AIRCRAFT ACCIDENT REPORT 2/2013

ACCIDENT INVESTIGATION DIVISION

Civil Aviation Department
The Government of
Hong Kong Special Administrative Region

Report on the accident to Airbus A330-342
B-HLL operated by Cathay Pacific Airways Limited
at Hong Kong International Airport, Hong Kong
on 13 April 2010

Hong Kong
July 2013

In accordance with Annex 13 to the Convention on International Civil Aviation and the Hong Kong Civil Aviation (Investigation of Accidents) Regulations, the sole objective of this investigation is the prevention of aircraft accidents. It is not the purpose of this activity to apportion blame or liability.

民航處
CIVIL AVIATION DEPARTMENT

香港特別行政區政府
The Government of the Hong Kong Special Administrative Region

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3 July 2013

The Honourable C Y Leung, GBM, GBS, JP
The Chief Executive
Hong Kong Special Administrative Region
People's Republic of China

Dear Sir,

In accordance with Regulation 10(6) of the Hong Kong Civil Aviation (Investigation of Accidents) Regulations, I have the honour to submit the report by Captain LIU Chi-yung, Victor, an Inspector of Accidents, on the circumstances of the accident to an Airbus A330-342 aircraft, registration B-HLL landed at Hong Kong International Airport on 13 April 2010.

Yours faithfully,

(Norman S M LO)
Director-General of Civil Aviation

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GLOSSARY OF ABBREVIATIONS

AAHK	Airport Authority Hong Kong
AAIB	Air Accidents Investigation Branch of the United Kingdom
ACARS	ARINC Communication Addressing and Reporting System
ACMS	Aircraft Condition and Monitoring System
AFC	Airport Fire Contingent
AFQRJOS	Aviation Fuel Quality Requirements for Jointly Operated Systems
AFS	Automatic Flight System
AMS	aircraft maintenance schedule
AMSL	Above Mean Sea Level
AOC	Air Operator's Certificate
AP	Autopilot
APS	Approach Supervisor
APU	Auxiliary Power Unit
ASU	Aerodrome Supervisor
ATA	Air Transport Association of America
ATC	Air Traffic Control
A/THR	Autothrust
ATIS	Automatic Terminal Information Service
ATMD	Air Traffic Management Division
BEA	Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (The air accident investigation agency of France)
BITE	Built-in test equipment
C	Celsius
CAD	Civil Aviation Department, Hong Kong, China
CAS	Calibrated Air Speed
Cb	cumulonimbus
CCTV	Close Circuit Television
CCQ	Cross Crew Qualifications
CIDS	Cabin Intercommunication Data System
CLB	climb
CMC	Central Maintenance Computer
CMS	Central Maintenance System
CPA	Cathay Pacific Airways Limited

CPA780	The accident flight operated by B-HLL on 13 April 2010 unless otherwise specified
CPV	Constant Pressure Valve
CSV	Control Servo Valve
CVR	Cockpit Voice Recorder
DAR	Digital ACMS Recorder
DGCA Indonesia	Director-General Civil Aviation of Indonesia
DMU	Data Management Unit
DP	differential pressure
DU	Display Units
EASA	European Aviation Safety Agency
ECAM	Electronic Centralised Aircraft Monitoring
EEC	Engine Electronic Controller
EFIS	Electronic Flight Instrument System
EGT	Engine exhaust gas temperature
EI	Energy Institute
EIS	Electronic Instrument System
EGPAR	Engine Gas Path Advisory Reports
EGPWS	Enhanced Ground Proximity Warning System
EPR	Engine Pressure Ratio
EWD	Engine Warning Display
FADEC	Full Authority Digital Engine Control system
FC	Flight Cycle
FCOM	Flight Crew Operations Manual
FD	Flight Director
FDR	Flight Data Recorder
FDRS	Flight Data Recording System
FE	Flight Envelope
FG	Flight Guidance
FH	Flight Hour
FIDS	Fault Isolation and Detection System
FIR	Flight Information Region
FL	Flight Level (e.g. FL390 means flight level of 39,000 ft AMSL at standard atmosphere conditions)
FLRS	Flap Load Relief System
FM	Flight Management
FMGEC	Flight Management, Guidance and Envelope Computers

FMU	Fuel Metering Unit
FMV	Fuel Metering Valve
FPA	Fuel Pump Assembly
fpm	Feet per minute
FR	flow-rate
FSV	Fuel Servo Valve
ft	feet
FWC	Flight Warning Computers
G-16	A committee sanctioned by SAE International within their Aerospace General Projects Division
HP	high pressure
hPa	HectaPascal
hrs	Hour(s)
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IFQP	IATA Fuel Quality Pool
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IOC	Integrated Operations Centre
IP	intermediate pressure
ISM	In-flight Service Manager
JIG	Joint Inspection Group
kt	knot
km	kilometre
LP	low pressure
LPM	litre per minute
LVDT	linear variable differential transformer
MC	Maintenance Control
MCDU	Multipurpose Control and Display Unit
MCT	Maximum Continuous Thrust
ME1	maintenance engineer 1
ME2	maintenance engineer 2
METAR	Meteorological Aerodrome Report
MMV	main metering valve
N1	Rotation speed of the engine LP compressor and turbine rotor expressed as a percentage of its maximum rotation speed

N2	Rotation speed of the engine IP compressor and turbine rotor expressed as a percentage of its maximum rotation speed
ND	Navigation Displays
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board of the United States of America
NTSC	National Transportation Safety Committee of Indonesia
PA	Public Address
PDR	pressure drop regulator
Pertamina	PT. Pertamina
PF	Pilot Flying
PFD	Primary Flight Displays
PFR	Post Flight Report
PM	Pilot Monitoring
PRSOV	pressure raising / shut off valve
QAR	Quick Access Recorder
QNH	Mean Sea Level Pressure
QRH	Quick Reference Handbook
RA	Radio altimeter
RAT	Ram Air Turbine
SAP	super absorbent polymer
SARP	standards and recommended practices
SATCOM	Satellite Communication
SD	System Display
SPR	servo pressure regulator
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
TAD	Terrain Awareness Display
TCF	Terrain Clearance Floor
TFG	Technical Fuel Group
TM	torque motor
TSD	Trouble Shooting Data
US	United States of America
VFE	Velocity Flap Extended
VHF	Very High Frequency
VHHH	ICAO airport code for Hong Kong International Airport
VLS	Minimum Selectable Speed

Vmax	Maximum Allowable Speed
VMC	Visual Meteorological Conditions
VSV	variable stator vanes
VSVA	VSV Actuators
VSVC	VSV Control unit
WARR	ICAO airport code for Juanda International Airport of Surabaya, Indonesia
WMR	Watch Manager
ZFW	Zero Fuel Weight

ACCIDENT INVESTIGATION DIVISION

CIVIL AVIATION DEPARTMENT

Aircraft Accident Report 2/2013

Registered Owner:	Cathay Pacific Airways Limited
Operator:	Cathay Pacific Airways Limited
Aircraft Type:	Airbus A330-342
Nationality:	Hong Kong, China
Registration:	B-HLL
Place of Accident:	Hong Kong International Airport
Date and Time:	13 April 2010 at 0543 hour (1343 hour Hong Kong local time) *(All times in this report are in UTC. Surabaya time is UTC+7 hrs. Hong Kong time is UTC+8 hrs)*

SYNOPSIS

Cathay Pacific Airways Limited (CPA) flight CPA780 declared "MAYDAY" when approaching Hong Kong International Airport (VHHH) with control problem on both engines. The aircraft landed at a groundspeed of 231 knots, with No. 1 engine stuck at about 70 % N1 and No. 2 stuck at about 17 % N1. Five main tyres were deflated after the aircraft came to a complete stop on Runway 07L of VHHH. After being advised by the rescue leader that there was fire and smoke on the wheels, the Commander initiated an emergency evacuation of passengers. A total of 57 passengers and six cabin crew were injured during the evacuation. Most of them sustained minor injuries and were given medical treatment immediately at the airport. Ten of them were sent to hospitals for medical treatment with one passenger suffered from bone fracture and ankle joint dislocation. Before departure for VHHH, the accident aircraft had uplifted 24,400 kg of fuel at Juanda International Airport, Surabaya, Indonesia (WARR).

The Accident Investigation Division of the Civil Aviation Department, Hong Kong, China (CAD) was immediately notified of the accident. The Chief Inspector of Accidents ordered an investigation in accordance with the Hong Kong Civil Aviation (Investigation of Accidents) Regulations (CAP 448B) to identify the causes leading to the accident with a view to preventing recurrence in future. The investigation was carried out in accordance with the CAP 448B and Annex 13 to the Convention on International Civil Aviation.

The investigation was conducted by an investigation team consisting of investigators from the CAD, the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) of France and the Air Accidents Investigation Branch (AAIB) of the United Kingdom. The National Transportation Safety Committee (NTSC) of Indonesia, the National Transportation Safety Board (NTSB) of the United States of America also provided assistance in the investigation and experts from Airbus (aircraft manufacturer), Rolls Royce (engine manufacturer), CPA (aircraft operator), and Shell Global Solutions (aviation fuel expert) also assisted in the investigation.

The investigation had identified that contaminated fuel uplifted at WARR had caused stiction in the Fuel Metering Units of both engines and eventually the total seizure of these components, rendering the loss of both engine thrust control of the aircraft during approach to VHHH.

A series of causal factors had led to the uplift of contaminated fuel to the aircraft. Noting the safety actions taken by various parties throughout the investigation, the investigation team have made four safety recommendations.

1. FACTUAL INFORMATION

1.1 History of the Flight

Cathay Pacific Airways Limited (CPA) flight number CPA780 , an Airbus A330 (registration B-HLL) powered by two Rolls Royce Trent 700 engines (the accident aircraft which is referred to as CPA780 in this report), was scheduled to operate from Surabaya of Indonesia to Hong Kong on 13 April 2010 with a Scheduled Time of Departure at 0120 hours (hrs). The crew had carried out the sector from Hong Kong to Surabaya on the previous day with the accident aircraft before this sector without any event. The accident aircraft stayed overnight at Juanda International Airport of Surabaya, Indonesia (WARR).

1.1.1 Pre-flight Preparation

a. The crew, which included one commander, one co-pilot and 11 cabin crew, reported for duty at 0020 hrs on 13 April 2010. During the pre-flight stage, there was no engine system-related or fuel system-related defect reported in the aircraft technical log. The actual and forecast weather along the flight plan route, and at the departure and arrival airports, were accepted by the flight crew.

b. The accident aircraft was parked at Stand No. 8 at WARR. The Commander completed the walk-around inspection with no abnormality identified. He noticed that the fuelling dispenser operator was completing a water check of the fuel sample taken. He observed that the fuel sample in the beaker was clear and bright, and the water check was clean.

c. The accident aircraft uplifted 24,400 kilogram (kg) of fuel at the stand by PT. Pertamina (Pertamina), which was the supplier and operator of aviation fuel storage, fuel hydrant system and fuelling dispensers at WARR. Dispenser JUA06 was used for the refuelling. During the refuelling, there were several occasions where vibration of fuelling hose occurred. The dispenser operator considered the vibration was due to air trapped inside the hydrant piping which had been disturbed in an extension work recently. The dispenser operator stopped the refuelling at each occasion to stop the vibration and resumed the refuelling afterwards. At the end of the refuelling, a visual and water check of the dispenser fuel sample were performed together with the CPA ground engineer and it was reported that the result was clear and bright, with no trace of water.

d. The departure fuel quantity was 33,400 kg, which was planned by the CPA and accepted by the Commander. The Zero Fuel Weight (ZFW) of the aircraft was 165,372 kg and the actual Take-off Weight was around 198,700 kg. Total number of passengers onboard the flight was 309.

e. The co-pilot was the Pilot Flying (PF) for the flight, and the Commander was the Pilot Monitoring (PM).

f. The cabin crew also conducted the cabin safety demonstration to the passengers, which included the emergency evacuation procedure, in accordance with company requirements with the assistance of in-flight video and safety cards.

g. The Aviation Routine Weather Report (METAR) issued at 0030 hrs at WARR for departure flight indicated that the wind was from variable direction at two knots (kt) with seven kilometres (km) visibility. Scattered clouds at 1,800 feet (ft) and few Cumulonimbus (Cb) clouds at 2,000 ft. The temperature was 28 degrees Celsius (C) with dew point at 25 degrees C. The Mean Sea Level Pressure (QNH) was 1009 Hectopascal (hPa) with Cb clouds to the northeast of the airport.

1.1.2 Departure and Climb Phases

a. The aircraft left the stand at 0111 hrs and was airborne at 0124 hrs using Runway 28. The departure was flown in Visual Meteorological Conditions (VMC) and was away from any significant weather. On passing 1,144 ft above mean sea level (AMSL), "AP 2" (No. 2 Auto-pilot) was selected and engaged. The departure was uneventful.

b. According to the flight crew, CPA780 did not encounter any significant weather en route which was confirmed from the satellite imageries for the period.

c. During the climb, the flight crew noticed some abnormal Engine Pressure Ratio (EPR) fluctuations on No. 2 engine, with a range of approximately ± 0.015 around EPR target. No. 1 engine also had abnormal EPR fluctuations but within a narrower range.

1.1.3 Cruise Phase

a. At 0158 hrs, when the aircraft was still inside the Indonesian Ujung Pandang Flight Information Region (FIR) and shortly after levelling off at FL390 (i.e. 39,000 ft AMSL at standard atmosphere conditions), Electronic Centralised Aircraft Monitoring (ECAM) message "ENG 2 CTL SYS FAULT" was annunciated. ECAM information "ENG 2 SLOW RESPONSE" was shown for crew awareness. At 0200 hrs, the flight crew contacted the CPA Integrated Operations Centre (IOC) call-sign "Maintenance Control" (MC) via Satellite Communication (SATCOM) for technical advice. The maintenance engineer (ME1) at the IOC asked the flight crew to check the responses of the engines to thrust lever movements. The flight crew advised that the EPR was fluctuating around an EPR target. Both the flight crew and ME1 reviewed Flight Crew Operations Manual (FCOM) Volume 3 "Flight Operations". The option of setting the engine control to "N1" mode was discussed between the flight crew and the ME1. Since the engine control was normal and without any other abnormal engine indications or ECAM message at that time, ME1 advised the flight crew to maintain the engine control at "EPR" mode and indicated that IOC would continue to monitor the flight. As all engine parameters were considered normal other than the EPR fluctuations, the flight crew elected to continue the flight to Hong Kong.

b. At 0315 hrs, CPA780 started to descend to FL380 when it entered the Malaysian Kota Kinabalu airspace. At 0316 hrs, ECAM message "ENG 2 CTL SYS FAULT" reappeared when the aircraft was levelling off at FL380. This time ECAM information “AVOID RAPID THR CHANGES” was also displayed in addition to the “ENG 2 SLOW RESPONSE”. Engine anti-ice for both engines was selected “ON” by the flight crew between 0317 hrs to 0327 hrs for the purpose of checking its effect on the EPR fluctuation but apparently it had no effect to the fluctuation. The flight crew called MC again via SATCOM for further discussions. Another maintenance engineer (ME2) responded to the call and confirmed that he was aware of the earlier situation as they had been monitoring the engine parameters during the flight. The flight crew, with more concern this time, reported the ECAM message and the observed increase in EPR fluctuation (± 0.1 for No. 2 engine and ± 0.03 for No. 1 engine). The flight crew queried whether it was safe to continue the flight. ME2 confirmed that there was no maintenance carried out overnight in WARR before the flight. ME2 considered that No. 1 engine was functioning properly and that No. 1 engine EPR instability might be caused by the Full Authority Digital Engine Control system (FADEC) in using No. 1 engine to compensate for the EPR fluctuation of No. 2 engine. ME2 further advised the flight crew that they had seen this kind of fluctuation before and that the ECAM information “AVOID RAPID THR CHANGES” was related to P30, which was related to the Variable Stator Vane (VSV) System. ME2 suggested that the flight crew monitor the parameters with care to avoid exceedance and additionally move the thrust levers with care. ME2 also reminded the flight crew to follow the FCOM procedures if exceedance occurred. ME2 said that the Fuel Metering Unit (FMU) in No. 2 engine would be replaced upon arriving at VHHH. The crew accepted ME2’s explanation and continued the flight to Hong Kong.

c. At around 0455 hrs, before entering the Hong Kong FIR, the flight crew obtained the arrival Automatic Terminal Information Service (ATIS) information “Hotel” issued at 0435 hrs through Very High Frequency (VHF) and ARINC Communication and Reporting System (ACARS) in preparation for the arrival. The runway in use at VHHH was 07L. Wind was from 160 degrees at nine kt with wind direction varying between 100 degrees and 230 degrees. Visibility was 10 km with few clouds at 600 ft and scattered clouds at 1,800 ft. Temperature was 29 degrees C, dew point 24 degrees C and QNH 1013 hPa. Significant windshear was forecasted for both runways 07L and 07R.

d. At 0458 hrs, before entering the HK FIR, CPA780 contacted Hong Kong Radar on 128.75 MHz and was cleared for standard arrival route "SABNO 2A" for Runway 07L. The flight crew carried out the arrival and approach briefing in accordance with company procedures, planning for a normal arrival and completed the descent checklist. "CONFIG FULL" (i.e. full flap setting) was maintained as the default setting in the Multipurpose Control and Display Unit (MCDU). Instrument Landing System (ILS) frequency for Runway 07L was automatically tuned. Autobrake system was set to LO (i.e. Low). CPA780 entered Hong Kong FIR via waypoint SABNO at 0504 hrs and at around the same time Hong Kong Radar had radar contact with CPA780. The Commander made a normal arrival Public Address (PA) to the passengers.

1.1.4 Descent, Approach and Landing Phases

a. At 0519 hrs during the descent to a cleared level of FL230, ECAM messages "ENG 1 CTL SYS FAULT" and "ENG 2 STALL" were annunciated within a short period of time. According to the Commander, a light "pop" sound was heard and some "ozone" and "burning" smell was detected shortly before the ECAM message "ENG 2 STALL". At that time CPA780 was at about 110 nautical miles (nm) southeast of VHHH, and was descending through FL300 with a Calibrated Air Speed (CAS) of 295 kt and a true heading of 330 degrees. Vertical mode "Open Descent" was selected. The flight crew completed the necessary ECAM actions and set No. 2 thrust lever accordingly to IDLE position. ECAM information "ENG 1 SLOW RESPONSE" and "AVOID RAPID THRUST CHANGES" were also annunciated. No. 1 thrust lever was advanced to Maximum Continuous Thrust (MCT) position as per the "SINGLE ENGINE OPERATIONS" strategy stated in the Quick Reference Handbook (QRH). However No. 1 engine N1 only temporary increased to about 57% N1 and then dropped back to about 37% N1 at 0521 hrs.

b. At 0521 hrs, the flight crew declared "PAN PAN" (i.e. an urgent signal) on Hong Kong Radar frequency 126.3 MHz and advised that No. 2 engine was operating at idle thrust. The flight crew considered and briefed for the one-engine-inoperative approach and missed approach procedures. "CONFIG 3" (i.e. flap setting no. 3) was re-selected in the MCDU. The crew made the request to shorten the track for a priority landing. Hong Kong Radar then cleared CPA780 to proceed directly to waypoint "LIMES". Air Traffic Control (ATC) also alerted the Airport Fire Contingent (AFC) accordingly by declaring a "Local Standby".

c. With this abnormal situation, the Commander instructed the cabin crew to prepare the cabin for landing via the PA channel. He also established communication with the In-flight Service Manager (ISM) and advised her that there was a problem on No. 2 engine and a priority landing would be accorded by the ATC. The ISM was asked to prepare the cabin for landing and to report to him if there were any abnormal signs in the cabin or at No. 2 engine.

d. At about 0526 hrs, the Commander took control of the aircraft as the PF in accordance with CPA standard operating procedures for one engine inoperative and the co-pilot became the PM.

e. At 0530 hrs, when the aircraft was approximately 45 nm southeast from VHHH and was about to level off at 8,000 ft AMSL, ECAM message "ENG 1 STALL" was annunciated. The CAS at that moment was about 295 kt. ECAM actions were carried out by the flight crew and No. 1 thrust lever was put to IDLE position accordingly. Autothrust (A/THR) was disengaged and both engine master switches remained at the "ON" position. With both thrust levers at IDLE position, the Commander then tested the controllability of the engines by moving the thrust levers one at a time. There were no thrust changes corresponding to the engine lever movements initially. At 0532 hrs, ECAM messages "ENG 1 STALL" was annunciated again.

f. At 0532 hrs, the crew declared "MAYDAY" (i.e. a distress signal) on Hong Kong Approach frequency 119.1 MHz and advised Hong Kong Approach of the double engine stall situation. CPA780 was then cleared to descend to 3,000 ft AMSL. At that time, the aircraft was still in Instrument Meteorological Conditions (IMC) and the CAS was at about 233 kt and reducing, with a true heading of approximately 320 degrees. At around the same time, the Commander disconnected the Autopilot and the Flight Directors (FD) and flew the aircraft manually. Flight Path Vector was selected. The altitude increased from 6,760 ft to 7,164 ft AMSL with the CAS reducing and the aircraft started to descend again when the CAS decreased to about 200 kt. The Green Dot Speed (i.e. engine-out operating speed in clean configuration) at that time was approximately 202 kt.

g. At 0534 hrs, the flight crew selected the Auxiliary Power Unit (APU) to "ON". Engine Start Selector was switched to "IGN" shortly afterwards. When the aircraft was on base leg during the approach, the flight crew reported that they were flying in VMC.

h. The crew moved the thrust levers to check the engine control but there was no direct response from the engines. The No. 1 engine speed eventually increased to about 74% N1 with the No. 1 thrust lever in the CLB (climb) detent position. The No. 2 engine speed remained at sub-idle about 17% N1, with the No. 2 thrust lever at the IDLE position.

i. At 0536 hrs, the co-pilot made a "cabin crew please be seated for landing" PA followed by a "cabin crew to stations" PA. Shortly afterwards, the cabin crew advised the flight crew that the cabin was ready for landing. At 0537 hrs, the ATC made both runways 07L and 07R available for CPA780. During the descent and approach, there were a number of other ECAM warning messages announced in the cockpit which were not relevant to the engine control problem.

j. The flight crew carried out the "ENG ALL ENG FLAMEOUT - FUEL REMAINING" checklist in the QRH for No. 2 engine in an attempt to clear the thrust control fault of that engine. As per the checklist, the Ram Air Turbine (RAT) was deployed manually, APU bleed was selected "ON" and No. 2 engine MASTER switch was set to "OFF" then "ON" at 0538 hrs. However, No. 2 engine remained at a sub-idle speed of 17% N1.

k. At 0538 hrs, Flap CONF 1 was selected. At 0539 hrs, when CPA780 was at 5,524 ft AMSL with a true heading of 329 degrees, a CAS at 219 kt and a distance of nine nm from VHHH, the Commander tried to decrease the speed by retarding the No. 1 thrust lever. However, there was no corresponding decrease in No. 1 engine speed. Eventually, No. 1 thrust lever was left at the IDLE position and No. 1 engine speed remained at 74% N1.

l. At 0539 hrs, the Commander made another PA advising the passengers of having "small problem with the engines" with small vibrations and requesting them to remain seated and follow the directions from the cabin crew.

m. At 0540 hrs, Hong Kong Approach cleared CPA780 for a visual approach for Runway 07L. Flight crew deployed the speedbrakes when the aircraft was at 5,216 ft AMSL descending with a CAS of 234 kt at around 8 nm from VHHH. Flight crew selected landing gear down shortly afterwards.

n. The Commander aimed to fly the aircraft at a CAS as close as possible to the Minimum Selectable Speed (VLS), which was 158 kt at that time. The aircraft went through the runway extended centreline and recaptured the centreline from the north in order to manage altitude and airspeed. Landing checklist was actioned. At around 0541 hrs, with the Maximum Allowable Speed (Vmax) at 240 kt and actual CAS at 244 kt, an overspeed warning was generated by the onboard system. A short while later Hong Kong Approach cleared CPA780 to land on Runway 07L and advised that the current surface wind was 150 degrees at 13 kt. Flight crew stowed the speedbrakes when the aircraft was at 984 ft AMSL and armed the ground spoilers at 816 ft AMSL.

o. At 0542 hrs, when CPA780 was still at flap CONF 1, with a CAS of 227 kt and a vertical speed of 1,216 ft per min at an altitude of 732 ft AMSL and at about two nm to touchdown, the warning "Too Low Terrain" was generated by the Enhanced Ground Proximity Warning System (EGPWS). Flap CONF 2 was selected at around one nm to touchdown with a CAS of 234 kt and at an altitude of 548 ft AMSL. A flashing "F RELIEF" message was displayed at Engine Warning Display (EWD) as the TE flap was extended to 8-degree position instead of the commanded 14-degree position. With a Vmax of 205 kt, another overspeed warning was generated shortly after Flap 2 selection. The "Too Low Terrain" warning changed to "Pull Up" warning briefly at 176 ft AMSL and back to "Too Low Terrain" within a very short timeframe. The EGPWS warning stopped at 24 ft above the ground.

p. During the final approach, No. 1 engine speed decreased to about 70% N1 at touchdown, with the No. 1 thrust lever at IDLE position. No. 2 engine speed remained at about 17% N1 throughout the final approach and landing.

q. Flight track with significant events from WARR to VHHH, and the descent and final approach to VHHH are highlighted at ***Appendix 1*** A1.1 to A1.4.

r. CPA780 touched down on Runway 07L at 0543 hrs at a position between abeam Taxiways A4 and A5 and with a distance of around 680 metres (m) from the beginning of the runway threshold at a ground speed of 231 kt. The landing weight was approximately 173,600 kg. The landing wind recorded by the onboard system was 143 degrees at 14 kt. Immediately after both main gears touched down on the runway, the right main gear bounced and the aircraft became airborne again briefly. The aircraft then rolled left seven degrees and pitched down to -2.5 degrees at the second touchdown during which, the lower cowling of No. 1 engine contacted the runway surface. Spoilers deployed automatically. Both engine thrust reversers were selected by the Commander. Only No. 1 engine thrust reverser was deployed successfully and ECAM message "ENG 2 REV FAULT" was annunciated. Maximum manual braking was applied. As required by the company procedure for the purpose of drawing the PF's attention in the status of the deceleration devices, the co-pilot called out "no spoilers, no REV green, no DECEL" during the landing roll.

1.1.5 After Landing

a. The aircraft came to a complete stop on the runway at a position just passed Taxiway A10, with its nose wheel at about 309m from the end of Runway 07L. The total distance for stopping the aircraft from the initial touchdown was approximately 2,630m. Refer to Figure 1 for aircraft stopped position.

Figure 1: The aircraft stopped on end of Runway 07L (upper photo) with its nose wheel at about 309m from the end of runway (lower photo)

b. After the parking brake was set to ON, the Commander made a PA to request the passengers to remain seated. No. 1 engine was still running at

76-79% N1, with No. 1 thrust lever at IDLE. The flight crew shut down both engines by selecting No. 1 and No. 2 engine MASTER switches to "OFF". The brake temperatures were monitored and discussed between the Commander and the co-pilot. The brake temperatures reached the top of the scale at 995 degrees C in the cockpit display. The Commander made another PA advising the passengers that the flight crew was evaluating the situation and the passengers were requested once again to remain seated and to follow the cabin crew's instructions.

c. At 0545 hrs, the flight crew contacted ATC Tower North on frequency 118.2 MHz and asked for any indication of a wheel fire. The Tower Controller advised that she had not seen any fire yet and advised CPA780 to contact the on-scene officer-in-charge of the AFC (callsign "Rescue Leader") on 121.9 MHz. Before making communication with the Rescue Leader, the Commander called for the emergency evacuation checklist. Checklist actions before the item "EVACUATION" were completed. Accordingly, an instruction "cabin crew to stations" was broadcasted through the PA system and the fire pushbuttons for both engines were pushed. After further confirmation on the Rescue Leader frequency with the Tower Controller, the Commander eventually established communication with the Rescue Leader on 121.9 MHz at 0548 hrs. The Rescue Leader confirmed that brakes on left and right gears were hot and that he could see "smoke and small fire". The Rescue Leader further advised the flight crews that water was applied to cool down the hot brakes. The Commander then ordered an emergency evacuation and shut down the APU by using the APU fire pushbutton as per the emergency evacuation checklist.

d. Inside the cabin, when the aircraft came to a complete stop on the runway, the cabin crew repeated and shouted out the Commander's instruction and instructed the passengers to remain seated. Most of the passengers followed that instruction except a few who intended to rise from their seats and looked outside the windows. Later, when the Commander ordered "evacuate evacuate" the cabin crew responded to the command immediately and initiated the evacuation.

e. All eight emergency exits doors were used after the cabin crew had confirmed the absence of fire or smoke outside the exits. Exit doors L1, R1 and R4 were each attended by two cabin crew members, and the remaining five exit doors were each attended by one cabin crew member. Some passengers took their cabin bags along and did not follow the cabin crews' instruction to leave their bags behind before jumping onto the slides. The whole evacuation was completed in about two mins and 15 seconds. The Commander, the co-pilot and the ISM walked through the cabin to make sure there was no one left inside the aircraft before they left.

Figure 2: All Emergency Evacuation Slides were deployed

1.2 Injuries to Persons

a. There were a total of 322 persons on board the aircraft including 13 crew members and 309 passengers. Injuries to the persons on board are shown in the table below. There was no injury to other person.

Injuries	Crew	Passengers	Total in Aircraft
Fatal	0	0	0
Serious	0	1	1
Minor	6	56	62
Nil Injuries	7	252	259
TOTAL	13	309	322

b. All the injuries occurred during the evacuation when the passengers were coming down the slides. There were 56 passengers sustained minor injuries (such as abrasions, bruises, shoulder pain, back pain, buttock pain and sprain ankle etc.). Most of the injured passengers received medical treatment at the airport and were discharged. Ten passengers had been sent to hospitals for treatment. Nine of them were discharged on the same day and one passenger sustained serious injury due to a fractured and dislocated left ankle and was later hospitalised for surgery.

c. Six cabin crew members had sustained minor injury during the evacuation coming down by the slides. All of them received medical treatment from either the company clinic or private medical practitioners after the accident and reported back to CPA.

1.3 Damage to Aircraft

The aircraft was slightly damaged as described in 1.12.

1.4 Other Damage

A scrape mark on the surface Runway 07L of VHHH located on the left hand side between Taxiway A6 and A7 caused by the contact of No. 1 engine lower cowl during landing.

1.5 Personnel Information

1.5.1 Commander

Sex / Age	:	Male / 35 years
Licence	:	Hong Kong Airline Transport Pilot's Licence valid to 3 October 2012
Type rating	:	A330/340 valid until 28 July 2010
Instrument rating	:	Valid to 17 January 2011
Medical certificate	:	Class 1, valid to 30 April 2011, no limitation
Date of last proficiency check	:	18 December 2009
Date of last line check	:	5 July 2009
Date of last emergency drills check	:	24 July 2009
Flying experience:		
Total all types	:	7,756 hrs
Total on type (A330)	:	2,601 hrs
Total in last 90 days	:	205 hrs
Total in last 30 days	:	76 hrs
Total in last 7 days	:	16 hrs
Total in last 24 hours	:	9 hrs
Duty Time:		
Day of the accident	:	5 hrs 53 mins
Day prior to accident	:	6 hrs 8 mins

1.5.2 Co-pilot

Sex / Age	:	Male / 37 years
Licence	:	Hong Kong Airline Transport Pilot's Licence valid to 2 March 2019
Type rating	:	A330/340 valid until 21 May 2010
Instrument rating	:	Valid to 21 December 2010
Medical certificate	:	Class 1, valid to 31 January 2011, no limitation
Date of last proficiency check	:	22 November 2009
Date of last line check	:	23 November 2009
Date of last emergency drills check	:	23 February 2010
Flying experience:		
Total all types	:	4,050 hrs
Total on type (A330)	:	1,171 hrs
Total in last 90 days	:	100 hrs
Total in last 30 days	:	58 hrs
Total in last 7 days	:	16 hrs
Total in last 24 hours	:	9 hrs
Duty Time:		
Day of the accident	:	5 hrs 53 mins
Day prior to accident	:	6 hrs 8 mins

1.5.3 Crew Training and Qualification

1.5.3.1 Flight Crew

a. Both the Commander and the co-pilot had the proper licences, qualifications, recency and medical certificates for their assigned duties. Both of them had Cross Crew Qualifications (CCQ) with the A330 and the A340.

b. They were trained and checked out in accordance with the company training requirements, which were approved by the CAD. These included the A330 type rating course (ground and simulator training), Proficiency Check, base training, Line Flying Under Supervision, Line Check, Safety and Emergency Procedure training and Crew Resources Management training. The Commander underwent his command training in 2007 and was successfully checked out in the same year.

1.5.3.2 Cabin Crew

The flight was serviced by a team of 11 cabin crew which was led by an ISM. The ISM was supported by one Senior Purser, three Pursers and six Flight Attendants. They completed all required trainings, including the Emergency Procedures and maintained valid recency on Annual Emergency Procedures training in accordance with the company requirement before carrying out duty on board.

1.5.4 Crew Rest

a. Both flight crew members had a rest period of 11 hrs 27 mins between the end of the previous duty and the start of the duty on the day of the accident. Both of them indicated that they had about eight hour sleep during that rest period.

b. The whole set of cabin crew had also operated with the flight crew from VHHH to WARR on the previous day. They all indicated that they had proper rest before operating CPA780.

c. All crewmembers were properly rostered to operate the flight in accordance with the company Approved Flight Time Limitations Scheme, which was approved by the CAD. Both the flight crew and the cabin crew had appropriate rest before operating CPA780. There is no evidence to suggest that crew rest was an issue related to this accident.

1.6 Aircraft Information

1.6.1 Aircraft

Aircraft manufacturer	:	Airbus
Model	:	330-342
Serial number	:	244
Year of Construction	:	1998
Nationality / Registration Mark	:	Hong Kong, China / B-HLL
Name of the owner	:	Cathay Pacific Airways Ltd
Name of the operator	:	Cathay Pacific Airways Ltd
Certificate of Airworthiness	:	326-9
Valid to	:	24 November 2010
Certificate of Registration	:	462
Issued on	:	9 January 2009
Maximum Take-off Weight	:	217,000 kg
Actual Take-off Weight	:	198,700 kg
Total Hours Since New	:	33378
Total Cycles Since New	:	12590
Total Hours Since Last Inspection	:	291 FH since last A Check on 3 March 2010
		44 FH since last Weekly Check on 6 April 2010
Total Cycles Since Last Inspection	:	100 FC since last A Check on 3 March 2010
		14 FC since last Weekly Check on 6 April 2010

1.6.2 Engine

Manufacturer	:	Rolls-Royce
Engine Type	:	Turbofan
Model	:	Trent 700
Engine No 1 (Left):		
Serial Number	:	41461
Total Time Since New	:	9350 hrs
Total Time Since Overhaul	:	9350 hrs
Engine No. 2 (Right):		
Serial Number	:	41268
Total Time Since New	:	20740 hrs
Total Time Since Overhaul	:	20740 hrs

1.6.3 Engine Components

Information on FMU, Engine Variable Stator Vane Control Components, and Fuel Pump Assembly (FPA) are listed in ***Appendix 2*** Engine Components Information.

1.6.4 CPA A330 Aircraft B-HLM

On 12 April 2010, i.e. one day before the accident, the same scheduled flight CPA780, operated by aircraft B-HLM which is an Airbus A330-300 similar to the accident aircraft, also received fuel at WARR through dispenser JUA06 at Stand No. 8 before departure. The flight crew of B-HLM reported fluctuation of No. 1 engine parameters during the flight from WARR to VHHH. There was no associated ECAM message or engine control problem. That flight was completed without further event. As a result of the trouble shooting on ground after the aircraft landed at VHHH on 12 April 2010, No. 1 engine FMU was replaced. In light of the B-HLL accident on 13 April 2010 and the possibility of ground fuel contamination, the investigation team also examined the engine fuel sample, No. 1 engine fuel components, and the flight recorder data of B-HLM. The results of the examination are discussed in 1.16.

1.6.5 Cabin Layout and Configuration

The cabin has eight exit doors in total for emergency, with four on each side of the cabin. The cabin configuration is divided into business and economy classes, and can accommodate a total of 311 passengers. The layout of the cabin configuration and the locations of the emergency exits for CPA780 are detailed in ***Appendix 3***.

1.6.6 Maintenance History

1.6.6.1 Maintenance Checks

The aircraft was required to be maintained in accordance with the approved aircraft maintenance schedule (AMS) reference MS/A330-342/343/CX/1 Rev 27 dated November 2009. The scheduled maintenance checks of the accident aircraft completed before the accident are listed below:

Schedule Maintenance Inspections	**Interval of Inspection**	**Last Completion**
Phase Checks A1/A2/A3/A4	600 FH and was escalated to 800 FH on 7 December 2009 via approved AMS Temporary Amendment TMSD 0718/27	A1: 4 March 2010 @ 33083 FH A4: 8 December 2009 @ 32377 FH A3: 21 September 2009 @ 31782 F A2: 16 July 2009 @ 31270 FH
C Check	21 Months	21 October 2008
2C Check	42 Months	21 October 2008
4C Check	72 Months	21 October 2008
8C Check	120 Months	21 October 2008

1.6.6.2 Microbiological Growth Contamination

a. CPA reported an occurrence via the Mandatory Occurrence Reporting

Scheme reference number O3053-10 dated 21 April 2010 that there was a lapse in the fuel system related AMS task. Task referenced 280000-03-01-CX "Fuel sampling for microbiological growth" requires the testing of microbiological growth in fuel sample freshly collected from aircraft fuel tanks. When the result of the test exceeds a specified limit, a further test has to be performed within a specified period of ten days. However, maintenance record of the accident aircraft revealed that while further test was required, such test had not been carried out. Upon knowing the lapse, CPA immediately carried out the test and with a pass result indicated that there was no excessive growth of microbiological organism in the fuel tanks.

b. The failure of conducting the microbiological test could lead to undetected excessive growth of microbiological organism inside the fuel tanks which could affect the fuel supply to the engine but not the engine thrust control system. This maintenance lapse was considered not relevant to the accident.

1.6.7 Fuel and Control System

a. Fuel is stored in the inner and outer tanks in the wings and also in the trimmable horizontal stabiliser. Each inner tank contains two collector cells. The main fuel pump system supplies fuel from the collector cells of the inner tanks to the engines. In each wing there are three fuel pumps, two main fuel pumps in the collector cell and one standby pump outside the collector cell. A crossfeed valve separates the system into two parts when closed and their associated fuel pumps supply the engines. The crossfeed valve allows any pump to supply any engine when opened. An engine low pressure valve can stop the fuel supply to the respective engine when closed via Engine Master Switch or the ENG FIRE pushbutton. See Figure 3 for the aircraft fuel system architecture.

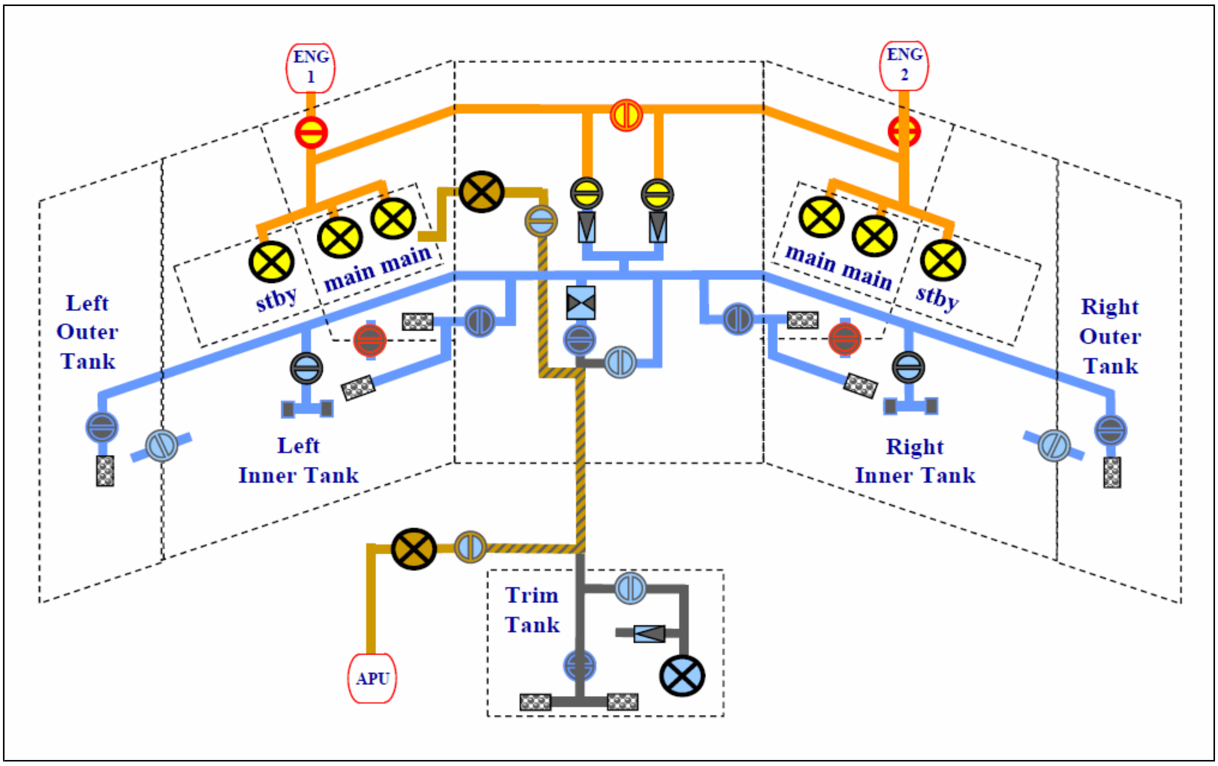


Figure 3: Aircraft Fuel System Architecture

b. The engine fuel system is designed to supply metered fuel to the combustion chamber according to the engine power demand. The fuel system is also used to cool the engine oil and supply servo pressure to operate valves and actuators. Each engine has an independent Engine Electronic Controller (EEC) which is a dual channel computer that controls the operation of the engine, including the engine fuel system. The EEC also monitors the engine sub-systems for normal operation.

