefficient S_{SEI} was greater than 1. Moreover, given the value obtained for the first lethal effects of 0.78, taking into account the non-penalising hypotheses, it is probable that the first lethal effects threshold was also reached.

Comparative audio analysis

Title: Result of cigarette and propagation tests

Tests carried out and audio pick-up sources available:
Six tests including a fire break-out in an oxygen box were carried out:

- Three tests were carried out in an oxygen box with glass panel to illustrate the fire damage sequence to the oxygen box and mask assembly.
- Three fire tests using a lateral storage compartment to analyse the propagation of the fire to the elements in the vicinity of the oxygen box.

During these tests, the audio pick-up sources consisted of:

- an oxygen mask microphone,
- a boomset microphone (placed close to oxygen box),
- a cockpit area microphone (CAM),
- one or more Gopro cameras.

Note: the signals from the oxygen mask, boomset and CAM microphones were recorded by a CVR.

All these tests were carried out with a 5-bar oxygen supply.

Description of tests (conditions and short description)

"Cigarette_00" test[1]:

An oxygen box with glass panel holding an oxygen mask nose cup equipped with its microphone. An "open" hose replaced the original hose of the oxygen mask (i.e. the oxygen mask regulator was not connected to the oxygen supply. The "open" hose reproduced a leak in the box upstream of the mask). The door was opened and then closed again and the supply of oxygen cut-off by means of the solenoid valve. A cigarette was placed in the oxygen box and the oxygen flow was opened again to create a continuous leak. The combustion of the cigarette - accelerated by the continuous flow of oxygen - quickly caused damage to the nearby elements with the fire spreading to the oxygen box + mask assembly.

"Cigarette_03" and "Cigarette_04" tests:

An oxygen box with glass panel holding an oxygen mask equipped with its microphone. The mask was connected to the outlet of the oxygen box valve. Pressing and holding the "Push To Test" pushbutton of the oxygen box enriched the oxygen box with oxygen. A cigarette was then placed in the oxygen box and its combustion caused an element to catch fire with the fire then spreading to the oxygen box + mask assembly.

"Propagation_01" test:

A lateral storage compartment equipped with two oxygen boxes (each holding its oxygen mask) connected to an oxygen supply controlled by a solenoid valve. One of the two oxygen boxes was modified (put in a "non-reset" configuration) and the mask inside it, set to the EMERGENCY position. The oxygen box was enriched with oxygen by opening the oxygen supply for 5 s. A flame was produced[2] inside the box and the solenoid valve opened again to allow a continuous flow of oxygen (via the mask EMERGENCY position) into the box. The elements of the box + mask assembly caught fire and the fire spread to their environment (lateral storage compartment).

[1] This test is not mentioned in the study

[2] Using a remote-controlled system

“Propagation_02” test:

A lateral storage compartment equipped with an oxygen box (holding its oxygen mask) was connected to an oxygen supply controlled by a solenoid valve set to open. The left door of the oxygen box was opened and then closed again without pressing the box’s “Push To Test” button (i.e. no reset). The oxygen box was enriched with oxygen by pressing the oxygen mask knob twice for a total time of 8 s[3]. A flame was then produced inside the box and the elements of the box + mask assembly successively caught fire. The fire caused an element to rupture resulting in a continuous oxygen leak. The fire spread to the immediate environment. A fire extinguisher was activated and completely emptied to try and put out the fire.

“Propagation_03” test:

A doc storage compartment equipped with two oxygen boxes (each holding its oxygen mask) was connected to an oxygen supply controlled by a solenoid valve set to open. The left door of the oxygen box was opened and then closed again without pressing the box’s “Push To Test” button (i.e. no reset). The oxygen box was enriched with oxygen by pressing the oxygen mask knob for 7 s. A flame was then produced inside the box and the elements of the box + mask assembly successively caught fire. The fire caused an element to rupture resulting in a continuous oxygen leak. The fire spread to the immediate environment. The oxygen supply was cut off and a fire extinguisher activated and completely emptied.

Definition:

Leaking noise: Broadband noise over the entire bandwidth of the microphone picking up the sound.

Sound runaway: Presence of noise bumps - broadband energy bumps - where the frequency increases rapidly to concentrate around 1.2 and 2 kHz (the phenomenon could be described in psychoacoustic terms as a "hissing sound increasing in pitch"). The sound runaway is accompanied by an increase in the overall noise level.

[3] 6 s then 2 s

Analysis of data:
The sound sequences picked up during these tests were analysed and compared with the sequence from flight MS804:

- Page #1 shows the waveform of the audio recording (oxygen mask microphone signal and CAM signal) during the "Cigarette_00" test and the associated sequence of images. In the presence of an established oxygen leak, the cigarette introduced into the box immediately ignited, and very quickly set fire to the entire box and its contents (oxygen mask). There was a sound runaway 2.5 s after the cigarette was introduced and the microphone on the oxygen mask stopped working 3.5 s after the mask ignited.

- Page #2 shows the waveform of the audio recording (oxygen mask microphone signal and boomset microphone signal) during the "Cigarette_03" test and the associated sequence of images. The cigarette introduced into the oxygen-enriched box progressively damaged the oxygen mask hose (28 s of crackling noises are present during which the combustion of the braided protection is visible) until the core of the hose was pierced. When the hose was pierced, there was a broadband noise followed 1s later by a sound runaway. The fire that immediately followed the piercing of the hose very quickly engulfed the entire box and its contents (oxygen mask). The oxygen mask microphone stopped working 6 s after the mask caught fire.

- Page #3 shows the waveform of the audio recording (oxygen mask microphone signal and boomset microphone signal) during the "Cigarette_04" test and the associated sequence of images. The cigarette introduced into the oxygen-enriched box progressively damaged the oxygen mask hose (22 s of crackling noises are present during which the combustion of the braided protection is visible) until the core of the hose was pierced. When the hose was pierced, there was a broadband noise followed 0.5 s later by a sound runaway. The fire that followed the piercing of the hose very quickly engulfed the entire box and its contents (oxygen mask). The oxygen supply was cut off 5 s after the mask ignited and before the oxygen mask microphone was damaged.

- Page #4 shows the waveform of the audio recording (GOPRO camera sound band) during the "Propagation_01" test and the associated sequence of images. Smoke and flames could be seen coming out of the oxygen box 5 s after the remote lighting of a cotton pad placed in the bottom of the oxygen box. The mask hose was probably pierced 18 s after the start of the fire. This was shown by a broadband noise followed 1s later by a sound runaway. The fire that followed the piercing of the hose spread rapidly to the surrounding elements. The leaking noise suddenly stopped for 0.5 s - without any action by the test operators - 50 s after the mask hose was probably pierced. This short interruption in the leak preceded a detonation, the resumption of the leak and the enrichment of the fire.

- Page #5 shows the waveform of the audio recording (oxygen mask microphone signal and CAM signal) during the "Propagation_02" test and the associated sequence of images. Smoke and flames could be seen coming out of the oxygen box 6 s after the remote reactivation of the cotton pad fire in the bottom of the oxygen box[4]. The mask hose was probably pierced 13 s after the reactivation of the fire. It was preceded over the same period by cracking noises picked up by the oxygen mask microphone. The probable piercing of the hose produced a broadband noise. The sound runaway described for the previous tests was not perceived. The fire that followed the piercing of the hose spread rapidly to the surrounding elements. The leaking noise was continuous until the oxygen supply of the test set-up was cut off.

[4] The initial break-out did not last; the fire did not spread in the box.

The oxygen mask microphone stopped working 5 s after the probable piercing of the oxygen mask hose.

- Page #6 shows the waveform of the audio recording (oxygen mask microphone signal and CAM signal) during the "Propagation_03" test and the associated sequence of images. Smoke and flames could be seen coming out of the oxygen box 7 s after the remote lighting of a cotton pad placed in the bottom of the oxygen box. The mask hose was probably pierced 14 s after the start of the fire. It was preceded over the same period by cracking noises picked up by the oxygen mask microphone. The probable piercing of the hose produced a broadband noise followed 0.5 s later, by a sound runaway. The fire that followed the piercing of the hose spread rapidly to the surrounding elements. Cutting off the oxygen supply - which preceded the use of the fire extinguisher - stopped the leaking noise.

- Appendix 7 shows for comparison purposes, the waveform of the CVR audio recording of MS804 (co-pilot's oxygen mask microphone signal and CAM signal).

Results:
It was observed during these tests that:

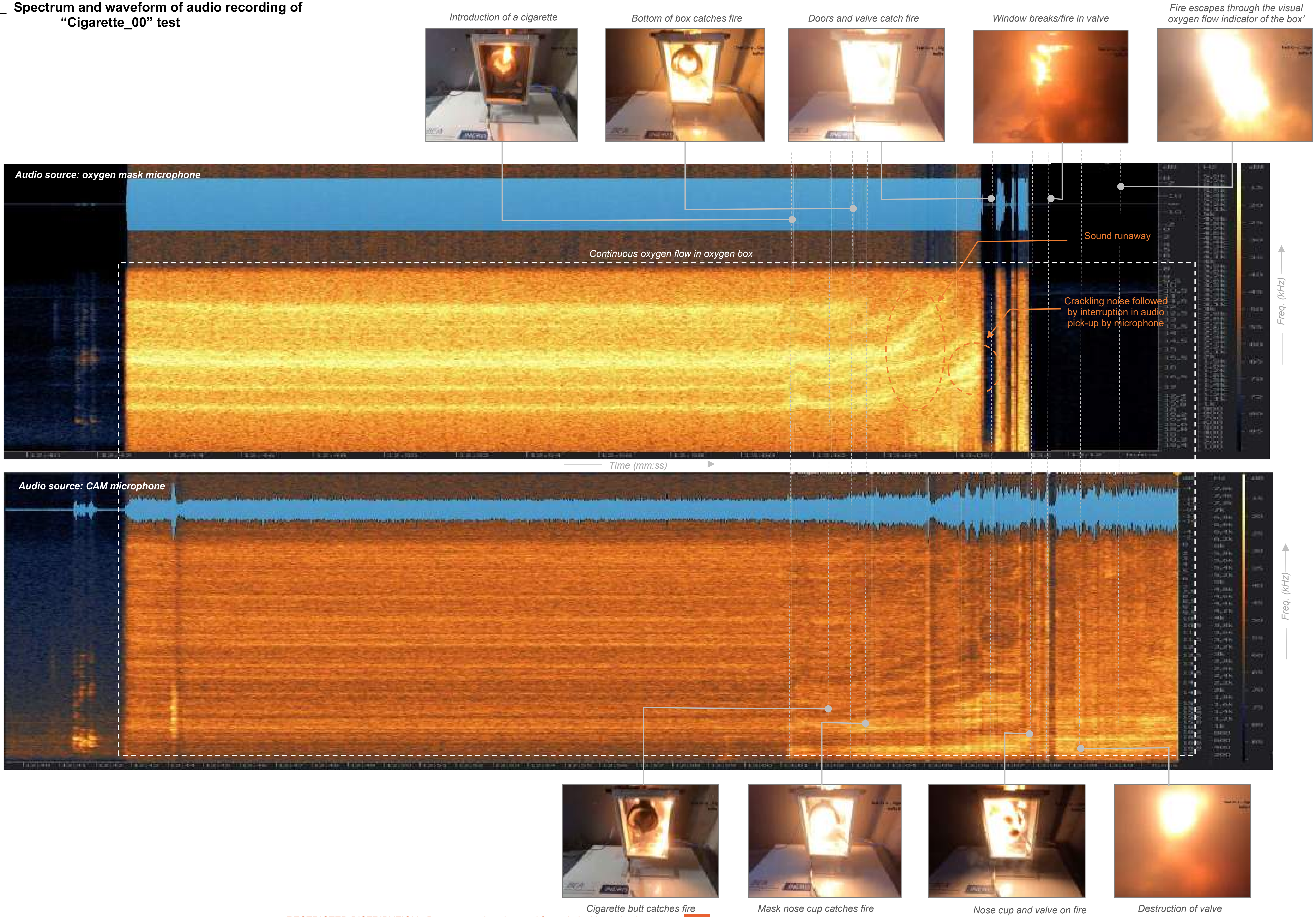
- The introduction of an external, glowing or ignited object into an oxygen box caused slow combustion of the protective elements of the oxygen distribution hoses of the assembly; the hose was pierced between 13 and 28 s after the introduction of an outside element into the crew oxygen assembly (oxygen mask and box). This slow combustion was accompanied by characteristic crackling noises.
- A sound runaway was present when the mask assembly caught fire.
- A screeching noise may precede the loss of signal from the oxygen mask microphone.
- The degradation mechanism produced by the propagation of the fire to the environment of the mask storage boxes (lateral storage compartment) seems to present significant and uncontrolled variations; these variations were shown by differences in the audio phenomena picked up with random variations in the level and timbre of the sound. During these tests there was one case of an unexplained interruption in the leaking noise for 0.5 s, followed by a detonation.

Comparison with the CVR recording of flight MS804:

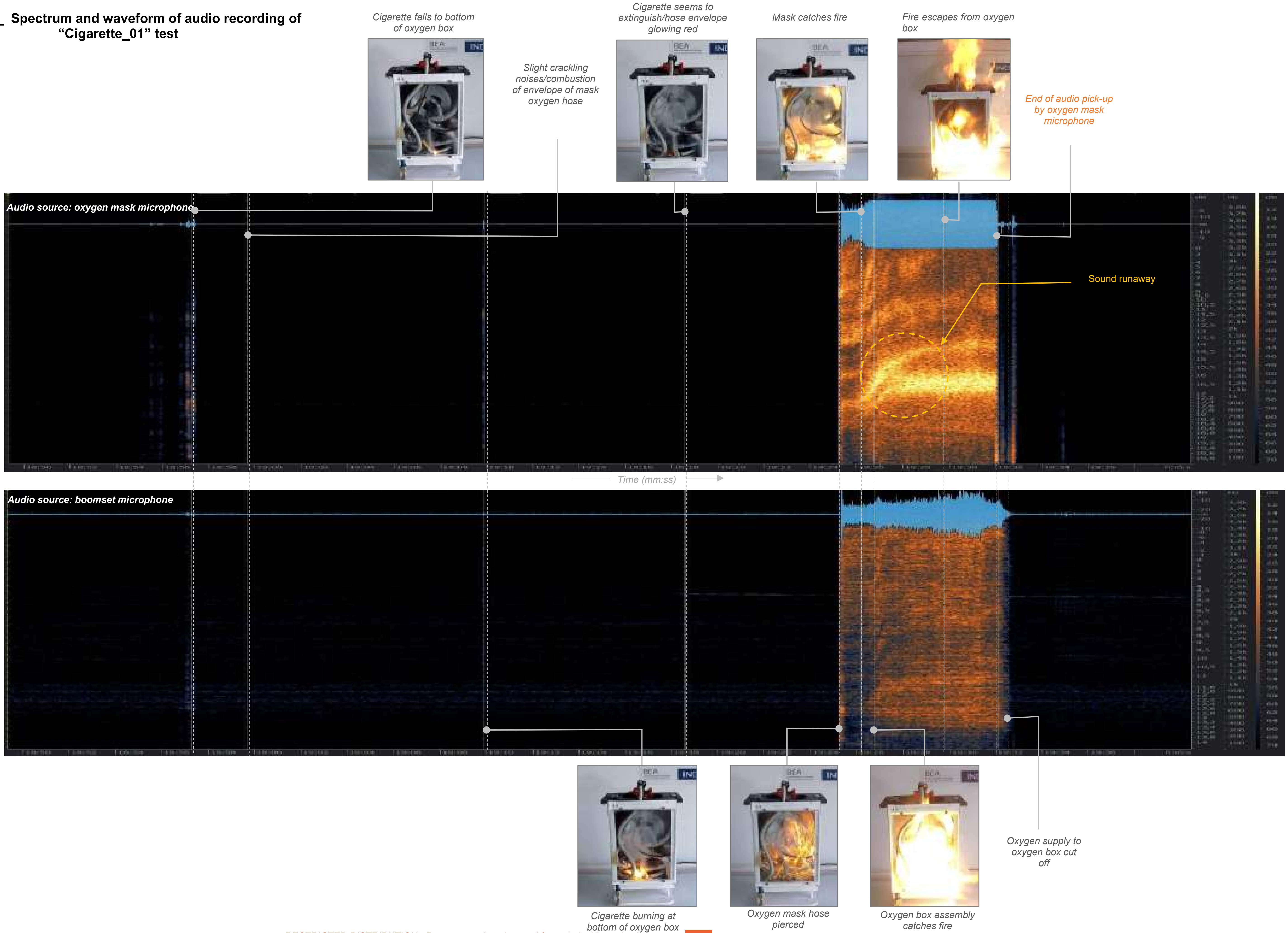
- No crackling noise can be perceived in the recording from the co-pilot's oxygen mask microphone.
- A sound runaway was present on the co-pilot's oxygen mask microphone and CAM channels at 00:25:31(EVT6). This noise can probably be attributed to the co-pilot's oxygen mask catching fire.
- The screeching noise that preceded the loss of the microphone signal from the co-pilot's oxygen mask at 00:25:33 (EVT7) was probably produced by the destruction of the mask microphone by the flames.
- The momentary interruption (510 ms) of the oxygen leak at 00:25:42 (EVT8) was probably produced by damage to the oxygen assembly[5] located in and/or under the lateral storage compartment.

[5] Oxygen supply T-connections and hoses on the two oxygen boxes (co-pilot and third person)

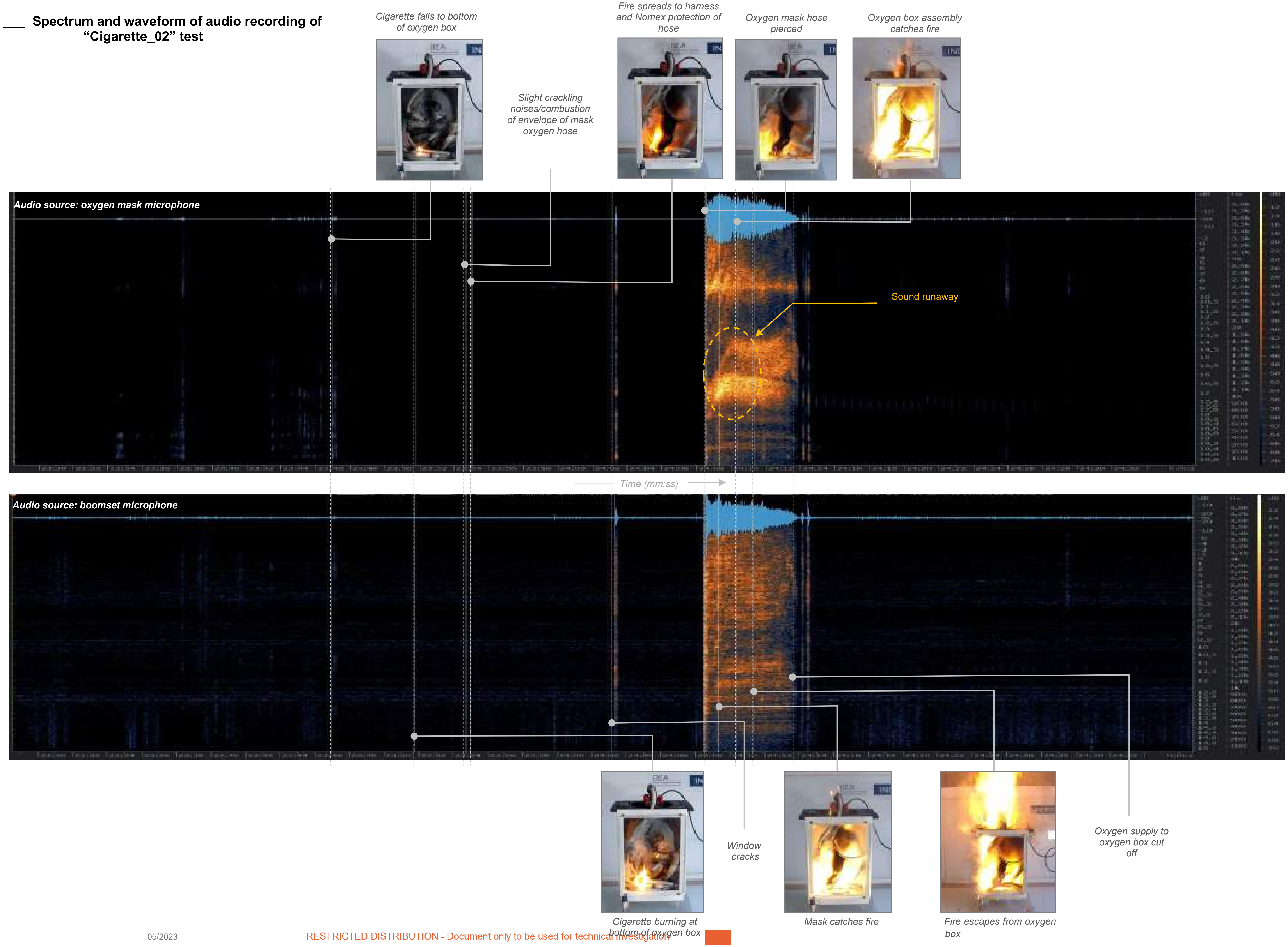
1 ___ Spectrum and waveform of audio recording of "Cigarette_00" test