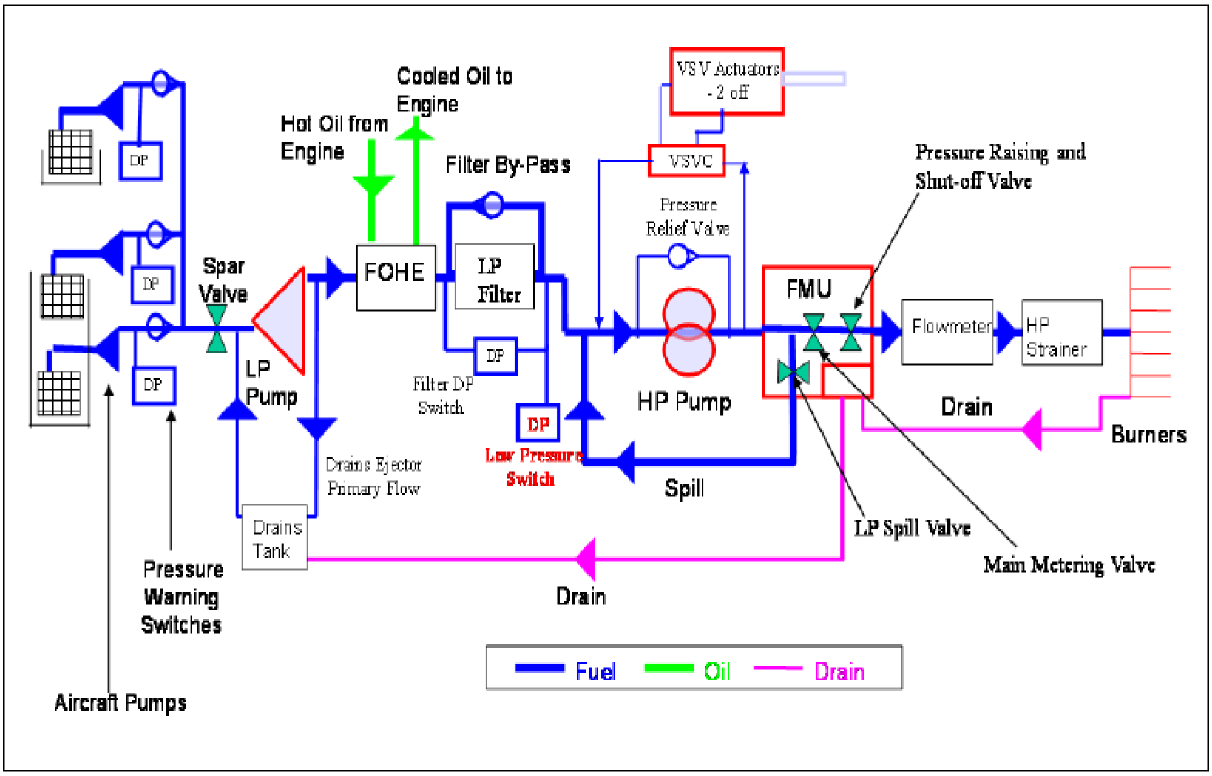


Figure 4: Schematic diagram of engine fuel system

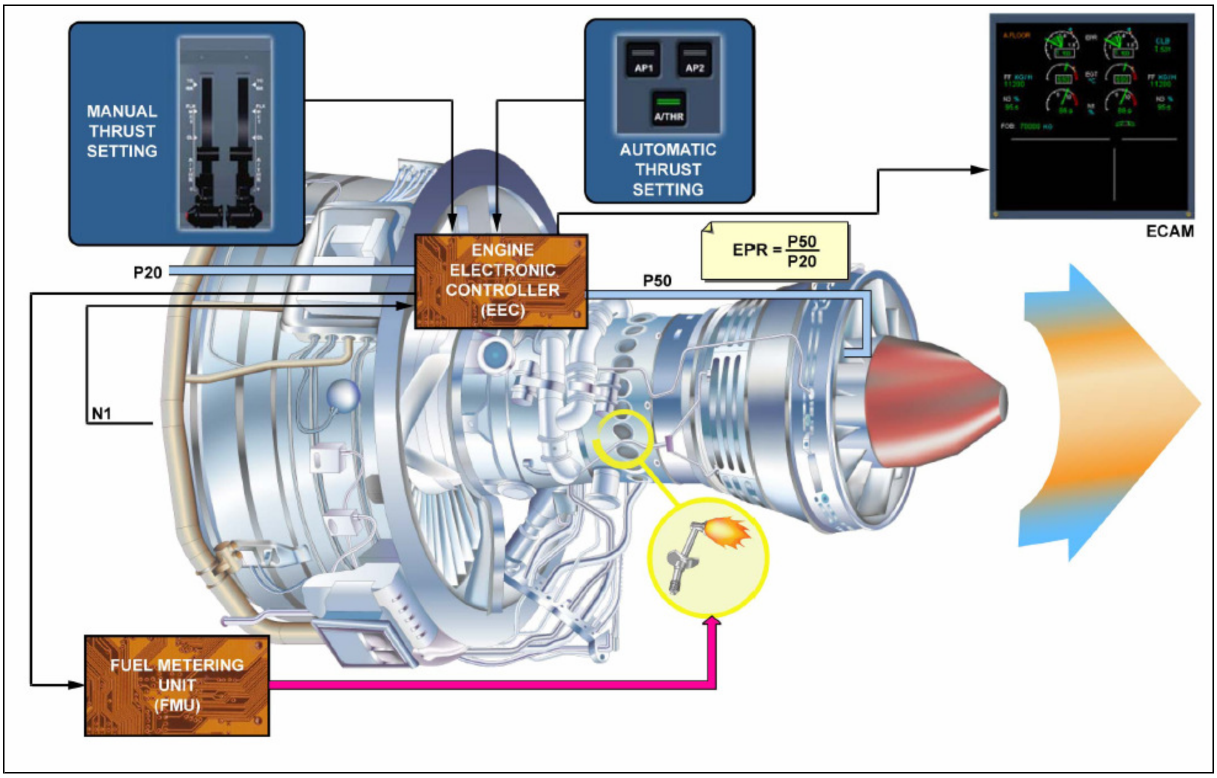


Figure 5: Schematic diagram of EEC and Thrust Control System

c. As illustrated in Figure 4, the engine low pressure valve controls the fuel supply from the aircraft fuel tanks to the engine fuel pump. The engine fuel pump includes a low pressure (LP) pump and a high pressure (HP) pump. Fuel from the tanks is initially supplied to the LP pump which is a single stage centrifugal impeller, then to the Fuel Oil Heat Exchanger for fuel heating and oil cooling, and to the LP fuel filter.

d. The LP fuel filter has a non-cleanable element with an absolute 40-micron filtration rating, which filters to 10 microns at 90% of the time. In the event of a partial blockage, a pressure differential switch which is set to 5 psi would provide a flight deck indication. If the filter becomes fully blocked, a filter bypass valve would open to allow unfiltered fuel to pass to the HP pump.

e. The HP pump is a positive displacement spur gear type pump which delivers fuel to the FMU. The HP pump is fitted with a full flow relief valve to prevent over pressurising the pump casing. The LP and HP pumps are integrated in the FPA, and the FMU is mounted to the FPA casing.

f. The main function of the FMU is to supply metered fuel to the nozzles for combustion. The FMU contains the following key sub-assemblies:

i. The servo pressure regulator (SPR) keeps the servo fuel pressure to the metering valve at a constant value greater than LP return pressure.

ii. The main metering valve (MMV) controls the rate of fuel flow for all operating conditions. It is a mated piston and sleeve design which acts as sliding valve mechanism and with close clearance. It is hydraulically actuated and controlled by the metering valve torque motor (TM). MMV position feedback for the control loop is sent to both channels of the EEC by a position resolver.

iii. The combined pressure drop and spill valve senses the pressure changes and operates the spill valve to maintain a constant pressure drop across the MMV.

iv. The pressure raising / shut off valve (PRSOV) is downstream of the MMV and maintains the metered fuel at a suitable pressure for engine operation, stops the fuel flow for engine shutdown and operates the dump valve. The PRSOV is controlled by a torque motor which receives signals from the EEC, flight deck fuel control switch, or engine fire switch.

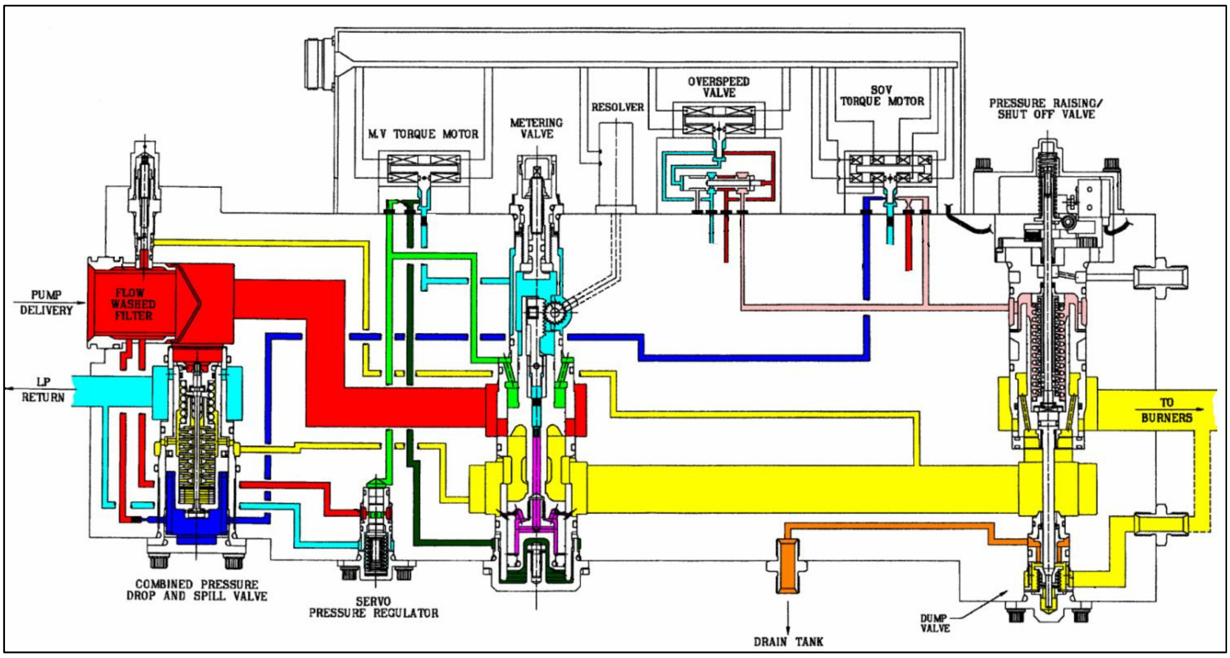


Figure 6: Schematic diagram of Fuel Metering Unit

g. Metered fuel flows through the fuel flow transmitter and the HP fuel filter before supplying the fuel manifold and the 24 fuel spray nozzles for combustion.

1.6.8 Engine Airflow Control

a. The engine compressor system is designed to function efficiently when the engine is operating in its normal range, i.e., at higher rotation per minute (rpm) range. In the low rpm range and during acceleration and deceleration, the airflow through the intermediate pressure (IP) and HP compressors could be unstable (stall / surge). An airflow control system which consists of variable stator vanes and IP and HP bleed valves is used to prevent a stall / surge condition in the IP and HP compressors.

b. The VSVs are adjusted during starting, acceleration, deceleration, and surge conditions to maintain the correct operation of the IP and HP compressors within the operational envelope. The angle of the VSVs are varied using a link and unison ring arrangement which is actuated by two fueldraulic VSV Actuators (VSVA).

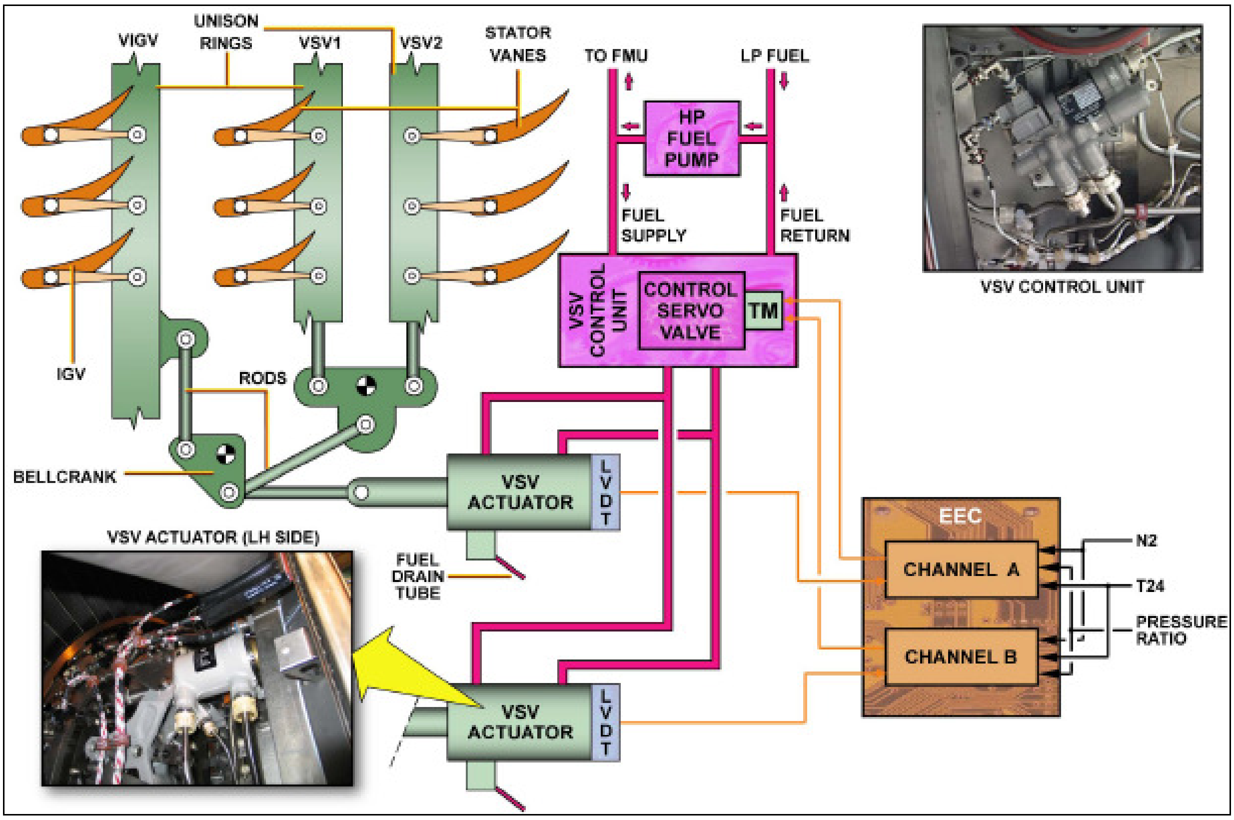


Figure 7: Schematic diagram of VSV control system

c. A VSV control unit (VSV Controller i.e. VSVC) uses a torque motor to divert HP fuel to either end of a control servo valve (CSV), which allows the fuel to flow to either the extend or the retract port of the VSVAs to operate the actuators. There are a constant pressure valve (CPV) and a pressure drop regulator (PDR) at upstream of the torque motor and CSV to regulate the pressure. The VSVC receives control signals from the EEC. A linear variable differential transformer (LVDT) in the VSVA feeds back the VSV position to enable closed loop control of the system.

1.6.9 Engine Thrust Control

a. The engine thrust (power) is controlled by the EEC which can be set either manually by the pilot via the thrust lever or automatically by the A/THR of the Automatic Flight System (AFS).

b. When A/THR is disconnected, the thrust levers control thrust directly. There are four detents dividing each of the lever sectors into three segments. Each position of the thrust lever within these limits corresponds to a predicted or commanded thrust. When the thrust lever is in a detent, the related thrust is equal to the thrust rating limit computed by the EEC of the engine:

i. TOGA: Max thrust for takeoff and go-around

ii. FLX MCT : Max continuous thrust or flex rating takeoff

iii. CLB: Maximum climb thrust

iv. IDLE : Idle

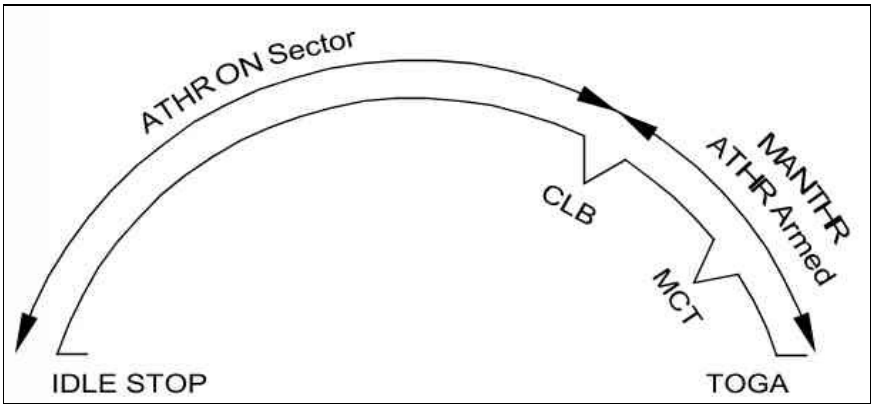


Figure 8: Thrust lever detents and segments

c. A/THR is a function of two independent Flight Management, Guidance and Envelope Computers (FMGEC).

d. A/THR includes two independent A/THR commands, one per FMGEC. Each one is able to control the thrust of both engines simultaneously through two Engine Interface Units and two EECs when A/THR is active. The A/THR, when active, will maintain a specific thrust in THRUST mode or controls the aircraft speed or Mach in SPEED/MACH mode. The A/THR can operate independently or with AP/FD. When performing alone, A/THR controls the speed. When working with the AP/FD, the A/THR mode and AP/FD pitch modes are linked together (e.g AP/FD descent mode is associated to A/THR Thrust mode, and Open DES mode to A/THR "Idle thrust" mode, etc.). Monitoring of the thrust demand is provided by the FMGEC.

e. The A/THR sends to both EECs the thrust targets that are needed to obtain and maintain a target speed when in SPEED mode, or obtain a specific thrust setting (e.g. CLB, IDLE) when in THRUST mode. When in SPEED or MACH mode, the A/THR does not allow speed excursions beyond certain limits, regardless of the target speed or Mach number.

1.6.10 Indicating System

a. The Electronic Instrument System (EIS) presents data to the pilots on six identical Display Units (DUs). The EIS is divided into two parts, the Electronic Flight Instrument System (EFIS) and ECAM. EFIS displays mostly flight parameters and navigation data on the Primary Flight Displays (PFDs) and Navigation Displays (NDs); and the ECAM presents data from the various aircraft systems on the Engine/Warning Display (EWD), System Display (SD), and "Attention Getters".

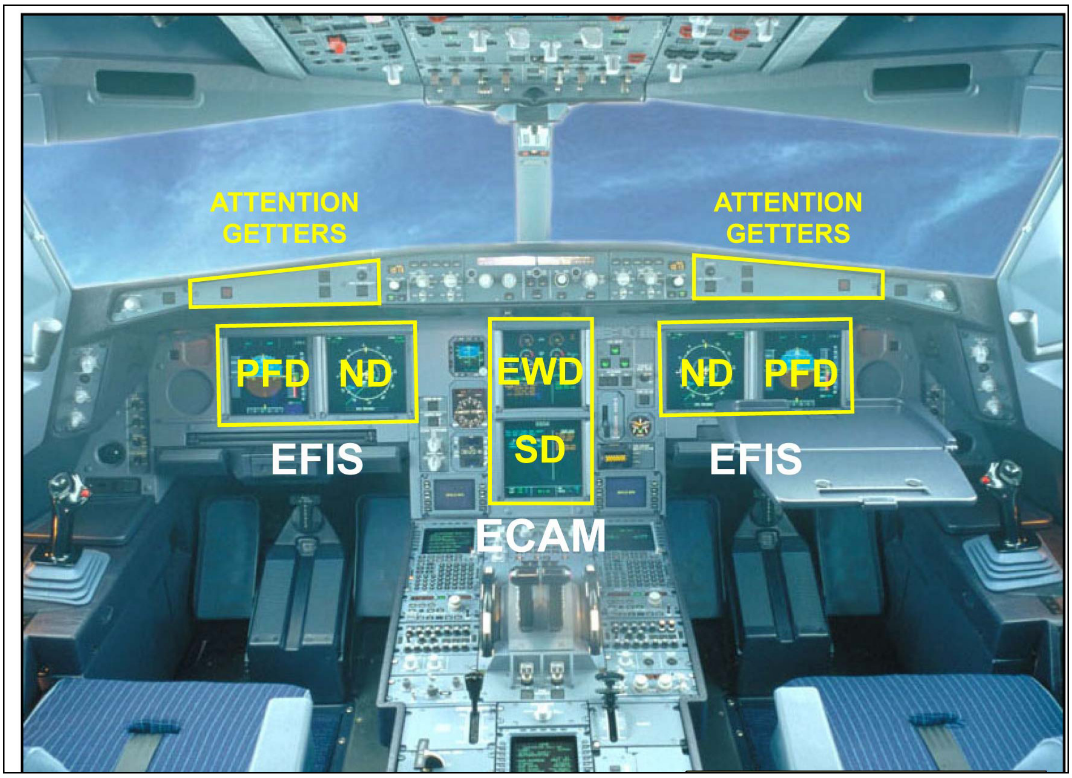


Figure 9: Overview of EIS

b. The ECAM information is presented on the centre instrument panel on an EWD and a SD. The EWD displays engine parameters, fuel on board, slat and flap position, warnings and memo messages. The SD displays synoptic giving the configuration of various aircraft systems.

c. The EWD, also called upper ECAM display, is divided into two areas. The upper area displays primary parameters such as engines parameters and the lower area displays warning and caution alert messages (including crew action checklists for these failures), secondary failures and memo messages.

d. The SD, also called lower ECAM display, is divided into two areas. The upper area displays system or status pages and the lower area displays the permanent data such as air temperatures and time.

e. ECAM alerts are classified in three levels, namely Alert Advisory (Level 1), Cautions (Level 2) and Warnings (Level 3), which reflect the importance and urgency of the corrective actions required. There are three priority levels for ECAM alerts, a Level 3 warning has priority over a Level 2 caution, which has priority over a Level 1 alert.

1.6.11 Acquisition of Aircraft System Data

a. The acquisition of aircraft system data is done by four major electronic systems, the ECAM system, the Flight Data Recording System (FDRS), the Central Maintenance System (CMS) and the Aircraft Condition and Monitoring System (ACMS).

b. The CMS includes the built-in test equipment (BITE) data of all electronic systems and two fully redundant Central Maintenance Computers (CMCs). The CMS produces Post Flight Report (PFR) which displays the ECAM messages such as WARNINGS/CAUTIONS occurred during the last flight, and Trouble Shooting Data (TSD) which presents internal snapshot data concerning any failure of any class for airline/manufacturer use.

c. The main functions of the ACMS are to monitor the engine condition, APU condition and aircraft performance, as well as provide trouble shooting assistance. The ACMS generates a set of pre-programmed reports, including the Engine Gas Path Advisory Report, when there is an exceedence of one of the primary engine parameters (EGT/N1/N2), or a stall, shutdown or flame out condition exists on one engine.

1.6.12 Wheels and Brakes

a. The landing gear system consists of two inboard retractable main gears and a forward retractable nose gear. Each main gear is a four wheel, twin tandem bogie assembly having an oleo-pneumatic shock absorber. The numbering of the wheels is from left to right, starting from front as seen in Figure 10.

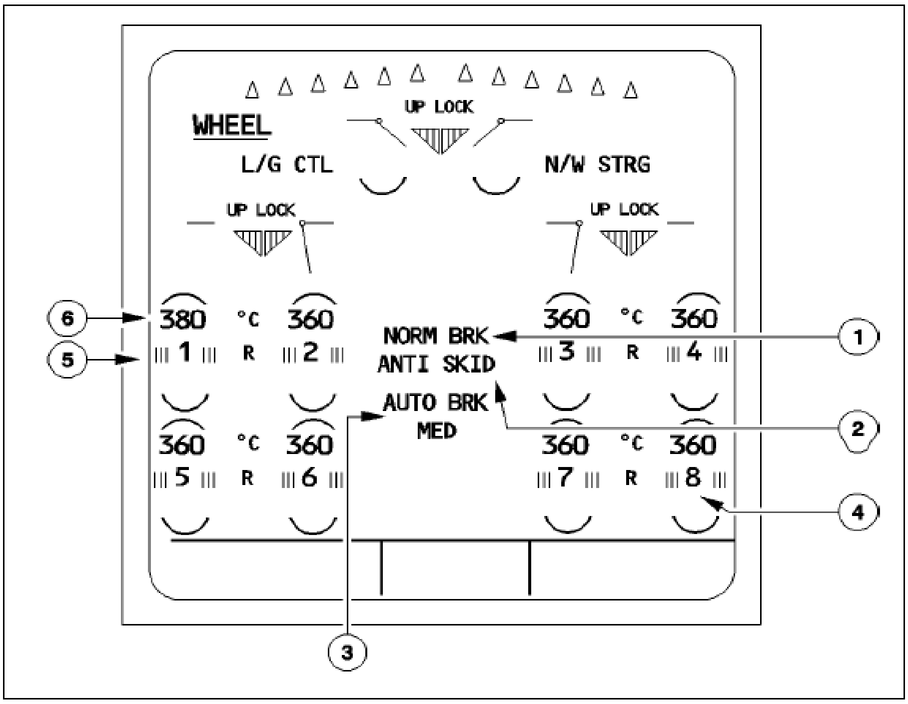


Figure 10: ECAM Wheel Page on System Display. Circle 5 shows wheel position and Circle 6 shows brake temperature

b. The wheels on the main gears are equipped with carbon multi-disc brakes which can be actuated by either of the two independent brake systems with antiskid function. The normal system uses green hydraulic system pressure whilst the alternate system uses the blue hydraulic system pressure backed up by a hydraulic accumulator. The antiskid function provides maximum braking efficiency by maintaining the wheel speed at the limit of an impending skid.

c. The heat generated during braking of the aircraft would increase the tyre pressure which is uncontrolled and if becomes excessive, could be hazardous to the safe operation of the aircraft. Temperature of brakes is monitored by the brake temperature monitoring system and each brake temperature is displayed in the ECAM System (see Figure 10). When the corresponding brake temperature exceeds 300°C, an ECAM caution with amber brake indication will be generated.

d. The wheel is fitted with a thermal relief plug which melts at a preset temperature as a result of the excessive heat generated from high energy braking action. The melting of the plug would release the tyre pressure and deflate the wheel preventing a tyre burst.

e. The deflation of No. 1, 2, 3, 5 and 7 main wheel tyres after the accident aircraft stopped was per the system design.

1.6.13 Emergency Evacuation

1.6.13.1 Exit Doors

a. There are eight exit doors, four on each side of the fuselage and are designed for use in an emergency evacuation for occupants inside the cabin. Of these eight exit doors, six are passenger doors and two are emergency doors. They are outward and forward opening plug type doors.

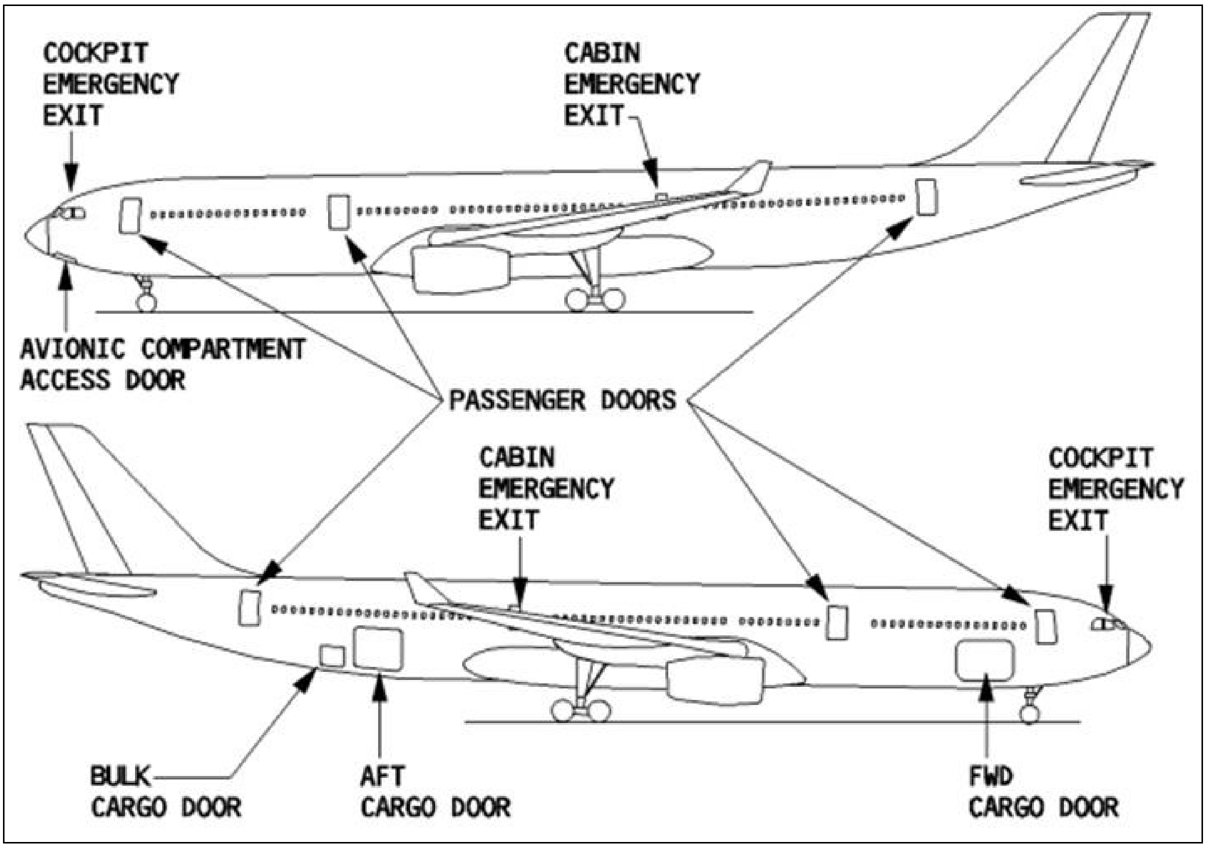


Figure 11: Exit door locations

b. Each exit door is fitted with:

i. two mechanical locking indicators for visual check of lock/unlock position.

ii. one warning light to show the ARMED or DISARMED condition of the escape slide.

iii. one CABIN PRESSURE warning light to indicate a residual pressure in the cabin.

1.6.13.2 Escape Slides

a. A slide/raft stowed in a container is attached to the inboard lower side of each door and allows passenger evacuation from the cabin. It can be converted to a raft during ditching.

b. Normal operation of the door is manual with hydraulic damping and a gust lock mechanism. The arming lever is placed in DISARMED mode and the door can be operated from inside or outside. An emergency opening system is also installed on each door. The system comprises:

i. an escape slide/raft for each passenger door, and an escape slide for the emergency exit. Each slide has its own inflation system. The Cabin Intercommunication Data System (CIDS) monitors the status of the inflation reservoir pressure sensor and the locking pin of the inflation system.

ii. a damper actuator which limits the door travel in normal mode and in the event of emergency, it acts as an actuator for automatic door opening.

iii. an arming lever.

c. For emergency evacuation, the slide arming lever on the door is placed in the ARMED position. The girt bar of the slide is connected to the floor brackets on both sides of the door. When the door is opened, the slide pack will then be pulled out from the door container and fall down under gravity, triggering the automatic inflation mechanism. If the inflation bottle fails to discharge automatically, it can be activated manually. Opening from the outside disarms the door and escape slide.

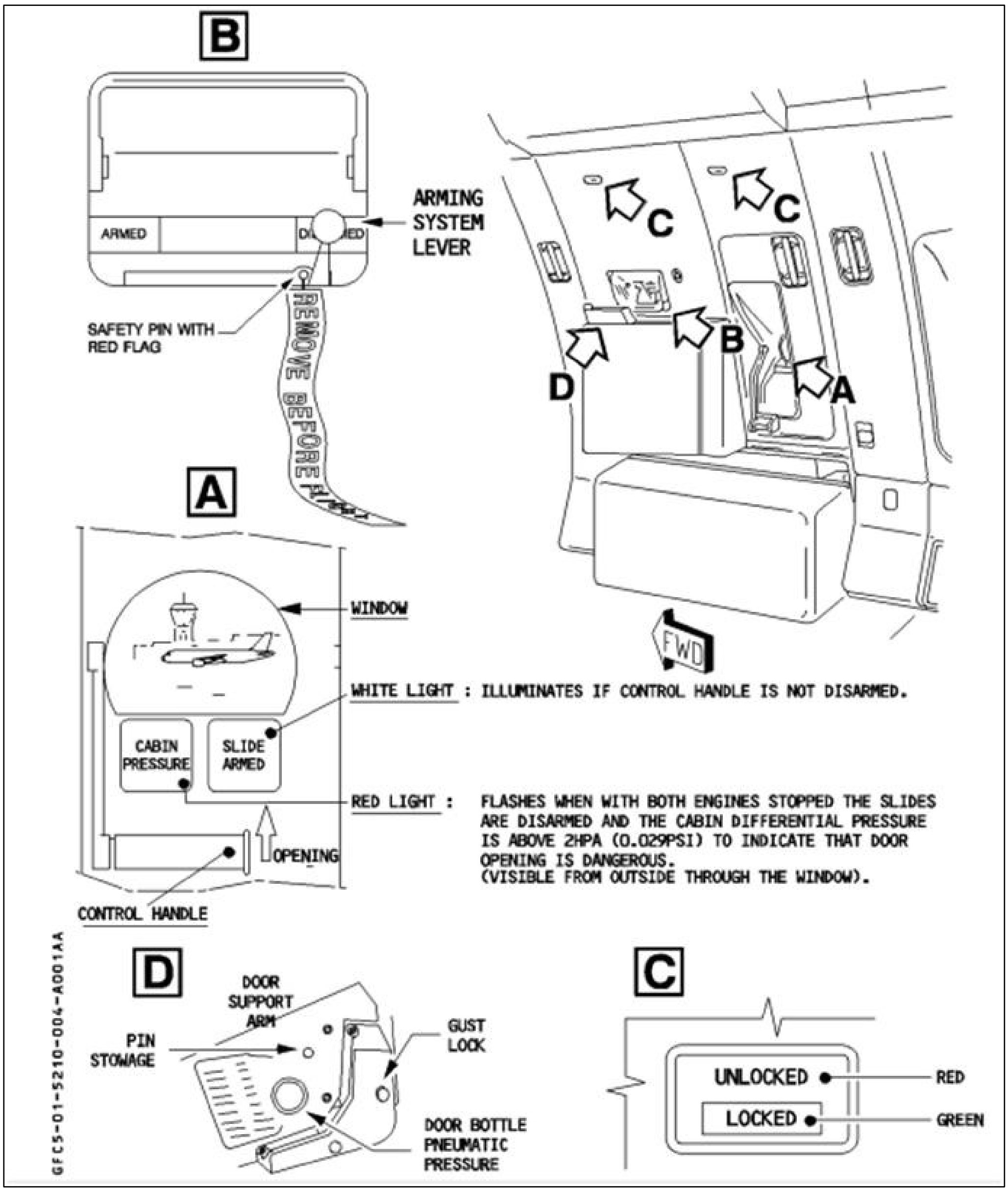


Figure 12: Exit door - inside view

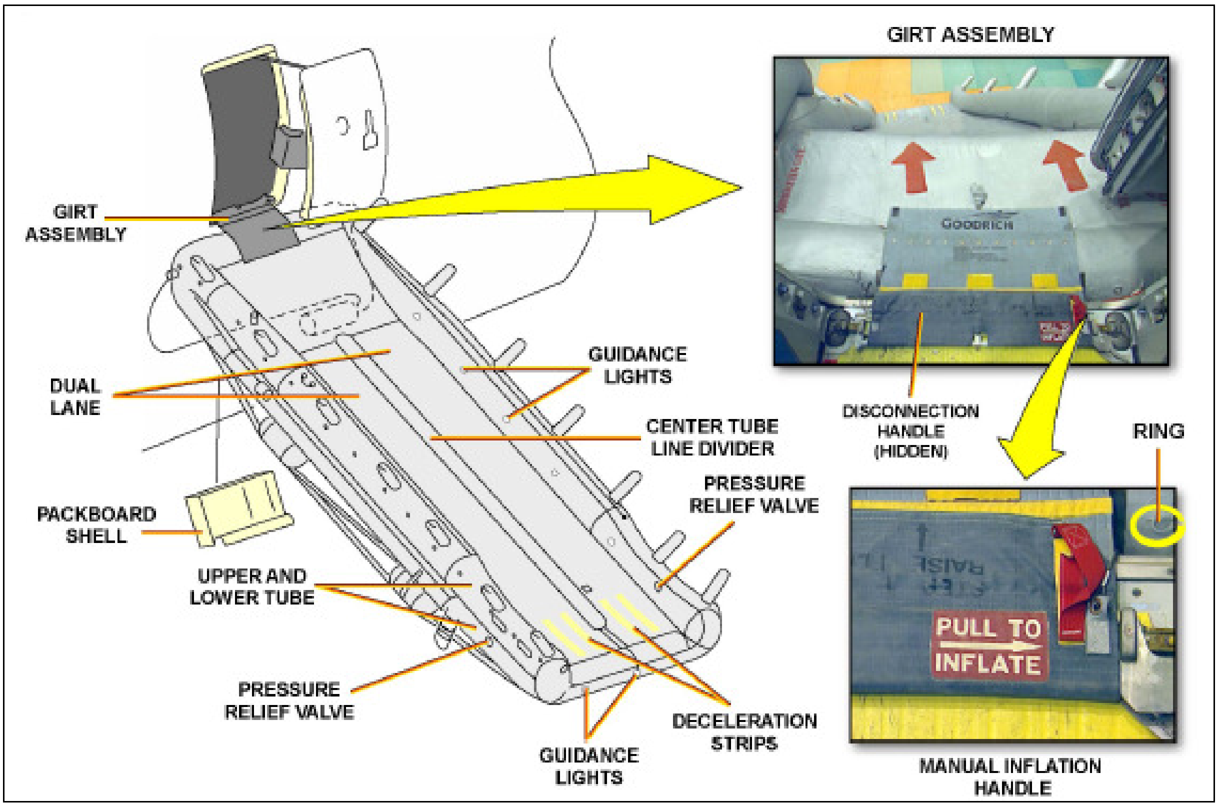


Figure 13: Typical slide/raft installation – slide mode

1.6.14 Enhanced Ground Proximity Warning System

1.6.14.1 General

a. The Enhanced Ground Proximity Warning System (EGPWS) is a system designed to alert pilots if their aircraft is in immediate danger of flying into the ground or an obstacle. It generates aural and visual warnings when one of the following conditions occurs between radio altitudes 30 feet and 2450 feet (for modes 2, 4, 5), and between 10 feet and 2450 feet (for modes 1 and 3):

- i. Mode 1 : excessive rate of descent
- ii. Mode 2 : excessive terrain closure rate
- iii. Mode 3 : altitude loss after takeoff or go around
- iv. Mode 4 : unsafe terrain clearance when not in landing configuration
- v. Mode 5 : excessive deviation below glide slope

b. In addition, the enhanced function provides, based on a world-wide terrain database, the following:

i. Terrain Awareness Display (TAD), which predicts the terrain conflict, and displays the Terrain on the ND.
ii. Terrain Clearance Floor (TCF), which improves the low terrain warning during landing.

c. The cockpit loudspeakers broadcast the aural warning or caution messages associated with each mode. "PULL UP" lights illuminate to give a visual indication when a "PULL UP" warning alert is triggered for modes 1, 2, and TAD. GPWS lights illuminate to give a visual warning for mode 1 to 4, TAD and TCF.

1.6.14.2 Mode 2

Mode 2 is associated with excessive terrain closure rate and has sub-mode of 2A for flap not in landing configuration and aircraft not on the glide slope beam. Mode 2A warning provides alerts to protect the aircraft from impacting the ground when rapidly rising terrain based on the Radio Altitude (RA) closure rate is detected. For CPA780, this warning was triggered before landing when the aircraft entered the edge of the VHHH airport island and at RA of 217 feet with a closure rate 2100 fpm. This fell into the Mode 2 triggering envelope and the warning was triggered as per system design.

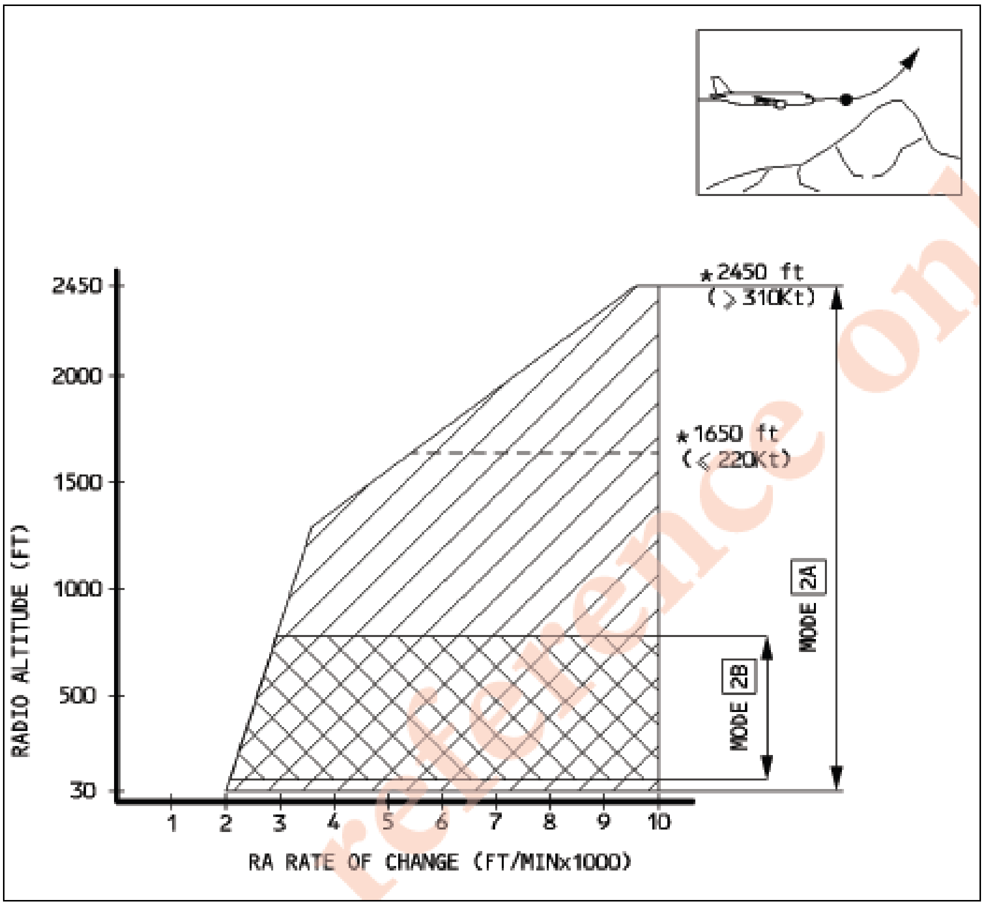


Figure 14: Operation of Mode 2 – Excessive Terrain Closure Rate

1.6.14.3 Mode 4

Mode 4 is associated with unsafe terrain clearance and has sub-mode of 4B for landing gear down and flaps not in the landing configuration or landing gear up and flaps in the landing configuration. Depending on the area and the configuration, three aural warnings may be generated: "TOO LOW-GEAR", "TOO LOW-FLAPS" or "TOO LOW-TERRAIN". For CPA780 during final approach, the warning "Too Low Terrain" was generated by EGPWS Mode 4B which provides alerts for insufficient terrain clearance with respect to flight phase, configuration and speed. This warning was triggered as per the system design.

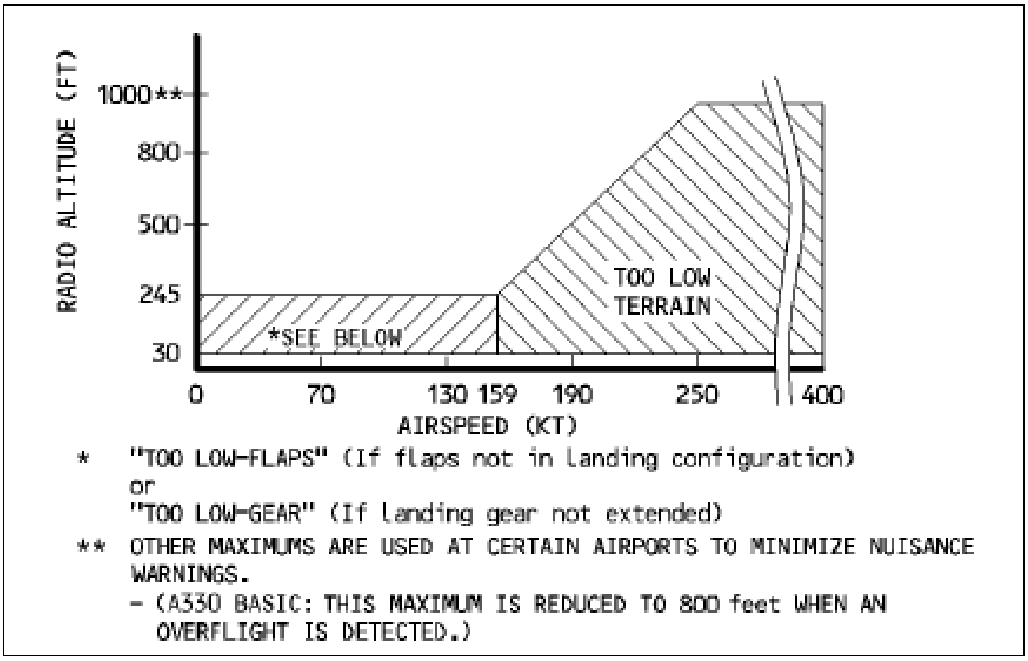
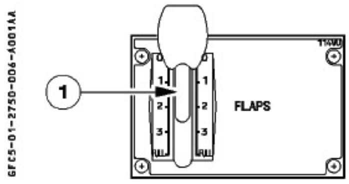


Figure 15: Operation of Mode 4B

1.6.15 Flap Load Relief System

a. Lift augmentation is achieved on each wing at the trailing edge by two flap surfaces and two aileron surfaces via the aileron droop function, and at the leading edge by the seven slat surfaces. These surfaces are electrically signalled and hydraulically operated and are simultaneously controlled by selection of the “FLAPS” control lever located on the centre pedestal. The control lever has five positions: 0, 1, 2, 3, and FULL.

PEDESTAL



① FLAPS lever

The FLAPS lever selects simultaneous operation of the slats and flaps.
The five lever positions correspond to the following surface positions:

Lever Position	SLATS	FLAPS	AILERONS	Ind. on ECAM	FLIGHT PHASE		
0	0	0	0				CRUISE
1	16	0	0	1			HOLD
		8	5	1 + F	TAKEOFF		
2	20	8	10	2(a)			
	20	14	10	2			APPR
3	23	14	10	3(b)	TAKEOFF		
3	23	22	10	3		LDG	
FULL	23	32	10	FULL			
(a) This slats/flaps position corresponds to CONF 1*							
(b) This slats/flaps position corresponds to CONF 2*							

Before selection of any position, the lever must be pulled out of detent.
Moreover, balks are provided at position 1 and 3 to avoid excessive flap / slat travel demand by a single pilot action.

Note : It is not possible to select an intermediate lever position.

Figure 16: Flap control lever and flaps/slats configuration

b. Due to the structural limitation of the flap/slat surfaces, each flap/slat position (configuration) has an airspeed limit to prevent overloading of the flap/slat surface by the air loads during flight. The Flap Load Relief System (FLRS) relieves the loads by limiting flap / slat surface extension to a relief angle when the airspeed exceeds the Velocity Flap Extended (VFE) of respective flap/slat setting.

c. When activated, the FLRS automatically retracts the flaps to the deflection corresponding to the next further retracted lever position, and a green flashing "F RELIEF" message is displayed on the EWD. When the airspeed drops below VFE, the flaps automatically extend again to the flap lever setting. FLRS protection is available only in CONF 2, 3 or FULL.

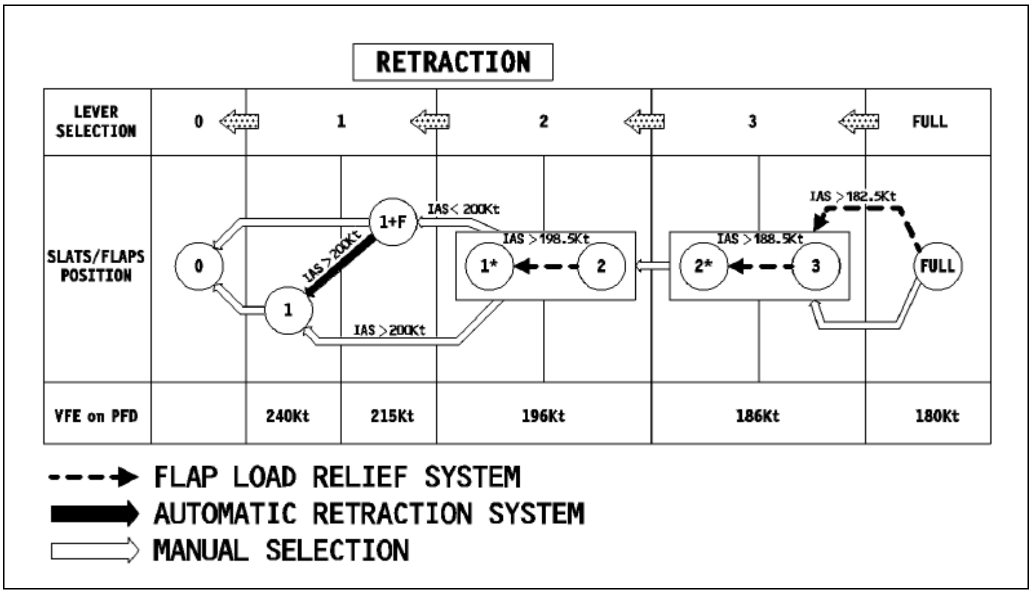


Figure 17: Flap retraction cycle

d. With flap/slat at CONF 2, auto retraction results in CONF 1* (20 slats /8° flaps). In CONF 3, auto retraction results in CONF 2* (23 slats / 14° flaps). CONF 1* and CONF 2* can only be obtained when FLRS is activated.

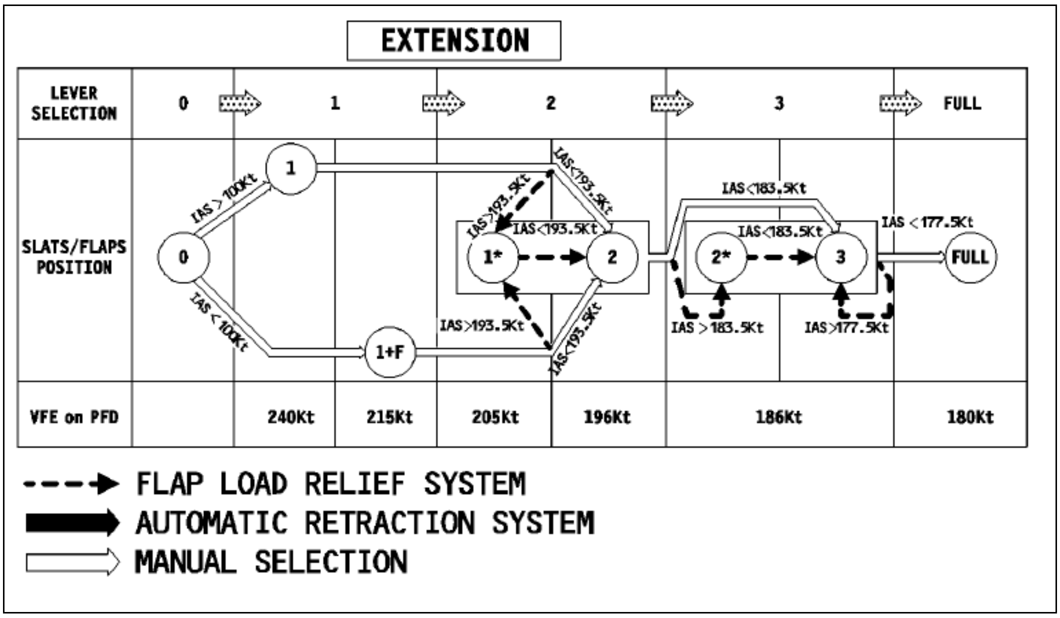


Figure 18: Flap extension cycle

e. During FLRS activation, the ECAM upper display shows a flashing "F RELIEF" message. If the airspeed is increased by 4 kt above the VFE corresponding to the actual flap / slat configuration, an overspeed warning is provided on ECAM.

f. During the final approach of CPA780, the activation of the FLRS was per the system design.

1.7 Meteorological Information

1.7.1 Meteorological Information at the Departure Aerodrome

a. The METAR for WARR at 0030 hrs indicated that the wind was from a variable direction at two kt. The visibility was seven km, with scattered clouds at 1,800 ft and few Cb clouds at 2,000 ft. Temperature was 28 degrees C and dew point at 25 degrees C. QNH was 1009 hPa. There were some Cb clouds to the northeast of the airfield.

b. The prevailing meteorological conditions at the departure airport were not a contributing factor in the accident.

1.7.2 Meteorological Information En Route

a. According to the flight crew, there was no significant weather encountered by CPA780 en route, which was confirmed from the satellite imageries.

b. The prevailing meteorological conditions en route were not a contributing factor in the accident.

1.7.3 Meteorological Information at the Destination Aerodrome

a. The arrival ATIS information "India" at 0536 hrs stated that the arrival runway in use was 07L. Significant windshear was forecasted. Surface wind was 130 degrees at 18 knots, wind direction varying between 100 and 170 degrees. Visibility was 10 km with few clouds at 800 ft and scattered clouds at 2,000 ft. Surface temperature was 29 degrees C and dew point at 24 degrees C.

QNH was 1012 hPa. According to the ATC, one aircraft carried out missed approach on Runway 07L as a result of windshear and subsequently landed on the second approach 1 hr 45 mins before the arrival of CPA780. A windshear warning was in force for all runway corridors during the 15 mins before the arrival of CPA780 but no actual windshear alert was issued for the Runway 07L corridor.

b. The prevailing meteorological conditions at the arrival airport were not a contributing factor in the accident.

1.8 Aids to Navigation

There was no report of malfunction on any navigation aids along the route of CPA780. Ground-based navigation aids and aerodrome visual ground aids were not a factor in the accident.

1.9 Communications

a. The aircraft was equipped with three VHF radio communication systems. All VHF radios were serviceable. All communications between Hong Kong ATC and the crew were recorded by ground based automatic voice recording equipment. The quality of the aircraft's recorded transmissions was good.

b. The aircraft was equipped with SATCOM. The flight crew had contacted the company IOC using the SATCOM to discuss the ECAM messages that appeared during flight. The communication was clear throughout to both parties, apart from the normal slight delay encountered in satellite communication.

c. At VHHH, VHF 121.9 MHz was assigned for rescue services with callsign "Rescue Leader". This frequency was shown on the VHHH "Port Page" provided by CPA. The quality of the communication recorded by ATC was good.

1.10 Aerodrome Information

1.10.1 Aerodrome of Departure

Aerodrome Code	:	WARR
Airport Name	:	Juanda International Airport
Airport Authority	:	DGCA Airport Administrator
Airport Operator	:	Angkasa Pura I
Owner of Aviation Fuel Storage, Hydrant System and Dispensers	:	DGCA Airport Administrator
Aviation Fuel Supplier and Fuel Quality Control	:	PT. Pertamina
Operator of Aviation Fuel Storage, Hydrant Dispensers and Hydrant System	:	PT. Pertamina
Coordinates	:	7° 22' 53" S, 112° 46' 34" E
Elevation	:	9 ft
Runway Length	:	3, 000 m
Runway Width	:	45 m
Stopway	:	Nil
Azimuth	:	R10 / R28
Category for Rescue and Fire Fighting Services	:	CAT 8

1.10.2 Aerodrome of Destination

Aerodrome Code	:	VHHH
Airport Name	:	Hong Kong International Airport
Airport Address	:	Chek Lap Kok, Lantau Island
Airport Authority	:	Airport Authority Hong Kong
Air Navigation Services	:	Approach Control, Aerodrome Control, Ground Movement Control, Zone Control, Flight Information Service, Clearance Delivery Control, Automatic Terminal Information Service
Type of Traffic Permitted	:	IFR/VFR
Coordinates	:	22° 18' 32" N, 113° 54' 53" E
Elevation	:	28 ft
Runway Length	:	3,800 m
Runway Width	:	60 m
Stopway	:	Nil
Runway End Safety Area	:	240 m x 150 m
Azimuth	:	07L / 25R, 07R/ 25L
Category for Rescue and Fire Fighting Services	:	CAT 10

1.11 Flight Recorders

1.11.1 Flight Data Recorders (FDR)

a. The aircraft was equipped with a Honeywell 25-hour Solid State Flight Data Recorder (SSFDR) of P/N 980-4700-003. There were 359 parameters recorded in the SSFDR. The SSFDR was not damaged in the accident and the flight data record was successfully downloaded and retrieved for the investigation.

b. The flight path derived from the SSFDR was examined during the investigation and is shown in ***Appendix 1***. The relevant engine data plot is discussed in 1.11.3. The 'Sequence of Events' for the relevant flight data is presented in ***Appendix 4***. The occurrence sequence is described with reference to the UTC time from the start until the end of the CPA780 flight.

c. The Flight Data Recorder (FDR) recording of both engines EPR and N1 in conjunction with Pressure Altitude, and Calibrated Airspeed during climb, cruising and final approach phases were plotted and are shown in ***Appendix 5***. Engine thrust command and performance when engine stall are summarised in ***Appendix 6***. The data indicated at about UTC 05:31, when the aircraft was at pressure altitude 8,000 feet during approach, flight crew changed both engine thrust levers and the corresponding engine EPR command signals changed synchronously. However the associated fuel flow values of the engines did not change according to the command signals. This indicates that the fuel control systems of both engines were not functioning in accordance with the thrust command.

d. The aircraft was also equipped with an optional Penny and Giles Quick Access Recorder (QAR) of P/N D52000-62200 which has a recording capacity of 179 hours. The QAR was installed in the Digital ACMS Recorder (DAR) position and the source of the data was from the Data Management Unit (DMU). There is no mandatory requirement on QAR system and the dataframe is operator re-programmable and is based on a standard dataframe initially defined by the aircraft manufacturer. For the accident aircraft, the QAR data provided additional aircraft and engine system data to supplement the FDR data during the investigation. The QAR was not damaged in the accident and the flight data record was successfully downloaded and retrieved for the investigation.

1.11.2 Cockpit Voice Recorder (CVR)

The aircraft was equipped with a Honeywell 120-minute Solid State Cockpit Voice Recorder (SSCVR) of P/N 980-6022-001. The SSCVR was not damaged in the accident and the cockpit voice record were successfully downloaded and retrieved. The last 120 minutes crew communications and cockpit aural alerts/voice messages associated with ECAM messages were recorded and retrieved successfully. The transcript derived from the SSCVR was examined. As the duration of the CPA780 flight was about four hours, the CVR data recorded in the earlier phases of climb and cruising had been overwritten by the subsequent record. Extract of communication among the flight crew, cabin crew, ATC and rescue leader is shown in ***Appendix 7***.

1.11.3 Post Flight Report Analysis

The aircraft system data from CPA780 recorded by PFR, TSD, and Engine Gas Path Advisory Reports (EGPAR) were reviewed. A tabulated result is presented in ***Appendix 9.*** Each relevant event was explained by the manufacturers. There were instances of high control currents in the torque motors and unresponsive fuel components at 0158 hrs, 0316 hrs, 0519 hrs, 0530 hrs, 0532 hrs and 0538 hrs indicating control problems in the FMUs and VSVs. The high control currents indicated the presence of stiction (i.e., the static friction that needs to be overcome to enable relative motion of stationary objects in contact) in the relevant engine fuel components. Such components had eventually seized.

1.11.4 Engine Parameter Fluctuations

a. The engine EPR fluctuations of CPA780 were reviewed. As the other company aircraft B-HLM was refuelled at WARR and operated CPA780 for the previous two days (i.e. 11 and 12 of April 2010) before the accident, the engine EPR parameters of these flights were also reviewed.

b. The engine data indicated that the EPR fluctuation on both engines of the accident aircraft were initially observed during climb from WARR and continued throughout the flight. The No. 1 engine of the accident aircraft had a smaller range of fluctuation than that of No. 1 engine of B-HLM for the flight from WARR to VHHH on 12 April 2010. The No. 2 engine of the accident aircraft had a larger range of fluctuation than that of the No.2 engine of B-HLM. While both engines of the accident aircraft had engine ECAM messages, there was no engine ECAM message on B-HLM.

1.12 Wreckage and Impact Information

a. No. 1 engine (LH engine) cowl lower surface sustained impact damage as it contacted the runway surface during touch down causing consequential damage to the engine. There were engine fan blade tip rub marks at six and 12 o'clock positions on the fan case caused by deformation of the casing as the engine contacted the runway.

Figure 19: Damage on No. 1 engine cowl lower surface

b. No. 1, 2, 3, 5 and 7 main wheel tyres deflated after the aircraft stopped. The associated thermal relief plugs installed on the wheels were found melted.

Figure 20: The deflated No. 3 and 7 wheels

c. Analysis of the flight data by the manufacturer concluded that the left main landing gear and nose landing gear had experienced a vertical load which exceeded the designed limit load.

1.13 Medical and Pathological Information

No medical or pathological investigations were conducted as a result of this occurrence, nor were they required.

1.14 Fire

a. There was no evidence or report of in-flight fire. After the aircraft came to a complete stop on the runway after landing, the AFC reached the aircraft within 1.5 minutes. The AFC Rescue Leader reported a small fire and smoke coming out from the landing gear wheels on both sides. The AFC used water to extinguish the fire as well as cool down the landing gear.

b. Post accident shop examination did not reveal any fire damage to the landing gears, wheels and brakes.

1.15 Survival Aspects

1.15.1 The Evacuation

a. After the aircraft came to a complete stop, the atmosphere in the cabin remained generally quiet. The Commander made a PA informing everyone to "remain seated". The ISM repeated the same instruction via PA. Some cabin crew members shouted out the same message to remind the passengers. Most passengers were cooperative except that a few had risen from their seats and looked outside the windows. Later, the Commander gave the order "evacuate, evacuate". The cabin crews responded to the command immediately and initiated the evacuation.

b. After confirming the absence of fire or smoke outside the emergency exits, the cabin crew opened all the eight aircraft doors for evacuation. During the process, doors L1, R1 and R4 were each manned by two cabin crews, and the other five doors were each attended by one cabin crew. From the airfield CCTV camera installed at VHHH, it could be seen that the aircraft doors began to open at around 0550 hrs and followed by the slide inflation except that after door R4 was opened, the slide did not come out. After being aware that the arming lever on the R4 door was at DISARM position, the cabin crew closed the door, put the arming lever to ARM position, and reopened the door. This time the R4 door slide was successfully deployed.

c. The cabin crew guarded the doors whilst the escape slides were inflating. Once the slides were deployed, the cabin crew instructed passengers to "come this way, follow me, leave bags" and assisted them to jump down whenever necessary. Some Indonesian speaking passengers could not understand the evacuation commands, which were given in English and Chinese, and some misunderstood that it was just a normal but quick disembarkation. The cabin crew had used body languages, including hand motion and pointing of directions, to instruct passengers to evacuate. Some passengers carried their cabin bags despite the cabin crew instruction asking them to leave their bags behind. Some passengers lost their balance and rolled down the slides. There was congestion at the bottom of some slides at certain stages during the evacuation. There was no evidence that the reported wheels fire and smoke had hampered the evacuation process or affected the survivability of the crews and passengers. The evacuation process was completed in about two minutes and 15 seconds.

d. After confirming that there were no passengers remaining on board, the crew evacuated the aircraft. The ISM, the First Officer and the Commander were the last to leave the aircraft. After the evacuation, the AFC officers entered the aircraft cabin to confirm that there was nobody remained on board the aircraft.

e. During the evacuation, a female passenger at seat 31G, exiting through door L2, was seriously injured. Her left ankle was fractured and dislocated. She was assisted by other passengers and policeman at the bottom of the slide and was subsequently hospitalised for surgery. Apart from this passenger, 56 other passengers sustained minor injuries such as abrasions, bruises, shoulder pain, back pain, buttock pain and sprained ankle, etc. Most of them received medical treatment at the airport and were all discharged. Nine of the minor injured passengers were sent to hospital for further treatment. Six cabin crew members also had minor injury during evacuation from the slides.

1.15.2 Airport Emergency Response

a. At 0521 hrs, the accident aircraft made a PAN call to Hong Kong Radar advising No. 2 engine was operating at idle thrust. On receipt of the PAN call from the accident aircraft, the air traffic controller immediately notified the Approach Supervisor (APS) who in turn informed the Aerodrome Supervisor (ASU) and other units in accordance with standing instructions. Workstations of the involved air traffic controller, APS and Watch Manager (WMR) were all located in the Air Traffic Control Centre of the ATC Complex. Workstation of ASU was separately located in the Tower Cab on the top floor of the ATC Tower building. After ascertaining the accuracy of all information available, the ASU initiated a Local Standby (see Note below) for the accident aircraft in preparation for its arrival. Within five minutes upon receipt of the notification, two units of AFC appliances were mobilised and positioned at two locations in the vicinity of Runway 07L touch-down area.

[Note – Local Standby is a situation in which an aircraft approaching the airport is known to have, or is suspected to have, developed some defects, but one that would not normally involve any serious difficulty in effecting a safe landing.]

b. At 0532 hrs, the accident aircraft called "MAYDAY" and advised Hong Kong Approach of the double engine stall situation. On receipt of the "MAYDAY" call from the accident aircraft, the air traffic controller again notified the APS immediately. APS, faced with a sudden surge of workload associated with the emergency, passed on the information to the WMR for onward dissemination to all concerned parties including the ASU. As per established practice, the WMR of ATC contacted the CPA IOC for more information regarding CPA780. The update provided by CPA IOC was that the No.2 engine of the accident aircraft was at idle power. Based on this reply from CPA IOC, the WMR accordingly briefed the ASU who concluded that it was not necessary to upgrade the emergency category to Full Emergency (see Note below).

[Note – Full Emergency is a situation in which an aircraft is known or suspected to be in such trouble that there is danger of an accident. Under the circumstance where a twin-engine aircraft encountered dual engine stall, ATC

would, in accordance with standing instructions, upgrade the emergency category to Full Emergency.]

c. CPA780 landed on Runway 07L at 0543 hrs. AFC reported the landing was unusual and some abnormal white and black smoke was observed coming out from the landing gear. AFC appliances immediately accelerated and followed the aircraft. After obtaining ATC clearance, one unit of AFC appliance entered Runway 07L and the other unit made use of Taxiway B to pursue the aircraft. Throughout the aircraft landing roll, AFC noticed that smoke kept coming out from the aircraft landing gear.

d. The first AFC appliance arrived at the stationary accident aircraft at 0545 hrs. The AFC reported seeing smoke and fire from both sides of the landing gear and applied water to extinguish the fire and to cool the hot brakes. The AFC Rescue Leader on scene established communication with the cockpit at 0548 hrs and informed the pilots of presence of the small landing gear fire. Refer to ***Appendix 8*** for ATC recording between CPA780, AFC and ATC. The Commander then ordered an emergency evacuation. Noting the deployment of slides from the aircraft at 0550 hrs, the ASU upgraded the emergency category to Ground Incident (see Note below) in accordance with standing instructions.
[Note - Ground Incident is a situation in which an aircraft on the ground is known to, or suspected to have, an emergency situation other than an accident, which requires the attendance of emergency services.]

e. The AFC officers assisted the passengers at the foot of some slides. With the assistance from Airport Police and the staff of Airport Authority Hong Kong, (AAHK) all passengers, uninjured or with minor injury, and the crew were gathered at nearby grass areas on both sides of the aircraft.

f. The AAHK deployed passenger buses to transfer passengers and crew to the North Apron Passenger Vehicle Lounge for further medical treatment and processing.

g. Fire Service Department Ambulance Services were notified of the “Local Standby” at around 0535 hrs. The first ambulance responded upon notification of the "Ground Incident". Other ambulances arrived subsequently. Ten passengers were sent to hospitals.

h. All emergency response units responded promptly and in accordance with the standing instructions.

1.16 Tests and Research

1.16.1 General

a. After the accident, the following items were collected for examination and analysis:

i. Fuel samples from the accident aircraft and its engines.

ii. Engine fuel components from the engines of the accident aircraft and No. 1 engine of aircraft B-HLM.

iii. Fuel samples from the ground fuel supply system in WARR.

iv. Filter monitors (the final filtration used on fuelling vehicle before the fuel enters aircraft fuel tank) of the dispenser JUA06.

b. Analysis of certain aircraft fuel samples were performed at laboratory in Hong Kong, and examination and further analysis of the above items were performed in the United Kingdom (UK). A series of examinations and tests on the filter monitors were also performed by Shell Global Solutions (UK) Aviation Fuels and Analytical Technology groups at Shell Technology Centre Thornton, UK.

c. The above items were examined under a low to medium power stereomicroscope, and the following techniques were also used in analysing the composition and chemistry of foreign substance identified on these items. The results of the examinations were analysed in a collective manner and presented in the following Sub-sections.

i. Scanning electron microscopy (SEM)

ii. SEM with energy dispersive X-ray spectroscopy (EDX)

iii. X-ray diffraction (XRD)

iv. X-ray photoelectron spectroscopy (XPS)

v. Fourier Transform Infra-red spectroscopy (FT-IR)

1.16.2 Fuel Samples

1.16.2.1 Aircraft Fuel Samples

a. Fuel samples were collected from the aircraft fuel tank sump drains, APU fuel line, and APU fuel filter drain of the accident aircraft. The fuel samples met the specification of Turbine Fuel Jet A1 as defined in Defense Standard 91-91 (Issue 6 incorporating Amendment 1 of August 2008) and the AFQRJOS (Aviation Fuel Quality Requirements for Jointly Operated Systems) Check list 24 dated on 1 October 2008. The aircraft fuel met the fuel specification of A330 Trent 700 as stated in the A330 Airplane Flight Manual.

b. There were trace quantity of translucent spherical particulate matters in some fuel samples. As discussed later in this Sub-section, similar spherical particulate matters were also identified in other fuel samples and inside some engine components. The particulate matters were further examined and their structure and source were analysed. The results indicated that they were predominantly made up of carbon, oxygen, and sodium, with moderate amount of chlorine and sulphur, and were mainly sodium polyacrylate which was consistent with the super absorbent polymer (SAP) material used in the filter monitors installed in a fuelling dispenser. This particulate matter will be called “SAP sphere” in this Report and its structure and composition will be further discussed in this Sub-section.

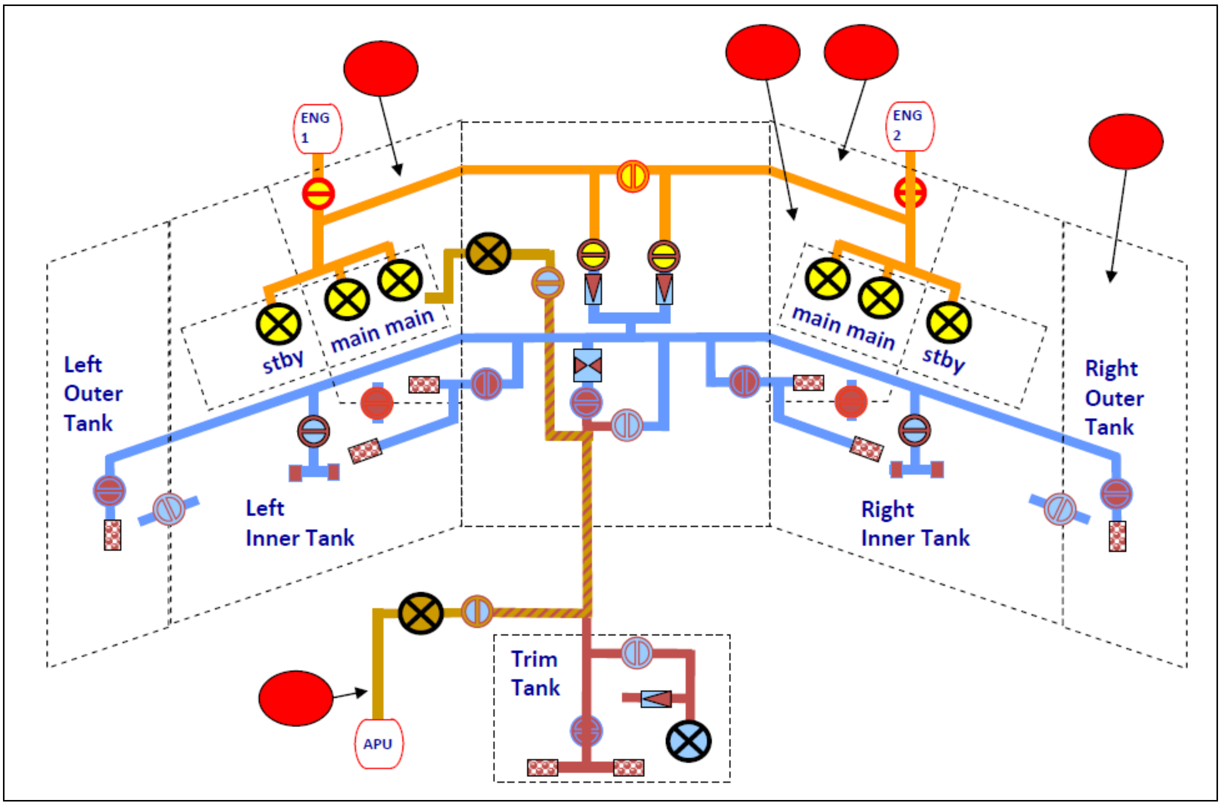


Figure 21: Aircraft fuel sampling locations.
Red dots highlight those locations where the SAP spheres were present.

1.16.2.2 Engine Fuel Samples

Fuel samples were collected from the engine fuel lines and the engine fuel components. There were significant quantity of SAP spheres in fuel samples drained from the VSVA, the VSVC, and the FMU, including from the FMU of the No 1. engine of aircraft B-HLM.

1.16.2.3 WARR Ground Fuel Samples

Fuel samples were collected from both the upstream and the downstream of the filter vessel on Dispenser JUA06, the ground refuelling hydrant at Stands No. 8 and 11, the fuel storage tank of WARR, and three low points of the WARR hydrant circuit. There was no sign of SAP spheres in the ground fuel samples. Water containing sodium chloride (NaCl) was found in the fuel sample collected from Header Pit 3 which was a low point in the hydrant circuit supplying Stands No. 1 to 10. Inspection of fuel storage facilities, which is located upstream of the hydrant circuit, revealed no sign of NaCl corrosion. One SAP sphere was found trapped in the wire mesh of the gauze strainer which was fitted to the outlet hose of the dispenser (the hose end strainer).

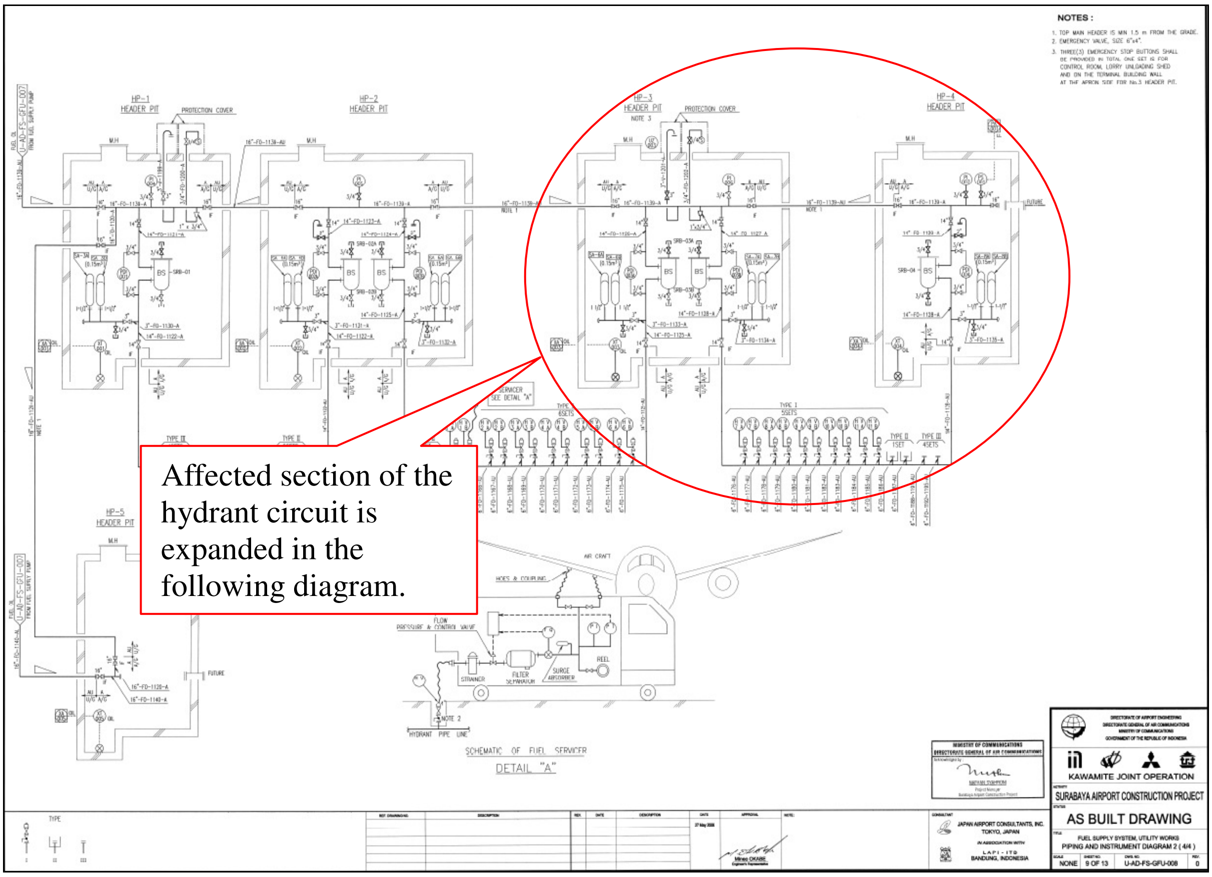


Figure 22: The WARR Ground hydrant refuelling circuit

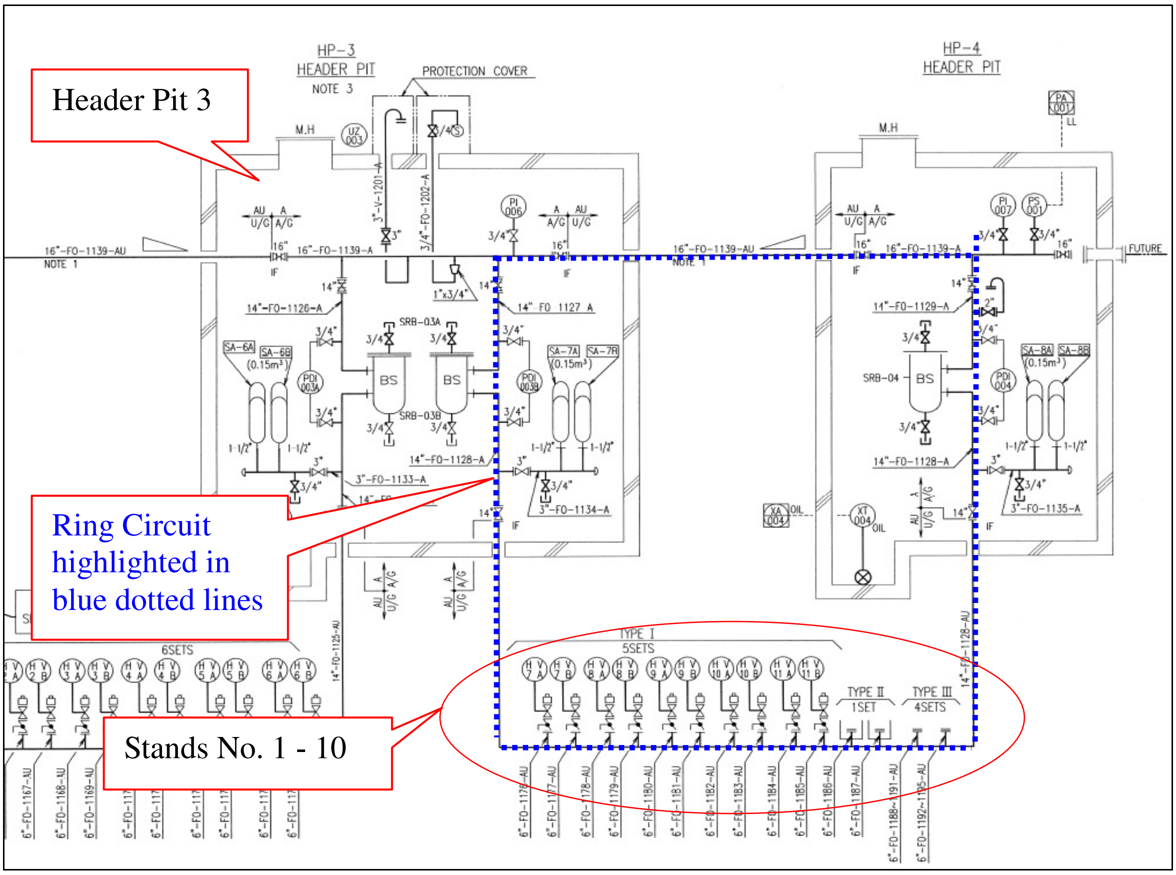


Figure 23: The WARR Ground hydrant refuelling circuit showing Header Pit 3 and the ring circuit that supplies fuel to Stands No. 1 to 10

1.16.3 Engine Components

1.16.3.1 General

Fuel components from both engines of the accident aircraft were removed for examination. The No.1 FMU of aircraft B-HLM was also removed for examination after the accident. Refer to Figures 24, 25 and 26 for locations where SAP spheres were present. The examination results of removed components are presented in the following paragraphs.

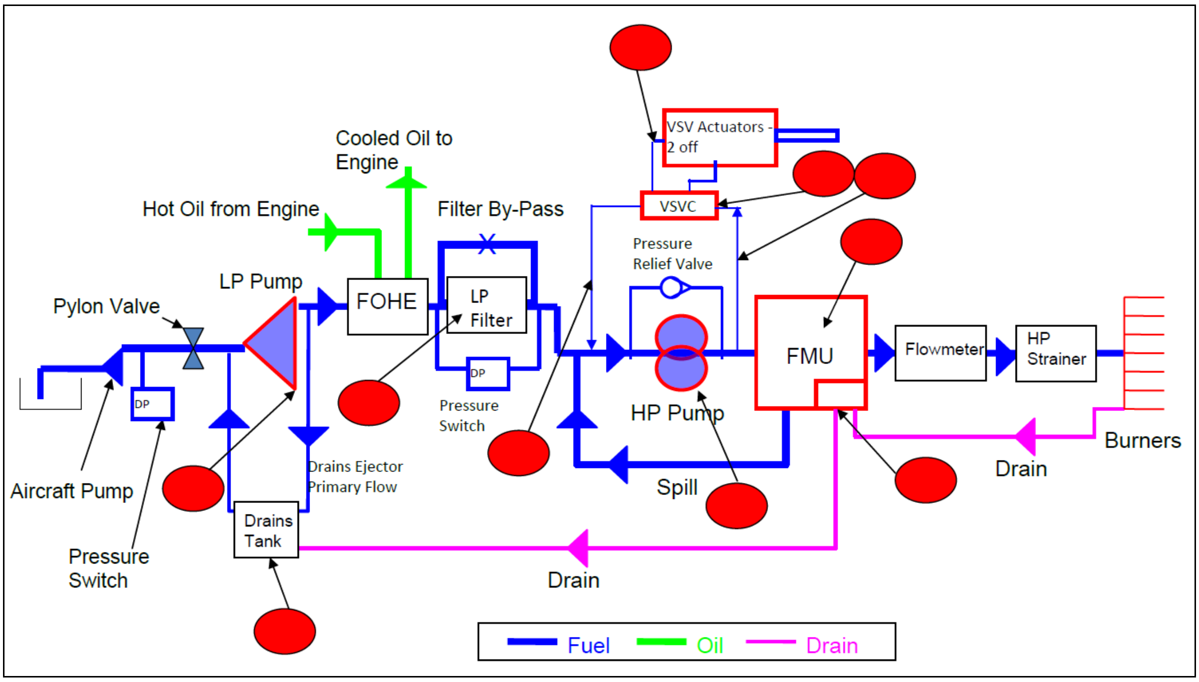


Figure 24: Samples were collected from various locations of B-HLL No. 1 engine. Red dots highlight those locations where the SAP spheres were present.