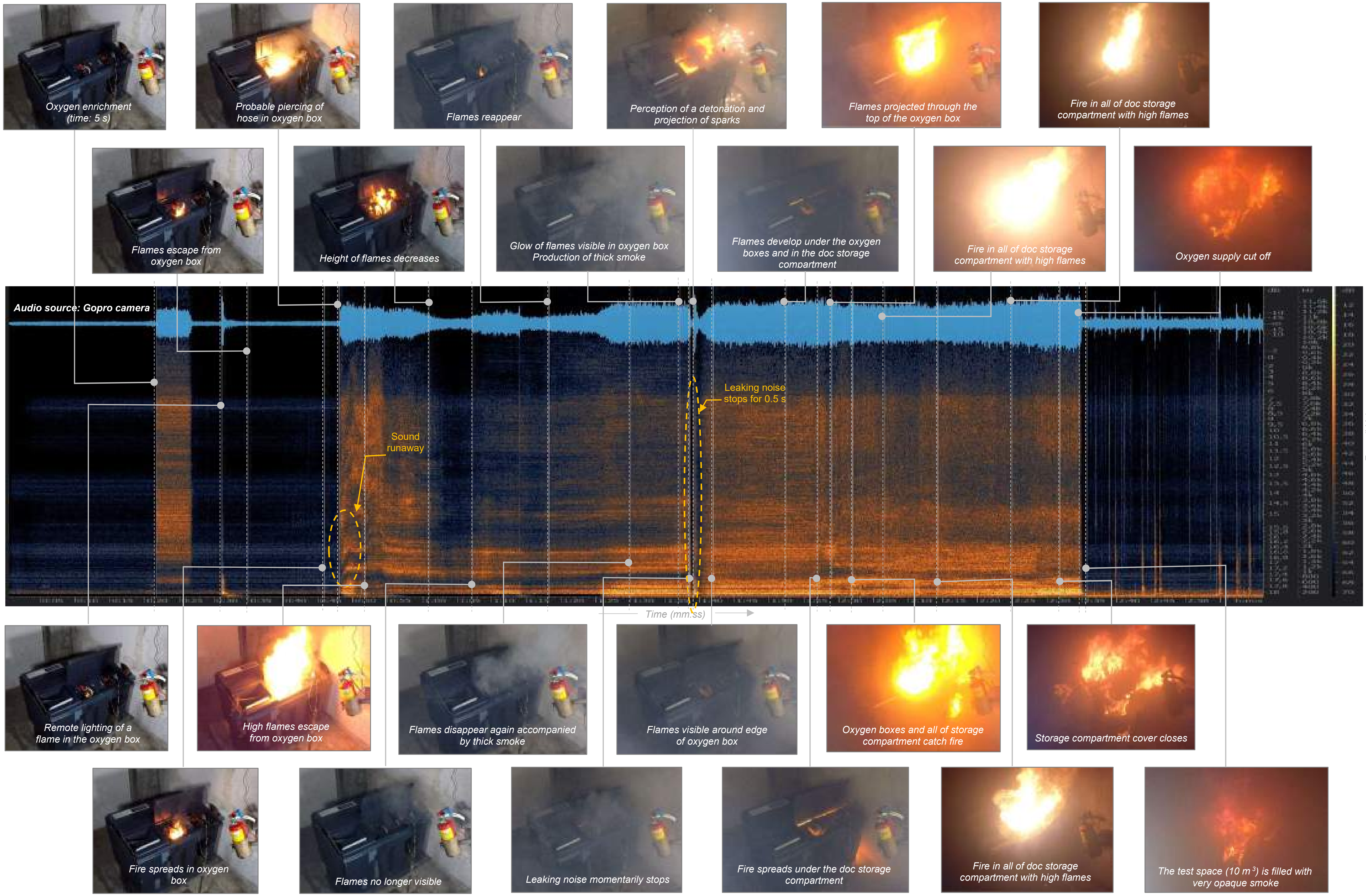
2 ___ Spectrum and waveform of audio recording of "Cigarette_01" test



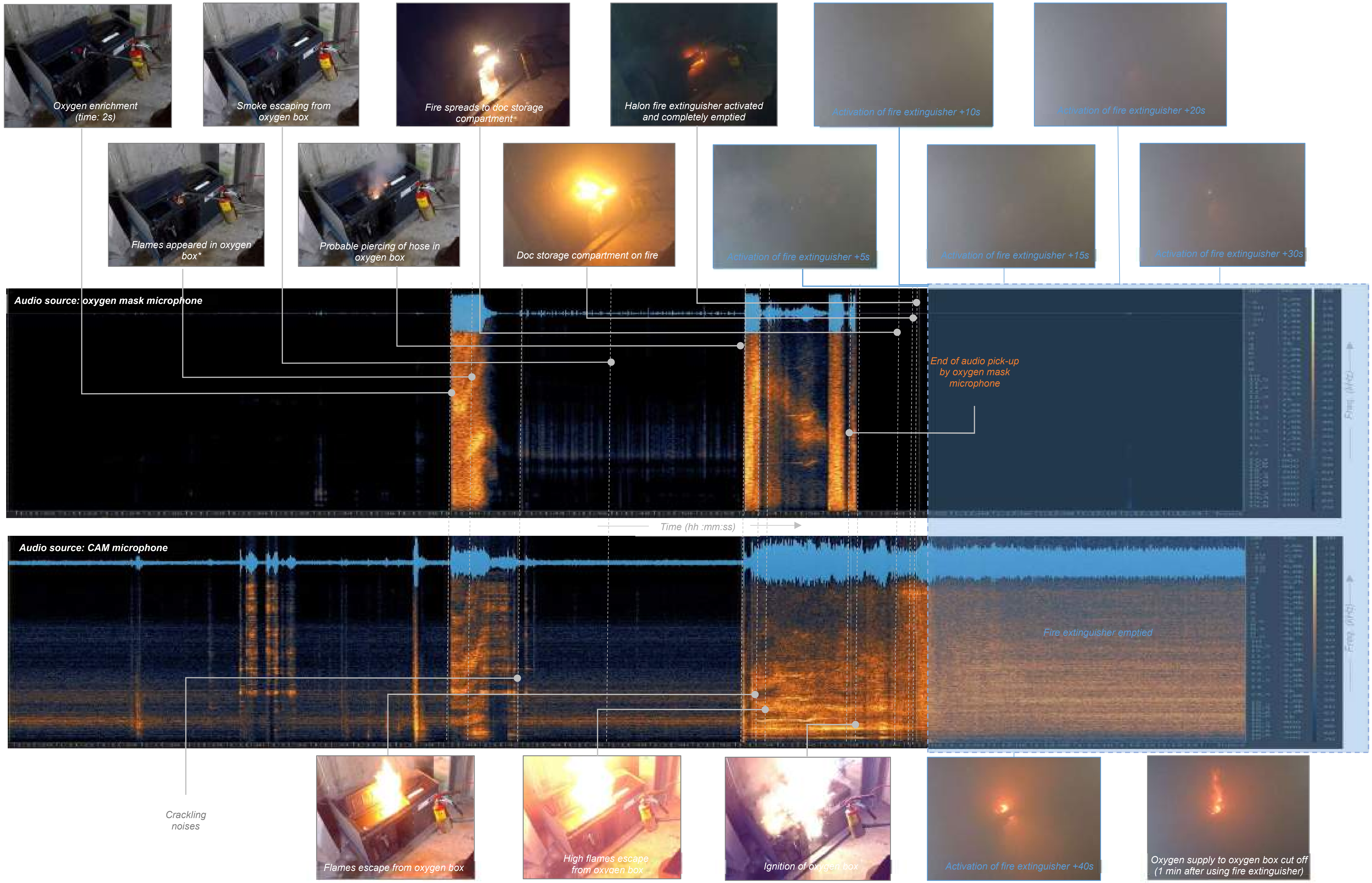
3 ___ Spectrum and waveform of audio recording of "Cigarette_02" test