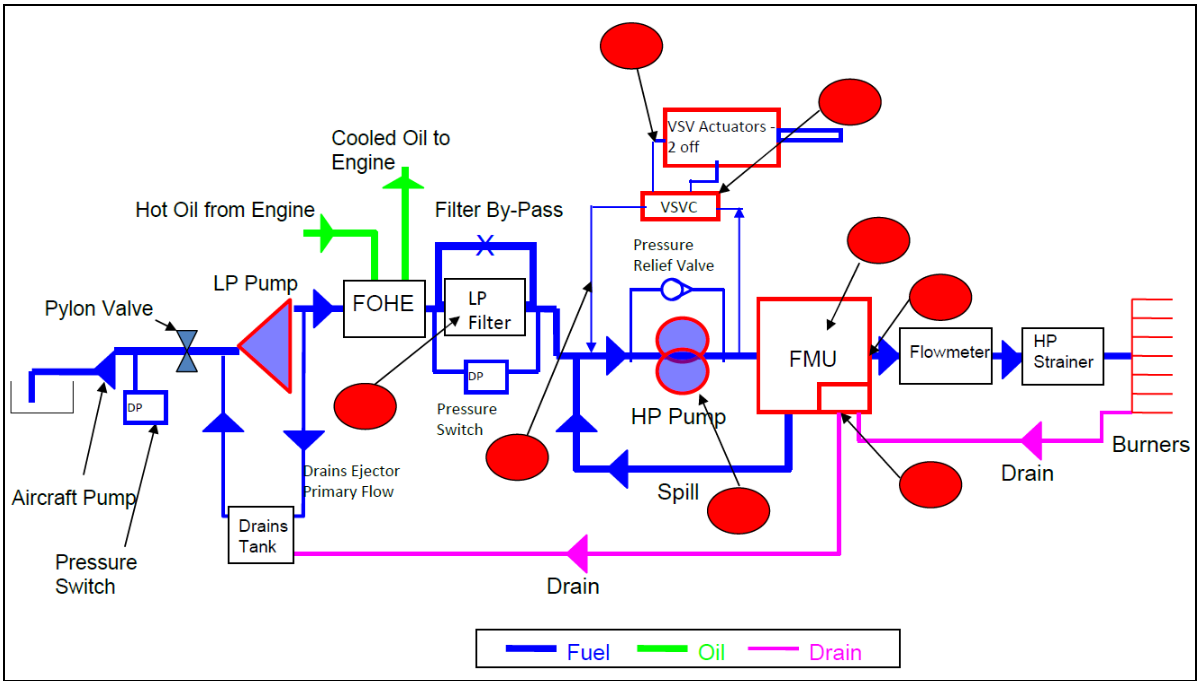


Figure 25: Samples were collected from various locations of B-HLL No. 2 engine. Red dots highlight those locations where the SAP spheres were present

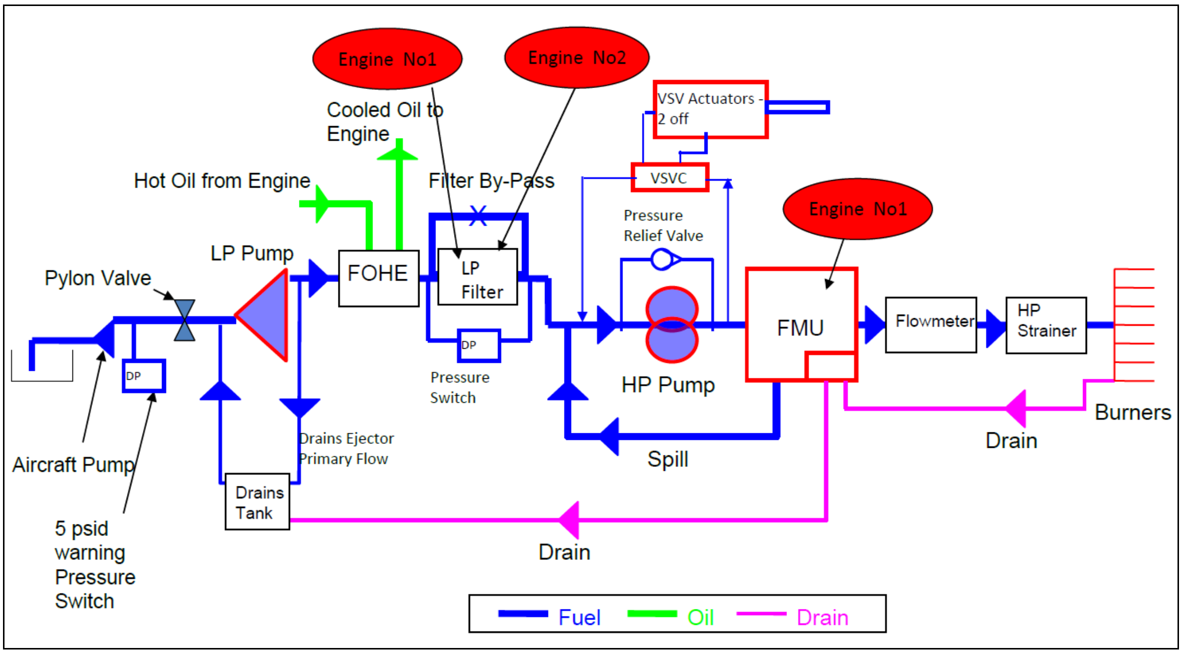


Figure 26: Samples were collected from various locations of B-HLM engines. Red dots highlight those locations where the SAP spheres were present

1.16.3.2 B-HLL No. 1 and 2 Engine Fuel Pump Assemblies

Both No. 1 engine and 2 main fuel pumps did not reveal any anomaly that could have contributed to the accident.

1.16.3.3 B-HLL Low Pressure Fuel Filters / Delta Pressure Switches

a. Visual examination of the No. 1 and 2 engine low pressure fuel filters did not identify any gross contamination. A Bubble Point Test was carried out which confirmed that the filters had no blockage. Tests on the filter differential pressure switches confirmed they were functioning correctly. There was no ECAM warning of high filter differential pressure indication during the CPA780 flight. This confirmed that the low pressure filters had not been bypassed during the occurrence.

b. Detailed examination of filter media revealed the presence of SAP spheres ranging in size of up to 20µm (see Figure 27). Similar spheres were also found in the media of the LP filters fitted to the aircraft B-HLM engines.

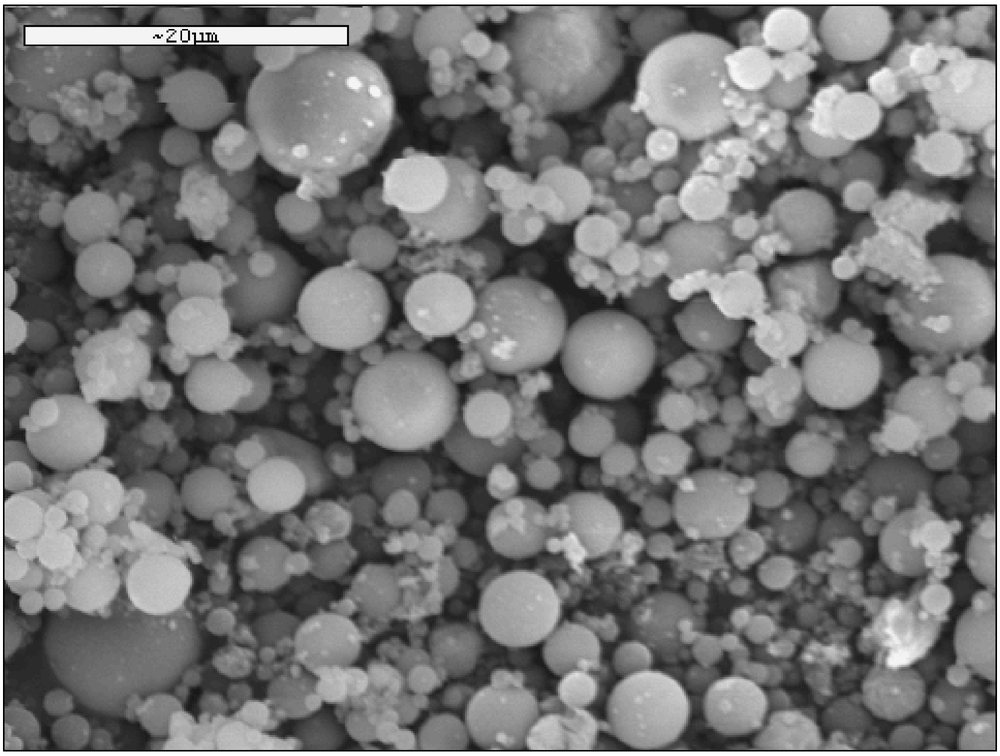


Figure 27: SAP spheres found in the engine LP fuel filter media

1.16.3.4 B-HLL No. 1 Engine Fuel Metering Unit

a. Examination of No. 1 engine FMU in a controlled strip revealed the MMV was seized at a position corresponding to the position at the moment this engine was shut down as recorded in the QAR. The Servo Pressure Regulator piston was also found seized, but was able to be released with the application of gentle hand pressure.

b. The MMV sleeve was cut axially into two halves and the piston was removed to allow full assessment of the internal surfaces. There were fine white particulate matters, which were later confirmed to be SAP spheres, throughout the assembly. Tide marks were visible on the sleeve suggesting that the piston had stopped there. When the piston was later removed from the sleeve half, it was apparent that an agglomeration of the SAP spheres had migrated to the bottom of the sleeve which had likely caused the seizure of the MMV. Detail study of the SAP spheres revealed they were of varying sizes, mostly from 5 to

25µm. Refer to ***Appendix 10*** for the cutaway views of the MMV sleeve and the piston.

1.16.3.5 B-HLL No. 2 Engine Fuel Metering Unit:

a. Examination of No. 2 engine FMU in a controlled strip revealed the MMV was seized at a position corresponding to the position at the time this engine was shut down as recorded in the QAR. The Pressure Raising and Shut-off Valve inside the FMU failed to fully close when the engine was shut down, and the Spill Valve and Servo Pressure Valve were also seized.

b. Similar to No. 1 engine FMU, the MMV sleeve was cut axially into two halves and the piston was removed to allow full assessment of the internal surfaces. The examination of No. 2 engine MMV identified SAP spheres similar to those of No. 1 engine and had seized the MMV. SAP spheres were also found inside the Pressure Raising and Shut-off Valve, the Spill Valve, and the Servo Pressure Valve.

1.16.3.6 B-HLL No. 1 Engine Variable Stator Vane Controller

Examination of No. 1 engine VSVC revealed that the CSV and the CPV inside the VSVC were seized. SAP spheres were identified in the residual fuel, and on internal surface of the CSV and the CPV.

1.16.3.7 B-HLL No. 2 Engine Variable Stator Vane Controller

Examination of No. 2 engine VSVC revealed that the CSV, the PDR and the CPV inside the VSVC were seized or have had some stiction. Again, SAP spheres were identified in the residual fuel, and on internal surfaces of the CSV, the PDR and the CPV.

1.16.3.8 B-HLL No. 1 and 2 Engine Variable Stator Vane Actuators

Examination of all VSVAs (two units per engine) revealed no seizure of such components. However, there was evidence of contamination by SAP spheres on their internal surfaces.

1.16.3.9 B-HLM No. 1 Engine Fuel Components

Examination of aircraft B-HLM No. 1 engine FMU during a controlled strip revealed that the FMU was in a good condition and there was no other anomaly that could have contributed to the occurrence. Other fuel components were also assessed and no anomalies were identified. As discussed previously, SAP spheres were found in the filter element media of the engine LP fuel filter.

1.16.3.10 Other Components Associated with Thrust Control

The EEC, EIVMU, TCU, and FMGEC, all of which are relevant to the engine thrust control, were tested. The results concluded that there was no anomaly in these components that could have contributed to the accident.

1.16.4 WARR Filter Monitors

a. For a hydrant refuelling, the fuelling dispenser is an interface between the hydrant system and the aircraft. Hydrant fuel under supply pressure is delivered to the aircraft fuel tank via a fuelling dispenser and its connecting hoses. Similar to all fuelling dispensers used in WARR, the event dispenser JUA06 (see Figure 28) had filtration provisions with 40 filter monitors of part number FG-230-4 installed in a filter vessel to remove particulate matter and free water (i.e., not dissolved water) from the fuel during the refuelling process.

Figure 28: Fuelling Dispenser JUA06

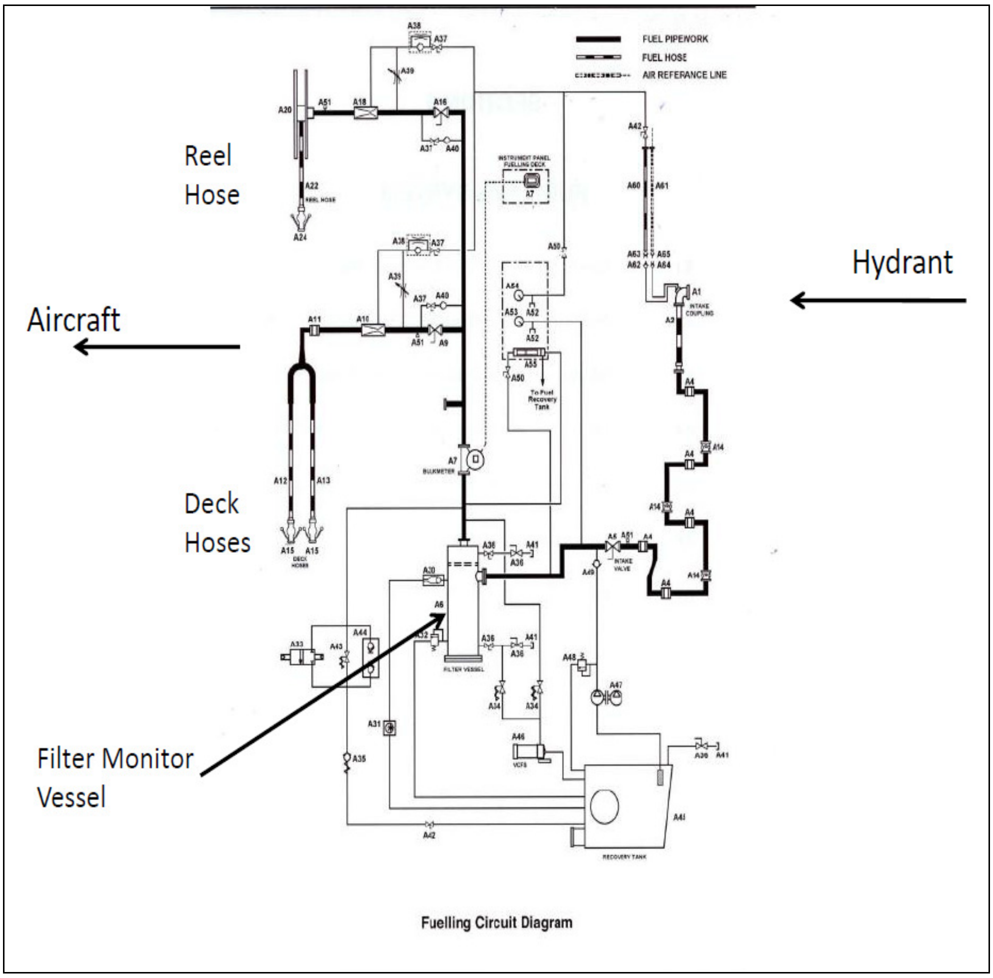


Figure 29: Schematic diagram of a typical fuelling dispenser

b. The 40 filter monitors (i.e. the accident filter monitors) installed in the dispenser JUA06 which had been used for the refuelling of CPA780 were removed six days after the accident. Twenty of them (Batch 1) were sent to UK for examination and analyses. Later, ten (Batch 2) of the remaining 20 filter monitors, which had been kept under quarantined in Indonesia were also sent to UK for examination and analyses. Another set of 40 filter monitors in JUA06 (Batch 3), which replaced the accident filter monitors and had been used for six weeks in WARR after the isolation of the disturbed Stands No. 1 to 10 hydrant circuit, were also removed and sent to UK for testing. These Batch 3 filter monitors which had been exposed to fuel but not to the contaminated hydrant fuel were used as reference standard to assist in the examination and analysis of the accident filter monitors.

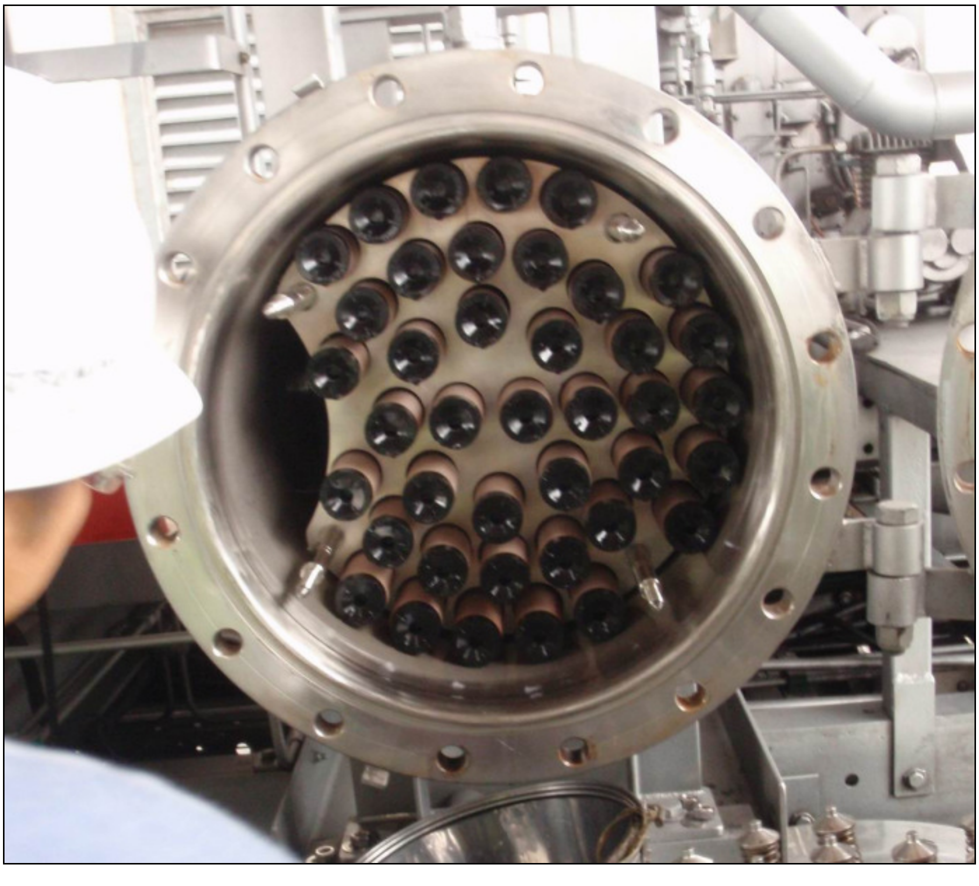


Figure 30: Filter monitors (Batch 3) installed in the filter vessel of JUA06

c. A total of three Batch 1 filter monitors were dissected and an area of the multi layered media was removed from each one for examination. A new pristine filter monitor of the same part number was also dissected for comparison.

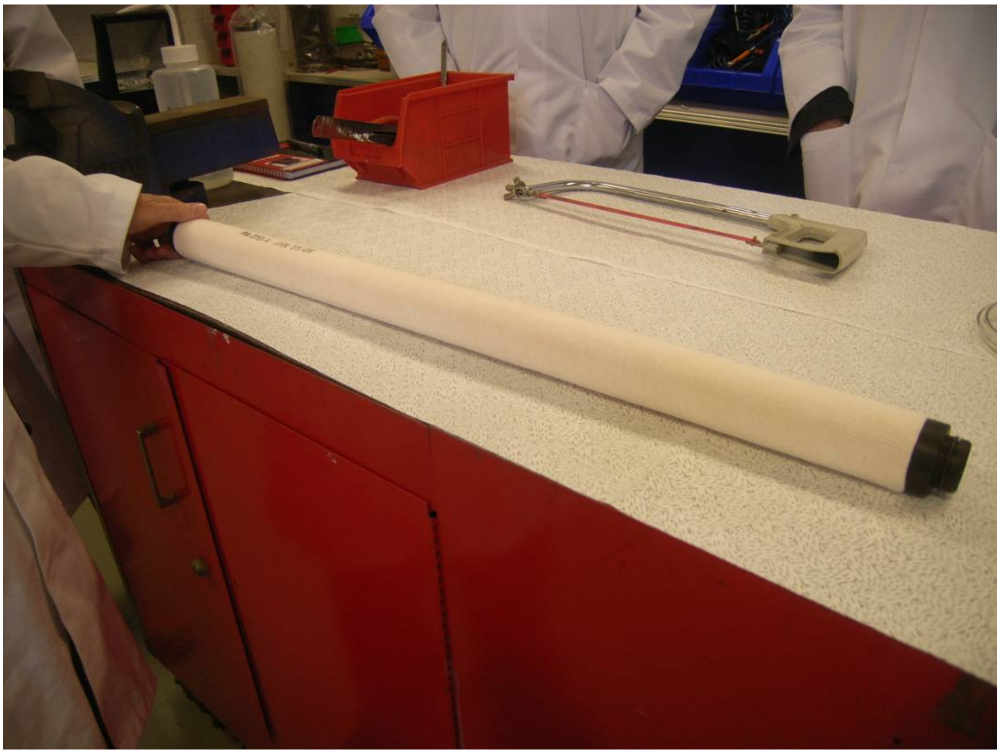


Figure 31: A new pristine filter monitor

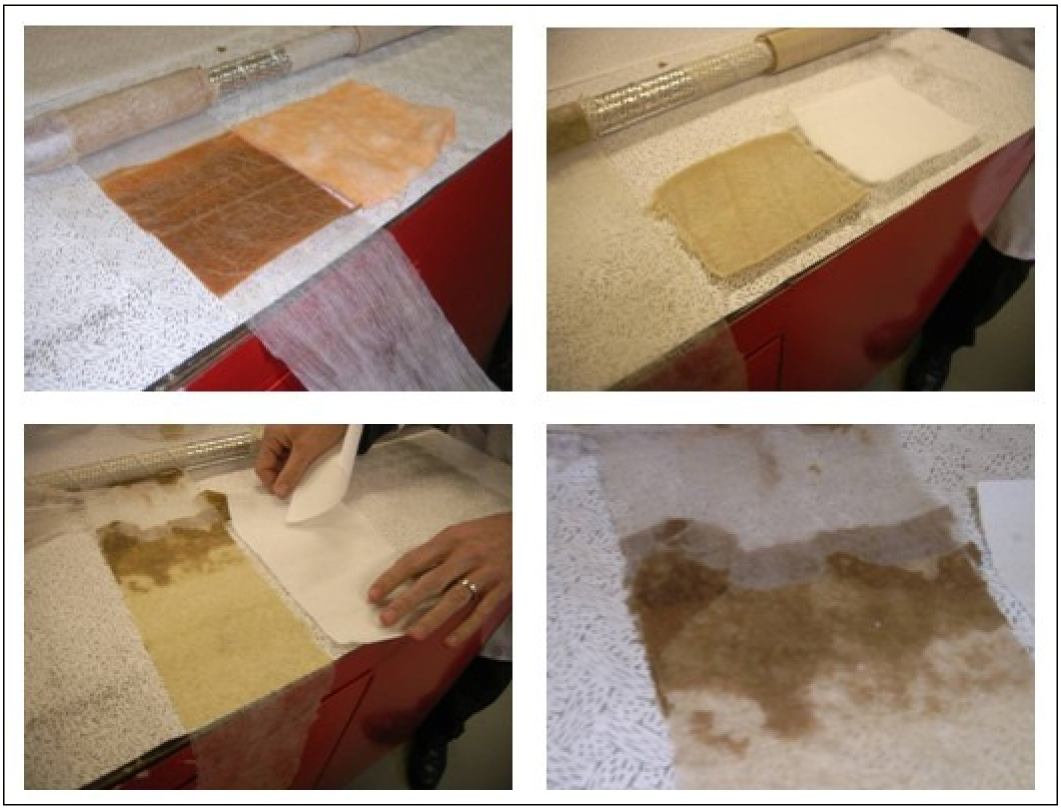
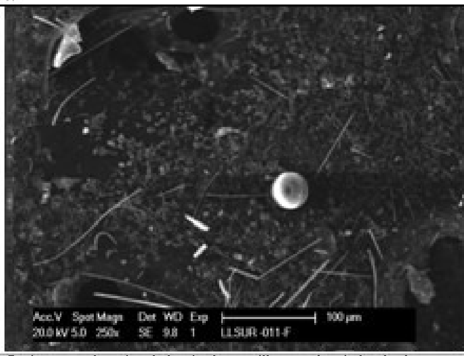
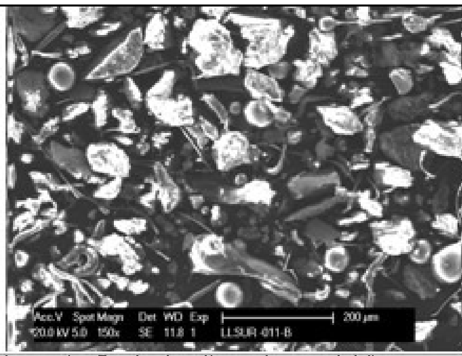


Figure 32: Dissecting one of the event filter monitors

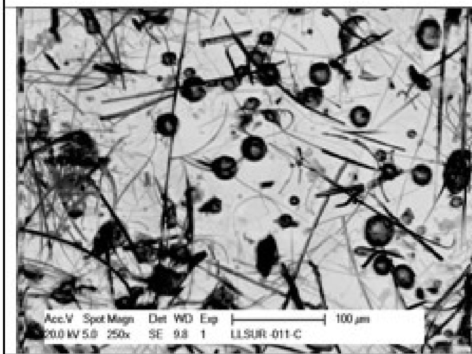
d. Examination of the dissected filter monitors revealed that the construction of the accident filter monitors was identical in terms of media type to a recently manufactured element, and that the SAP layers had been exposed to water. There was very little evidence of dirt trapped in the media layers. Isolated SAP spheres were found in one filter monitor (see Figure 33). No SAP sphere was identified in the new pristine filter monitor when it was dissected and examined by using similar technique.



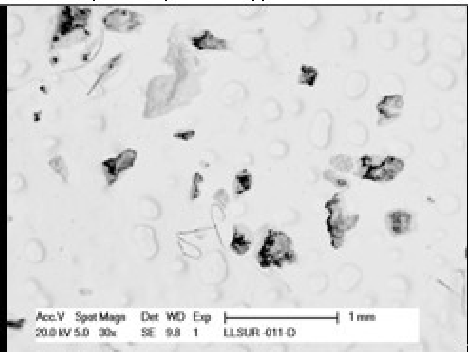
Outer sock – Isolated glass fibres, isolated glass spheres isolated Na/S/Cl spheres.



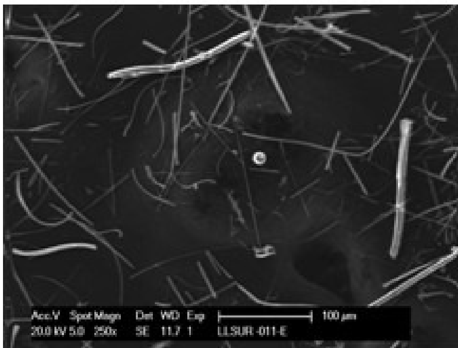
Layer 1 – Predominantly environmental fines, significant quantity of glass spheres, isolated Na/S/Cl spheres (30micron), few metallic fines.



Layer 2 – Predominantly glass fibres, glass spheres & environmental fines. No Na/S/Cl spheres found.



Layer 3 – Predominantly environmental fines, isolated Na/S/Cl spheres, isolated glass spheres.



Layer 4 – Predominantly glass fibres, isolated glass spheres isolated Na/S/Cl spheres.

Figure 33: Isolated SAP spheres (Na/S/Cl spheres) found in the media layers of the filter monitor.

1.16.5 SAP Spheres

The presence of SAP spheres was identified in aircraft fuel samples, engine fuel samples, engine fuel components of the accident aircraft, as well as the fuel monitors of the JUA06 dispenser. Most of the SAP spheres found had a size ranging from five to 30 µm with majority in the order of five to 15 µm. Analysis showed that these SAP spheres contained the elements of carbon, oxygen, sodium, chlorine, and sulphur (see Figure 34), and were mainly sodium polyacrylate, which was consistent with the SAP material used in the filter monitors installed in a fuelling dispenser (see Figure 35). Further analysis revealed the presence of crystalline sodium chloride on the surface of some SAP spheres (see Figure 36). Refer to ***Appendix 11*** for results of examinations on SAP and SAP spheres by various techniques.

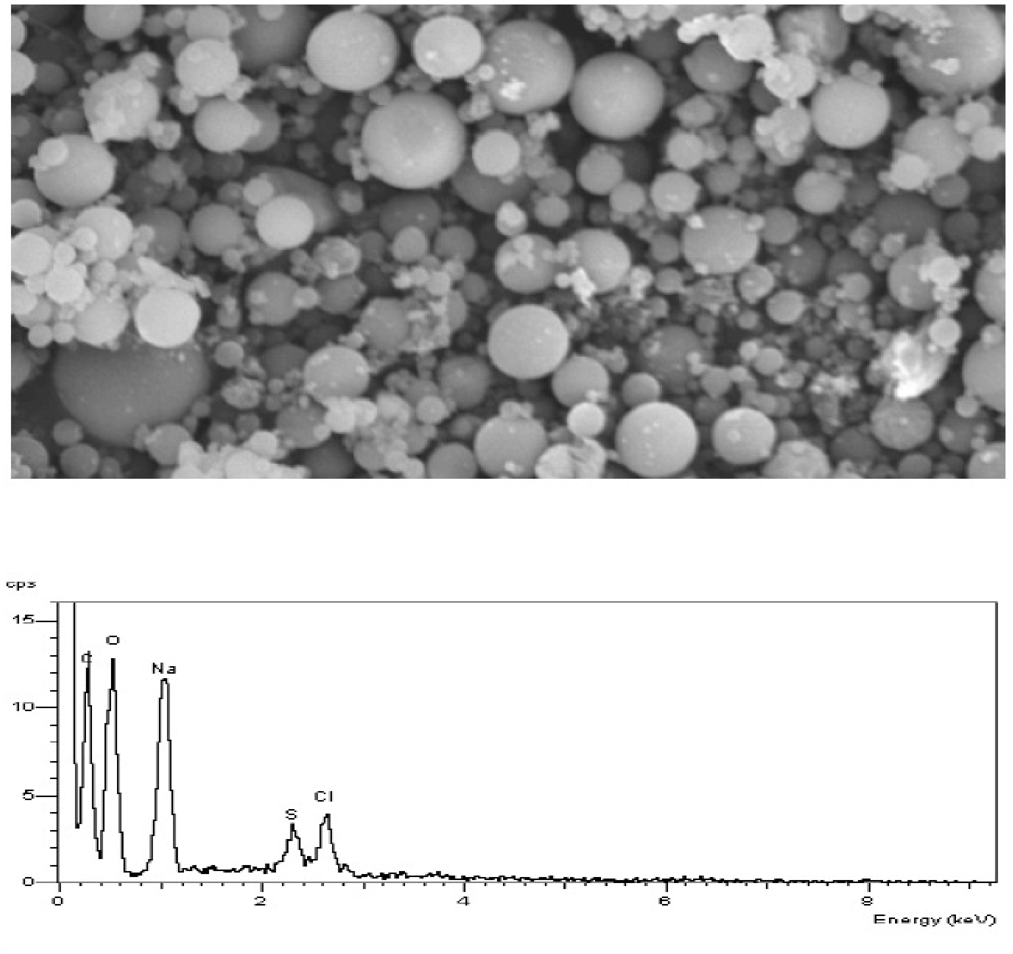


Figure 34: Microscopic view of spheres and their composition under Scanning Electronic Microscope (SEM) analysis.

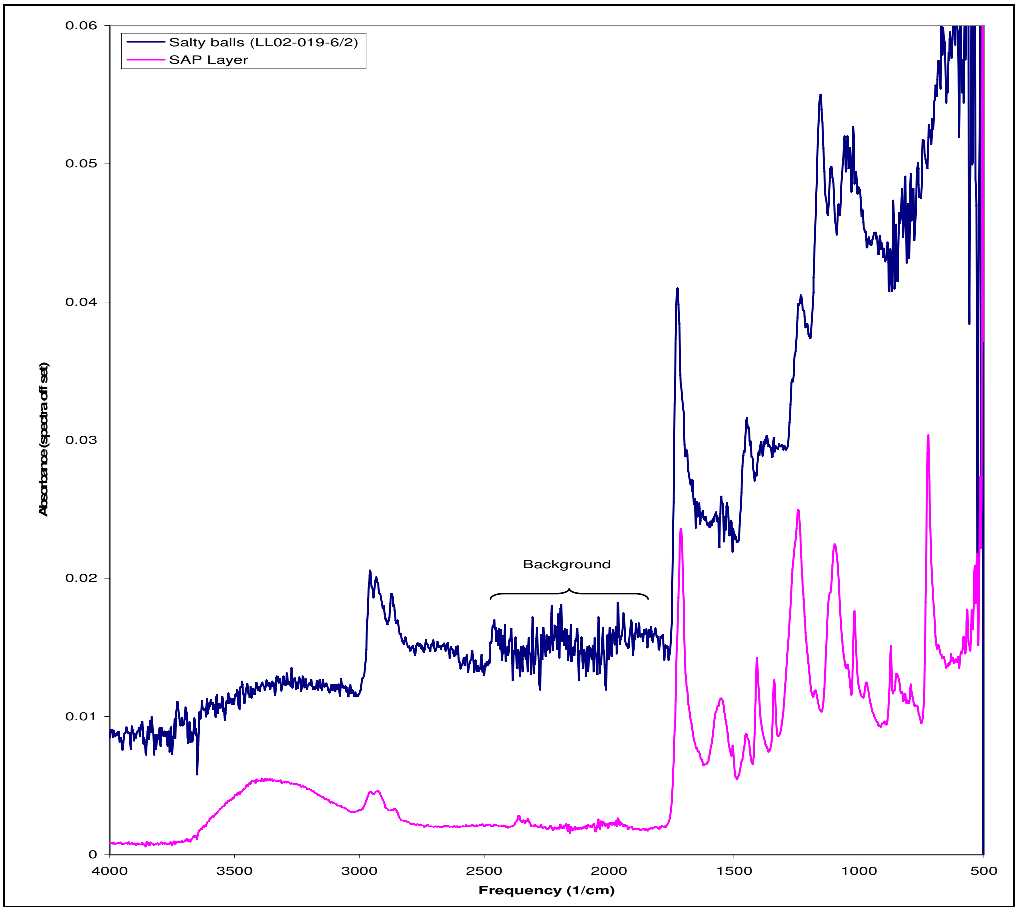
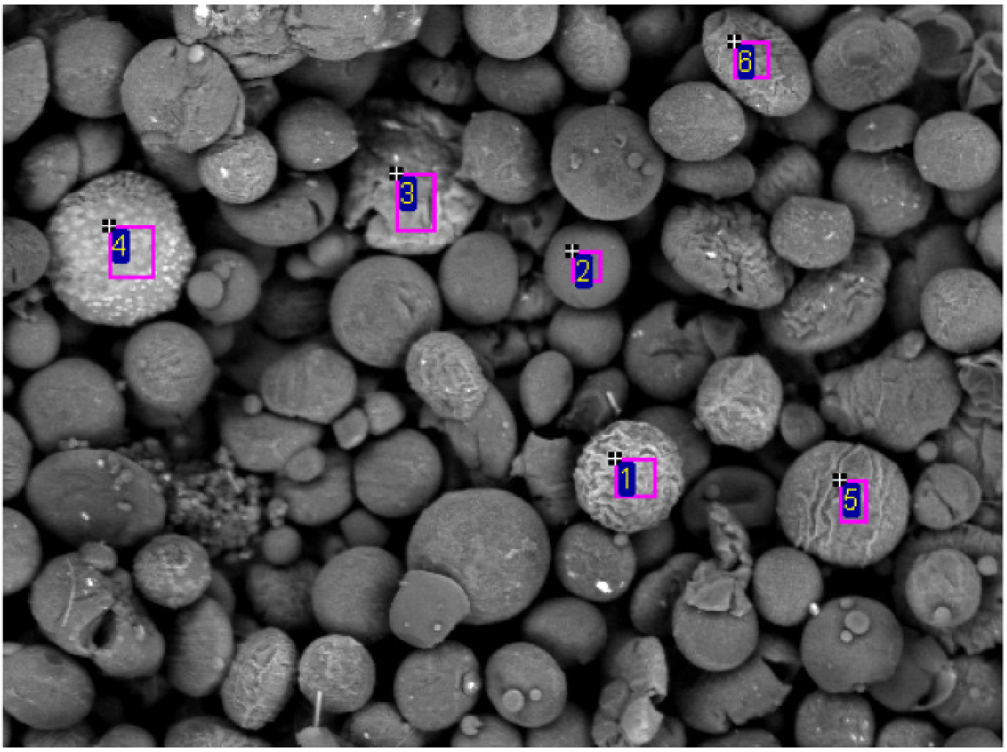


Figure 35: FTIR spectrum obtained from the SAP Layer sample compared to a sample of Na/Cl/S spheres indicating similar composition.



Spectrum	C	O	Na	S	Cl	
1	51.71	30.98	13.40	0.58	3.33	More Cl (and presumably NaCl) on brighter spheres
2	71.52	20.42	7.39	0.25	0.42	
3	53.93	29.74	11.60	0.60	4.13	More Cl (and presumably NaCl) on brighter spheres
4	35.50	42.06	16.46	2.83	3.15	More Cl (and presumably NaCl) on brighter spheres
5	54.82	32.16	11.47	0.46	1.08	
6	54.87	31.48	10.69	0.66	2.30	

Figure 36: The presence of crystalline sodium chloride on the surface of some spheres

1.16.6 Tests on Filter Monitors

1.16.6.1 Filter Monitor

a. As explained in a guidance material EI 1550 "Handbook on equipment used for the maintenance and delivery of clean aviation fuel" which is published by Energy Institute (EI), a standard developing organisation in the fuel and oil industry, "*the intended performance of a filter monitor system is to remove low levels of particulate matter and trace levels of free water from aviation fuel to levels acceptable for servicing modern aircraft. It is also intended that in* *service a filter monitor system will restrict the flow of fuel before its capacity for particulate matter and/or/water removal is exhausted*". The specification of a filter monitor is defined in EI 1583 "Laboratory tests and minimum performance levels for aviation fuel filter monitors".

b. The accident filter monitors were manufactured by Facet International, part number FG 230-4, which were in compliance with the 4th edition of the EI 1583. These 50mm diameter filter monitors were of layered construction with the media being wound onto an aluminium centre tube of approximately 28mm diameter. The length of the FG 230-4 is 770 mm. The media is supported throughout by a polyester scrim and retained within an outer woven sock. The flow of fuel is from out to in across the filter monitor layers with a rated maximum flow-rate (FR) of 113 litre per minute per element. The layers in generic terms according to the flow direction are in the following order:

i. Outer woven sock
ii. Fibreglass filtration layer
iii. First water absorption layer (sodium polyacrylate)
iv. Second water absorption layer (carboxymethyle cellulose)
v. Final filtration / media migration layer
vi. Perforated aluminium centre tube

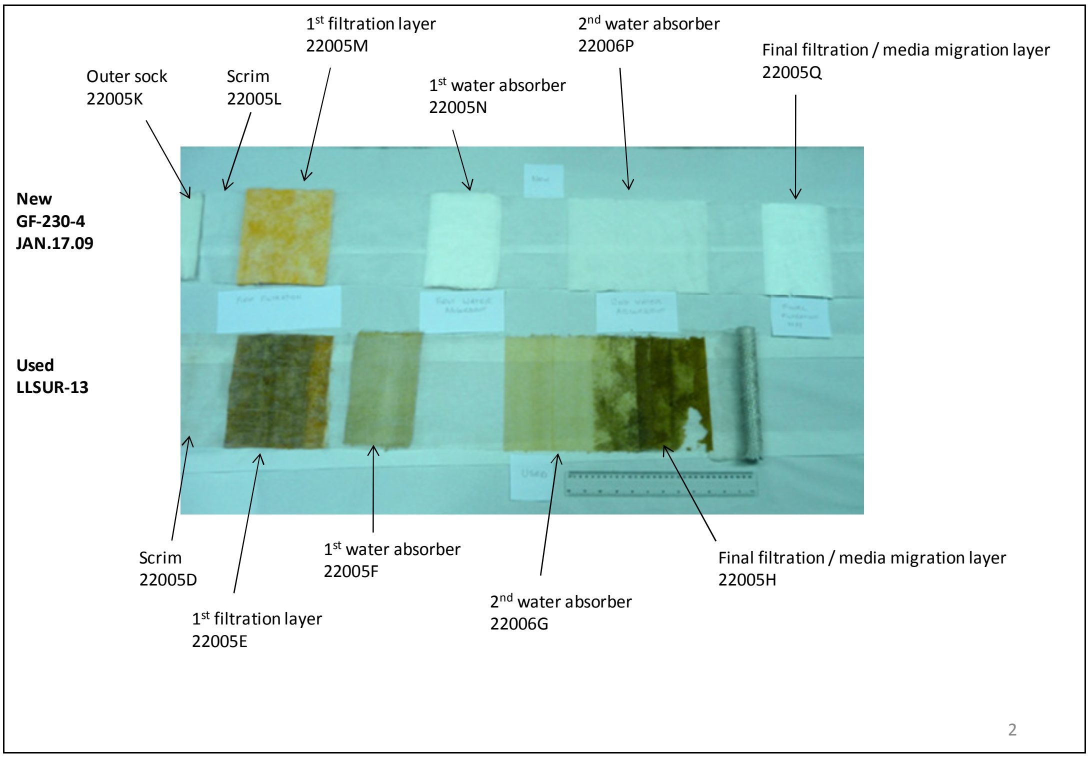


Figure 37: Media layers of filter monitor

c. The composition of the SAP spheres was mainly sodium polyacrylate which was consistent with the material used in the first water absorption layer of the filter monitor. Sodium polyacrylate is a kind of SAP which when in contact with water, activated to absorb the water, and turns into a gel that swells to fill the filter monitor. As stated in EI 1550, "*In extreme situations, the gelling process may shut off the flow [across the filter monitor] completely*."

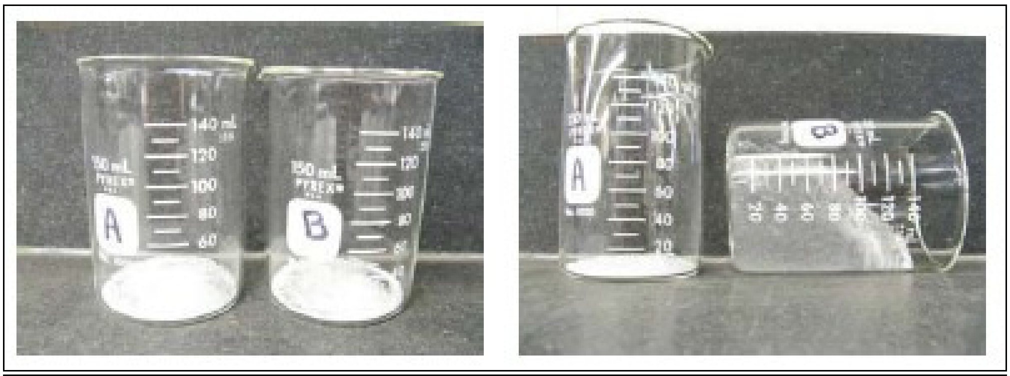


Figure 38: Beakers of SAP in powder form. After the addition of water to beaker B, the SAP powder swollen and turned to gel form

d. As described in EI 1550, the water removal performance of filter monitor elements may be sensitive to certain environment or operational condition which would degrade such performance to an unacceptable level. It is known that high salinity in any free water will compromise the shut off function of the SAP in a filter monitor. The EI 1550 also pointed out that filter monitors are only one set of components in a comprehensive system to protect aviation fuel quality.

1.16.6.2 Flow Tests and the Microfilter

a. Batches 1, 2 and 3 filter monitors were tested in an aviation fuel handling rig in Shell Technology Centre Thornton in UK. Refer to Figures 39, 40 and 41 for the set up and schematic diagram of the test rig. New pristine filter monitors were also tested for comparison purpose.

b. The rig was configured in accordance with EI 1583 with appropriate modification, i.e. the inclusion of an one (1) μm rating microfilter downstream of the test vessel. Fuel flowed through the filter monitors under test and the microfilter will capture any particulate released from the filter monitors. After the test, the filter monitors and the microfilter were examined for the presence of SAP spheres.

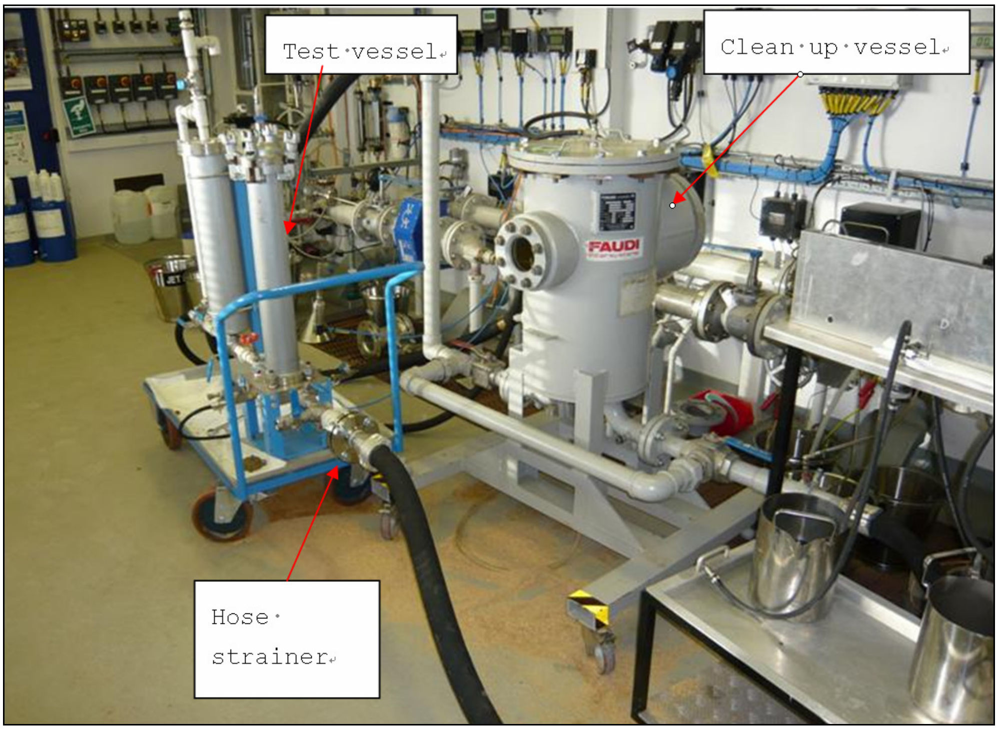


Figure 39: The Flow Test Rig

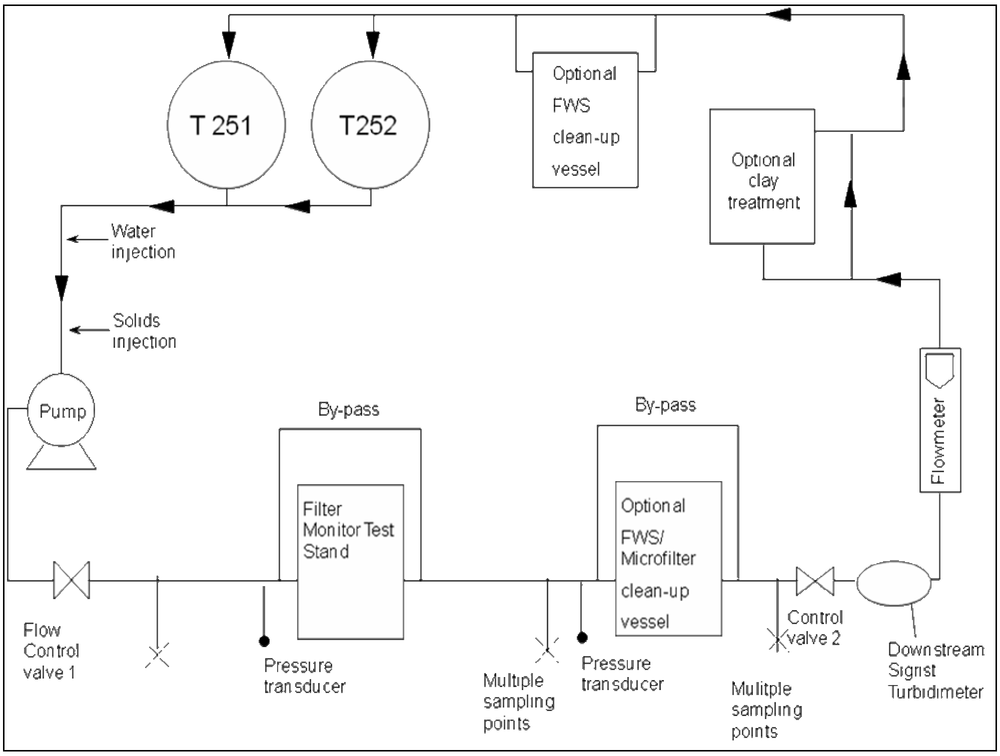


Figure 40: Schemetic of Test Rig

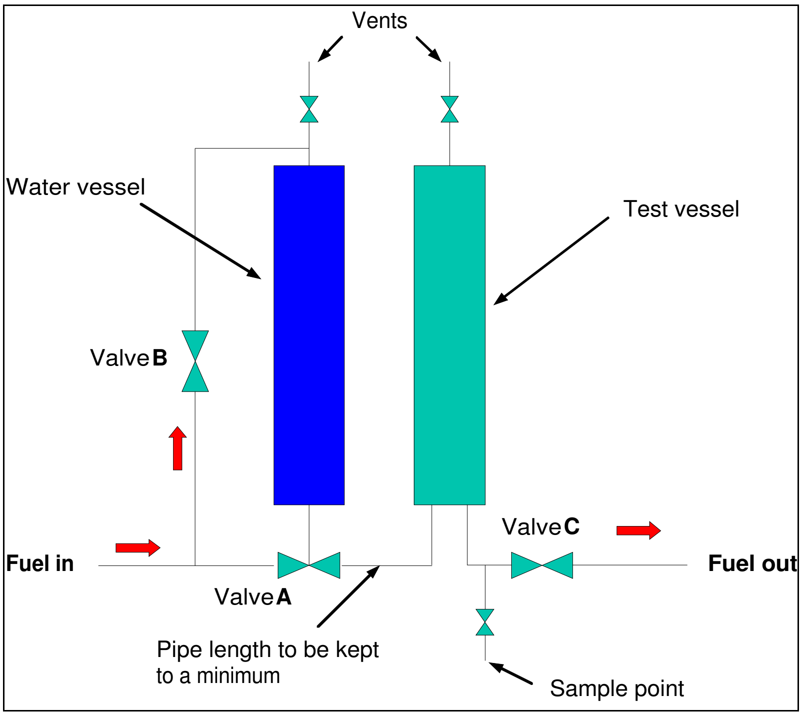


Figure 41: Filter monitor test vessel set up

c. Examination of the microfilter media (Figure 42) after the flow tests of Batch 1 and 2 filter monitors revealed the presence of SAP spheres (Figure 43).

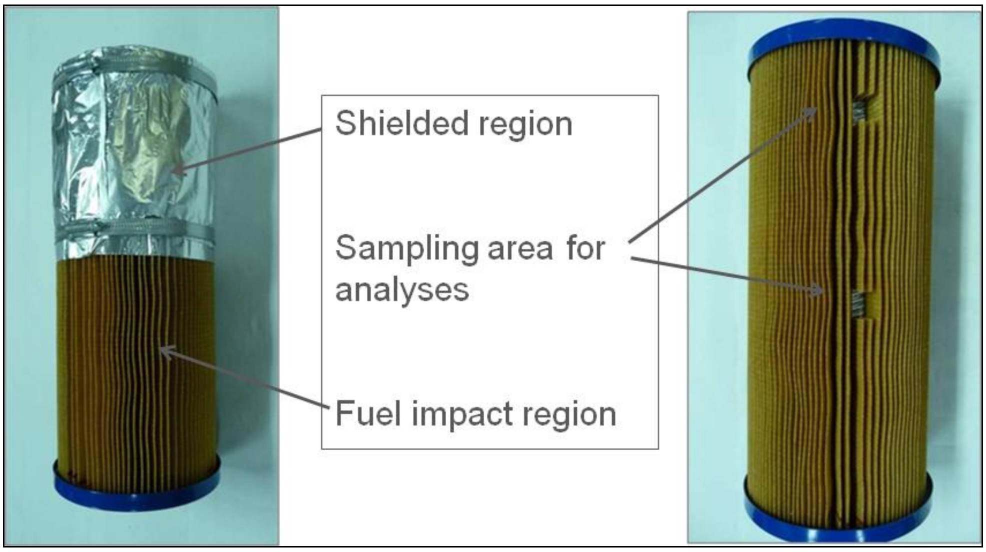


Figure 42: Microfilter used in clean up vessel downstream of test vessel to capture any media released during filter monitor testing

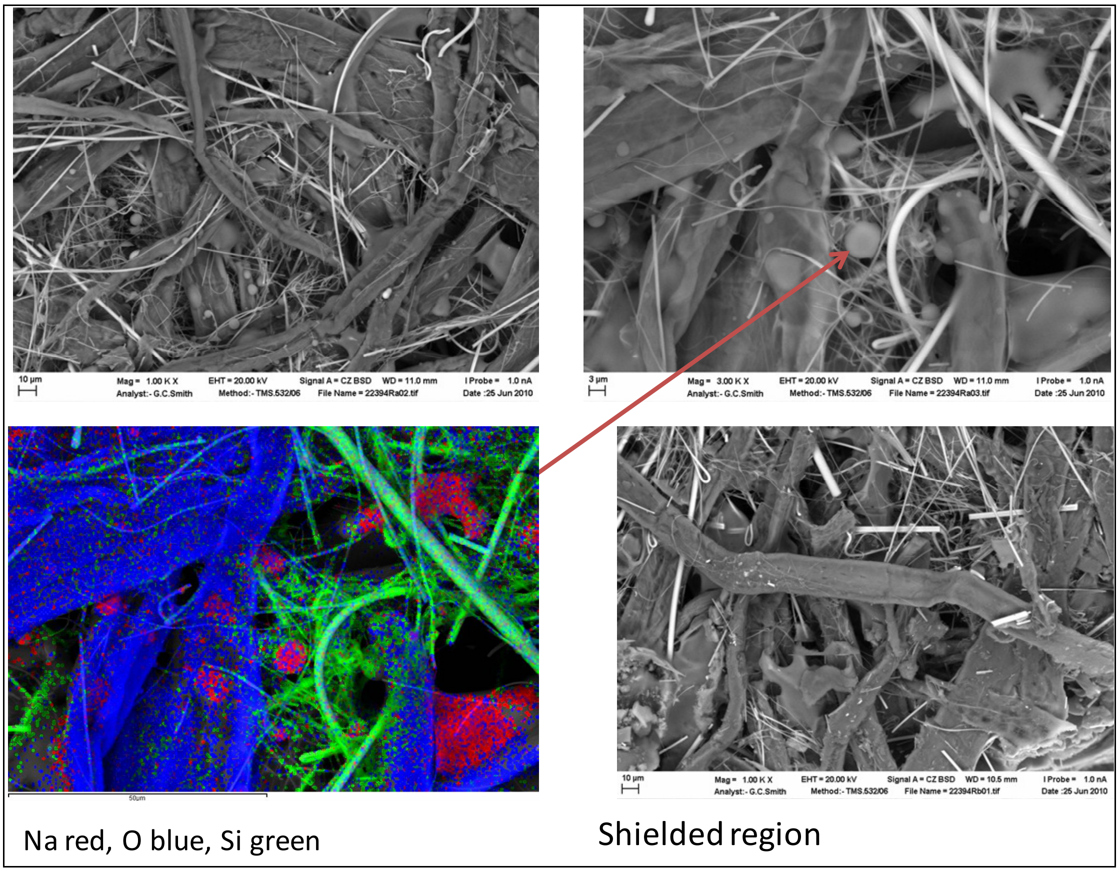


Figure 43: Backscattered electron SEM images and element distribution map from the fuel impact region of the micro-filter. Arrow indicating the presence of a SAP sphere. Lower right is a reference image from the shielded area.

1.16.6.3 Element Flow-rate Test

a. The element flow-rate test gives an indication of the level of contamination a filter monitor that has been subjected to during its time in service. During the test, fuel flowed through the filter monitor under system pressure of the test rig, and the pressure and flow-rates were recorded. Refer to ***Appendix 12*** for summary of the test results. A filter monitor that exhibits blockage or restricted flow when subjected to maximum operating pressure of the test rig (approximately 100 psi) is likely to have been subjected to extreme levels of dirt or water contamination.

b. The test results for Batch 1 sample filter monitors indicated a near complete blockage. These suggested that they had been subjected to contamination. Subsequent visual inspection of one filter monitor confirmed that the filtration media was clean and reasonably free from dirt but the SAP layers were clearly activated. These indicated that Batch 1 filter monitor had been exposed to significant amount of free water during their operation.

c. The test result for Batch 2 sample filter monitors did not indicate complete blockage. However further experiment on Batch 1 samples suggested that Batch 2 filter monitor media could have dried out during their storage in Indonesia, thus allowing restricted flow during the tests.

1.16.6.4 High (100%) Flow-rate Water Slug Test

a. The high flow-rate water slug test demonstrates the water removal and shut down performance of a filter monitor. During the test, a slug of 9 litres of water was introduced at a point upstream of the filter monitor whilst the test rig was operating at maximum rated flow of 113 litre per minute. When the water penetrated the filter monitor, the SAP layer was activated and swelled quickly to reduce the flow. The EI 1583 test specification allows a leak-by rate of 1% of the rated flow.

b. The test result for a new filter monitor demonstrated an effective shut down of the flow with minimal leak-by rate after the element water absorbent media had been activated by the water.

c. The test result of a Batch 3 filter monitor demonstrated that the filter monitor still achieved the leak-by rate below the EI 1583 limit although it did not fully shut down the flow. The filter monitor was also found collapsed (distorted and flattened) after this test. The phenomenon of collapsed filter monitors is further discussed in 1.16.6.8.

d. SAP material was found on the fuel entry surface of the final filtration / media migration layer. This suggested that having reacted with water, the SAP extruded through the layers (SAP extrusion) but was contained by the media migration layer.

1.16.6.5 Low (10%) Flow-rate Water Slug Test

a. The low flow-rate water slug test is run identically to the high flow-rate water slug test but at a rate of 10% of the rated flow, trying to simulate a low flow-rate refuelling operating condition similar to that in WARR.

b. The test result for a Batch 3 filter monitor demonstrated an effective shut down of the flow with minimal leak-by rate.

1.16.6.6 Salt Water Slug Test

a. The salt water slug test was run on a new filter element and was identical to the high flow-rate water slug test but with salt water which the sodium chloride concentration was increased to 4% to exaggerate the impact. The purpose was to challenge the filter monitor by trying to recreate the possible failure mode of the ground fuel contamination in WARR.

b. The test results of a new and Batch 3 filter monitors demonstrated that the performance of the filter monitors were compromised in terms of both effective shut down of flow and the leak-by rate. Similar to the high flow water slug test, the Batch 3 filter monitor was also found collapsed after this test.

c. SAP material was found on the fuel exit surface of the final filtration / media migration layer and onto the perforated aluminium centre tube. This suggested that the SAP having reacted with salt water, had extruded through all layers of the filter monitor. SAP material was also found on the fuel exit surface of the fibreglass filtration layer, implying possible reverse flow and therefore movement of SAP within the filter monitor. The collapse of the filter monitor during the test might have allowed for the potential reverse flow.

1.16.6.7 Event Mimicking Test

a. The purpose of the event mimicking test was to simulate the environment and the operating profile with respect to the flow-rate and duration of the dispenser JUA06 in WARR from when they resumed operation of the disturbed hydrant (on 11 April 2010 which will be discussed in 1.17.2) to the refuelling of CPA780 (on 13 April 2010). The objective was to verify if similar SAP spheres could be reproduced under the simulation profile. Based on the flow-rate and duration of the refuelling performed in WARR, a 3-day simulation profile of defined start-stop / flow-rate cycles was established. It was also based on the facts that the majority of the refuelling operation of JUA06 were performed at low flow-rate and salt water was present in the hydrant circuit, the test was done in a sequence of two stages: the 50 ppm salt water test, and then the salt water ad-hoc test.

b. The 50 ppm salt water test was to expose the water absorbent media of a new filter monitor to salt water which is added to the fuel in a gradual manner. Salt water that contained 4% NaCl was added to the flow at a rate of 5.65 ml per minute and with the filter monitor operating at the rated flow of 113 litre per minute until a differential pressure (DP) of 26 psi was reached in approximately 30 minutes.

c. The salt water ad-hoc test was to further expose the water absorbent media of the filter monitor with a slug of salt water that contained 4% NaCl at 10% rated flow. The shut down performance of the filter monitor was then established by measuring the leak-by rate. A 200 mesh inline gauze strainer (mimicking the hose end strainer of the fuelling dispenser) and a clean-up microfilter was fitted downstream of the filter monitor to collect debris. The operation of the filter monitor was then continued by following the 3-day simulation profile. The filter monitor layers and the microfilter were examined afterwards.

d. Similar to the water slug tests, the examination revealed that SAP extrusion was evident in the filter monitor layers, gauze strainer and the microfilter media. Moreover, several discrete SAP spheres were found embedded in the microfilter media (Figure 44). Although the simulation could not be conducted in identical operating environment and condition as that in WARR, the result indicated that SAP spheres could be generated under certain operating conditions.

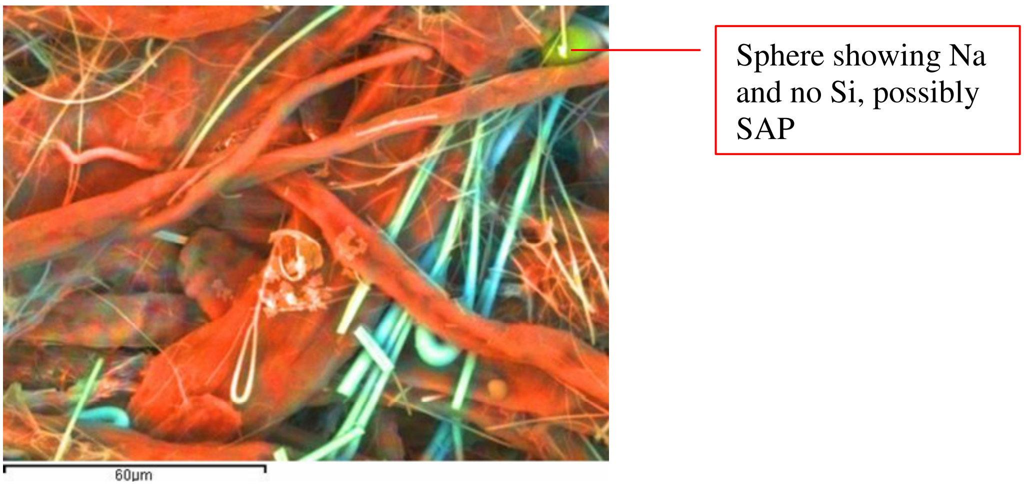


Figure 44: SEM-EDX chemical phase map of the area of the downstream micro-filter.

1.16.6.8 Collapsed Filter Monitor

a. A FG-230-4 filter monitor from Batch 2 was found to have a collapsed centre tube when removed from the filter vessel of dispenser JUA06 (Figures 45

& 46). The cylindrical shape filter monitor was twisted and flattened, and its total length was shortened. During the rig tests, two more FG-230-4 filter monitors from Batch 3 were also found collapsed after the high flow water slug test. In all cases, the flow test result indicated that the filtration function of a collapsed filter monitor was not compromised. However, as a collapsed FG-230-4 filter monitor could lose its structural rigidity and shorten in length by up to 20 mm (Figures 47 & 48), a study of the installation inside the filter vessel of the dispenser was carried out. The study indicated that a collapsed FG-230-4 filter monitor could become dislodged inside the vessel when there is sufficient back pressure, which could result in fuel bypassing the filtration system and going into an aircraft.

Figure 45: The collapsed Batch 2 filter monitor placed adjacent to a normal filter monitor

Figure 46:The centre aluminium core tube of the collapsed filter monitor was crushed

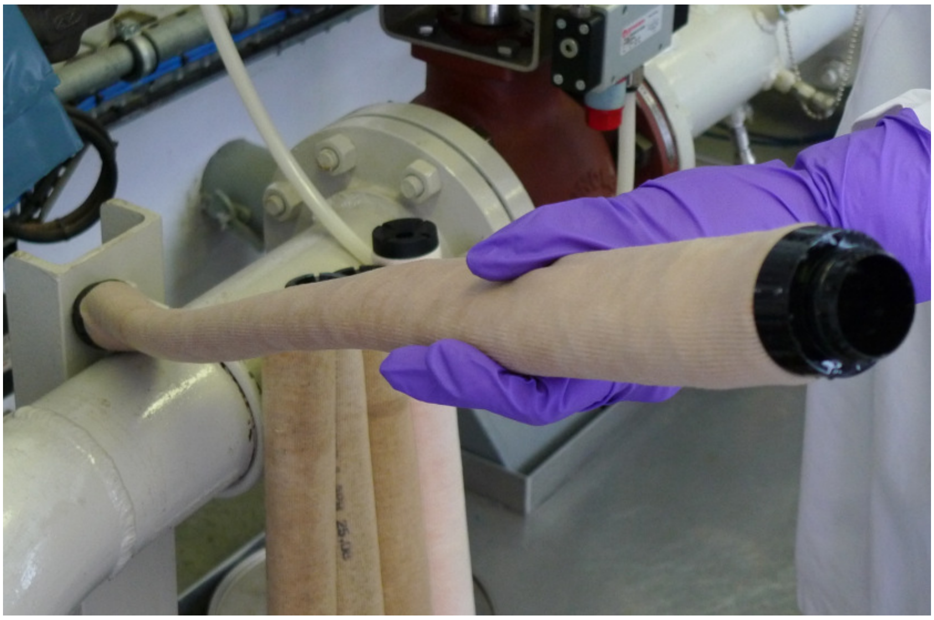


Figure 47: A collapsed filter monitor loss it structural rigidity

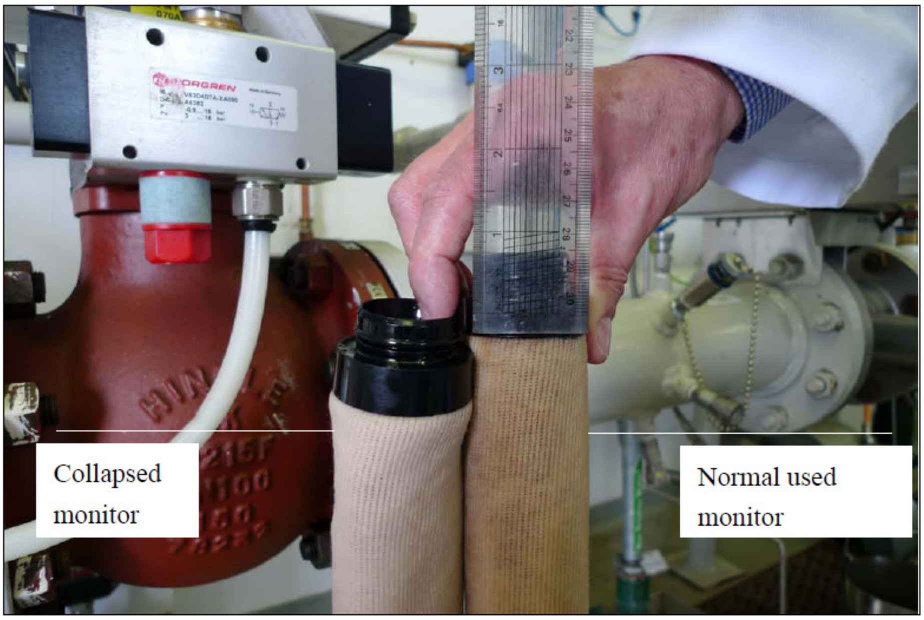


Figure 48: The length of a collapsed filter monitor (left) is shortened

b. The perforated centre tube of the FG-230-4 filter monitor is made of aluminium and should withstand a DP of 12 bars (174 psi) as required by EI 1583 4th Edition. It is noted that in a typical operating condition, the refuelling system seldom reached 11 bar pressure and a 12 bar requirement is in place to allow a considerable margin above typical operation.

c. A finite element analysis on the centre tube of the FG-230-4 filter monitor was conducted and the calculation indicated that the critical buckling pressure of the core tube is 8.7 bar (126 psi) and the pressure which may cause the stress exceeding the yield strength is about 12.4 bar (180 psi). The data supported that the centre tube is more prone to collapse due to buckling than to yielding of the material.

d. Facet International (Facet), the manufacturer of this filter monitor was informed of the collapsed FG-230-4 filter monitor. Facet indicated that their FG-230-4 passed annual quality testing which includes the collapse pressure test. However, additional tests after the occurrence on FG-230-4 filter monitor from the stock of various lots showed a collapse pressure of 11 to 11.5 bar range which fell below the 12 bar requirement. Facet carried out product improvement and in September 2011, announced that their new filter monitors met EI 1583 6th

Edition (the latest edition) and to address the strength and media extrusion concern, included the following:

i. Improved performance in removing salt water from fuel

ii. Changed centre tube design from aluminium to stainless steel to provide added durability

iii. Added support scrim to the fine filtration media to strengthen these sheets

iv. Included additional media migration barriers

v. Added outer screen to support the media in a fully water saturated condition

1.16.7 Other Components Associated with the Occurrence

1.16.7.1 Brakes

Workshop inspection and testing concluded that the brakes from the accident aircraft had no manufacturing deficiency, and there was no evidence of fire damage. The brakes functioned as intended during the workshop test.

1.16.7.2 Wheels

Wheel Nos. 1, 2, 3, 5 and 7 deflated after the aircraft came to rest due to the melting of the fusible plugs. Wheel Nos 4, 6 and 8 did not deflate and the fusible plugs were intact. Workshop inspection and testing confirmed that the fusible plugs fitted to Wheel Nos 4, 6 and 8 had not been exposed to the design melting temperature. There was no evidence of fire damage to the wheels and tyres.

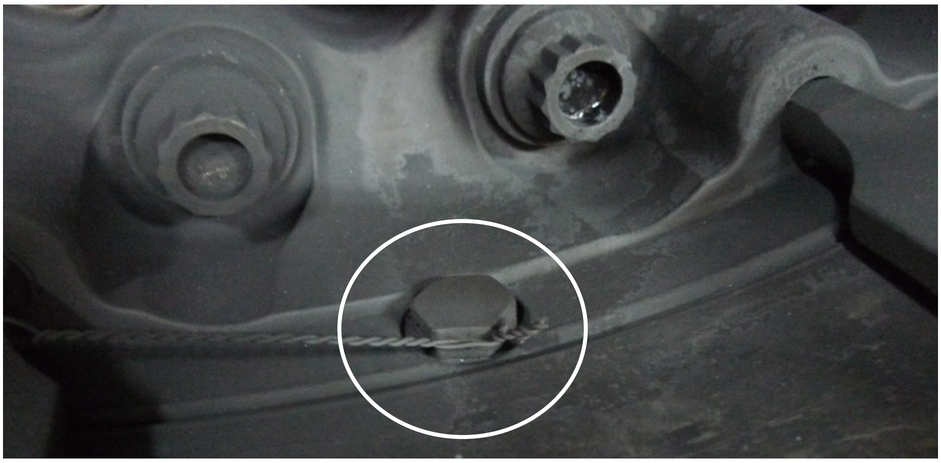


Figure 49: One event fusible plug installed to the wheel showing the centre core was intact

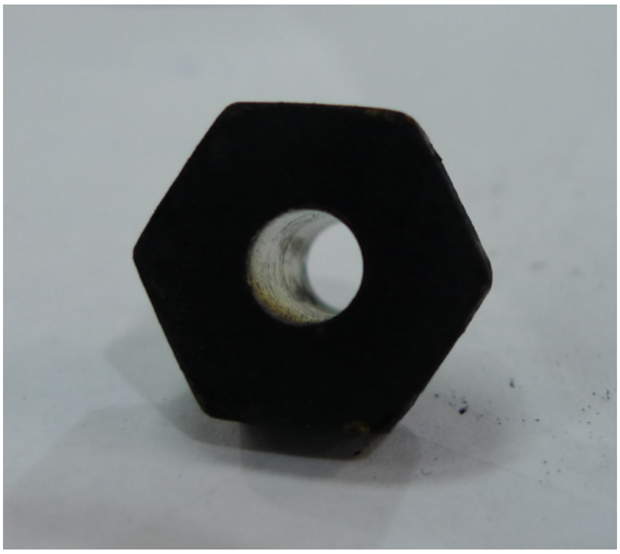


Figure 50: One event fusible plug showing the core had melted

1.16.7.3 Escape Slides

All eight cabin emergency escape slides were deployed during the evacuation. Refer to 1.15, the R4 slide did not deploy during the first opening of the door by the cabin crew but operated normally in the subsequent opening. Post event investigation of the R4 emergency door opening system and the shop examination of the slides did not reveal any anomaly. Shop inspection concluded that all slides had been correctly installed to their respective locations on the aircraft. The CIDS which monitors cabin door system had not registered any fault that could have contributed to the reported anomalies.

1.17 Organisational and Management Information

The CAD investigators visited WARR and conducted interviews with the relevant personnel and documentation review with the assistance and presence of the NTSC investigators. This part covers the relevant circumstances in WARR.

1.17.1 Fuel Supply at WARR

CPA780 had uplifted 24,400 kg of fuel at WARR at Stand No. 8 from the fuel hydrant system by dispenser JUA06 on 13 April 2010 before the departure. Pertamina was the sole and designated fuel supplier in WARR to provide fuel, fuelling dispensers and refuelling personnel to perform refuelling services to aircraft. Pertamina also operated the refuelling facilities in WARR.

1.17.2 Extension Work of Fuel Hydrant System in WARR

1.17.2.1 The Apron Extension Project

a. The WARR facility at the time of the accident was constructed under Surabaya Airport Construction Project and opened in 2006. The fuel hydrant system was part of the project. The specification of the project was detailed in the 2001 contract document (No. LN/130/2001), including the fuel hydrant system, which was detailed in drawing reference U-AD-FS-GFU-000. The hydrant for parking Stand No. 8 where the accident aircraft had the fuel uplifted was part of an “into-plane” refuelling ring circuit that supplies fuel to Stands No. 1 to No. 10. In 2006, only Stands No. 5 to No. 10 were opened as operational parking stands. A piece of vacant grass land adjacent to the operational stands was reserved to be the future locations of Stands No. 1 to No. 4. The hydrant refuelling circuit layout of WARR is shown in ***Appendix 13*** and the portion affected by the extension work is highlighted in Figure 51 below.

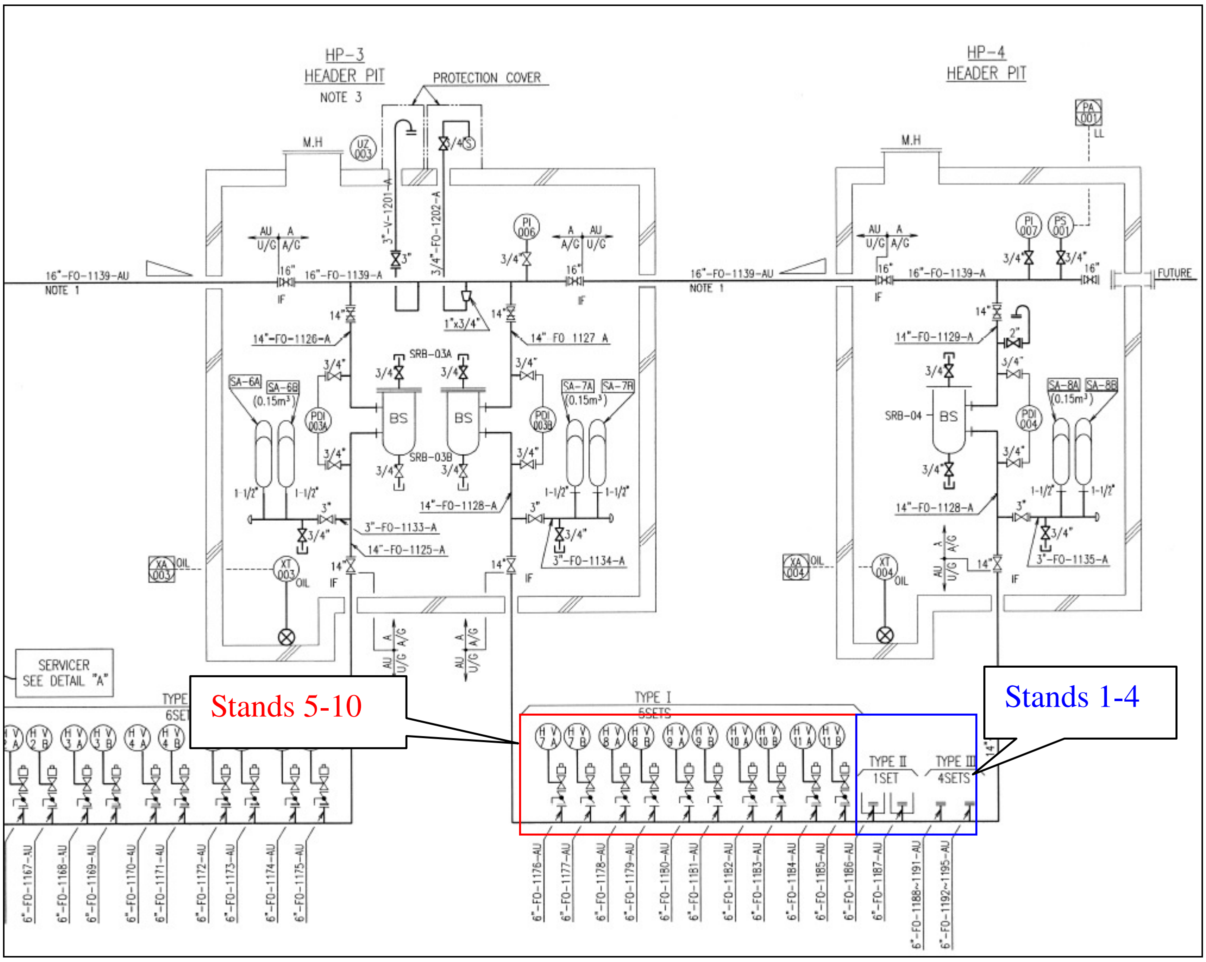


Figure 51: WARR hydrant refuelling circuit before the Extension Work

b. In 2009, an apron extension project was initiated by the Minister of Transportation of Indonesia to develop Stands No. 1 to No. 4. The project included the extension of an existing underground fuel hydrant system to provide a total of eight hydrant refuelling provisions to Stands No. 1 to No. 4.

c. The Director-General Civil Aviation of Indonesia (DGCA Indonesia) assigned Satuan Kerja Pengembangan Bandar Udara Juanda Surabaya (i.e. the Juanda Surabaya Airport Development Taskforce) to administer the project. The hydrant extension was designed by PT. Billitonica Indomatra (consultant design), the work was performed by PT. Adhi Karya (the contractor), and the quality control and supervision was done separately by PT. Surya Cahaya Utama (consultant supervision).

d. The specifications of the project, including the extension work of the fuel hydrant system was documented in the 2009 contract document

(02/PBUJ-SUB/VI/2009). The consultant design indicated that the 2009 specification was derived from the relevant parts of the 2001 contract document.

1.17.2.2 Shutdown of Fuel Hydrant System

a. The extension work on the fuel hydrant system commenced on 5 March 2010. Pertamina had been requested by the Taskforce to assist the contractor to shut a set of valves in the Header Pit 3 to isolate the affected hydrant piping. WARR airport operator, Angkasa Pura I issued a NOTAM on 11 March 2010 to indicate the shutdown of the hydrants for Stands No. 5 to No. 10 from 11 to 20 March 2010, and later issued another NOTAM on 18 March 2010 to extend such shutdown period to 18 June 2010. Refer to ***Appendix 14*** for details of the NOTAMs.

b. As explained by the Taskforce during the CAD visit, the completion of the project, including the fuel hydrant extension, had to be accepted by the DGCA Indonesia, who would deploy a technical team to the site and conduct acceptance inspection. Final acceptance for the completion of the extension work would be issued by the DGCA Indonesia upon all comments raised by the technical team were satisfactorily addressed by the contractor. Only after DGCA Indonesia issued the final acceptance, the new Stands No. 1 to No. 4 would then become operational, and the refuelling operation of the affected fuel hydrant system could be resumed. There was no record of such acceptance as the final check had not been done.

1.17.2.3 Environment of Fuel Hydrant Extension Work Site

a. WARR is located close to the seashore and has three regulating ponds. As illustrated in Figures 52 & 53, the distance between the closest regulating pond and the work site was about 300 meters. After the accident, water samples were collected from the closest regulating pond and sent for analysis. The result indicated that the water in the regulating pond contained sodium chloride.

Figure 52: WARR Stands and surrounding

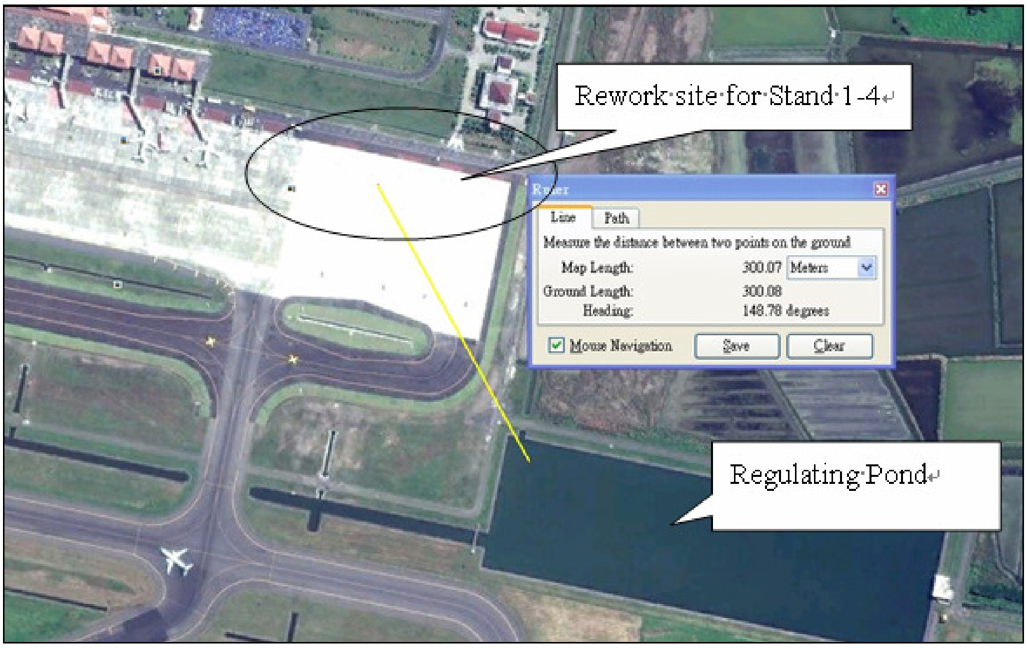


Figure 53: The extension work site and the closest regulating pond was approx 300m apart

b. During the extension work period of 15 - 25 March 2010, weather record indicated that WARR had daily rainfall of up to 20 mm and a heavy rainfall of 139 mm was recorded on 25 March 2010.