4 ___ Spectrum and waveform of audio recording of “Propagation_01” test

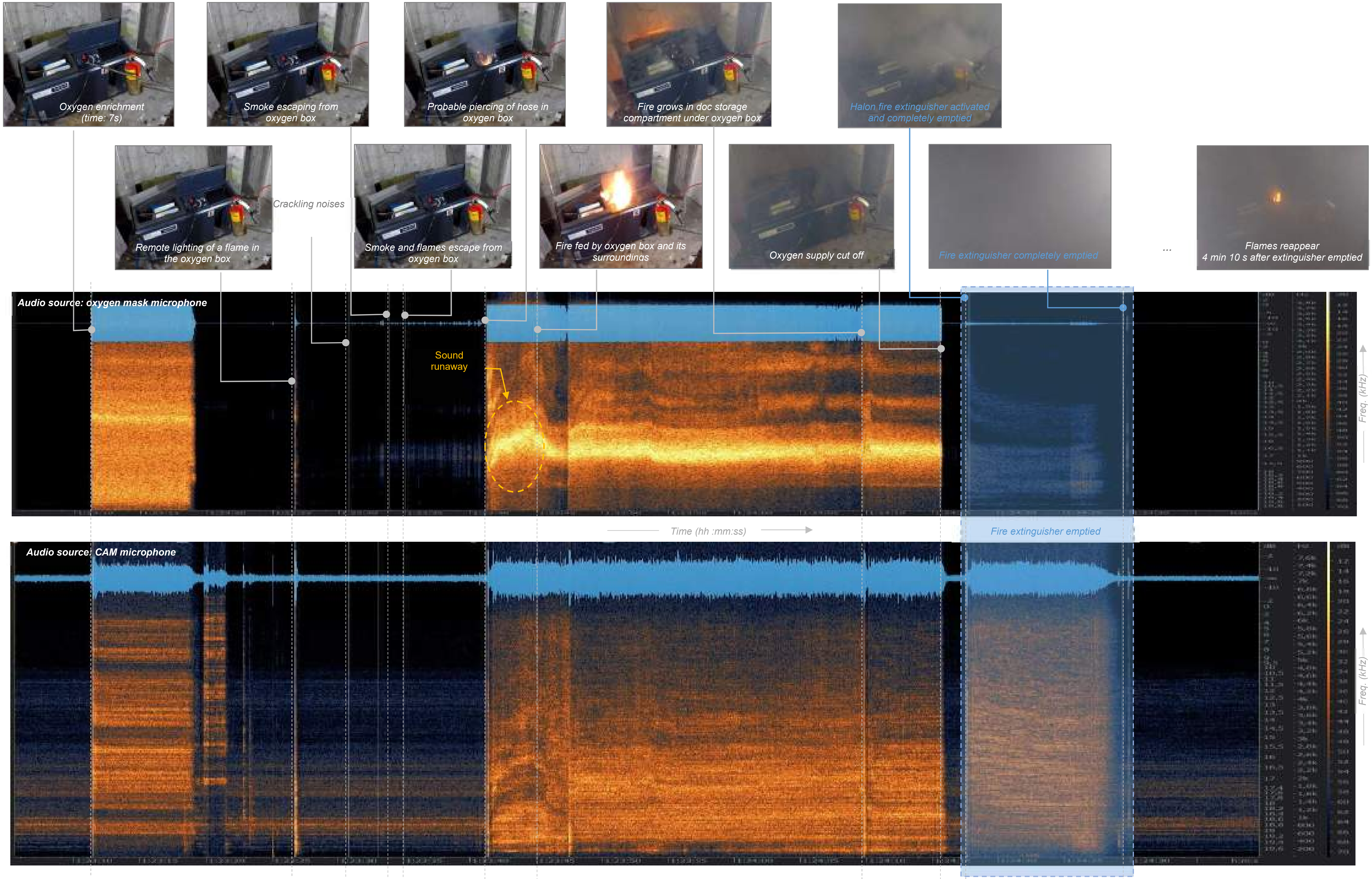


5 ___ Spectrum and waveform of audio recording of “Propagation_02” test

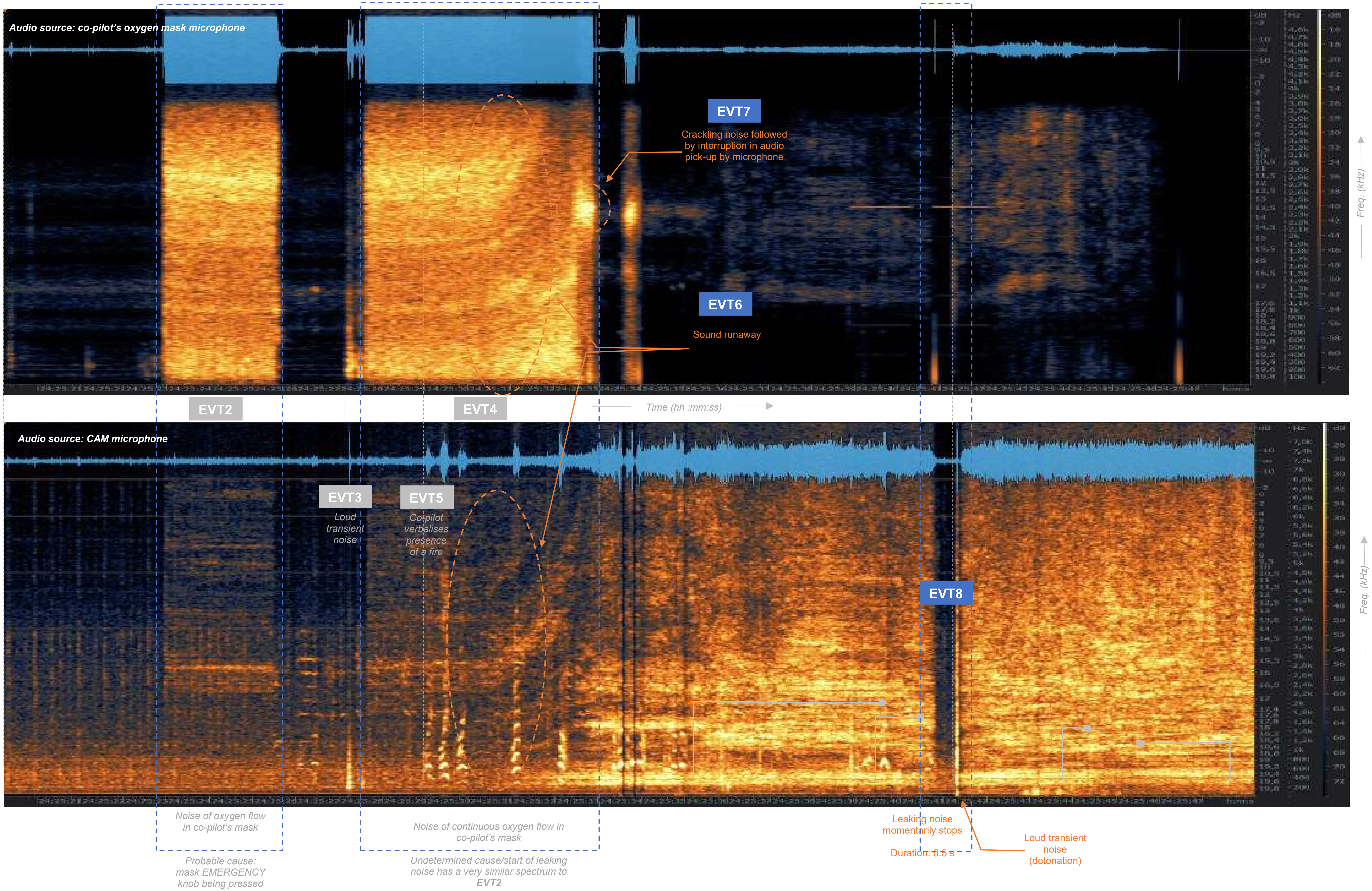


* residual embers from a previous aborted remote lighting of a fire flame up

6 ___ Spectrum and waveform of audio recording of "Propagation_03" test



7 ___ Spectrum and waveform of occurrence recorded on CVR of MS804



Ignition of hydrocarbon oil and greases

This document is based on the knowledge and experience of both the oxygen system manufacturer SAFRAN AEROSYSTEMS and the WHA[1] institute specialized in Oxygen Fire Risk Analysis (OFRA).

(…) WHA provides failure analysis services (…) ignition of hydrocarbon oils and greases has frequently been implicated in oxygen fires for the last several decades. Their low AIT[2] in oxygen, as well as their high heat of combustion combine to make them very undesirable in oxygen systems. WHA test experience and failure analysis experience also indicate that these oils and greases are among the most easily ignited materials in oxygen systems, especially as oxygen pressure/temperature increases and as ignition mechanisms such as compression heating become more severe.

Pressures in the 1 MPa range are low, but, under a sufficient ignition energy, if the hydrocarbon contaminant exists in the right concentrations, then ignition can certainly occur. WHA have been able to ignite hydrocarbon contaminants as test samples in our adiabatic compression test system at pressures as low as 2-3 MPa. WHA failure analysis experience also has indicated that with contaminated hospital systems, operating in US Hospitals at less than 1MPa, fires have developed in oxygen ventilators where hydrocarbon contaminants have been identified by chemical analysis where they shouldn't be in the post-fire residues, both upstream and downstream of the fire's origin location, implicating them in the ignition process.

ASTM standards G 63 and G 93[3] address the concerns with hydrocarbon oils/greases, ASTM G63 from an ease of ignition standpoint and ASTM G93 from a cleaning standpoint. It is noteworthy that the guidance from these two standards is generally harmonized with the standard guidance from EIGA, CGA, and other oxygen practitioners worldwide.

The following provides some of the discussion in ASTM G63 pertaining to hydrocarbon contaminants (*underlining is for the purpose of this annex*):

5.2.1 <u>Factors Affecting Ease of Ignition</u>—Generally, when considering a material for a specific oxygen application, one of the most significant factors is its minimum ignition temperature in oxygen. Other factors that will affect its ignition include relative resistance to various ignition energies, geometry, configuration, specific heat, relative porosity, thermal conductivity, preoxidation or passivity, and "heat-sink effect." Heat-sink effect is the heat-transfer capacity of the material relative to that of the material in intimate contact with it, considering the mass, physical arrangement, and physical properties of each. For instance, a gasket material may have a relatively low ignition temperature but be extremely resistant to ignition when confined between two steel flanges. <u>The presence of a small amount of an easily ignitable contaminant, such as a hydrocarbon oil or a grease film, can promote the ignition of the base material</u>. Accordingly, cleanliness is vital to minimize the risk of ignition.

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[1] https://wha-international.com

[2] AIT : Auto Ignition Temperature

[3] ASTM G 63, *Standard Guide for Evaluating Nonmetallic Materials for Oxygen Service* and ASTM G 93, *Standard Guide for Cleanliness Levels and Cleaning Methods for Materials and Equipment Used in Oxygen-Enriched Environments*

(It is difficult to find AIT data for hydrocarbon oils/greases because they are universally avoided in oxygen systems. However, ASTM G 63 does publish the following for hydrocarbon oils as a comparison to other classes of oils)

7.8.6.3

Oils in these candidate classes are found to have the following autoignition temperatures in Table X1.2:

CTFE 374 °C to 427 + °C
PFPE 410 °C to 427 + °C
PE 235 °C to 266 °C
Fluorosilicone 232 °C to 249 °C
<u>HC 190 °C to 199 °C</u>
Silicone 216 °C to 241 °C

The following are from ASTM G93 (*underlining is for the purpose of this annex*):

10.1.4

Fluids Versus Solids—Through the years, more attention has been focused on fluid oil films than on solid contaminants. This is due to several reasons. <u>Oil films tend to be more easily ignited. They migrate. They vaporize. They are more likely to be present in greater total amounts</u>. Also, when an oil film is scrupulously removed, it is likely that there will be little if any unacceptable particulate contaminant remaining.

10.1.2.2

Adiabatic compression is the primary ignition mechanism of oils and greases, <u>having produced ignition experimentally at approximately 6 mg ⁄ft2 [65 mg ⁄m2]</u>; also, <u>migration</u> and collection of nonviscous oils <u>appears to occur above ~20 mg ⁄ft2 [~220 mg ⁄m2]</u>. This suggests 6 mg⁄ft2 [65 mg ⁄m2] may be the highest conservative limit that may be applicable for incompatible oils in severe service. In a system that does not experience rapid compression, this conservative limit might be extended to 20 mg ⁄ft2 [220 mg ⁄m2] on small components or regions that are difficult to clean whether they are part of larger systems or not.

In addition to the above, WHA has tested some representative mineral oils and hydrocarbon hydraulic oils for their AIT using ASTM Standard G72 (at 1500 psig) and have obtained the following results:

Mineral Oil 238 °C AIT

Hydraulic Oil 222 °C AIT

These AITs were obtained at elevated pressure; but, the AIT of many hydrocarbons may not change with pressure too substantially.

(…)

Appendix 12 Grease ignition

Exhibit F

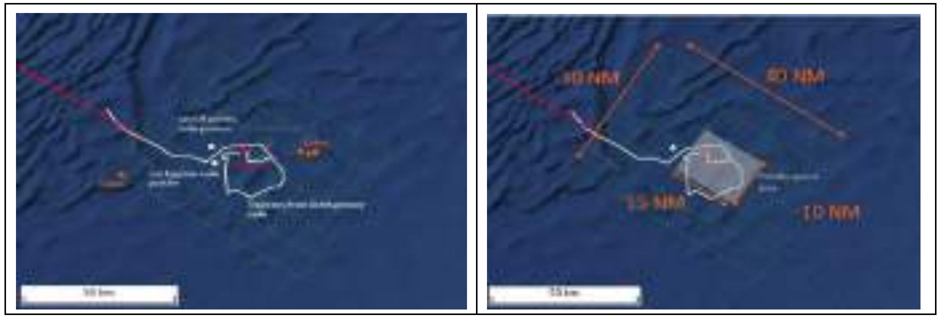
EAAID response to comments received concerning the Draft Final Report and comments appended

EAAID response to BEA comments received dated 31/7/2024 concerning the Draft Final Report for Accident, Aircraft Registered SU-GCC, Airbus A320-231, Flight number MSR 804 from LFPG to HECA on 19/05/2016

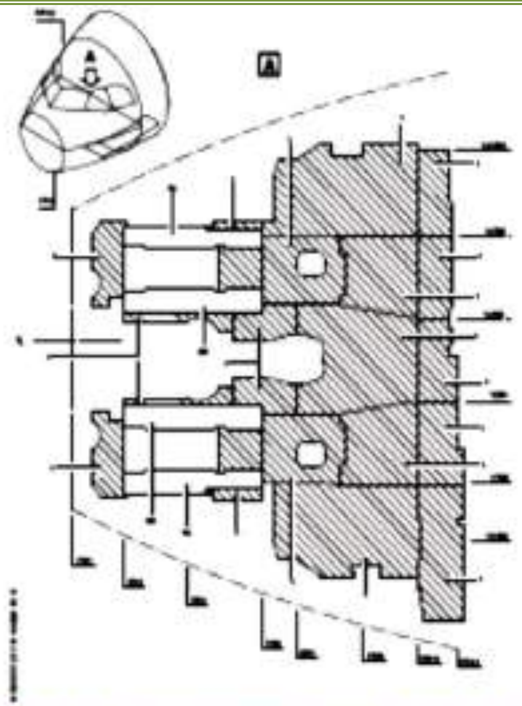
EAAID response to the received comments

General

- After the accident took place the EAAID invited states participating in the investigation, the accredited representatives and their advisors arrived to Cairo. They were gathered for the initial meetings in EAAID headquarter to start coordination work and set plan for human remains and wreckage retrieval from seabed.
- By coordination with the French side it was agreed to lease the ship (John Lethbridge) for search and retrieval.
- Experts from Egypt, France and Airbus boarded the ship and collaborated in wreckage retrieval phase.
- Also collaborated on identification and classification of retrieved wreckage parts on ship.
- Airbus issued Debris survey - Part identification report in June 2016. This report helped the investigation committee in the wreckage investigation activities and the preparation of the draft final report.
- On May 21st, 2017 the EAAID issued a technical statement report.
- On June 02nd, 2017 the BEA issued a contribution report.
- On October 20th, 2023 the EAAID received a study on the oxygenated fire from the BEA.
- In December, 2023 the EAAID received amended study on the oxygenated fire from the BEA.
- During the preparation phase of the draft final report the EAAID sent those finished parts of the draft final report to the French side for consultation.
- Within the period before issuing draft final report four online meetings were held with the French side on February 15th, March 12th, May 2nd and June 25th 2024.
- On June 30th, 2024 the draft final report was issued and sent to all participating states.
- On July 2nd, 2024 the EAAID received the amended version of the French study.
- On July 31st, 2024 the investigation committee received the BEA comments on the draft final report. The committee did not receive comments from other participating states until August 28th 2024 which was the deadline for receiving comments.
- On October 24th, 2024 EAAID received the final version of the French study that was originally issued on October 2023 for inclusion in the final report, the EAAID appended it in Exhibit E of the final report
- In accordance with paragraph 6.3 of ICAO Annex13, The following table includes the BEA comment, the EAAID response and the impact on final report.

ITEM	BEA Comments	EAAID response	Impact on final report
Significant comment A– Main factual discrepancies			
Sub Theme Wreckage Debris field	Two investigators from the BEA and two Airbus specialists participated in the first part of the recovery of the debris. Based on their observations, the following clarifications are necessary: The debris of the aircraft was scattered in a rectangle measuring 1.2 km by 525m. All extremities of the aircraft were located within the identified rectangle: cockpit, wings and tail parts. The small size of the debris is consistent with a high energy impact with the water surface.	- The Wreckage recovery priority rectangle was 1.2 km by 525m. Other aircraft parts existed outside this rectangle as illustrated in the below figures (30 X40 NM) according to History of operations report dated 25th June 2016, EgyptAir Sea Search Operations presentation dated 21th September 2016 and Contribution report dated 2nd June 2017 issued by BEA. - The Exact structural condition of the accident aircraft cannot be predicted. - Partial aircraft break up in flight cannot be confirmed or refuted.  	– BEA comment attached in Exhibit F. – The Wreckage recovery priority rectangle was 1.2 km by 525m. Other aircraft parts existed outside this rectangle was added to the final report for more clarification.

Parts from cockpit affected by fire	When listing the parts of the aircraft affected by heat, the report omits to mention the parts from the cockpit (references #21, #31, #25, #37). These parts not only exhibit dark spots but also show traces of soot and heat exposure. Furthermore, the traces of fire on the forward fuselage part with stand by static port are located on the upper part of the wreckage piece, just under the R/H side window of the cockpit, above the floor. Electric cables with their insulation layers are located below the cockpit floor in the avionics compartment. Therefore, the deduction "Wire insulations in part 31 were intact leading to the conclusion that temperature was not high enough to affect wire insulation. This highly suggest that the fire did not originate in the right hand side of the cockpit" is false and misleading.	1- Part #21 is the upper central segment of Frame 20 which is well out of the cockpit (as the cockpit ends at frame 12, where cockpit door is fitted). So it is 8 frames away from cockpit. And is not part of cockpit (thus indicating fire outside the cockpit.) 2- Part #37 (Fuselage skin RHS extending from frame 23 to frame 24 which is 11 frames away from the cockpit) is not part of cockpit (thus indicating fire outside the cockpit.) 3- Part #25 (Upper third part of the FWD RHS PAX door.) which is definitely outside the cockpit (thus indicating fire outside the cockpit). 4- Part #31, having soot coincides with scenario 3 of the draft final report where fire (which have started outside the cockpit) propagated to the cockpit from the right hand side, yet electric cables with their insulation layers are located above and under cockpit floor level, The space between the cockpit interior and fuselage skins is not divided by cockpit floor panels as cockpit floor panels do not cover the whole area from RHS fuselage to LHS fuselage skins , there is an undivided empty space between cockpit interiors and fuselage skins as shown in figure below so the area where electric wires run between cockpit interiors and fuselage skin is one undivided space . (as per Airbus Structure Repair Manual , SRM 53-12-11-01-A , shown below)	– BEA comment attached in Exhibit F. – The photo with zoom-in clarification will be inserted in final report.