1.17.2.4 Extension work of Fuel Hydrant System

a. The extension work involved the addition of a 6" diameter extension pipe with hydrant coupling valve to the existing 14" diameter distribution pipe as referenced in drawing reference AT-HP-001. The fabrication of the 6" diameter extension pipe was done at a remote work site involving pipe preparation, welding, and pressure testing of steel pipes per the drawing and specification. As explained by the contractor and consultant supervision, the fabrication used standard cutting, grinding, swab cleaning, and electric arc welding process. Water was used for pressure testing of the completed pipe; compressed air and rags were used to dry out the pipe interior afterwards. The pipe exterior was protected by wrapping tapes, and after inspection, the open ends were capped with press fit blanks. These fabricated pipes were then connected to the 14" diameter distribution pipe in the "tie-in" process.

b. Before the "tie-in", the affected hydrant circuit was isolated and emptied to prepare for the connection of the extension pipe. During "tie-in" process, a fabricated 6" diameter extension pipe was transferred to the site on the day of connection. For each of the eight connections, the existing 6" diameter end pipe fitted onto the 14" diameter distribution pipe was cut open by hand sawing. The open end was blanked to be air tight with a "cap seal", and a "gas free" test of the open end was performed. The edge of the 6" pipe opening was grounded to create a bevel edge for subsequent joining by electric arc welding. The interior was swab cleaned by canvas or leather ball per specification. The fabricated extension pipe was then positioned and welded to the 6" diameter end pipe. According to the contractor, this "tie-in" process usually took 3 to 4 hours to complete. From the photos taken during the "tie-in" process (Figure 54), the work site was in a recess with water puddles, probably caused by recent rainfall, and with a drain pump to remove the water puddles in the work area.

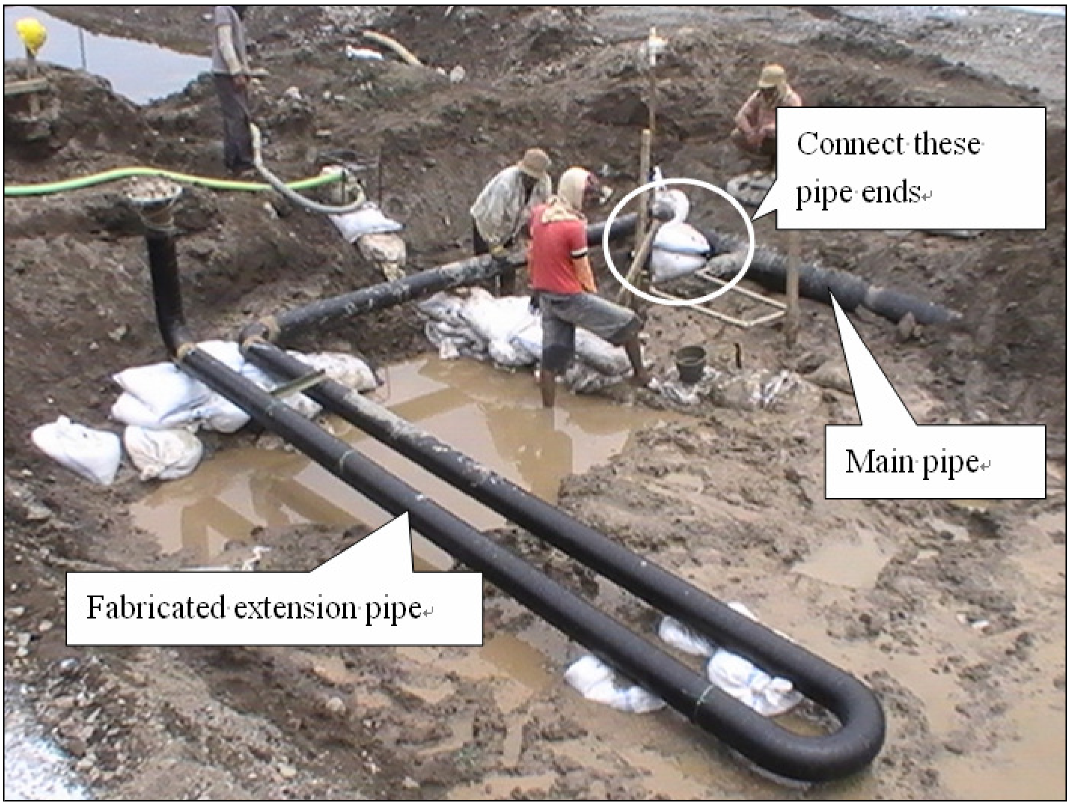


Figure 54: The tie-in process to connect the fabricated extension pipe to the main distribution pipe

1.17.2.5 Re-commissioning and Resumption of Hydrant Refuelling

a. On 7 April 2010, the Taskforce sent a fuel purchase order to Pertamina with reference number 149/UM/PBUJ-SUB/IV/2010 for an amount of 6,972 litres of fuel for the flushing of the affected hydrant refuelling circuit.

b. On 9 April 2010, the contractor asked Pertamina to provide personnel and a dispenser to assist the flushing from hydrant coupling valves at Stands No. 1 to No. 4. With the assistance of Pertamina personnel, fuel was bled from the affected piping, and the flushing process was commenced by using Pertamina dispenser JUA05 and a tanker provided by the contractor. An amount of fuel three times the volume of the extension pipe was flushed from each coupling valve. The flushed fuel was collected by the tanker and its disposal was taken care of by the contractor. The contractor stated that they had originally planned a secondary flushing on the following week, but later rescheduled it to the end of April 2010 when the DGCA Indonesia's Technical Team would be present. Pertamina had no information from the Taskforce or contractor prior to the event that the project would involve primary and secondary flushing.

c. After the primary flushing process on 9 April 2010, the Pertamina personnel assisting the flushing assumed that since the ring circuit for Stands No. 1 to No. 10 had been re-opened, hydrant refuelling from Stands No. 5 to No. 10 could be resumed. Pertamina then further flushed a volume of 16, 000 litres of fuel from a header pit of the fuel hydrant circuit and another 6000 litres in total from all coupling valves of Stands No. 5 to No. 10. On 10 April 2010, Pertamina flushed another volume of 5, 000 litres of fuel from the same header pit and 5, 000 litres in total from all coupling valves of Stands No. 5 to No. 10.

d. Visual checks were carried out on the samples of fuel collected during the flushing process and the results were "clear and bright". Fuel samples were also sent to a laboratory designated by Pertamina for testing. An "on specification" and "fit for use" test result issued by the laboratory was received by Pertamina on the same day. Pertamina then informed the Taskforce and Angkasa Pura I of the laboratory test result and that the refuelling operation of the hydrant system for Stands No. 5 to No. 10 would be resumed on 10 April 2010. Angkasa Pura I issued a NOTAM on 19 April 2010 notifying the normal hydrant refuelling operation at Stands No. 5 to No. 10 with effective from 16 April 2010 (***Appendix 14***). The final acceptance inspection by the technical team of DGCA Indonesia had not been carried out before the resumption of the hydrant system operation.

1.17.2.6 Suspension of Hydrant Refuel after CPA780 Accident

a. After the CPA780 accident on 13 April 2010, Pertamina was informed by CPA local representative in Indonesia of possible uplift of contaminated fuel in WARR. Pertamina then quarantined the dispenser JUA06 that had been used to refuel the accident aircraft. Pertamina also retained the fuel sample of CPA780 that was normally collected after each refuelling but usually discarded after 24 hours. On 15 April 2010, the CAD also advised the DGCA Indonesia of the accident and the concern on the quality of fuel supplied to CPA780 in WARR.

b. On 16 April 2010, more fuel samples from dispenser JUA06 and the hydrant system of WARR were collected. The filter monitors of dispenser JUA06 were also removed for further examination and analysis. On 19 April 2010, Pertamina issued a safety notice to require the stoppage of hydrant refuelling at Stands No. 1-10 of WARR, daily flushing from a high point at Header Pit 3, and dispenser filter performance check. On 21 April 2010, Angkasa Pura I issued another NOTAM notifying the suspension of hydrant refuel for Stands 5 to 10 from 1045 UTC of 21 April to 1029 UTC of 21 July 2010 (***Appendix 14***). On 26 April 2010, the DGCA Indonesia also informed CAD that NTSC had instructed Pertamina to isolate the fuel hydrant system for Stands No. 1 to 10 until the investigation was complete.

1.17.2.7 The International Practice on Re-commissioning

a. The EI published EI 1585 "Guidance in the cleaning of aviation fuel hydrant system in airports" which includes guidance on the commissioning / re-commissioning of new and extensions / additions to existing hydrant systems. The guidance material accepts that a hydrant system is a custom designed item and is very site specific, thus no one set of conditions can be applied to all systems. While users of the EI 1585 should amend the guidance to suit local conditions, a customised re-commissioning procedure should cover the following essential elements to ensure the extension work to a hydrant system does not cause adverse effects on fuel quality:

i. Pressure and soak test after filling the system with fuel
ii. Flushing at an average flow velocity of 2 to 3 metre per second
iii. Flushing flow direction which may include reverse flow
iv. Flush with a fuel quantity equal to 2 to 3 times the section capacity
v. Assessment of the efficiency of the cleaning operation which includes monitoring during cleaning and assessment on completion of the work

b. As described in 1.17.2.5, the re-commissioning process in WARR had not adequately addressed these essential elements stated in the EI 1585 guidance. Since then, Juanda Surabaya Airport Development Taskforce has developed a revised re-commissioning procedure. Cleaning and draining of the affected hydrant refuelling circuit were completed. Internal inspection of hydrant piping was done in September 2011 and the result was being evaluated by the Taskforce. At the time of writing this report, the affected hydrant circuit remained isolated. Refuelling at Stands No. 1 to No. 10 is continued to be done by refuellers / bowsers.

1.17.3 Refuelling Operation in WARR

1.17.3.1 Monitoring of Dispenser Differential Pressure

a. As discussed earlier under 1.16.6.1, a filter monitor system will restrict the flow of fuel before its capacity for particulate matter and/or water removal is exhausted. Such restriction is reflected by an increase of DP across the filter monitor system, indicating a drop in the supplied fuel cleanliness. On each fuelling dispenser operated by WARR, there is a Gammon gauge (mechanical piston type pressure gauge) with a range of zero to 30 psi to indicate the DP across the filter monitors. There is also an electronic device to measure and display the total fuel quantity uplifted, which also displays the current FR by pressing a button on the device.

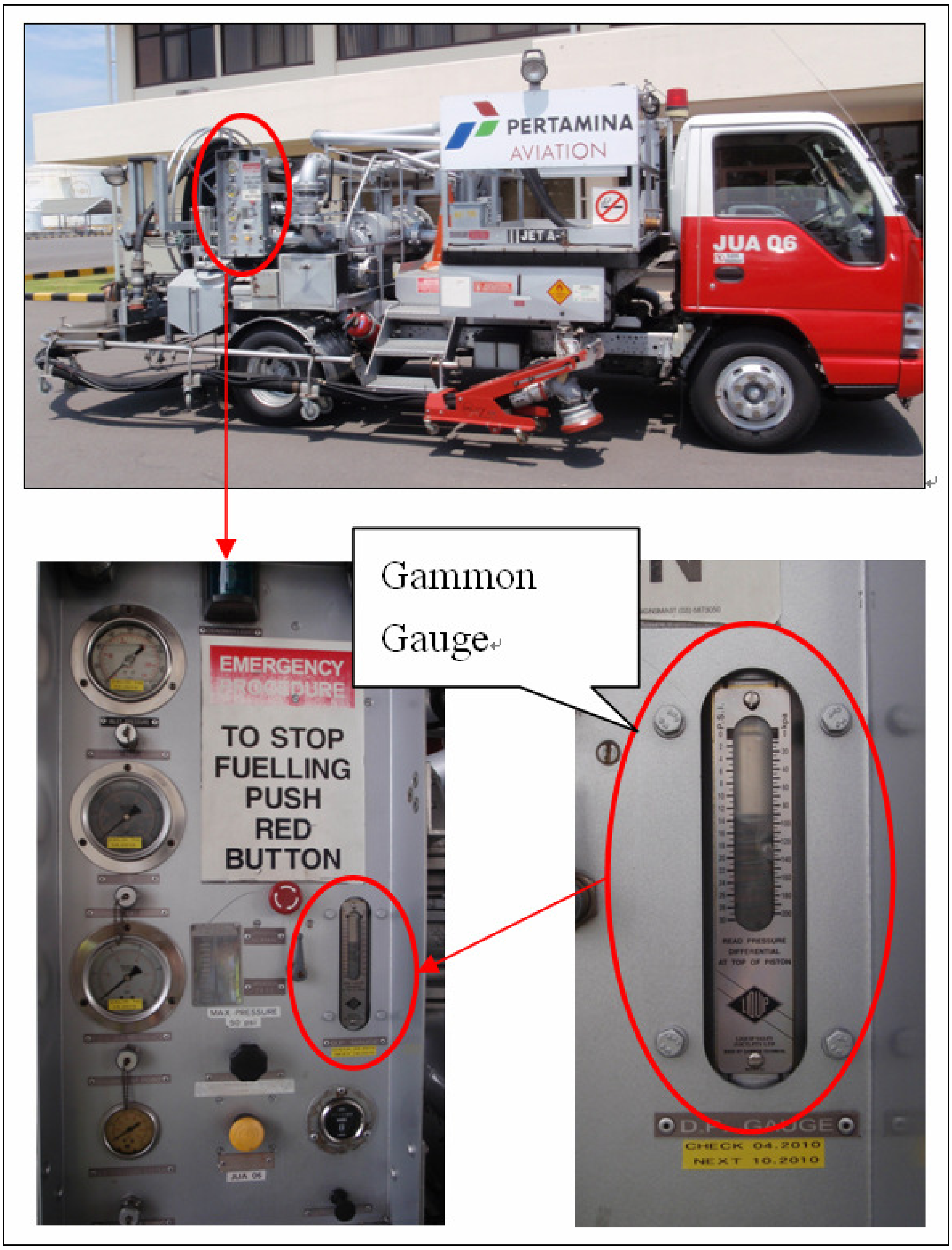


Figure 55: The differential pressure gauge (Gammon Gauge) of a fuelling dispenser

b. The Joint Inspection Group (JIG) is a limited company formed by the member oil companies. The current membership is ENI, BP, Chevron, ExxonMobil, Kuwait Petroleum, Shell, Statoil and Total. JIG develops a set of standards which governs the operation of the shared fuel storage and handling facilities at the world's major airports where the JIG companies operate. In addition, these standards are often used as a reference by other airport operators. Based on these standards, JIG performs regular inspections of airport fuelling facilities operated by its members to ensure that they are operated in accordance with their procedures. Such JIG oversights are applied at locations outside the Untied States (US). JIG published guidance JIG 1 “Guidelines for Aviation Fuel Quality control & Operation Procedures for Joint Into-Plane Fuelling Services” and was at Issue 10. Pertamina indicated that their operations followed the guidance stipulated in JIG 1.

c. JIG 1 Appendix A1 paragraph A1.2 requires that the DP and FR should be recorded daily and the record checked to ensure that the DP at maximum achievable FR does not exceed 22 psi for filter monitors. Weekly graph of DP corrected to, or recorded at, maximum achievable FR should also be prepared. It further emphasises that the conversion from observed DP to corrected DP at maximum achievable FR is not accurate when DP readings are taken at low flow-rates and is not valid where a reading is taken at less than 50% of the maximum flow.

d. The filter vessel of the fuelling dispensers used in WARR had 40 filter monitors installed thus the maximum FR of 4542 litre per minute (LPM). The refuelling records in WARR indicated that the DPs of the fuelling dispenser were only recorded by a weekly graph and without the associated FR. Nearly all of the DP recorded in the 2010 and 2011 were below one psi. The daily utilisation record of fuelling dispensers showed the aircraft type, total amount of fuel uplifted and the start / stop time of the refuel. This data indicated that majority of the refuelling were on A320 and B737 aircraft and with an average FRs below 1000 LPM, i.e., less than 50% of the dispenser maximum FR. The capacity of the dispensers were over-rated for WARR refuelling operation and the corresponding DP value could not provide a true indication of the cleanliness of the fuel. Upon being aware of the dispenser capacity "over-rated" issue, Pertamina had down-rated one dispenser and acquired two additional dispensers with lower capacity to support WARR fuelling operation.

e. The weekly graphic record of the event dispenser JUA06 (see ***Appendix 15***) showed that the DP reading for the week of the accident had a jump from one psi to four psi. Pertamina indicated that the four psi record was taken during the refuelling of CPA780. Pertamina explained that it was a common practice for the refuelling personnel to record the DP during a refuelling operation with flow-rate of approximately 800 LPM. For this "four psi" recording as recalled by the refuelling personnel concerned, the DP was recorded at a flow-rate of 2000 LPM. Knowing that the DP was taken at a higher than 800 LPM FR, the Kepala Depot Pengisian Pesawat Udara Juanda Surabaya (Superintendent of Airfield Depot Juanda Surabaya) concluded that the "four psi" did not indicate a problem of the filter element condition thus no action was required. He made a note of *"≠ 800 l/min"* next to the four psi DP record.

1.17.3.2 Other Relevant Refuelling Information

a. During refuelling of CPA780, there were several occasions where vibration of fuelling hose occurred. The dispenser operator stopped the refuelling at each occasion to stop the vibration and resumed the refuelling afterwards. This incident however was not investigated in accordance with the JIG guidance.

b. According to Pertamina's maintenance program, the dispenser filter monitors would be replaced when there was abnormal change of DP in the weekly graphic record, or every 12 months in accordance with manufacturer's recommendation. The following unscheduled filter monitor replacements in April 2010 were noted in the dispenser maintenance records:

Dispenser	Date of replacement	Reason
JUA01	15 April 2010	DP moved up
JUA02	13 April 2010	DP moved up
JUA03	11 April 2010	DP moved up
JUA04	11 April 2010	DP moved up
JUA05	10 April 2010	After flushing of disturbed hydrant
JUA06	19 April 2010	Evidence collection after the accident

c. The replacement for JUA05 on 10 April 2010 was done after the primary flushing of the disturbed hydrant as part of the re-commissioning process. The replacement for JUA06 on 19 April 2010 was done as part of the evidence collection process after the accident. The other replacements made after the extension work were due to an increase in DP.

d. The four unscheduled replacements for JUA01 to 04 indicated that the cleanliness of the hydrant fuel being handled by the dispensers JUA01 to 04 had deteriorated. However, such quality drop had not been investigated by Pertamina.

1.17.3.3 Monitoring and Recording of Differential Pressure during Refuelling

a. The dispenser utilisation records indicated that majority of the refuellings in WARR were completed in less than 10 minutes. Typical refuelling process in WARR normally involved one refuelling personnel who had to carry out a number of tasks, which included the visual checking of the fuel, the holding of the "Deadman" control switch, the monitoring and recording of the DP, and the monitoring of fuel load distribution. The dispensers in WARR did not have automatic provisions, such as electronic monitoring and alerting devices, to assist the refuelling personnel in monitoring abnormal DP values and changes.

b. As informed by Pertamina at the time of writing the report, it was evaluating the trial installation of electronic devices to the dispensers to automatically monitor unusual DP changes. Such devices are capable of automatically calculating the corrected DP according to the flow-rate, monitoring the changing condition of the filter monitors, providing alarming function, and stopping the fuelling process.

c. It was also noticed that installation of such electronic devices on fuelling dispenser is not common in the fuel industry. Being an active body coordinating fuel industry suppliers and refuelling service providers to ensure a reliable supply of safe and quality fuel to aircraft, the Technical Fuel Group (TFG) of International Airline Transport Association (IATA) had brought up a discussion at the IATA Aviation Fuel Forum held in November 2011. The need for DP monitoring and correction devices and how sensors technologies can be used to provide additional protection were discussed. The Forum concluded to take the following actions:

i. Organise a workshop on electronic sensors and "gadgets" at the Fuel Forum in Chicago, May 2012, together with the EI and Air Transport Association of America (ATA).

ii. Create a special Task Force, with specialists in this field and to develop the charter of the TF (Task Force) for the Global Application of Electronic Sensors. Detail of the charter would include mapping the approval of the devices with EI 1598 as basis, mapping the available types of sensors, analysing safety benefits and costs benefits, and possible world-wide implementation.

iii. The Task Force to report the progress of Global Application of Electronic Sensors in the next TFG meeting.

iv. Discuss with the main standardisation bodies JIG, ATA, IATA Fuel Quality Pool (IFQP) and G-16 to have the electronic devices implemented in their standards within 12-24 months.

1.17.3.4 Training and Qualification of Personnel

To operate a dispenser for into-plane refuelling in WARR, a refuelling operator had to be qualified by the Ministry of Energy, Gas and Mineral of Indonesia with the issuance of a certificate of qualification which has a 4-year validity. Based on this certificate and further assessment, the operator would receive a licence issued by the DGCA Indonesia, which had a 2-year validity. Training, recurrent training and examination are required before the issuance and renewal of such certificate and licence. Pertamina maintained records of training and qualification of all refuelling operators, including the personnel who performed refuelling of CPA780. Such records include copies of training certificates and licences relevant to the operation and safety of the refuelling and defuelling truck.

1.17.3.5 Quality Audits of Refuelling Operation in WARR

a. Pertamina indicated that there were regular audits of the aviation fuel storage and delivery operation in WARR, which were performed by Pertamina's quality assurance department. There had been no audit carried out to WARR facilities by an external regulating body.

b. After the CPA780 accident, Pertamina organised an external audit to its fuel storage and delivery facilities, and the refuelling operation system in July 2010. This audit was conducted by an external auditor who was suitably qualified in the aviation fuel quality control and operation system. Among other issues not relevant to this accident, the audit had identified weaknesses in the operating procedures, and training and competency of Pertamina staff. Since then, Pertamina has implemented a series of corrective actions to address the findings, which include revising the procedures, development of new training material, and conducting refresher training to relevant personnel according to the auditor's recommendations **(**see ***Appendix 19*****)**.

1.17.4 Quality Control of Aviation Fuel at Airport

1.17.4.1 Aviation Fuel Quality

a. From the refinery to the into-plane delivery, aviation fuel has to go through a complex distribution and supply system, which could affect the cleanliness of fuel (see Figure 56). Free water, particulate matters, and microbiological growth could be introduced into fuel at any stage in the distribution system.

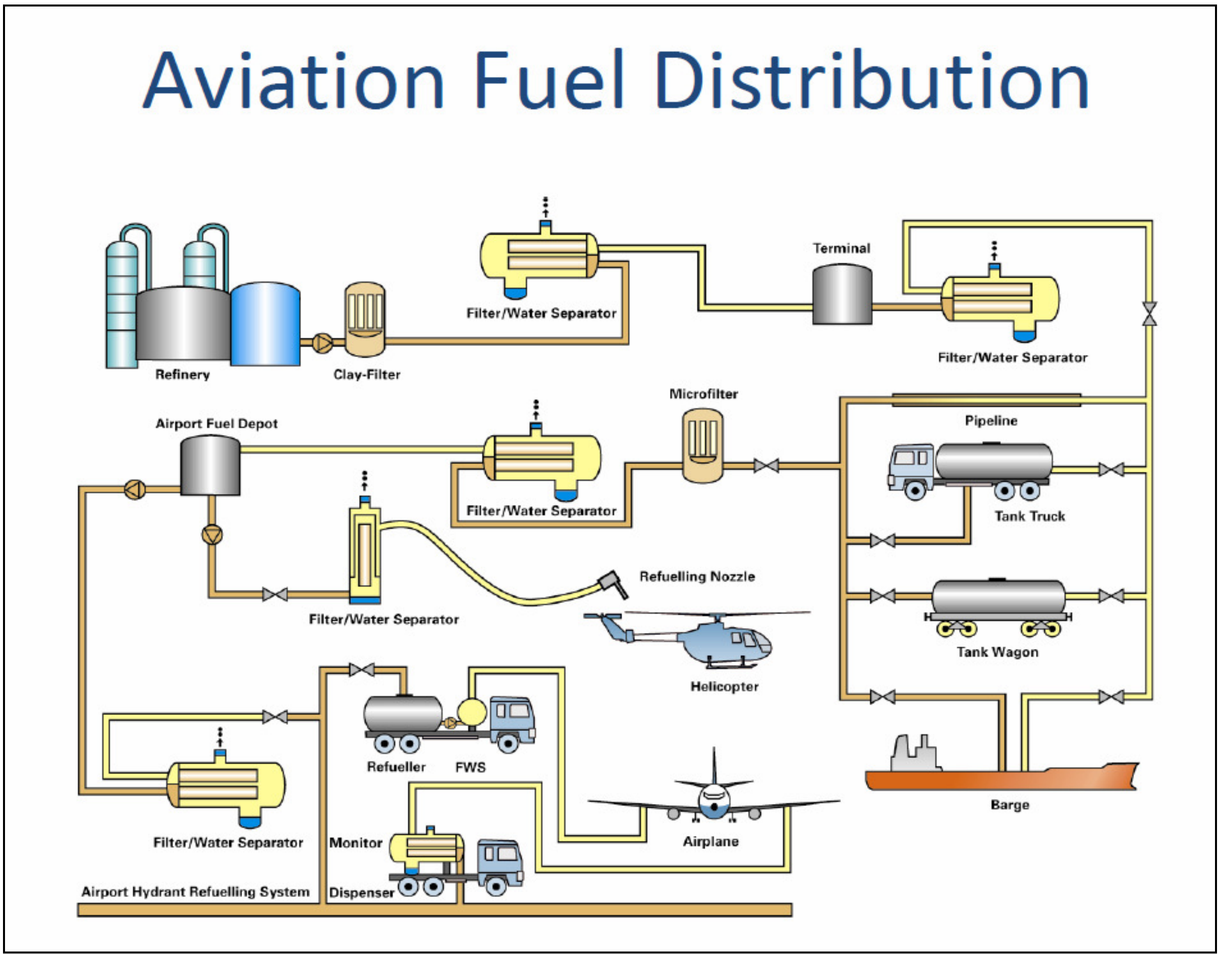


Figure 56: The supply and distribution of aviation fuel from refinery to aircraft

b. Free water in fuel could be caused by precipitation of dissolved water when the fuel temperature drops to exceed the solubility limit of the fuel, or introduced by gross contamination from an external source. Particulate matter can occur from sources such as rust and scale from pipelines and storage tanks, equipment failure, and ingress of airborne particles. Microbiological growth is from micro-organism (bacteria, yeasts, and moulds) that naturally occur in air and water, and fuel readily comes into contact with them in the handling system. Micro-organism cannot survive and proliferate without the presence of water, therefore draining and dewatering procedures together with effective filtration provisions throughout the storage and delivery system are essential to eliminate microbiological growth.

c. The fuel storage tanks in an aircraft are interconnected and the fuel is supplied to all engines. The presence of contaminants in fuel could be detrimental to engine operation, and in extreme case, contaminated fuel could lead to total loss of engine power which would be catastrophic to the safe operation of the aircraft. As such, the fuel industry has developed robust measures to ensure the quality of fuel supplied to aircraft. As illustrated in Figure 57, filtration components are installed at various stages of the aviation fuel storage and supply system. The monitoring and the application of preventive measures are part of an aviation fuel handling system and procedures.

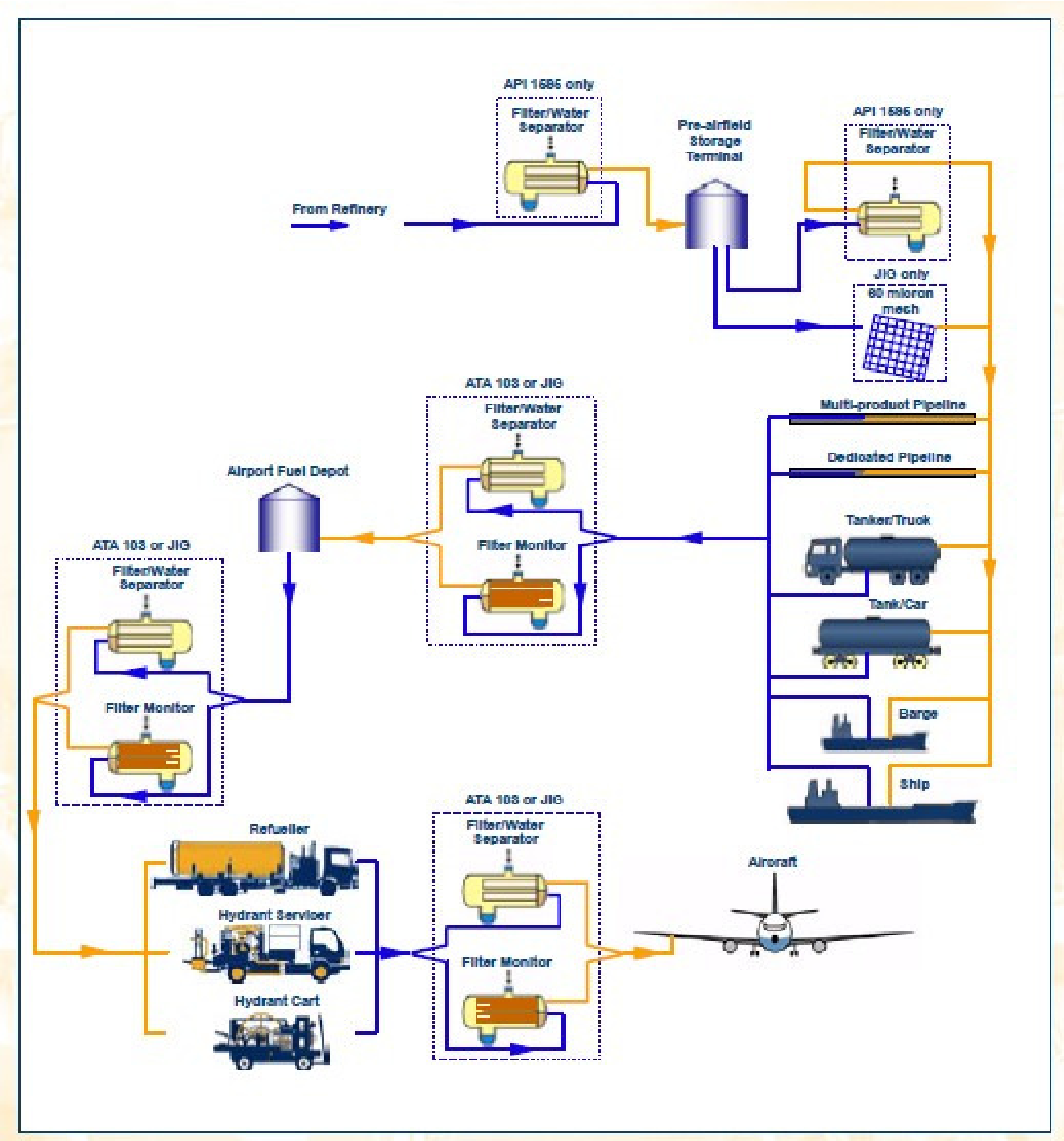


Figure 57: Schematic of minimum requirement for filter application

1.17.4.2 Fuel Quality Control by Fuel Industry

a. The fuel industry has stringent specifications, requirements, and guidance materials to ensure the quality of aviation fuel supplied to aircraft meets the aircraft specification. Relevant publications are issued by controlling organisations, which include standard developing organisations, trade associations, and professional societies. Typical organisations are EI, JIG, and ATA. The ATA is an American trade association which issues recommendations that are intended for and typically implemented in the US.

b. The JIG and the ATA, based on their publications, carry out regular audits to aviation fuel facilities in locations operated by their members. For facilities not covered by the above audit programs, such as located outside the US or not operated by a member of the JIG, requirements of any of the publications could be mandated or applied at the discretion of the local fuel supplier and operator, who may develop their own oversight provisions.

1.17.4.3 Fuel Quality Control in WARR by Civil Aviation Authority

The Indonesian civil aviation legislation does not empower the DGCA Indonesia to perform the necessary control on aviation fuel quality in the airports. The DGCA Indonesia only requires Indonesian aircraft operators to ensure fuel supplied to their aircraft around the point of delivery complies with a standard in accordance with Civil Aviation Safety Regulations, i.e., the fuel should be clear and bright and with no trace of water. Indonesian aircraft operators have a quality system which includes a minimum of one audit per year to the fuel suppliers, but there is no technical guidance from the DGCA Indonesia on the standard of fuel supply installation, equipment and operation.

1.17.4.4 Fuel Quality Control by CPA

In accordance with the Hong Kong Air Operator's Certificate (AOC) requirements, CPA, being a holder of HK AOC, must be satisfied with the quality of all fuel taken on board its aircraft and carry out checks at line and route stations for quality monitoring of fuel suppliers. From their own operational experience, CPA had developed a fuel farm audit checklist which was used when auditing its line stations that have scheduled flight operations.

1.17.4.5 Fuel Quality by Airlines Industry

On an international level, the IATA TFG has established the IFQP. Through the TFG and the IFQP, IATA coordinates with fuel industry suppliers and refuelling service providers to ensure a reliable supply of safe and quality fuel to aircraft. The IFQP member airlines share fuel supplier inspection workload and the inspection reports. Trained inspectors from the IFQP member airlines perform regular inspections through the IFQP programme on fuel suppliers at airports around the world, but restricted to those operated by IFQP member airlines.

1.17.4.6 International Civil Aviation Standards and Recommended Practices

There was no specific standards and recommended practices (SARP) published by International Civil Aviation Organisation (ICAO) requiring Member States to establish safety oversight legislation and operating requirements to ensure the fuel quality delivered to aircraft at airport. There is also no specific documentation to provide guidance to Member States to develop technical guidance material such that the Member States' AOCs and airport operators can establish effective and efficient oversight element in their quality system to monitor the fuel quality in airport. The AOCs and airport operators largely depend on the self-regulation of the aviation fuel supply industry to provide clean and fit for purpose fuel to aircraft.

1.18 Additional Information

1.18.1 Other Flights Received Fuel from WARR

a. As mentioned in 1.6.4, aircraft B-HLM powered by Trent 700 engines after received fuel from WARR reported No. 1 engine parameter fluctuation in the subsequent flight. Examination revealed the presence of SAP spheres in the low pressure fuel filter. These spheres were similar to those found in the accident aircraft.

b. As ground fuel contamination was the likely cause of the accident, the CAD investigation team sent out questionnaires to operators who had flights that were refuelled from Stands No. 5 to 10 at WARR from 11 to 19 April 2010, i.e., from the resumed operation of the affected hydrant circuit after the re-commissioning process until its suspension. The enquiry requested feedback from operators on crew reports of abnormal engine performance, such as parameter fluctuation or engine warning messages, that had occurred subsequent to the refuelling in WARR. Feedback from operators indicated that there was no report of abnormal engine performance by their crew.

1.18.2 Other Cases of Fuel Contamination by SAP Material

a. There is no published accident investigation report regarding similar occurrence of engine fuel contamination by SAP spheres, and there has been no report of a commercial aircraft engine fuel filter clogging attributed to SAP contamination. There was an occurrence of engine flame out during a military flight in 2005 and the investigation revealed large amount of SAP material and debris in the engine filter. The SAP material, which had not reacted with water, was released due to the effect of Fuel System Icing Inhibitor used in the aviation fuel. The released SAP material had clogged the fuel filter and caused engine flame out during flight due fuel starvation.

b. Although the event was related to military operation, the IATA TFG had then set up the Fuel Filter Monitor Task Force to study if there were release and migration of SAP material from filter monitors onto commercial aircraft engine fuel filters.

c. The Fuel Filter Monitor Task Force issued the "Investigation of Super Absorbent Polymer (SAP) Migration in Commercial Aviation Turbine Fuels Report" in February 2007 which confirmed SAP migration from filter monitors and contamination of aviation fuel in trace quantities has occurred in commercial aircraft, but these did not appear to affect flight operations. The report made a series of recommendations to various stakeholders, such as airlines, aircraft and engine manufacturers, oil companies, into-plane services providers, and EI to improve the situation. Among others, the following key areas were specific to SAP material migration which was relevant to the filter monitors used in fuelling dispensers:

i. Fuel filter monitor manufacturers should improve their designs and develop standard flushing procedure for filter monitors before they are put into service such that it will eliminate the release of SAP dust from migrating from the element into aircraft systems.

ii. The EI should include a new laboratory testing requirement for manufacturers to analyse for SAP downstream of filter elements being tested with a condition that none is detected.

d. In addressing these recommendations, the EI has revised EI 1583 to the 6th Edition in 2010 which among other improvements, has new test requirement on the level of SAP in the effluent. The changes in the EI 1583 from 4th through to 6th edition do not specifically address SAP spheres that were found in this accident investigation.

1.18.3 Certification of Trent 700 Engine on "Contaminated Fuel"

a. The investigation confirmed that spherical particulate matter, originating from outside the aircraft, had entered the aircraft fuel tanks and eventually led to the seizure of the MMV of the FMU on both engines, and loss of engine control. The Trent 700 engines did not function satisfactorily with this contaminated fuel. As such, the certification requirement, the means of compliance and finding of compliance with respect to "JAR-E 670 Contaminated Fuel" of JAR-E at Change 8 were reviewed.

b. Rolls Royce (RR), the Trent 700 Engine Type Certificate Holder demonstrated the compliance with JAR-E 670 (Refer to ***Appendix 16*** for details of JAR-E 670 requirement) by a series of tests as recorded in a RR report

c. The report recorded that to comply with the certification requirements and to provide accelerated life testing to give service life confidence, all fuel system components had been subjected to a 15-hour test which was performed with the LP fuel filter fitted at fuel flows equal to or greater than low altitude maximum continuous conditions and with high concentration (50 gm/1000 gallons) of MIL-E-5007E contaminant. The composition of MIL-E-5007E is a range of various sizes of material mainly consists of iron oxide (rust), quartz (soils), cotton linter, and general dirt, which could be generated in the ground fuel storage and distribution system. The MIL-E-5007E does not contain SAP spheres. Refer to ***Appendix 17*** for composition of MIL-E-5007E.

d. A further test of 5-hour duration without LP fuel filter fitted to simulate the filter bypass condition was carried out with fuel contaminated with MIL-E-5007E at a rate of 5 gm/1000 gallons.

e. The weight of the contaminant passed through the test components was 2,314 gm during the 15-hour test, and 77 gm during the 5-hour test. The FMU that was seized in this accident was one of the fuel components being tested. The report recorded that the FMU "*performed satisfactorily throughout both the 15 hour test with LP fuel filter protection and the 5 hour test without filter*".

f. The analysis in the report recorded that for a typical flight, the engine would consume 7,000 gallons of fuel and at contamination level specified in the JAR-E 670 test (4.5 gm/1000 gallons), that 31.5 gm of contaminant would pass through the system. The ACJ E 670 requires that the fuel system shall function satisfactorily after 500 hours of normal operation with fuel at contamination level of 0.5 gm/1000 gallons. For a typical long range flight at this contaminant level, a total of 196 gm would pass through the system. The actual amount (2314 gm under the 15-hour test and 77 gm under the 5-hour test) passed through the system during the certification tests are many times more than that required by the certification requirement.

g. The reports indicated that the test was performed at "*fuel flows equal to or greater than low altitude maximum continuous conditions*". It was noted that the ACJ E 670 item 1.4 states in part that "*The test should be continued at typical running conditions with respect to Rotational Speeds, pressures, fuel flow, etc., ….*". For the subject accident, the indication of stiction and eventually seizure of the MMVs happened when the engines were operating at cruise and descent conditions which the fuel flow would be lower than the "*low altitude maximum continuous conditions*".

h. EASA, the Type Certification Authority of the Trent 700 engine, indicated that low altitude maximum continuous condition would have been considered at the time to be the worst case for delivering a large quantity of contaminant into the system while staying within the "*typical running condition*" stipulation. The theory at the time was that exercising the valves during the test would actually clean out any depositing contaminant and therefore compromise the test, hence the power condition was held steady. However the test method for this requirement has evolved since then and a more representative flight profile is now employed. The testing on the Trent 500 engine involved regular MMV movements with some cruise and descent conditions included, and the planned testing for the Trent XWB engine will represent a more recognisable flight profile with take-off, climb, cruise and descent conditions.

1.18.4 ECAM Messages and FCOM Procedures

a. The following ECAM messages relevant to the engine control problem were annunciated at various time and flight phases during the event flight:

Time	Flight Phase	ECAM Message	Associated ECAM Information
0124 hrs	Took off		
0158 hrs	Climb	ENG 2 CTL SYS FAULT	ENG 2 SLOW RESPONSE
0316 hrs	Cruise	ENG 2 CTL SYS FAULT	ENG 2 SLOW RESPONSE / AVOID RAPID THR CHANGES
0519 hrs	Descent	ENG 1 CTL SYS FAULT	ENG 1 SLOW RESPONSE / AVOID RAPID THR CHANGES
0519 hrs	Descent	ENG 2 STALL	
0530 hrs	Descent	ENG 1 STALL	
0532 hrs	Descent	ENG 1 STALL	
0539 hrs	Descent	ENG 2 STALL	
0543 hrs	Landed		

b. At each of the "ENG 1(2) CTL SYS FAULT" ECAM messages, there was associated ECAM information shown to the flight crew as seen from the above table. According to the respective FCOM 3 "Flight Operations" which is a manual providing operating procedures, techniques and performance information to the flight crew, these ECAM messages were generated due to failure of certain engine system or component. As stated in the FCOM 3 (Rev 36 dated 15 Apr 10) Section 3.02.70 P 10 under "ENG 1(2) CTL SYS FAULT", "IN CASE OF P30 failure" the ECAM action is "AVOID RAPID THR CHANGES", and "IN CASE OF FMV OR FSV position failure", the ECAM action is "ENG 1(2) SLOW RESPONSE". Other failures are "N1, N2 Sensor" (ENG 1(2) IDLE) and Bleed Valve (THR LEVER 1(2) – IDLE). These ECAM actions have not specified that fuel contamination could be a cause of these ECAM messages.

c. After this accident, Airbus revised the QRH to include new procedures 70.07 dated 20 September 2011 "SUSPECTED ENG FUEL SYS CONTAMINATION" for A330 with RR engines. Refer to ***Appendix 18*** for details of the new procedures in the QRH. Airbus has also published similar procedure for A330 with Pratt and Whitney engines and in the process of publishing similar procedure for A330 with General Electric engines.