	In total, after adding the 4 additional parts mentioned above, twelve pieces were identified as having been affected by fire and/or high temperature. Some of them are parts of the passenger cabin, some are from the cockpit and structure.	 Figure 53-12-11-992-001-0 (SHEET 1) - Panels - Cockpit Floor ** ON A/C MSN 00001-19999 Photo of the debris below, shows the intact insulation wire immediately below the RHS window side console significantly above cockpit floor level. (Refer to Draft final report item 2.11 (sub-item 3).	

The above photo is inserted in final report for more clarification.

BEA contribution report page 11/29 Fig. 3, Airbus Debris survey –part identification page 49, Pic. 4/5 nose fuselage frame 3 to 8 area (D149) show the intact wire insulation above floor level.

If the fire had started at the oxygen box RHS and propagated then, the electric wires insulations would have been affected by heat which was not the case as shown in the above photo and referred reports.

Concerning the 12 parts affected by fire and/or high temperature, only one part (part #31) is in the cockpit

Sub Theme Timing discrepancies in flight data			
Accuracy of ATSU data and sequence of warnings	Regarding the timing of the different sources of flight data, the BEA emphasizes these limitations: - The FDR data timestamp includes seconds and has to be taken as the reference - The ATSU data timestamp includes seconds but this time does not correspond to the exact time of occurrence. The accuracy of the timing has to be indicated (it is not known if the timing corresponds to the emission of the signal or its reception or its recording). The sequence differs from that of the Current Flight Report (CFR) data provided earlier. As a consequence, the timing sequence of warnings (Lavatory smoke, Anti-ice right windows, Avionics smoke, Right sliding window sensor, Right fixed window sensor) is inaccurate and should not be used as such for the establishment of a scenario. The lavatory smoke warning preceded the avionics smoke alarm by 46 seconds. Although this sequence of alerts might suggest that the fire started in the cabin, this fact taken in isolation cannot be conclusive.	The FDR/CVR has already been taken as the primary reference in the draft final report. The ATSU messages time received was changed with ARINC raw data message generation time recorded in HH:MM format. The ARINC raw data messages were referred to as a supporting data and not primary reference. e.g. : "draft final report item 2.12.3 findings • At 00:26:14 Lavatory smoke started, continued to the end of the recording as shown by the FDR, master warning came on after one second supporting this information. This lavatory smoke warning was supported by ARINC Raw Data. • At 00:27:00 Avionic smoke started, continued to the end of the recording as shown by FDR. ARINC Raw Data supported the avionics smoke detection. The ECAM messages downlinked from ATSU can be retrieved as raw data through ARINC Hermes web based application or viewed on AIRBUS AIRMAN web based application.	– BEA comment attached in Exhibit F. – The ATSU messages time received was changed with ARINC raw data message generation time for clarification.

	Therefore, a fire in the cockpit could also have led to this sequence. Additionally, there was no cargo smoke warning.	All CFD messages downlinked from the aircraft were forwarded from ARINC to Airbus in order to be interpreted and displayed on AIRBUS AIRMAN. Based on the fact that the design of the A320 lavatory and avionics compartment have completely isolated and separate ventilation systems from each other, and consequently completely separate smoke detection units (detailed in section 1.6 of draft final report) so, if a fire had started and propagated from the cockpit it would have definitely generated avionics smoke warning prior to lavatory smoke warning, not lagging it by 46 seconds as evident by FDR. As per the FDR the SDCU failed and the cargo smoke warning were recorded at the same time (00:29:35). Therefore, the investigation committee concluded that this warning was unreliable.	
Accelerometers - recorded values at the end of the FDR recording	At the end of the FDR recording (at 00 h 29 min 43 s), the recorded values of the three accelerometers dedicated to the FDR show spikes that are not consistent with a realistic aircraft movement. There is no correlation between these acceleration values and altitude, attitude (on the three axes) and	FDR data is valid up to 00:29:45 seconds. The sudden changes in the acceleration values occurred at 00:29:44, 00:29:45. This indicates that these changed occurred within the valid data recorded by the FDR.	– BEA comment attached in Exhibit F. – Item 2.13.2.1 Regarding the Load factors changes" in the draft final report will be updated to better explain the EAAID view.

	speed parameters. From that time, the accelerometers values recorded in the FDR are no longer valid. These abnormal variations might be the consequence of damages in the cockpit or in the avionic bay caused by the growing fire. The accelerometers are located near the aircraft center of gravity but the power supply wires, or the wiring connecting the accelerometers to the data concentrator computer, could have been affected by the fire at that time. Additionally, the BEA database contains some recording flight parameters from accidents with inflight explosions produced by explosive materials or missile strikes. The impact of an explosion on acceleration is quite different from the variations recorded on these parameters at the end of the FDR recording of the flight MS804. Therefore, the recorded values of the accelerometers at the end of the FDR recordings should not be used as an input for the establishment of a scenario	The altitude, attitude (on the three axes) and speed parameters shall be affected by the changes in the accelerations. However, the time interval recorded for the acceleration sudden changes is very short (2second), and the speed and attitudes changes are deducted by integrating these acceleration, therefore the changes in the other parameters might not be noticed through this very short period of time. Explosions can widely vary in type, location and magnitude, BEA Accidents database cannot be used for proving that these changes in acceleration are not valid. Validity of the acceleration changes at the last valid two seconds cannot be ruled out.	
ELT	Regarding the ELT, the first burst occurred at 00 h 36 min 52 and the second one at 00 h 36 min 59. The two bursts were emitted in test mode. The ELT 406 ATP manufacturer	ELTs are designed to function in case of accidents. It is an extreme remote possibility that the ELT would operate due to fire rather	– BEA comment attached in Exhibit F.

	(SAFRAN Electronic, formerly KANNAD) indicated to the BEA that this type of emergency beacon is equipped with only one electronic G-Switch that triggers in the case of a +2.0 to +2.6G acceleration in the longitudinal axis only (i.e the axis of the beacon installation on-board the A320). The reference to the three axis sensors is therefore incorrect. Although the ELT can be activated either to the detection of high acceleration lasting several seconds or manually (via manual command from the cockpit), the double emission of a test mode signal by the ELT during MS804 flight is not the behavior expected when activated by high acceleration. The activation of the ELT may have been accidental due to fire damage on the command line; indeed this line runs from the cockpit to the cabin via the upper central area. This possibility must not be ruled out.	than due to the high acceleration induced through the accident. It is concluded that the sudden changes in the accelerations are still valid and should not be ruled out. The EIAAD adapts the manufacturer information in the final report. Triggering acceleration value will be updated to 2.0 to 2.6 in the longitudinal axis only (i.e. the axis of the beacon installation on-board the A320), instead of 2.3 g.	– Final report changed ELT operating specifications to adapt manufacturer information
Sub Theme CVR and audio system	The BEA identified several significant inaccuracies and errors in the description of the on-board audio system, its operation, and the organization of the sound sources that feed it. These inaccuracies include:	▪ The draft final report included CVR system description (Item 1.6.14) with all figures illustrated are extracted from Aircraft Maintenance Manual (AMM).	– BEA comment attached in Exhibit F. – Illustrations from (AMM- FCOM- CMM- ASM) were added and others replaced for more clarification.

	- The lack of description of the wiring path for audio and CVR signals (See BEA study figure 18 p. 37). - The omission of the fact that the ACP/RMP does not manage the selection of microphone sources recorded by the CVR. (See BEA study appendix 1, Functional Description of the CVR Audio System). - Omissions in the description of the progressive losses of the various sound sources (see BEA study 4.6.2, Pick-up Sources). - The assertion that communications picked up by the headset microphone are not clearly audible when the oxygen mask microphone is active (See BEA study appendix 2, Audio Pick-up by Oxygen Mask Microphone). - A lack of precision and analysis regarding the beginning and end of the various oxygen flow noises in the "Tests and Research regarding the Inflight F/O Oxygen Mask Microphone Flow Test" (See BEA study appendix 5, EVT2). These factual discrepancies lead to the misinterpretation of the CVR sequence, particularly with regard to: - the signal degradation and gradual loss of the various capture sources	The draft final report included system illustrations: - CVR System description audio system (Item1.6.14) - CVR components location in the cockpit (Item1.6.14.2) - Oxygen mask microphone circuit block diagram (Item1.6.14.4). However, new illustrations from (AMM- FCOM- CMM- ASM) regarding item 1.6.14 were added and others replaced for more clarification. ▪ The draft final report stated the description of the wiring path in the general note (Item 2.10.2.2). ▪ The draft final report stated the sources of recording for CVR 5 audio tracks from the 4 recorded channels in details (Item 2.10.2.1) which showed that the ACP/RMP does not manage the selection of microphone sources recorded by the CVR. ▪ The draft final report stated the description of CVR Channels Content for 5 audio tracks from the 4 recorded channels and sources of recordings (Item 2.10.2.1). The draft final report stated sequence of main events table and audio tracks analysis with	

	- the pick-up by the co-pilot's oxygen mask microphone - the position of the emergency rotator on the co-pilot's oxygen mask Furthermore, the BEA participated in working sessions on the audio analysis of explosive events with different national safety investigation authorities. In addition, the BEA audio database contains some audio samples from on-ground and inflight explosion noises produced by explosive material or missile strike. It shows that the cockpit ambiance microphone is very sensitive to solid-borne and airborne noise transmission. An explosion noise at the galley level is normally picked up by the CAM due to both the wave shock transmitted by the structure and the over pressure produced by the blast. EAAID did not provide any evidence or analysis of the noises heard on the CVR consistent with an explosive material explosion. This absence should be mentioned in the report.	highlights including disconnect of microphones and status of radio communication (Item 2.10.2.2). ▪ The draft final report concluded that first officer boomset microphone was a hot microphone during the whole flight and oxygen mask microphone was only activated at the event time (Item 2.10.2.2). The BEA study appendix 2 discussed 4 audio samples showing pick up of hot microphone when oxygen microphone is active to compare them with MS804 based on acoustic analysis but no other evidence on CVR support this hypothesis. - Figure for microphones activation from AMM (Item 1.6.14.3). - The draft final report included a table showing communication with ATC in last 2 hours, all were done by the first officer (Item 2.10.2.3) ▪ Regarding the ‘Inflight F/O oxygen mask microphone flow test’: The test had a different approach from BEA tests, the objective of the test was to compare: - Sound intensity. - Wave form in the four channels.	

		Therefore, the oxygen flow time was not a factor in this test. ▪ Based on ICAO Doc. 9756 part 3 chapter 19 item 19.2.14, only on rare occasions the CVR has given a clue of the detonation of an explosives device. There are many factors that affect CVR recordings such as: (size, quantity, nature and location of the explosive materials. It's also affected by microphones aging and location) Therefore, it can be concluded that each CVR recording is unique and cannot be compared to other recorded database sounds.	
Sub Theme Sequence of events	As mentioned above, the warnings sequence, the CVR sequence and the wreckage description are partial and contain inaccuracies that lead to the misinterpretation of the data. The following figure summarizes the main data relevant to establishing the sequence of events: 	The FDR/ CVR has already been taken as the primary reference in the draft final report. The ARINC raw data messages were referred to as a supporting data. EAAID scenario and sequence of events agrees with BEA figure which states that lavatory smoke was generated before Avionic smoke which concludes that fire was originated outside the cockpit.	– BEA comment attached in Exhibit F. – No change in the Final report.

Sub Theme Findings regarding the oxygen system	The EAAID draft report states that: - the behavior of the flight crew, the cabin crew and the maintenance personnel is neither a root cause nor a contributing factor in the accident, - the aircraft systems failure was a consequence of fire, - The crew oxygen system was properly maintained in accordance with manufacturer’s documents, the approved maintenance program and applicable rules and regulations. By design and manufacturing, an aircraft is extremely safe; however the probability of a failure, even if extremely remote is not null. Furthermore, the oxygen hazard analyses do not take into account the failures due to human error during the assembly or disassembly/reassembly of the systems, in particular the oxygen system. This is why, the conclusion that there were no anomalies regarding the crew oxygen system and that it was airworthy should be less assertive. The BEA suggests the wording: "No anomalies regarding the crew oxygen system have been identified in the maintenance reports. All the problems reported in the Technical log book have been fixed by the maintenance."	Human error is manifested in the undesired outcome of a process. The aircraft flew 10 flight cycles of a total duration of 32 flight hours in 3 consecutive days, before the accident flight, without any finding from the flight crew when performing their checks prior to each flight and while monitoring ECAM messages during the flights. Additionally, there were no findings by the different maintenance crews who performed 10 transient checks before the accident flight. As a result of extensive review of maintenance documents It was concluded that Maintenance checks were carried out in accordance with applicable Airbus maintenance documents (refer to 1.6.3.4 Maintenance Activities carried out on the Oxygen System).	– BEA comment attached in Exhibit F. – No change in the Final report.

Significant comment B – Scenarios			
	The factual accuracy of the report is questionable (see significant comment A), and the reasoning for the scenarios appears to distort the facts. The report repeatedly mentions the presence of French experts concerning the discovery of TNT. The BEA would like to emphasize that the French experts acted as advisors and observers and had neither the role nor the possibility of validating any findings concerning the presence of explosives on human remains. The French experts involved indicated that the results obtained do not allow for a definitive conclusion regarding the presence of TNT. However, the presence of TNT is never questioned and is taken as an assumption or even as a starting point in all scenario analyses. This leads to an unrealistic scenario incompatible with the sequence of warnings, failures and crew announcements. The BEA disagrees with the scenario established by the investigation	Reference item 1.18.2 (Summary of the Egyptian Public Prosecution memorandum) The Egyptian Public Prosecution Memorandum included: Forensic experts from both French and Egyptian sides boarded the civilian search and recovery vessel, John Lethbridge, for the wreckage site in the Mediterranean Sea for human remains search, recovery, examination and analysis. Over the course of nine days, experts from both Egyptian and French sides recovered 105 human remains and some aircraft debris, the experts preserved them using appropriate scientific methods. The French team conducted the numbering of the human remains and debris using the updated barcode system. It also included that after the forensic tests result concluded the presence of TNT explosives, it was agreed between the Egyptian and the French experts to move to a more sensitive and advanced laboratory in order to confirm those results so, they agreed to move to (Pharma Gene) lab. Where more advanced tests were done and it was concluded again the presence of TNT explosives. It is obvious that the French expert did not object the processes or the results of the first forensic medicine tests (that concluded the presence of TNT), but rather it was agreed to move to a more sensitive lab. to	– BEA comment attached in Exhibit F. – No change in the Final report.

	committee and maintains the conclusions drawn from its study: The accident sequence began while the aeroplane was cruising at FL370, with a cabin crew member present in the cockpit, the captain resting in his seat and the co-pilot flying. It has not been possible to precisely explain the start of the accident sequence. It is likely to have been an oxygen flow resulting either from a component failure (in the oxygen storage box or in the upstream distribution system) or from pressing the EMERGENCY knob on the co-pilot's oxygen mask. A fire then started in the mask storage box, and was fed by a leak of pressurized oxygen. It has not been possible to determine which came first: the fire or the oxygen leak. Whichever the case, the oxygen-fed fire spread to the outside of the storage box. This type of fire is rapid, large-scale and uncontrollable. It produces a characteristic noise comparable to that of a blowtorch. The protective and extinguishing equipment items in the	confirm those results. The second advanced equipment confirmed the same results again. <u>While the BEA scenario stated:</u> “It has not been possible to precisely explain the start of the accident sequence”. “It is likely to have been an oxygen flow” “It has not been possible to determine which came first: the fire or the oxygen leak”. And while the BEA oxygen fire in cockpit study stated (6.4.1 External ignition sources to oxygen system) “The data available for flight MS804 did not make it possible to determine the source of ignition of the fire in the co-pilot’s mask storage box”. <u>The EAAID report stated that:</u> “Fire and smoke due to explosive materials located at the galley just aft of the rear section of the cockpit, the high energy and pressure generated from the explosion propagated affecting the right hand side oxygen system” “The aircraft flight path was uncontrollable as the aircraft and the flight crew were severely affected by fire and smoke. This resulted from the effects of the explosive materials located at the forward galley just behind the rear section of the cockpit. The aircraft crashed into the sea.”	

	cockpit were not sufficient to bring the fire under control. The fire damaged the computer power supply systems, which led to the disconnection of the autopilot in particular. No crew actions were recorded in the cockpit. It has not been possible to determine whether the crew remained in the cockpit, whether they were unconscious or whether they fled the fire and then returned or remained outside the cockpit. The airplane's flight path was uncontrolled and the aircraft collided with the sea.		

Significant comment C – Exhibits			
Exhibit E BEA study	As previously agreed, the version of the BEA study on Oxygen fire in cockpit to be added in exhibit is the one issued in December 2023. On 20th October 2023, the investigation committee received from the BEA a study concerning the oxygen fires in cockpit. The last version of this study was issued on December 2023 (Exhibit E)	On October 24th, 2024 the EAAID received the final version of the French study that was originally issued on October 2023 for inclusion in the final report.	– BEA study received on October 24th, 2024 is appended in Exhibit E of the final report.
Exhibit D Summary of forensic report	As per annex 13 paragraph 5.12.3, the BEA requires the EAAID to hide the name of the victims in this exhibit. Similarly, the name of the experts, especially the French ones, should also be hidden	Names were only included in the draft final report and removed from the final report.	– Names removed from the final report as previously stated.

BEA Comments

Significant comment A – Main factual discrepancies

Sub Theme Wreckage

Two investigators from the BEA and two Airbus specialists participated in the first part of the recovery of the debris. Based on their observations, the following clarifications are necessary:

Debris field

The debris of the aircraft was scattered in a rectangle measuring 1.2 km by 525m. All extremities of the aircraft were located within the identified rectangle: cockpit, wings and tail parts. The small size of the debris is consistent with a high energy impact with the water surface.

Parts from cockpit affected by fire

When listing the parts of the aircraft affected by heat, the report omits to mention the parts from the cockpit (references #21, #31, #25, #37). These parts not only exhibit dark spots but also show traces of soot and heat exposure.
Furthermore, the traces of fire on the forward fuselage part with stand by static port are located on the upper part of the wreckage piece, just under the R/H side window of the cockpit, above the floor. Electric cables with their insulation layers are located below the cockpit floor in the avionics compartment. Therefore, the deduction “Wire insulations in part 31 were intact leading to the conclusion that temperature was not high enough to affect wire insulation. This highly suggest that the fire did not originate in the right hand side of the cockpit” is false and misleading.

In total, after adding the 4 additional parts mentioned above, twelve pieces were identified as having been affected by fire and/or high temperature. Some of them are parts of the passenger cabin, some are from the cockpit and structure.