1.18.5 Further Research on SAP Spheres

The SAP spheres contaminant experienced in this accident was outside the current fuel certification requirements. A model contaminant of similar morphology to that identified in the investigation has been developed by Airbus. Rolls-Royce and Airbus have begun a test programme to establish an understanding of the behaviour of the engine fuel systems when subjected to this unusual fuel contaminant. The aim of the programme is to identify any key features within the engine fuel system which may be changed or additional fuel system operating parameters which may be monitored to enhance the robustness against fuel contamination of this nature. These tests will be conducted using a range of representative engine hardware.

1.19 Useful or Effective Investigation Techniques

Tests and examinations on filter monitors as elaborated in Section 1.16.6 were carried out to assist this investigation.

2. ANALYSIS

2.1 Flight Operations

2.1.1 Pre-flight

All the pre-flight preparations were carried out in accordance with the company procedures at the time of the accident and were in order.

2.1.2 Departure, Climb and Cruise

a. The departure was uneventful. The flight crew first noticed the EPR fluctuations during climb from WARR and kept that under monitoring. After top of climb, the ECAM message "ENG 2 CTL SYS FAULT" was annunciated. The crew responded in accordance with the Airbus and the company procedures for the A330 aircraft.

b. The flight continued as per the flight plan and started descent from FL390 to FL380. After the flight level change, a second ECAM message "ENG 2 CTL SYS FAULT" and EPR fluctuation on both engines were observed. Again, the crew action complied with the Airbus and the company procedures.

c. On both occasions, the flight crew contacted the company IOC MC for technical advice and reviewed all the information available before making any decision. Refer to 2.2 and 2.3 for more analyses on the handling of fluctuating engine parameters.

2.1.3 Descent and Approach

a. The flight crew initially planned for a normal arrival to VHHH as there was no information indicating or suggesting to them of the subsequent engines thrust control problem that they would encounter.

b. On descent to FL230 at 0519 hrs, the flight crew received the ECAM messages of “ENG 1 CTL SYS FAULT” and “ENG 2 STALL” within a short period of time. The flight crew handled the abnormal situation in accordance with the Airbus and the company procedures for the A330 aircraft. The crew appropriately declared a “PAN” call to ATC and also briefed the cabin crew of the situation. The abnormal landing to VHHH was planned in accordance with the company procedures.

c. At 0530 hrs, when the aircraft was approximately 45 nm southeast of VHHH, the ECAM message “ENG 1 STALL” annunciated. This became an emergency situation and the workload in the cockpit had understandably increased significantly. The crew again handled the emergency situation in accordance with the Airbus and the company procedures for the A330. They also appropriately declared a “MAYDAY” to ATC. Refer to 2.4 for analyses on the handling of CPA780 by ATC.

d. Owing to the control problem of the engine thrust and the limited power produced by the engines during descent, the flight crew had attempted to clear the faults from No. 2 engine by conducting the “ALL ENG FLAME OUT – FUEL REMAINING” checklist. This crew action is considered reasonable under the circumstances as that checklist provides the necessary procedures for restarting the engine(s) and also provides information on configuring the aircraft for an emergency landing should the engines fail. After the N1 of No. 1 engine had increased, it became apparent to the flight crew that CPA780 could reach VHHH for an emergency landing.

e. During the preparation of emergency landing, the co-pilot instructed the cabin crew to be seated for landing through the PA system. It was followed by another "cabin crew to stations" instruction by the co-pilot in order for cabin crew to be prepared for a possible evacuation. The Commander had also made a PA informing the passengers of the situation and requesting them to remain seated with seatbelt fastened. No "brace, brace" instruction was ordered by the flight crew during the final approach. With the abnormal approach configurations and speed, it would be more appropriate that the “brace, brace” instruction be given to the cabin crew and the passengers 30 seconds before touchdown so as to minimise the extent of possible injuries in the event of a problematic landing. It was very likely the flight crew did not provide the "brace, brace" instruction to the cabin due to high workload and limited time available. Nevertheless, the aircraft landed safely and there was no injury associated with the high speed landing manoeuvre.

f. During the visual approach to Runway 07L, the Commander manoeuvred the aircraft in order to manage altitude and airspeed. It was not until the aircraft on the final descent for landing that the Commander realised they could not reduce the thrust on the number 1 engine. The speed was not controllable and from that point, there was no time for the crew to consider other strategy nor procedure to cope with such emergency situation. The Commander operated the aircraft as close as possible to VLS for landing at whatever configuration they could achieve. High drag devices such as speedbrakes and landing gears were deployed. However, due to the high thrust from the No. 1 engine, it was clear to the Commander that they would be landing at high speed, and he manoeuvred the aircraft visually as required to achieve a touchdown as close as possible to the normal touchdown zone. The crew did not inform ATC of the abnormal high speed landing, very likely due to high workload and limited time available.

2.1.4 Landing

a. At the time of the landing there was a crosswind of about 13 kt from the right. The aircraft touched down at about 231 kt (the configuration full approach speed with landing weight of 173,600 kg was 135 kt), and at a position between abeam Taxiways A4 and A5 and with a distance of around 680 metres from the beginning of the runway threshold, and bounced. The aircraft rolled left to seven degrees and pitched down to -2.5 degrees at second touchdown. Eventually the lower cowling of No. 1 engine contacted the runway surface. The very high speed landing combined with the strong wind could have led to the bounce of the aircraft after landing. This, combined with the necessary directional control of the aircraft, could have subsequently caused the lower cowling of No. 1 engine contacting the runway.

b. Although the autobrake remained at "LO" (i.e. the lowest autobrake setting) due to time constraint and workload, the Commander applied full manual braking force after the touchdown. As a result of the high landing speed and abnormal landing configurations, the aircraft came to a stop near the runway centreline in the vicinity of the threshold area of the opposite Runway 25R, about 309m from the end of the landing Runway 07L. Landing distance for such abnormal configurations and speed was not provided, nor was it required to be provided, by the Airbus or the CPA documentations. The heat generated from the high energy braking also caused the thermal relief plug to deflate three of the left main gear tyres and two of the right main gear tyres, and the subsequent hot brakes and fire observed by the AFC.

2.1.5 Decision of Evacuation

a. After the engines were shutdown, the flight crew carried out the "EMERGENCY EVACUATION" checklist according to the QRH procedures down to the line before 'EVACUATION', as the decision for evacuation was not yet made.

b. The flight crew was mindful of the brake temperature reaching its maximum indication in the cockpit display. The crew asked ATC Tower Control for advice if there was any fire. ATC informed the crew that no fire was observed from the Tower and asked the crew to contact the Rescue Leader on frequency 121.9 MHz.

c. After reconfirming with the Tower of the Rescue Leader's frequency, the crew made contact with the Rescue Leader on 121.9 MHz. The Rescue Leader informed the crew that there was smoke and fire at the aircraft wheel. The Commander then ordered the evacuation. This decision of evacuation was considered reasonable.

2.1.6 Crew Resource Management

After observing the engine parameters fluctuations and having been alerted by the ECAM engine warning messages, the flight crew continued to closely monitor the engine operation throughout the flight. They also sought advice from the MC of IOC. When the engine control problem deteriorated further and the engine thrust could not be controlled during approach, the Commander and the co-pilot communicated effectively while acting promptly in completing the procedures relevant to the various ECAM messages. The flight crew also kept the cabin crew and the passengers appropriately informed of the situation while trying to overcome the emergency situation and eventually landed the aircraft safely under such a challenging situation. The crew, as a whole, had demonstrated good crew resource management throughout the flight.

2.2 Handling of ECAM Messages During Cruise

a. At 0158 hrs, the first "ENG 2 CTL SYS FAULT" ECAM message was annunciated shortly after CPA 780 levelling off at FL390. Only one ECAM action "ENG 2 SLOW RESPONSE" was shown for crew awareness. FCOM 3 section 3.02.70 page 10 stated that "IN CASE OF FMV OR FSV position failure: ENG 2 SLOW RESPONSE". There were no further information provided by the onboard ECAM system to assist the crew to evaluate the situation or additional procedures in the FCOM required to be following by the crew. Post accident investigation analysis of the PFR indicated during the onset of this ECAM message, the associated fault message generated was referred to high current above the threshold to control the MMV which indicating the jamming of the MMV, thus a fault in the FMU.

b. At 0316 hrs, the second "ENG 2 CTL SYS FAULT" ECAM message reappeared when CPA780 descended to FL380. This time the ECAM actions annunciated were "ENG 2 SLOW RESPONSE" and "AVOID RAPID THRUST CHANGES". These actions were also for crew awareness only. Page 10 of FCOM 3 section 3.02.70 showed that "IN CASE OF P30 failure – AVOID

RAPID THR CHANGES" and "IN CASE OF FMV OR FSV position failure: ENG 2 SLOW RESPONSE". Again no further crew action was required or recommended by the ECAM or the FCOM. Analysis of the PFR indicated that during the onset of this ECAM message, the associated fault message generated was referred to high current above the threshold to control the VSV which indicating the jamming of the VSV.

c. The ECAM actions and FCOM procedures related to the ECAM message "ENG CTL SYS FAULT" did not provide clear explanation on the background and severity of the FMV, FSV or P30 failures. No further procedures or guidance are provided to the flight crew through the ECAM or FCOM in the case of repeated faults on the same engine or with regard to the same fault occurring simultaneously on both engines.

d. The ECAM, FCOM, and QRH did not include procedure to handle situation of both engines' parameter fluctuation. There was also no information from any procedure indicating that there was a need to consider landing as soon as possible. After having consulted all the relevant manuals and the IOC MC, the flight crew decided to continue the flight as planned since there was no other anomaly apart from the EPR fluctuations and the engine ECAM messages that had happened.

e. In addition to 0158 hrs and 0316 hrs ECAM messages, other ENG STALL and ENG CTL SYS FAULT messages were also triggered when there were considerable changes of engine power setting, such as at 0519 hrs (when descending to FL230), 0530 hrs and 0532 hrs (when levelling off at 8,000ft during approach).

f. The crew handled the ECAM messages in accordance with the FCOM procedures. The operating procedures in the FCOM were unable to provide sufficient information to the flight crew and engineering personnel for consideration of possible fuel contamination and subsequent actions. In light of the circumstances of this accident, Airbus subsequently revised the QRH which included a new section 70.07 dated 20 Sep 11 "SUSPECTED ENG FUEL SYS CONTAMINATION" to assist the crew in determination and handling of fuel contamination incident.

2.3 Communications with the Company IOC MC

a. The flight crew contacted the company IOC MC twice, firstly after "ENG 2 CTL SYS FAULT" annunciation at 0158 hrs after top of climb, and secondly after "ENG 2 CTL SYS FAULT" annunciation at 0315 hrs after the step descent. The communication between both parties was clear, apart from the normal slight delay from satellite communications.

b. In the first conversation, ME1 at the IOC assessed the engine performance as reported by the flight crew. Having reviewed and discussed the FCOM 3 and QRH procedures and confirmed that nil action was required other than for the flight crew to monitor parameters, ME1 advised the flight crew to maintain the engine control at "EPR" mode. As all engine parameters were normal other than the EPR fluctuations, the flight crew elected to continue the flight to VHHH. In view of all the information available at the time, including the FCOM and QRH information, the comments and suggestions from ME1, the decision of the flight crew to continue the flight was considered reasonable.

c. In the second instance, the flight crew described to ME2 at the IOC about the second ECAM warning and the associated messages, and the increased range of EPR fluctuations on both engines, with No. 1 engine EPR fluctuations less than those of No. 2 engine. The flight crew queried if it was safe to continue. ME2 explained that the problem appeared to be with No. 2 engine FMU, and No. 1 engine EPR fluctuation might be caused by the FADEC system when using No. 1 engine to compensate for the EPR fluctuation of No. 2 engine. ME2 further advised that they were aware of similar ENG CTL SYS faults having been experienced by other aircraft in the past and that the FCOM and QRH guidance should be followed in such cases. Review and discussion of FCOM 3 and QRH procedures indicated nil further action was required other than for the flight crew to continue to monitor the engine parameters. Both the flight crew and MC were satisfied that it was safe for the flight to continue. The flight crew elected to continue the flight. The investigation cannot conclude that the loss of thrust control on both engines would have been avoided had CPA780 made an earlier landing after the onset of the engine ECAM messages.

d. System design of FADEC system and the A/THR system indicated that there is no compensation feature between the two engines. The A/THR sends to both EECs the thrust targets that are needed to obtain and maintain a target speed of the aircraft when in SPEED mode, or obtain a specific thrust setting (e.g. CLB, IDLE) when in THRUST mode. The A/THR feedback loop corresponds with aircraft CAS but not the N1/EPR. As there was no significant aircraft CAS fluctuation at that time, the A/THR would not send compensating command to the EEC of any engines. Such information was not known to the flight crew and the ME2 at the time of the discussion. The explanation given by ME2 that No. 1 engine EPR fluctuation was related to No. 1 engine compensating for No. 2 engine was therefore not correct.

2.4 Handling by Hong Kong ATC

a. Throughout the accident from the time the accident aircraft first established radio contact with HK ATC (refer to as ATC in this sub-section) via VHF prior to entering HK FIR until the aircraft switched frequency to communicate with the Rescue Leader after landing, clear and effective communication was maintained between the flight crew and the ATC. The ATC also provided efficient air navigation services at all time to the accident aircraft.

b. On receipt of the "PAN" call from CPA780 at 0519 hrs, the air traffic controller immediately notified the Approach Supervisor (APS) who in turn informed the Aerodrome Supervisor (ASU) and other units in accordance with standing instructions. The ASU who is separately located in the Tower Cab on the top floor of the ATC Tower building initiated a Local Standby for CPA 780.

c. At 0532 hrs, CPA780 called "MAYDAY" and advised HK Approach of the dual engine stall situation. Under the circumstance where a twin-engine aircraft encountered dual engine stall, ATC would, according to standing instructions, upgrade the emergency category to a Full Emergency. However, on this occasion ATC did not upgrade the emergency category. The investigation tried to establish why a "MAYDAY" call associated with a dual engine stall situation had not triggered ATC upgrading the Local Standby to a Full Emergency.

d. On receipt of the "MAYDAY" call from CPA780, the controller immediately alerted the APS who in turn alerted the Watch Manager (WMR), who then contacted the CPA IOC for the latest update. The update from IOC was that only the No.2 engine of CPA780 was at idle.

e. The investigation noted that communicating with the CPA IOC has been an efficient and effective means for ATC to obtain useful information related to all CPA flights. On many occasions, the IOC had provided useful supplementary information that was not given to ATC on the radio frequency by CPA flights which had reported technical or operational difficulties. However in this case, the CPA780 flight crew, due to the priority in handling the flight, was not able to provide further update of the engine performance to the IOC. As such and based on the latest information that only one engine was on idle, ATC concluded that no change to the emergency category would be necessary.

f. Eleven minutes after the "MAYDAY" call, CPA780 landed. When observing the aircraft was executing emergency evacuation, the ASU upgraded the emergency category to "Ground Incident" in accordance with standing instructions.

g. The investigation considered that the alerting of emergency services by ATC and mobilisation of rescue vehicles by AFC in the accident were carried out in good time prior to the arrival of CPA780. Had a Full Emergency been declared by ATC, it would have triggered Fire Services Department in mobilising a full turnout of fire and rescue service facilities i.e. extra support from outside the airport boundary in addition to the AFC. Nevertheless, given the limited time of 11 minutes available from the moment CPA780 declared "MAYDAY" to the time it landed at the airport, there is no evidence suggesting a different emergency category declared by ATC during the accident would have any bearing on the emergency resources attending to CPA780 and the subsequent emergency evacuation.

h. Subsequent to the accident, the Air Traffic Management Division (ATMD) of CAD had conducted a review of the ATC handling during the accident as well as the relevant standing instructions for air traffic controllers and Supervisors. ATMD also confirmed that for an in-flight twin-engine aircraft reporting dual engine stall situation, ATC would declare Full Emergency according to standing instructions because there would be imminent danger of an accident.

i. While the investigation noted the necessity for ATC to find out in a timely and detailed manner the exact nature of the problem with the accident aircraft through other means, it would however be prudent for ATC to act in response to the pilots declaration and to double-check with the pilot, as necessary, and not to rely solely on the information gathered from the CPA IOC. As in this case, there could be occasions that the CPA IOC would not be in receipt of the latest information from the flight crew. In this regard the investigation team noted that ATMD Management had already taken follow up action in highlighting the issue to all ATC Supervisors.

2.5 The Evacuation Process

a. The flight crew kept the cabin crew and the passengers appropriately informed of the abnormal situation as much as possible via PA and Intercom. The Commander had reminded the "cabin crew to stations" before landing, which is a CPA standard phraseology indicating that there could be a possibility of emergency evacuation. After the landing and when the aircraft came to a complete stop, the Commander also made a PA advising the passengers that they were evaluating the situation and reminding the passengers to remain seated and follow the cabin crew's instruction. The cabin crew therefore, while sitting in the cabin, also prepared themselves for a possible evacuation.

b. When the Commander ordered "evacuate, evacuate", the cabin crew responded to the command immediately and initiated the evacuation. All eight emergency exits were used after the cabin crew had confirmed the absence of fire or smoke outside the exits. Doors L1, R1 and R4 were each manned by two cabin crew members, while the other five doors were each manned by one cabin crew member. Door R4 was initially opened but the slide did not deploy. Since all the Doors had been armed before departure and there was no fault noted on R4, it was likely that the cabin crew had inadvertently selected the door to "DISARM" position before opening the door. The cabin crew had to close the door and re-armed the slide. This door was re-opened and the slide deployed successfully. The impact on the evacuation process by such short delay in the deployment of one slide was considered minimal.

c. Some Indonesian passengers reported that they could not understand the evacuation commands, which were given in English and Chinese. This might have caused initially a bit of confusion within the cabin. The investigation considered that the body languages of the cabin crew (including their clear motion and physical direction) together with the atmosphere in the cabin should have provided the passengers, who did not understand either English or Chinese, with adequate information of the abnormal situation rather than a normal disembarkation.

d. Some passengers carried their cabin bags despite the cabin crews had instructed them to leave their bags behind. This could have led to their loss of balance when sliding down the emergency slides, leading to injuries or blocking the way of other passengers on their way down.

e. The flight crew carried out the final cabin check and made sure that there was no passenger onboard before leaving the aircraft. The emergency evacuation was completed in about 2 mins and 15 seconds.

f. Emergency evacuation is a procedure with certain risk of injuries, which cannot be totally avoided. The flight crew had been mindful and had spent time in evaluating the situation when the aircraft came to a complete stop. Once they had confirmation from the AFC of the fire on the wheels, the crew immediately ordered the evacuation albeit without informing ATC of such a decision. The decision of emergency evacuation was considered reasonable. All the emergency response units at VHHH responded promptly to the scene and provided their corresponding support throughout the processes.

2.6 Loss of Thrust Control

a. A review of the aircraft maintenance history indicated that no maintenance work had been carried out on the aircraft fuel system and the engine fuel control system prior to the CPA780 flight. The aircraft technical logbook also had no record of defect related to engine performance or engine thrust control before the CPA780 flight.

b. During the accident flight, the ECAM messages "ENG 1/2 CTL SYS FAULT", "ENG 1/2 STALL", the ECAM action "ENG 1/2 SLOW RESPONSE" and "AVOID RAPID THR CHANGES" were shown on several occasions. Analysis of the PFR indicated that "ENG 1/2 SLOW RESPONSE" was associated with excessive current to control the MMV of the FMU, and "AVOID RAPID THR CHANGES" was associated with excessive current to control the VSVC and there was malscheduling of the VSV. These ECAM actions indicated stiction or seizure of the control parts inside the FMU and VSVC.

c. Post accident examination of fuel samples collected from engine fuel components indicated the presence of SAP spheres. Further examination of engine fuel components confirmed stiction in the control parts inside the FMU and VSVC, and the seizure of the MMV in both FMUs. SAP spheres were also present on the interior surfaces of these control components. There was also an agglomeration of SAP spheres between the piston and the sleeve of the MMV which caused its seizure. The stiction and seizure of the control parts had rendered the engine fuel components not properly responding to the EEC control input during the accident flight, and triggered the ECAM messages as per design. The loss of thrust control was a result of the stiction and seizure of the fuel control components caused by the SAP spheres.

2.7 MMV Seizure

a. The MMV of the FMU is a mated piston and sleeve design which acts as sliding valve mechanism and with close clearance for purposes of accuracy, efficiency and chip shear. The presence of significant fuel borne contaminant, such as the SAP spheres in this accident, may have compromised the close clearance and possibly affected the correct operation of the MMV.

b. The degradation of the MMV operation by contamination depends on the nature of the contaminant (hardness), the size, morphology and propensity for adherence, and its concentration and flow-rate. The design of the FMU also has controllability (force) to a certain extent to overcome the impact of operation degradation induced by known contamination.

c. The controllability over the impact of contamination within the mated clearance is dependant on the nature of the restraining force (friction) and the variation in control demand (noise) within the control system. During operation, the friction and noise would normally result in perturbation in fuel flow and subsequent EPR fluctuation but such fluctuation would not be noticeable to the flight crew.

d. As mentioned in 1.11.4, the magnitude of the fluctuation of No. 1 engine parameter of the aircraft B-HLM (which had no engine ECAM message) on the day before the accident flight was higher than that of No. 1 engine and lower than that of No. 2 engine of the accident aircraft B-HLL (both engines of which had ECAM messages). It appears that the magnitude of the EPR parameter fluctuation has no direct correlation to the triggering of ECAM messages.

e. EPR fluctuations are possible during onset of the effect of fuel-borne contamination at levels that the forces within the MMV can overcome. The extent and duration of the EPR fluctuation and whether the contaminant will seize the MMV will depend on the nature, concentration, and build up rate of the contaminant, which are variables. The investigation could only identify the nature of the contaminant but was unable to determine their concentration and build up rate during the accident flight. As such, it is not possible to determine the exact mechanism of how the contaminant had affected the MMV operation from stiction (engine parameter fluctuation) to finally the complete seizure (loss of thrust control).

2.8 Contaminated Fuel

a. The accident aircraft had received 24,400 kg of fuel at WARR before the flight. During the refuelling at WARR, there were several occasions where vibration of fuelling hose occurred. After the accident, all FDR data, QAR data, PFR and ACMS reports were reviewed and analysed. There was no evidence of unusual command signal from the EEC, or from the manual and auto thrust systems. Review of the engine thrust control system, the flight management system and the flight recorder data indicated that the loss of thrust control on both engines was a result of a failure in a system of the aircraft that was common to both engines. It was therefore suspected that the aircraft fuel system, and in particular, contaminated fuel in the aircraft fuel tanks was causal to the loss of thrust control.

b. The engine fuel system components were examined which revealed that the MMV in the FMU of both engines were seized at positions consistent with the corresponding final engine power (refer to 1.16.3.4 and 1.16.3.5). The VSVC from No. 2 engine was also found seized. These seizures were caused by contaminant in the form of SAP spheres, which were found throughout the engine fuel system and in fuel samples from the aircraft tanks.

c. SAP spheres were also present in one filter monitor (refer to 1.16.4 d) and the hose end strainer of the dispenser JUA06 (refer to 1.16.2.3) which was used to refuel CPA780 at WARR. Examination and analysis of the SAP spheres revealed a composition of substance that was external to the aircraft. It was apparent that the contaminated fuel had been supplied to the aircraft.

d. Although examination of the ground fuel samples collected from WARR did not reveal the presence of SAP spheres, examination of filter monitors from dispenser JUA06 which refuelled CPA780 revealed trace quantity of SAP spheres in one filter monitor. In addition, analysis of the fuel sample collected in the Header Pit 3 of the hydrant system indicated the presence of salt water which would compromise the shutdown performance of filter monitors. There were also unscheduled filter monitors replacement for some fuelling dispensers at WARR a few days prior to CPA780 due to high DP, which was an indication of possible contamination in the hydrant fuel. All these suggested that the generation of SAP spheres were external to the aircraft and could be a combination of the salt water contaminated fuel and the refuelling operation with dispenser JUA06 at Stand No. 8 in WARR.

e. During the event mimicking tests, similar SAP spheres were also collected by a microfilter installed in the test rig downstream of the filter monitor (refer to 1.16.6.7 d). It further indicated that SAP spheres could be generated from a filter monitor during certain operating environment.

f. The SAP spheres, which had contaminated the fuel, were uplifted to the aircraft before the accident flight and caused stiction and eventually seizure of the fuel control components.

2.9 SAP Spheres

a. Analysis indicated that these SAP spheres contained elements that were consistent with the SAP material used in the filter monitors installed in a fuelling dispenser. Crystalline sodium chloride (salt) was also present on the surface of some SAP spheres. According to the performance specified in the EI 1583 and as demonstrated during the salt water slug test, the SAP media turned to gel form when absorbing water but would not shut down the flow because of the presence of salt. Nevertheless, according to the design of the filter monitor, the scrim between different layers and the final filtration/media migration layer should have retained the SAP gel within the filter monitor.

b. Analysis of the operating pattern of dispenser JUA06 after the premature resumption of operation of the disturbed hydrant refuelling circuit on 11 April 2010 revealed that the majority of the refuelling operations were carried out at low flow-rates (well below 50% of the maximum flow-rate). A hypothesis for the generation of SAP spheres, as explained in the following paragraph, was that when a filter monitor was activated by salt water and operated under certain conditions and environment, it can generate spherical SAP particulates.

c. When the SAP was fully activated with the salt water left inside the fuel hydrant system, the performance of filter monitors was compromised and could not completely shut down the flow. This allowed continuous refuelling through the filter monitors. With such degraded performance of the filter monitors, fuel contamination was not detected by the dispenser operator unless the fuel flow was so restricted that warrant a filter change. According to the maintenance records at WARR, there were a number of unscheduled replacements of the filter monitors on some fuelling dispensers after resuming the operation on 11 April 2010. This indicated that the filter monitors had been exposed to contaminant, which in this case, very likely was salt water as salt was found in one hydrant fuel sample. As the contaminated filter monitors continued to operate under low flow condition, the activated SAP, which was in gel form, was repetitively exposed to cyclic refuelling pressure, and eventually extruded through the scrim and media migration layer (SAP gel extrusion). Large scale gel extrusion could also occur during the vibration event reported when refuelling CPA780. The extruded SAP gel could have changed to spherical shape particulates (SAP spheres) under certain flow condition and ended up downstream of the filter vessel.

d. The investigation team carried out a flow test (refer to 1.16.6.7) which mimicked the operating pattern of the refuelling operation in WARR in terms of cycles and duration preceding the refuelling of CPA780. A new filter monitor was initially exposed to salt water in a gradual manner, followed by a low flow-rate salt water slug test, then a series of cyclic operation mimicking the events that could have happened to the filter monitor during such period. After the event mimicking test, examination could not identify the presence of SAP spheres in the filter monitor layers but revealed trace quantity of SAP spheres embedded in the media of the microfilter installed downstream of the filter monitor under test. The result of the mimicking test supported the hypothesis that SAP spheres could be generated from the filter monitors under certain operating condition and environment.

2.10 Re-commissioning of WARR Hydrant Refuelling Circuit

a. The extension work of the fuel hydrant system for parking Stands No. 1 to 4 extension project was administered by the Satuan Kerja Pengembangan Bandar Udara Juanda Surabaya (Juanda Surabaya Airport Development Taskforce of DGCA), which is the project owner. Technical expertise was provided by three companies: designed by PT. Billitonica Indomatra (consultant design), constructed by PT. Adhi Karya (the contractor), and the quality control and supervision was by PT. Surya Cahaya Utama (consultant supervision).

b. In the re-commissioning process, the consultant supervision providing quality control and supervision to the extension work had a critical role. The development of the re-commissioning procedure was largely based on a specification detailed in the 2009 contract document (02/PBUJ-SUB/VI/2009). The consultant design stated that the 2009 specification was derived from the relevant parts of the 2001 specification, under which the contractor should submit a test program for engineer approval regarding the flushing of pipe. There was no record of such approval. Furthermore, the re-commissioning conducted after the extension work had not considered many critical issues as described in EI 1585 for cleaning up the disturbed hydrant circuit, in particular the flushing fuel velocity and volume of fuel. It was apparent that the knowledge and experience of the consultant supervision were not specific to aerodrome aviation fuel supply system thus could not identify shortcomings in the re-commissioning procedure. As such, the following safety recommendation was raised in Accident Bulletin 3/2010 published in August 2010.

Recommendation 2010-1

Satuan Kerja Pengembangan Bandar Udara Juanda Surabaya (i.e. The Juanda Surabaya Airport Development Taskforce) should, with suitably qualified personnel of aviation fuel hydrant operation and re-commissioning experience, conduct an extensive review of the re-commissioning procedures of hydrant refuel system in accordance with the best practice in aviation fuel industry.*

(The Juanda Surabaya Airport Development Taskforce is the project owner for the hydrant refuel system extension work at Stands No. 1 to 4 at WARR.)*

c. The record of the project revealed that the extension work of the hydrant was not properly coordinated by the project owner, the Juanda Surabaya Airport Development Taskforce. While Pertamina had assisted the isolation of the hydrant refuelling circuit in preparing for the extension work and the flushing of the affected piping afterwards, it was not fully aware of the re-commissioning plan. After the flushing process, Pertamina conducted its own quality check of the hydrant fuel by taking additional fuel samples. When the laboratory test result of its fuel samples was satisfactory, Pertamina believed that the affected hydrant circuit could be operational thus resumed the hydrant refuelling operation starting from 11 April 2010. Both the project administrator and Angkasa Pura I (airport operator) personnel had acknowledged the mobile phone SMS notification from Pertamina about its intention to resume the hydrant operation. It is apparent that the project was not properly coordinated by the project administrator which led to the premature resumption of hydrant refuelling from the affected circuit.

d. The lack of proper coordination was also reflected in the issuance of relevant NOTAM by the airport operator. For example, a NOTAM was issued on 19 April 2010 advising the resumed operation of the hydrant refuelling at the affected parking stands with effect on 16 April 2010. However, the operation had been prematurely resumed on 11 April 2010.

e. The following safety recommendation was therefore raised in Accident Bulletin 3/2010 published in August 2010.

Recommendation 2010-2

The Juanda Surabaya Airport Development Taskforce should ensure the re-commissioning procedures are completed before resuming the hydrant refuelling operation for Stands No. 1 to 10 at WARR.

2.11 Salt Water in Fuel Hydrant System

a. Fuel sample collected from a low point in Header Pit 3 of the hydrant circuit showed the presence of salt water which had very likely compromised the shutdown performance of the filter monitors of the refuelling dispensers at WARR. The presence of salt water inside the disturbed piping was investigated.

b. The airport was close to the seashore and a regulating pond in the apron nearby the worksite contained salt. It was therefore likely that the water puddles at the work site contained salt. As described by the contractor, the extension work of the hydrant involved a tie-in process during which the existing main distribution pipe was cut open and a fabricated piping was welded to the main distribution pipe. When there was shortfall in adherence to the tie-in procedures, such salt water could have entered the main distribution pipe of the fuel hydrant circuit.

2.12 Differential Pressure Monitoring in WARR

a. Filter monitors are installed in fuelling dispenser to remove small amount of particulate matters and dispersed free water from aviation fuel to levels acceptable for servicing modern aircraft. It is also intended that in service, a filter monitor system will restrict the flow of fuel before its capacity for particulate matter and/or water removal is exhausted. The restriction is reflected by decreased FR and increased DP. Both FR and DP readings are presented to the fuelling dispenser operator.

b. In WARR, the fuelling dispensers only used Gammon Gauge, which is a mechanical piston type gauge with fine divisions to show the DP reading. DP value is dynamic and changes according to the flow-rate. When FR is not corrected during low flow operation, the DP reading can be very small (1-2 psi) in the full scale marking of the DP gauge (30 psi). Moreover, reading the FR requires further pressing of a button on the total uplift counter on the fuelling dispenser, thus proper monitoring of DP requires extra effort from the fuelling dispenser operator.

c. Pertamina indicated that their operating procedure was based on JIG guidelines. However it was noticed that its operating procedure did not fully reflect the latest JIG guidance. According to JIG 1 Issue 10 published in 2008, a dispenser should have a weekly DP record to allow trend monitoring of the filter monitor condition. A high DP value or a sudden drop of DP should be investigated. In this context, JIG 1 highlighted that such DP record should be taken under the maximum achievable FR. It further emphasised that the conversion from observed DP to corrected DP at maximum achievable FR is not accurate when DP readings are taken at low flow-rates and not valid when a reading is taken at less than 50% of the maximum flow.

d. Pertamina maintained this weekly DP records but the readings were not taken at or corrected to the maximum achievable flow-rate. Therefore, the record could not reflect the actual conditions of the filter monitors. Moreover, most of the refuelling in WARR was done at FR well below 50% of the fuelling dispenser rated flow thus the actual DP value or DP change would be too small to be effectively monitored by the fuelling dispenser operator during refuelling. On this issue, both EI 1550 and JIG 1 suggested to down-rate the filter vessel by inserting blanking element available from filter monitor vendor to allow more effective monitoring of the DP changes. After the accident, Pertamina had down-rated one of its fuelling dispensers and brought in two additional fuelling dispensers with smaller capacity to be used for low flow-rate refuelling operation.

e. As DP and FR parameters are also indicators of the cleanliness of the fuel going into the aircraft, according to JIG guidance, the dispenser operator should closely monitor the DP and FR parameters from a clean fuel perspective and suspend the refuelling if in doubt, such as sudden change of these values. However during a typical refuelling, the dispenser operator also engages in other activities, which could distract their attention in monitoring these two critical parameters. With all refuelling tasks happening in a relatively short period of time, it would be difficult for the refuelling personnel to notice transient changes of DP and FR readings. Therefore, the investigation considers that manual monitoring of DP is not effective. A slow or even lack of reaction to changes of these two critical parameters which indicate possible fuel contamination, may in extreme case, resulted in undetected uplift of contaminated fuel into an aircraft. To prevent such from happening, the monitoring of these critical parameters should be done by a device in the fuelling dispenser that can automatically alert the dispenser operator and shut down the refuelling process when the DP is outside the dispenser designed value or range. Such device is also applicable to other equipment that has built-in filtration system and used to perform into-plane refuelling operation.

f. Fuelling dispenser equipped with automatic DP monitoring of DP is not common in the fuel industry. In November 2011, the IATA TFG had initiated a series of discussions in the IATA Aviation Fuel Forums on this issue. A Task Force was formed which would discuss with the main standardisation bodies of the fuel industry with an aim to having electronic devices implemented in the fuelling equipment standards. However, neither the IATA nor the standardisation bodies of the fuel industry has regulatory power over such implementation. Refer to 2.14 for discussion on the role of ICAO in implementing international requirements on aviation fuel oversight.

2.13 Training of Personnel

a. During the refuelling of CPA780 which demanded a larger volume of uplift and at a much higher FR, the dispenser operator recalled vibration of fuelling hose on several occasions, and a DP of 4 psi was indicated on the Gammon Gauge. The dispenser operator stopped the refuelling but resumed without further investigation. It was likely that the presence of salt in the water had compromised the shutdown performance of the filter monitors. While continuing the refuelling was possible, such practice was not in line with the guidance of JIG which requires an investigation of the vibration and unusual DP rise.

b. The weekly DP record of the event dispenser JUA06 was reviewed by Pertamina and the unusual 4 psi DP record was noted. However, the initial interpretation of the unusual 4 psi DP record by Pertamina senior staff (Superintendent of Airfield Depot Juanda Surabaya in WARR) was that the DP was recorded under a higher than usual flow-rate thus such rise was not unusual.

c. During review of individual dispenser maintenance records, it was noticed that nearly all dispensers had unscheduled filter monitor replacement within a short period of time after resuming operation of the disturbed hydrant on 11 April 2010. The reason for such replacements was high DP indication which implied blockage of the filter monitors. However, Pertamina personnel had not recorded the high DP events in the respective weekly DP record sheets and was not aware of the need to investigate these unusual DP events.

d. It was noticed that operational personnel had received the required training and obtained proper qualifications and operating licence issued by Ministry of Energy, Gas and Mineral and the DGCA Indonesia respectively. However they did not seem to have sufficient alertness to report and investigate refuelling anomalies, such as fuelling hose vibrations, unusual DP changes, and unscheduled FM replacement. The training to Pertamina personnel was apparently not effective.

2.14 International Requirements on Aviation Fuel Oversight

a. The fuel industry has stringent specifications, requirements, and guidance materials to ensure that the quality of aviation fuel supplied to aircraft meets the aircraft specification and they are self-regulated to include the quality control of aviation fuel.

b. While there are oversights carried out by suitably qualified auditors from trade associations of the fuel and aviation industry, such as JIG and ATA, fuel storage and into-plane facilities in airports that are not operated by their members are not covered by the audit program of these trade associations. Similarly in airlines industry, there are specifically trained auditors from IATA TFG IFQP who regularly audit fuel storage and into-plane facilities in airports. However the coverage is again only restricted to airports with operation by members of IFQP, and yet the IFQP membership is different from that of IATA.

c. Because of the above arrangement, the fuel storage and delivery systems in WARR has not been audited externally by JIG, ATA, or IATA IFQP before the accident. Regular audit on the aviation fuel storage and delivery operation in WARR were performed by Pertamina's quality assurance department. There had been no audit carried out to the WARR facilities by external regulating bodies.

d. Under international civil aviation requirements and practices, the air operators are required to have proper quality control and check on the aviation fuel supplied to their aircraft. In WARR, the DGCA Indonesia requires Indonesian aircraft operators to ensure fuel supplied to their aircraft comply with a standard in accordance with Civil Aviation Safety Regulations, i.e., the fuel should be bright and clear and free from water around the point of delivery. Indonesian aircraft operators have quality system to include a minimum of one audit per year to the fuel suppliers but there is no technical guidance from the DGCA Indonesia on the standard of the installation, equipment and operation of the fuel supply system. For CPA, being a holder of HK AOC, had from their own operational experience developed a fuel farm audit checklist which was used when auditing its line stations that have scheduled flight operations. However, air operators may not have sufficient qualified personnel to carry out the aviation fuel quality oversight function in every airport. They have been relying heavily on the self-regulation of the fuel industry and the fuel suppliers at airports to provide clean fuel to their aircraft.

e. The investigation revealed that there is neither overarching international civil aviation requirement on the control of aviation fuel quality nor requirement on the training of relevant personnel at airports. Even if individual civil aviation authority develops local legislation and guidance on this issue, and the aviation personnel having acquired the required expertise to perform proper oversight on the aviation fuel industry, it only has jurisdiction within its territorial boundaries. Moreover, the standard of such oversight might not be uniform across different ICAO Contracting States and Administrations.

f. As civil aviation is a global activity and civil aircraft operate frequently crossing international boundaries, to ensure the standard and compliance applied uniformly world-wide, it is considered that the ICAO is the most appropriate organisation to take the lead to establish requirements that shall be complied with by the Contracting States and Administrations. A safety recommendation was therefore raised in Accident Bulletin 1/2011 published in January 2011.

Recommendation 2011-1
International Civil Aviation Organization to establish requirements for oversight and quality control on aviation fuel supply at airports. Such requirements should also cover the refuel operational procedures and associated training for relevant personnel.

g. To address the above recommendation, the ICAO, with the assistance from the TFG of IATA, issued DOC 9977 "Manual on Civil Aviation Jet Fuel Supply" in June 2012. The DOC 9977 is a signpost document to relevant industry practices that cover all matters related to aviation fuel quality control, operations, and training across the entire supply and distribution system. The aim of the manual is to inform the aviation and fuel industry globally about the existence of internationally accepted practices and to reinforce the need for their compliance. ICAO was also considering the inclusion of relevant SARPs in Annex 14 and/or other Annexes, as necessary, to regulate the standard of delivering fuel to aircraft in aerodrome, including training of aviation fuel supply personnel.

h. In 2.12, the automatic monitoring of DP was discussed. While the IATA was working with the standardisation bodies of the fuel industry on having the electronic devices implemented in the standards of aviation fuelling equipment for automatic monitoring of DP, neither the IATA nor the standardisation bodies of the fuel industry has the required regulatory power over such implementation. In this connection, the ICAO is considered the most appropriate organisation to take the lead in establishing international requirements that should be followed by the Contracting States and Administrations. In light of the published DOC 9977, a safety recommendation is made in this report.

Recommendation 2013-2

International Civil Aviation Organization to specify the requirements of installing a device in equipment used in refuelling civil aircraft. This device should be able to automatically alert the equipment operator and stop the refuelling process when the differential pressure across the equipment filtration system is outside the equipment designed value or range.

2.15 Trent 700 Engine Certification

a. During the type certification of the event engine, the Type Certificate Holder demonstrated its compliance with the certification requirement of "JAR-E 670 Contaminated Fuel" by tests. In the certification tests, a large quantity of contaminants had passed through the engine fuel components, including the FMU, and the engine were able to operate satisfactorily. The composition of the contaminants met the required MIL-E-5007E specification which were a range of various sizes of material mainly consists of iron oxide (rust), quartz (soils), cotton linter, and general dirt. These contaminants could be generated in the ground fuel storage and distribution system and enter an aircraft during normal refuelling thus they have been considered appropriate to be used in the "JAR-E 670 Contaminated Fuel" certification test. The MIL-E-5007E does not contain SAP spheres.

b. In this accident, the SAP spheres were generated which caused stiction and seizure of the fuel control components. However, their presence in the aviation fuel system was unheard of before this accident. There was also no known accident or serious incident about fuel contamination by SAP spheres extrusion. The investigation revealed that similar SAP spheres could only be generated under certain operating condition. In this accident, there was a chain of failures resulted from a combination of lapses in the system in WARR, namely the re-commissioning process, the monitoring of DP, the low flow refuelling operation, and the lack of alertness of personnel.

c. It is apparent that the presence of SAP spheres in aircraft fuel system could be mitigated by compliance with procedures in the fuel delivery processes. While the consequence of fuel contamination could be significant, the likelihood of the presence of SAP spheres as contaminant is very remote. As such, the existing certification test of using the MIL-E-5007E specification is considered appropriate.