Sub Theme Timing discrepancies in flight data

Accuracy of ATSU data and sequence of warnings

Regarding the timing of the different sources of flight data, the BEA emphasizes these limitations:

- The FDR data timestamp includes seconds and has to be taken as the reference
- The ATSU data timestamp includes seconds but this time does not correspond to the exact time of occurrence. The accuracy of the timing has to be indicated (it is not known if the timing corresponds to the emission of the signal or its reception or its recording). The sequence differs from that of the Current Flight Report (CFR) data provided earlier.

As a consequence, the timing sequence of warnings (Lavatory smoke, Anti-ice right windows, Avionics smoke, Right sliding window sensor, Right fixed window sensor) is inaccurate and should not be used as such for the establishment of a scenario.

The lavatory smoke warning preceded the avionics smoke alarm by 46 seconds. Although this sequence of alerts might suggest that the fire started in the cabin, this fact taken in isolation cannot be conclusive. Therefore, a fire in the cockpit could also have led to this sequence.

Additionally, there was no cargo smoke warning.

Accelerometers -recorded values at the end of the FDR recording

At the end of the FDR recording (at 00 h 29 min 43 s), the recorded values of the three accelerometers dedicated to the FDR show spikes that are not consistent with a realistic aircraft movement. There is no correlation between these acceleration values and altitude, attitude (on the three axes) and speed parameters. From that time, the accelerometers values recorded in the FDR are no longer valid. These abnormal variations might be the consequence of damages in the cockpit or in the avionic bay caused by the growing fire. The accelerometers are located near the aircraft center of gravity but the power supply wires, or the wiring connecting the accelerometers to the data concentrator computer, could have been affected by the fire at that time.

Additionally, the BEA database contains some recording flight parameters from accidents with inflight explosions produced by explosive materials or missile strikes. The impact of an explosion on acceleration is quite different from the variations recorded on these parameters at the end of the FDR recording of the flight MS804.

Therefore, the recorded values of the accelerometers at the end of the FDR recordings should not be used as an input for the establishment of a scenario

ELT

Regarding the ELT, the first burst occurred at 00 h 36 min 52 and the second one at 00 h 36 min 59. The two bursts were emitted in test mode. The ELT 406 ATP manufacturer (SAFRAN Electronic, formerly KANNAD) indicated to the BEA that this type of emergency beacon is equipped with only one electronic G-Switch that triggers in the case of a +2.0 to +2.6G acceleration in the longitudinal axis only (i.e the axis of the beacon installation on-board the A320). The reference to the three axis sensors is therefore incorrect.

Although the ELT can be activated either to the detection of high acceleration lasting several seconds or manually (via manual command from the cockpit), the double emission of a test mode signal by the ELT during MS804 flight is not the behavior expected when activated by high acceleration. The activation of the ELT may have been accidental due to fire damage on the command line; indeed this line runs from the cockpit to the cabin via the upper central area. This possibility must not be ruled out.

Sub Theme CVR and audio system

The BEA identified several significant inaccuracies and errors in the description of the on-board audio system, its operation, and the organization of the sound sources that feed it.

These inaccuracies include:

- The lack of description of the wiring path for audio and CVR signals (See BEA study figure 18 p. 37).
- The omission of the fact that the ACP/RMP does not manage the selection of microphone sources recorded by the CVR. (See BEA study appendix 1, Functional Description of the CVR Audio System).
- Omissions in the description of the progressive losses of the various sound sources (see BEA study 4.6.2, Pick-up Sources).
- The assertion that communications picked up by the headset microphone are not clearly audible when the oxygen mask microphone is active (See BEA study appendix 2, Audio Pick-up by Oxygen Mask Microphone).
- A lack of precision and analysis regarding the beginning and end of the various oxygen flow noises in the “Tests and Research regarding the Inflight F/O Oxygen Mask Microphone Flow Test” (See BEA study appendix 5, EVT2).

These factual discrepancies lead to the misinterpretation of the CVR sequence, particularly with regard to:

- the signal degradation and gradual loss of the various capture sources
- the pick-up by the co-pilot's oxygen mask microphone
- the position of the emergency rotator on the co-pilot's oxygen mask

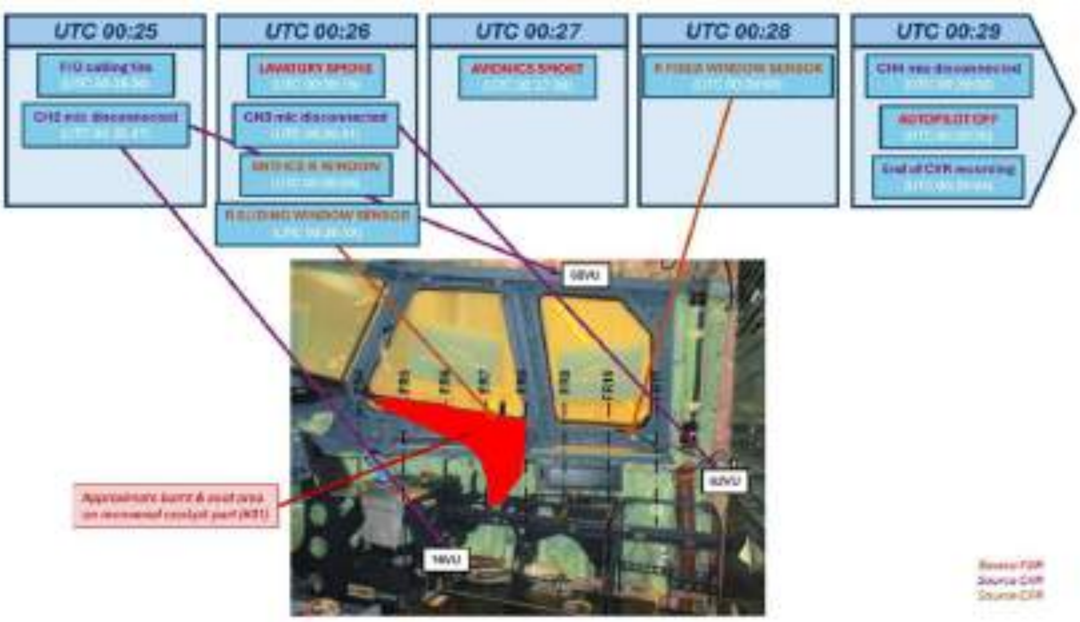
Furthermore, the BEA participated in working sessions on the audio analysis of explosive events with different national safety investigation authorities. In addition, the BEA audio database contains some audio samples from on-ground and inflight explosion noises produced by explosive material or missile strike. It shows that the cockpit ambiance microphone is very sensitive to solid-borne and airborne noise transmission. An explosion noise at the galley level is normally picked up by the CAM due to both the wave shock transmitted by the structure and the over pressure produced by the blast.

EAAID did not provide any evidence or analysis of the noises heard on the CVR consistent with an explosive material explosion. This absence should be mentioned in the report.

Sub Theme Sequence of events

As mentioned above, the warnings sequence, the CVR sequence and the wreckage description are partial and contain inaccuracies that lead to the misinterpretation of the data.

The following figure summarizes the main data relevant to establishing the sequence of events:



Sub Theme Findings regarding the oxygen system

The EAAID draft report states that:

- the behavior of the flight crew, the cabin crew and the maintenance personnel is neither a root cause nor a contributing factor in the accident,
- the aircraft systems failure was a consequence of fire,
- the crew oxygen system was properly maintained in accordance with manufacturer's documents, the approved maintenance program and applicable rules and regulations.

By design and manufacturing, an aircraft is extremely safe; however the probability of a failure, even if extremely remote is not null. Furthermore, the oxygen hazard analyses do not take into account the failures due to human error during the assembly or disassembly/reassembly of the systems, in particular the oxygen system. This is why, the conclusion that there were no anomalies regarding the crew oxygen system and that it was airworthy should be less assertive.
The BEA suggests the wording : "No anomalies regarding the crew oxygen system have been identified in the maintenance reports. All the problems reported in the Technical log book have been fixed by the maintenance."

Significant comment B – Scenarios

The factual accuracy of the report is questionable (see significant comment A), and the reasoning for the scenarios appears to distort the facts.

The report repeatedly mentions the presence of French experts concerning the discovery of TNT. The BEA would like to emphasize that the French experts acted as advisors and observers and had neither the role nor the possibility of validating any findings concerning the presence of explosives on human remains. The French experts involved indicated that the results obtained do not allow for a definitive conclusion regarding the presence of TNT. However, the presence of TNT is never questioned and is taken as an assumption or even as a starting point in all scenario analyses.

This leads to an unrealistic scenario incompatible with the sequence of warnings, failures and crew announcements.

The BEA disagrees with the scenario established by the investigation committee and maintains the conclusions drawn from its study:

> The accident sequence began while the aeroplane was cruising at FL370, with a cabin crew member present in the cockpit, the captain resting in his seat and the co-pilot flying.

It has not been possible to precisely explain the start of the accident sequence. It is likely to have been an oxygen flow resulting either from a component failure (in the oxygen storage box or in the upstream distribution system) or from pressing the EMERGENCY knob on the co-pilot's oxygen mask. A fire then started in the mask storage box, and was fed by a leak of pressurised oxygen. It has not been possible to determine which came first: the fire or the oxygen leak.

Whichever the case, the oxygen-fed fire spread to the outside of the storage box. This type of fire is rapid, large-scale and uncontrollable. It produces a characteristic noise comparable to that of a blowtorch. The protective and extinguishing equipment items in the cockpit were not sufficient to bring the fire under control.

The fire damaged the computer power supply systems, which led to the disconnection of the autopilot in particular.

No crew actions were recorded in the cockpit. It has not been possible to determine whether the crew remained in the cockpit, whether they were unconscious or whether they fled the fire and then returned or remained outside the cockpit.

The aeroplane's flight path was uncontrolled and the aircraft collided with the sea.