3. CONCLUSIONS

3.1 Findings

3.1.1 Flight Operations

a. CPA780 was a scheduled public transport flight operated by CPA from WARR to VHHH.

b. The same aircraft was flown by the same set of flight crew and cabin crew from VHHH to WARR on the day before without event.

c. The flight crew and the cabin crew were properly qualified and rested to conduct the flight.

d. Weather at departure, en route, and destination was not a contributing factor to the accident.

e. Before departure, CPA780 uplifted 24,400 kg fuel at WARR by using Pertamina fuelling dispenser JUA06 at Stand No. 8.

f. In accordance with the company procedure, the Commander performed a visual and water check of the dispenser fuel sample together with the CPA ground engineer. It was reported that the fuel was clear and bright, with no trace of water.

g. The fuel uplifted by the aircraft was of the proper grade Jet A1 but was contaminated with SAP spheres.

h. Fuel contamination was not known to the flight crew and any person before and during the flight.

i. During the flight with both engines operating, fuel contaminant SAP spheres started to affect the engine fuel components operations.

j. Some SAP spheres were trapped in the clearance of the moving parts of the FMU on both engines causing stiction in the control of the FMU and resulted in EPR fluctuations.

k. The stiction in the FMUs worsened and triggered various engine control ECAM messages related to No. 2 engine during cruise.

l. The flight crew discussed the situation with the operator's IOC MC twice. On both occasions, they consulted the aircraft FCOM and QRH procedures. There was no information suggesting the possible fuel contamination.

m. The flight crew decided to continue the flight to VHHH as there was no other anomaly apart from the EPR fluctuations.

n. The flight continued and the flight crew prepared for a normal approach and landing at VHHH.

o. During the descent to VHHH, the stiction in the FMU further worsened. The ECAM messages "ENG 1 CTL SYS FAULT" and "ENG 2 STALL" occurred. The crew handled the situation in accordance with the manufacturer and operator procedures and declared "PAN PAN" to the HK ATC. The ATC alerted the AFC accordingly by declaring a "Local Standby".

p. The ATC provided good support to facilitate the efficient arrival of CPA780.

q. While on descent, the ECAM message "ENG 1 STALL" also appeared and the flight crew declared "MAYDAY" to the ATC. The ATC contacted CPA IOC which indicated that No. 2 engine was at idle. Based on this information, the ATC did not upgrade the event to "Full Emergency".

r. During the approach, the flight crew had kept the cabin crew and the passengers appropriately informed by PA of the abnormal situation.

s. During the final approach with both thrust levers at IDLE position, No. 1 engine speed stuck at about 70% N1 and No. 2 engine speed remained at about 17% N1 sub-idle speed.

t. At that stage, there was no time for the flight crew to consider other strategy nor procedure to cope with such emergency situation. The flight crew concentrated on flying the aircraft for a safe landing.

u. The aircraft touched down with a very high ground speed of 231 kt. The right main gear bounced causing the aircraft airborne again briefly.

v. During second touchdown, the lower cowling of No. 1 engine contacted the runway surface.

w. The total distance for stopping the aircraft from the initial touchdown was approximately 2,630m.

x. The braking of the high speed landing resulted in brake overheat and the deflation of five tyres after aircraft stopped.

3.1.2 Evacuation and Survivability

a. The aircraft stopped at a position approximately 309m from the end of Runway 07L and the AFC reached the aircraft within 1.5 minutes.

b. After engines shutdown, the flight crew informed the passengers via PA that they were assessing the situation and requested them to remain seated and to follow cabin crew's instruction.

c. The flight crew was mindful of the high brake temperature. After the Rescue Leader confirmed that there was smoke and fire on the landing gears, the Commander ordered the emergency evacuation.

d. The cabin crew immediately carried out the emergency evacuation. All cabin exit doors were opened and the associated escape slides were successfully deployed.

e. When observing the deployment of the slides, the ATC immediately upgraded the event to "Ground Incident".

f. Some passengers did not follow the cabin crew's instruction and carried their baggage during the evacuation. Some passengers lost their balance when coming down from the slides.

g. The evacuation was completed in about two minutes 15 seconds.

h. A total of 57 passengers and 6 cabin crew members were injured during the evacuation. One passenger sustained serious injury.

i. All the injured passengers received treatment at the airport. Ten of them were later sent to the nearby hospitals. The six cabin crew received medical treatment either from the company clinic or private medical practitioners.

j. All the emergency response units at VHHH responded promptly to the accident and provided their best support throughout the processes.

3.1.3 Aircraft Examination

a. The aircraft had a valid Certificate of Airworthiness and was properly certified, equipped and adequately maintained.

b. There were no recorded technical defects with the aircraft prior to the departure from WARR that would have contributed to the accident.

c. The aircraft was certified as being airworthy when dispatched for the flight.

d. The mass and the centre of gravity of the aircraft were within the prescribed limits.

e. No. 1 engine cowl lower surface sustained impact damage as it contacted the runway surface during touch down causing consequential damage to the engine.

f. The thermal relief plugs on No. 1, 2, 3, 5 and 7 main wheels melted as a result of the high energy stop and caused the deflation of the respective tyres.

g. The left main landing gear and nose landing gear experienced a vertical load exceeding the designed limit.

h. Post accident shop examination did not reveal any fire damage to the landing gears, wheels and brakes.

i. SAP spheres were found in the aircraft fuel tanks, the engine fuel pipes, and engine fuel components. The SAP spheres could not be self-created in the fuel system under normal aircraft operation and therefore their source was external to the aircraft.

j. Both FMUs were seized by SAP spheres.

k. The investigation cannot determine the exact mechanism of how the SAP spheres had affected the MMV operations from stiction (engine parameter fluctuation) to finally the complete seizure (loss of thrust control), and therefore cannot identify when and at what stage the seizure of the MMV could occur.

3.1.4 Contaminated Fuel

a. The aviation fuel in the hydrant circuit supplying Stand No. 8 at WARR was contaminated with salt water.

b. The filter monitors of the dispensers JUA06 used to refuel CPA780 had been activated as per the design to remove free water from the fuel.

c. The SAP media in the filter monitors of the dispenser when reacted with salt water in the fuel turned to gel state and caused an increase in DP indication and vibration of the refuelling hose during the refuelling of CPA780.

d. The performance of the filter monitors was compromised by the presence of salt water in the fuel and could not activate the shut down mechanism to cut off the flow.

e. A low flow-rate refuelling operation also resulted in a smaller DP change in the fuelling dispenser. The refuelling operator was not aware that the filter monitors of dispenser JUA06 had been activated by water.

f. The refuelling of CPA780 was continued and fuel contaminated with SAP spheres was uplifted to CPA780.

3.1.5 SAP Spheres

a. The SAP spheres contained elements that were consistent with the SAP material used in the filter monitors.

b. The exact mechanism of SAP sphere generation from filter monitor during CPA780 refuelling could not be established. However as part of the investigation, the event mimicking test had generated SAP spheres. This demonstrated that the presence of salt water in the fuel and under an operating profile of repetitive low flow-rate refuelling as in WARR could have generated SAP spheres.

c. For the accident flight, it was likely that after the filter monitors were activated by salt water and under prolonged operation, the refuelling pressure had extruded the gelled SAP media through the media migration layer of the filter monitor. The extruded SAP gel formed SAP spheres downstream of the filter monitors and entered the aircraft fuel tanks along with the uplifting fuel.

3.1.6 Hydrant Refuelling System

a. WARR had an apron extension project started in 2009 which involved an extension work of the hydrant refuelling circuit that supplies fuel to Stand No. 8 where CPA780 was parked and refuelled before departure.

b. The DGCA of Indonesia assigned Juanda Surabaya Airport Development Taskforce to administer the project.

c. Fuel sample collected from the reworked hydrant after the accident contained salt.

d. The WARR is located close to the seashore and has three regulating ponds. The water of the regulating pond closest to the apron extension work site contained salt.

e. The tie-in process of the hydrant refuelling circuit required the cut open of the existing underground piping.

f. During the tie-in period, there were records of heavy rainfalls and there were water puddles at the work site.

g. It was likely that the water puddles at work site contained salt. It was likely that due to shortfall in adherence to tie-in procedures, salt water could have entered the hydrant refuelling circuit during the hydrant extension work.

h. The re-commissioning process of the reworked hydrant refuelling circuit involved flushing the affected circuit. WARR fuel supplier assisted the flushing as requested by the project contractor.

i. The flushing procedure had not adequately addressed all essential elements stated in EI 1585, which is a set of guidelines being accepted as an international practice in cleaning of aviation fuel hydrant systems in airports. In this connection, it was likely that the flushing did not completely remove the salt water in the hydrant refuelling circuit.

j. The re-commissioning process of the reworked hydrant circuit was not properly coordinated by the Taskforce and the operation of the reworked hydrant system was prematurely resumed.

k. After the pre-mature resumption of the hydrant, there were several events of unscheduled filter monitor replacements happened to the fuelling dispensers at WARR. These events indicated possible fuel contamination but were not investigated by the fuel supplier at WARR.

l. The refuelling operation in WARR, in particular the low flow-rate refuelling, DP recording and monitoring, did not fully comply with the international fuel industry latest guidance.

m. The manual monitoring of the DP changes in a fuelling dispenser during refuelling was not effective.

3.1.7 Aviation Fuel Quality Oversight

a. The fuel industry has stringent specification, requirement, and guidance material to ensure the quality of aviation fuel supplied to aircraft meets the aircraft specification.

b. The fuel industry follows the published specification, requirement, and guidance to establish operating procedures and performs audits to ensure compliance.

c. There were no published international standards and recommended practices specifically to require ICAO Member States/Administrations to establish safety oversight legislation and operating requirements to ensure the fuel quality delivered to aircraft at airport. There was also no published technical guidance material on oversight of fuel quality in airport.

d. There was neither overarching international civil aviation requirement on the control of aviation fuel quality nor requirement on the training of personnel who carry out the oversight of fuel quality at airports.

e. DGCA of Indonesia and CAD of Hong Kong had published requirement to airlines operators to ensure the cleanliness of fuel uplifted to their aircraft but in the absence of ICAO technical guidelines and requirements, did not provide further technical guidance materials.

f. Airline operators would, based on their operational experiences, develop oversight program, and had to rely on the fuel suppliers at airports to provide quality fuel to aircraft.

g. The jurisdiction of civil aviation authorities who published aviation fuel quality requirement to regulate aviation fuel quality in airports is restricted to the locations within their territorial boundaries.

h. Airline operators may not have sufficient qualified personnel to carry out the aviation fuel quality oversight function in every airport that they operate.

i. The civil aviation oversight on quality of aviation fuel supply is not standardised internationally.

3.2 Causes

a. The accident was caused by fuel contamination. The contaminated fuel, which contained SAP spheres, uplifted at WARR subsequently caused the loss of thrust control on both engines of the aircraft during approach to VHHH.

b. The following chain of events and circumstances had led to the uplift of contaminated fuel to CPA780:

i. The re-commissioning of the hydrant refuelling system after the hydrant extension work in WARR had not completely removed all contaminants in the affected hydrant refuelling circuit. Salt water remained in the affected hydrant refuelling circuit. (Reference 1.17.2 and 2.10 b)

ii. The re-commissioning of the hydrant refuelling system after the hydrant extension work in WARR was not properly coordinated which led to the premature resumption of the hydrant refuelling operations while the hydrant system still contained contaminant. (Reference 1.17.2 and 2.10 c)

iii. The refuelling operation in WARR, in particular low flow-rate refuelling, DP recording and monitoring, did not fully comply with the international fuel industry latest guidance. (Reference 1.17.3, 2.12 c; and 2.12 d)

iv. A number of unscheduled filter monitors replacements after the premature resumption of hydrant refuelling operation were not investigated by the fuel supplier and hydrant operator at WARR. (Reference 1.17.3, and 2.13 c)

v. The unusual vibration observed during the refuelling of CPA780 was not stopped immediately and properly investigated by the fuel supplier personnel. (Reference 1.1.1 c; 1.17.3; and 2.9 c)

c. The investigation also identified the following deficiencies and contributing factors that may cause possible fuel contamination:

i. There were no established international civil aviation requirements for oversight and quality control on aviation fuel supply at airports. (Reference 1.17.4 and 2.14 e)

ii. There were no established international civil aviation requirements for refuel operational procedures and associated training for aviation fuel supply personnel. (Reference 1.17.4 and 2.14 e)

iii. The manual monitoring of DP changes in a fuelling dispenser during refuelling was not effective. (Reference 1.17.3.3 and 2.12 e)

4. SAFETY RECOMMENDATIONS

4.1 Safety Actions

The actions taken during the course of the investigation are summarised below.

4.1.1 Safety Action Taken by Pertamina

i. To address the finding that the refuelling operation in WARR did not comply with international fuel industry latest guidance, Pertamina arranged an audit in July 2010 to their aviation fuel facility and refuelling operation in WARR by an external aviation fuel expert. The audit findings raised during this audit were subsequently addressed by Pertamina to the satisfaction of the auditor.

ii. To address the concern of the insufficient awareness of refuelling personnel on unusual refuelling events, Pertamina had arranged refresher training for their refuelling personnel by qualified aviation fuel expert with a view to improving their awareness during refuelling operation. The training was completed in September 2010.

iii. To address the finding that the fuelling dispenser at WARR has excessive refuelling flow-rate capacity for WARR operation, Pertamina has down-rated one of the fuelling dispensers by replacing 20 filter monitors in the filter vessel with blanking elements. Pertamina also acquired two additional fuelling dispenser with small flow-rate capacity. These fuelling dispensers with lower flow-rate capacity were in operation since October 2011.

iv. To enhance the effectiveness of DP monitoring during refuelling, Pertamina has been working on a trial installation program since January 2012 to install automatic DP monitoring devices on its fuelling dispensers. Such device has the ability to show corrected DP, register peak DP value, and provide visual and audio alert of DP changes to the dispenser operator and stop the refuelling. At the time of writing this report, Pertamina is evaluating the results of the trial.

Refer to ***Appendix 19*** for list of action taken by Pertamina.

4.1.2 Safety Action Taken by DGCA Indonesia

To address the shortfalls and improper coordination in the re-commissioning of the hydrant refuelling system, the Taskforce of DGCA Indonesia had coordinated a review to the re-commissioning procedure of the affected hydrant refuelling circuit. A revised re-commissioning procedure was formulated. Cleaning and draining of the affected hydrant refuelling circuit were completed. Internal inspection of hydrant piping was done in September 2011 and the result was being evaluated by the Taskforce. At the time of writing this report, the affected hydrant circuit remained isolated. Refuelling at Stands No. 1 to No. 10 is still being done by refuellers / bowsers.

4.1.3 Safety Action Taken by ICAO

To address the lack of established international civil aviation requirements for oversight and quality control on civil aviation fuel supply in airport, ICAO, with the assistance of IATA Technical Fuel Group, has issued DOC 9977 "Manual on Civil Aviation Jet Fuel Supply" in June 2012. DOC 9977 is a signpost document to relevant industry practices that cover all matter related to aviation fuel quality control, operations, and training across the entire supply and distribution system. The aim of DOC 9977 is to provide guidance to the aviation globally about the existence of internationally accepted practices and to reinforce the need for their compliance. ICAO also indicated the consideration of adding new SARPs in Annex 14 and/or other Annexes, as necessary, on the oversight and quality control on civil aviation fuel supply in airport.

4.1.4 Safety Action Taken by Airbus

i. To inform Airbus aircraft operators of the industry-wide recognised guidelines and practices to prevent uplift of contaminated fuel onto aircraft, Airbus has issued Service Information Letter 28-094 dated Nov. 26 2010. This Service Information Letter "highlighted the roles and responsibility of key players with regard to the fuel standards and specifications, up to the point of into-plane refuelling".

ii. To provide more guidance to flight crew to handle situation of suspected fuel contamination, Airbus has revised the QRH to include a new section 70.07 dated 20 September 2011 "SUSPECTED ENG FUEL SYS CONTAMINATION" for A330 with RR engines to assist the crew in determining and handling of fuel contamination incident. Moreover, Airbus has also published similar procedure for A330 with Pratt and Whitney engines and in the process of publishing similar procedure for A330 with General Electric engines.

4.1.5 Safety Action Taken by CPA

i. CPA has incorporated the new Airbus QRH 70.07 dated 20 September 2011 "SUSPECTED ENG FUEL SYS CONTAMINATION" to provide guidance to its flight crew to handle situation of suspected fuel contamination.

ii. Following the occurrence, CPA conducted a series of additional line station fuel farm audits in WARR with assistance from external aviation fuel experts. To further enhance its aviation fuel quality oversight function, CPA has since joined IATA-IFQP and now uses the IFQP audit checklist which reflects the latest specification, guidance, and procedures used in aviation fuel storage and refuelling operation.

4.1.6 Safety Action Taken by CAD

i. ATMD of CAD has reviewed its procedures and confirmed that declaration of "Full Emergency" and "Local Standby" will be based on the prevailing information presented by the pilots to ATC controllers.

ii. The Flight Standards and Airworthiness Division (FSAD) of CAD had revised the CAD 360 "Air Operator's Certificates Requirements Document" in August 2011 to provide the AOC holders with further technical guidelines by making reference to the requirements on specifications and standards of Jet A-1 that have been established by the fuel industry and airlines associations.

4.1.7 Safety Action Taken by Facet

To address the collapsing of filter monitors, Facet released their new FG230-4 filter monitors in September 2011 which have improved strength by using steel centre tube and also met the EI 1583 6^{th} Edition specification.

4.2 Safety Recommendations

The following recommendations are issued to address the safety issues identified in this investigation.

4.2.1 Safety Recommendation Issued Previously

a. Safety Recommendations issued previously in Accident Bulletin 3/2010 published on 11 August 2010:

Recommendation 2010-1

Satuan Kerja Pengembangan Bandar Udara Juanda Surabaya (i.e. The Juanda Surabaya Airport Development Taskforce)* should, with suitably qualified personnel of aviation fuel hydrant operation and re-commissioning experience, conduct an extensive review of the re-commissioning procedures of hydrant refuel system in accordance with the best practice in aviation fuel industry. (Reference 2.10 b)

(The Juanda Surabaya Airport Development Taskforce is the project owner for the hydrant refuel system extension work at Stands No. 1 to 4 at WARR.)*

Recommendation 2010-2

The Juanda Surabaya Airport Development Taskforce should ensure the re-commissioning procedures are completed before resuming the hydrant refuelling operation for Stands No. 1 to 10 at WARR. (Reference 2.10 e)

b. Safety Recommendation issued previously in Accident Bulletin 1/2011 published on 20 January 2011:

Recommendation 2011-1

International Civil Aviation Organization to establish requirements for oversight and quality control on aviation fuel supply at airports. Such requirements should also cover the refuel operational procedures and associated training for relevant personnel. (Reference 2.14 f)

4.2.2 Safety Recommendation issued in this Accident Report:

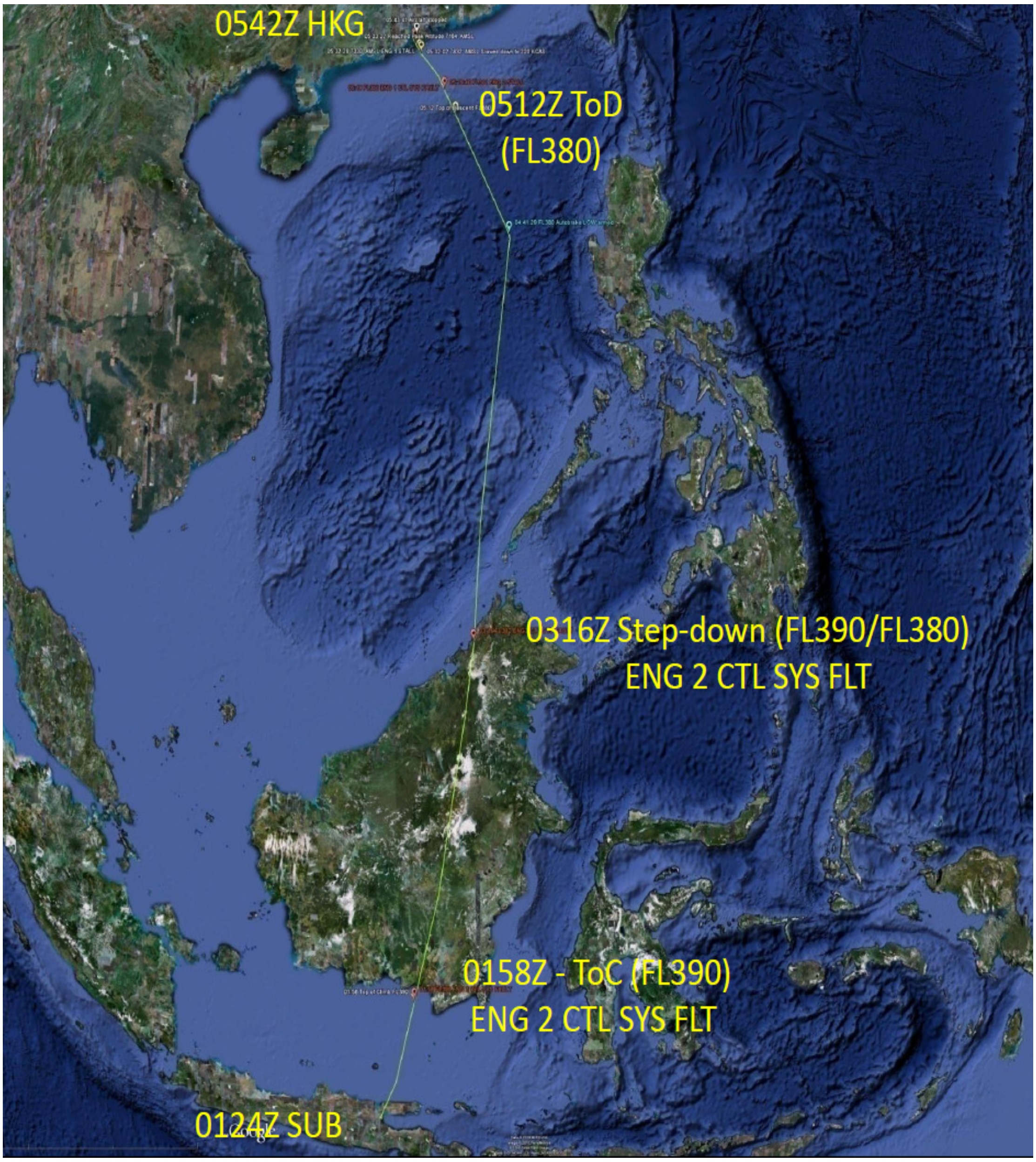
Recommendation 2013-2

International Civil Aviation Organization to specify the requirements of installing a device in equipment used in refuelling civil aircraft. This device should be able to automatically alert the equipment operator and stop the refuelling process when the differential pressure across the equipment filtration system is outside the equipment designed value or range. (Reference 2.14 h)

APPENDICES

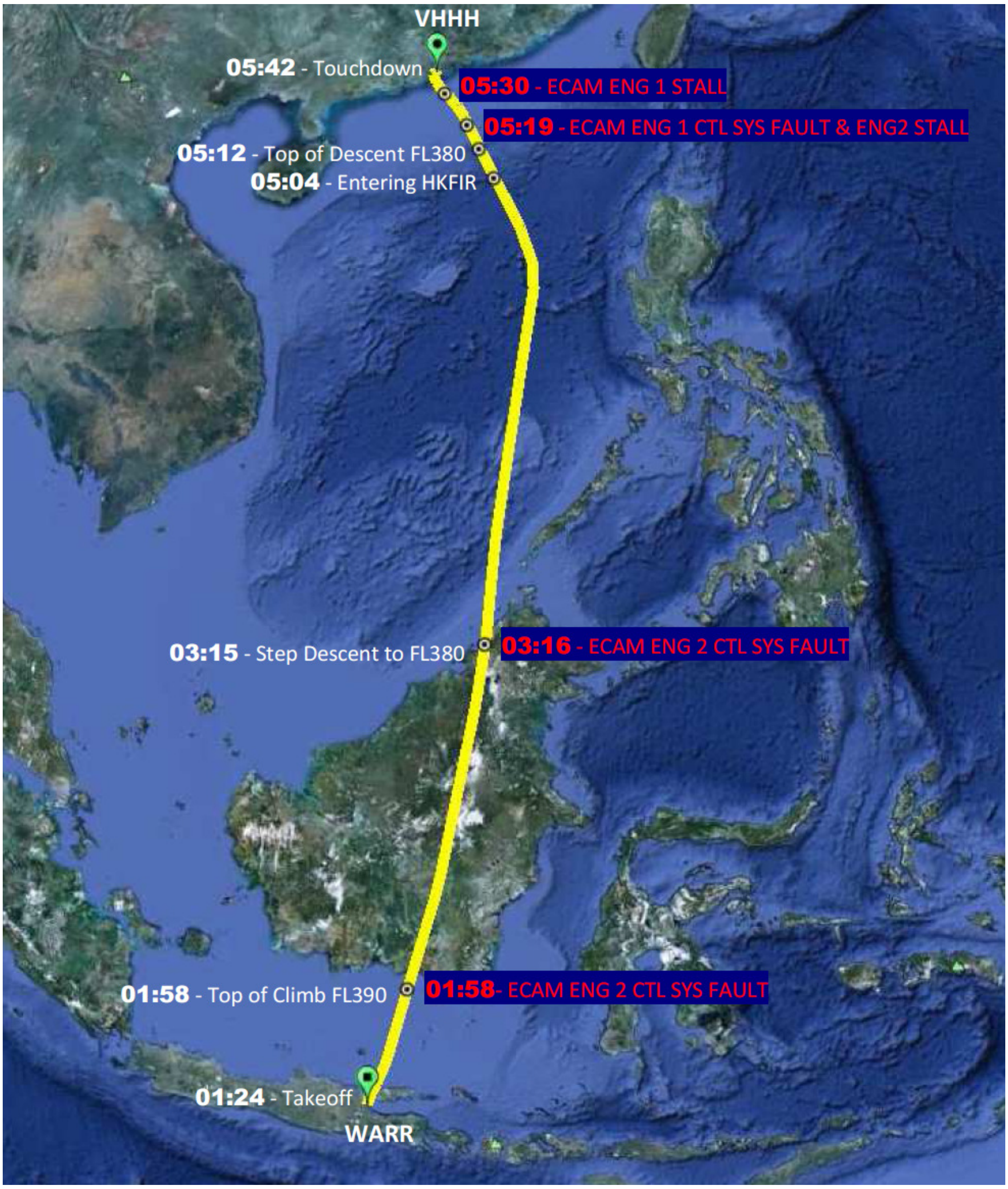
Appendix 1: CPA780 Flight Track from Surabaya to Hong Kong

A1.1 - CPA780 Flight from WARR (SUB) to VHHH (HKG)



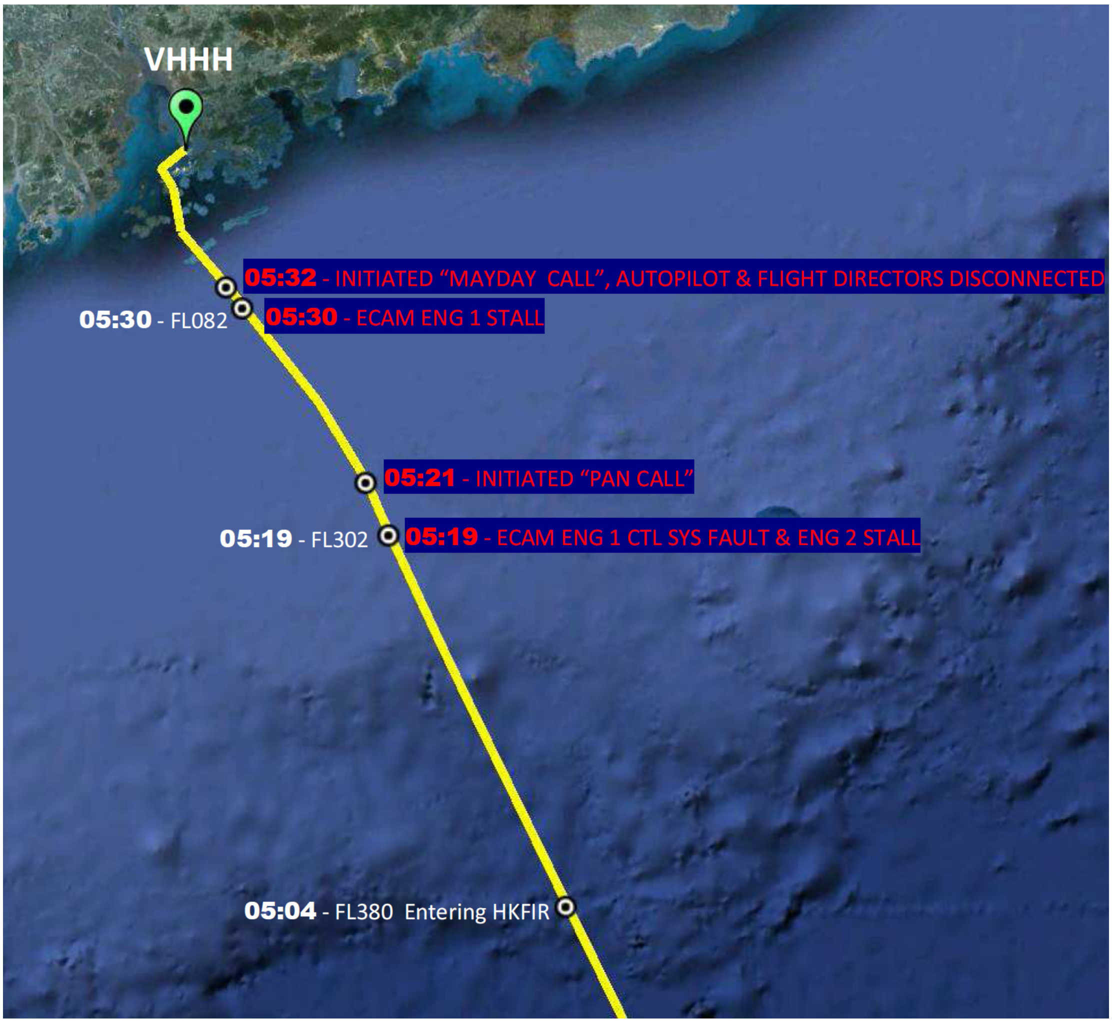
Appendix 1: CPA780 Flight Track from Surabaya to Hong Kong (Continued)

A1.2 - CPA780 Flight Path with Event Details - from WARR to VHHH:



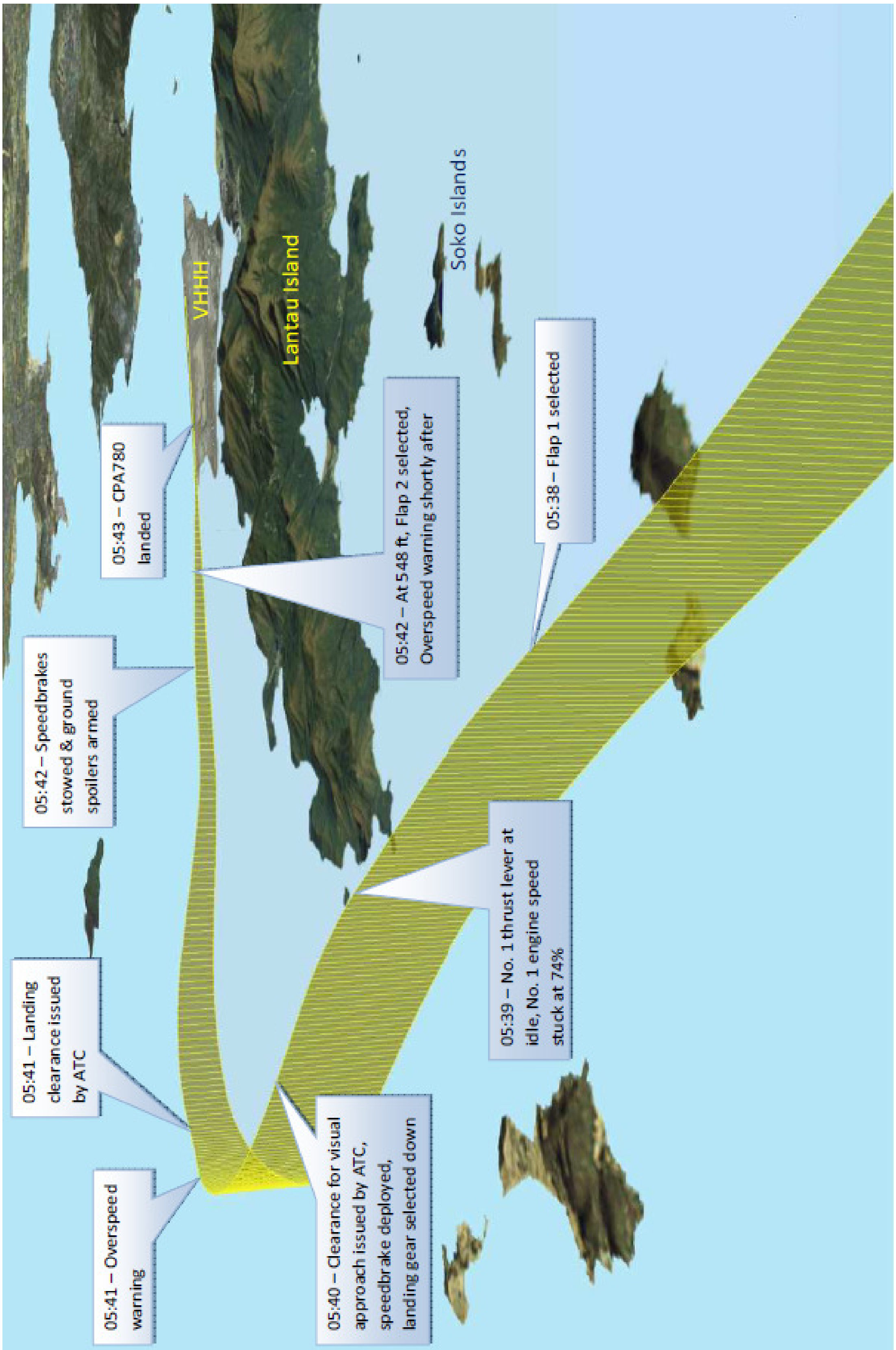
Appendix 1: CPA780 Flight Track from Surabaya to Hong Kong (Continued)

A1.3 - CPA780 Flight Path with Event Details - Descent to VHHH:



Appendix 1: CPA780 Flight Track from Surabaya to Hong Kong (Continued)

A1.4 - CPA780 Flight Path with Event Details -Final Approach to VHHH:



Appendix 2: Engine Components Information

A2.1 - Fuel Metering Unit (FMU)

Manufacturer	:	Goodrich Engine Control Systems
Model	:	FMU701 MK6
B-HLL Engine No. 1 FMU:		
Serial Number	:	BT54
Total Time Since New	:	31707
Total Time Since Overhaul	:	599
B-HLL Engine No. 2 FMU:		
Serial Number	:	BT276
Total Time Since New	:	16091
Total Time Since Overhaul	:	6895
B-HLM Engine No. 1 FMU:		
Serial Number	:	BT86
Total Time Since New	:	34724
Total Time Since Overhaul	:	3160

A2.2 - B-HLL Fuel Pump Assembly

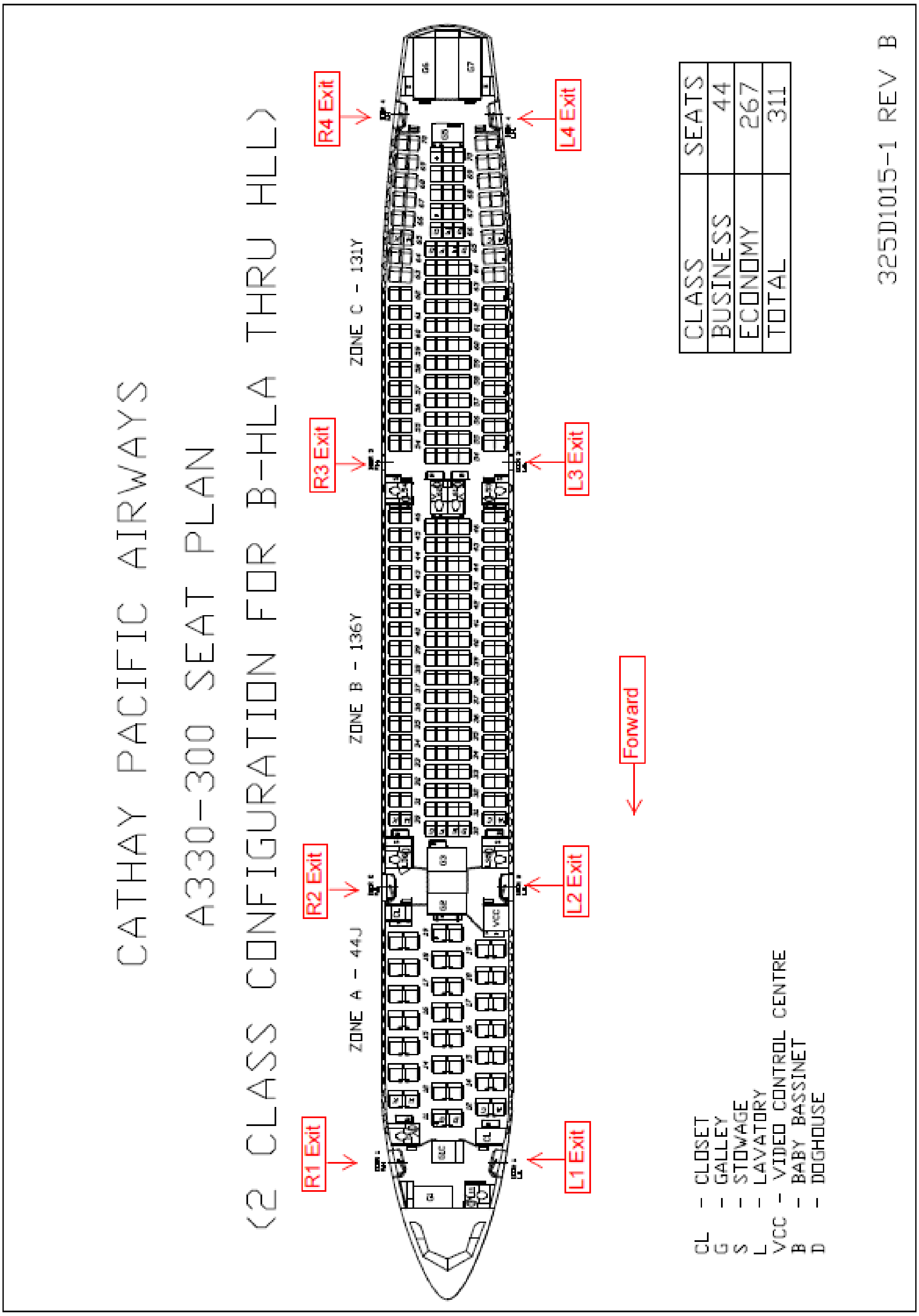
Manufacturer	:	Eaton-Argo-Tech Corporation
Part Number	:	721400-3
Engine No 1 Fuel Pump Assembly:		
Serial Number	:	0896
Total Time Since New	:	9350
Total Time Since Overhaul	:	9350
Engine No 2 Fuel Pump Assembly:		
Serial Number	:	0136
Total Time Since New	:	31153
Total Time Since Overhaul	:	6891

Appendix 2: Engine Components Information (Continued)

A2.3 - B-HLL Engine Variable Stator Vane Control Components:

Manufacturer	:	Goodrich Engine Control Systems
Engine No 1 VSVC:		
Part Number	:	1875 MK5
Serial Number	:	1875546
Total Time Since New	:	23561
Total Time Since Overhaul	:	4443
Engine No 1 Left VSVA:		
Part Number	:	1876MK3
Serial Number	:	SAA07024
Total Time Since New	:	9355
Total Time Since Overhaul	:	9355
Engine No 1 Right VSVA:		
Part Number	:	1876MK3
Serial Number	:	SAA07027
Total Time Since New	:	9355
Total Time Since Overhaul	:	9355
Engine No. 2 VSVC:		
Part Number	:	1875 MK5
Serial Number	:	1875014
Total Time Since New	:	30703
Total Time Since Overhaul	:	6891
Engine No. 2 Left VSVA:		
Part Number	:	1876MK3
Serial Number	:	18761470
Total Time Since New	:	20740
Total Time Since Overhaul	:	20740
Engine No 2 Right VSVA:		
Part Number	:	1876MK3
Serial Number	:	18761482
Total Time Since New	:	20740
Total Time Since Overhaul	:	20740

Appendix 3: CPA780 B-HLL Cabin Layout



Appendix 4: Sequence of Events

UTC	Events	Remarks
1:13:45	ENG 1 started	
1:15:13	ENG 2 started	
1:23:46	Take-off roll commenced. FLEX Takeoff Temperature +43 deg and Conf 2 were used. Take-off weight 198710 kg.	Determined by the TRA at MCT position
1:24:27	Aircraft takeoff	All wheels airborne
1:24:52	AP 2 engaged as the aircraft climbed through 1140 ft	
1:42:13	As the aircraft climbed through 25032 ft, TRA 1 was positioned from CLB detent (45 deg) to 39.4 deg and then advanced to 56.3 deg.	Auto thrust was engaged and active. The EPR1 and N1 of Eng 1 responded to the changes of TRA1 synchronously.
1:58:11	Reached TOC at 39000 ft	
1:58:31	Master caution on	ECAM Message - ENG 2 CTL SYS FAULT
3:15:03	Started to descend from 39000 ft to 38000 ft	
3:16:36	Master caution on	ECAM message - ENG 2 CTL SYS FAULT (indicated to crew but not recorded in PFR) Fault message - VSV SYSTEM / VSV CONTROL UNIT- Source EEC2A
3:17:56	EAI was selected ON on both engines.	
3:27:12	EAI was selected OFF on both engines.	
4:41:29	Autobrake LOW armed. The aircraft was cruising at 38000 ft.	
5:12:34	Top of descent from 38000 ft.	
5:19:23	ENG 2 EGT started to rise from 406 degrees to 722 degrees at 05:19:38. FF2 increased from 532 kg/hr to 1671 kg/hr.	The EPR and N1 of both engines started to differ.
5:19:26	Master caution on	ECAM Message - ENG 1 CTL SYS FAULT
5:19:40	Master caution on	ECAM Message - ENG 2 STALL
5:19:50	Engine 2 TRA was retarded to idle.	

5:20:01	Master caution on	Recorded in QAR but triggering source is not identified.
5:20:05	Engine 1 TRA was advanced to low end of MCT.	
5:21:31	Flight crew initiated "Pan Call"	This "Pan Call" time is different from that recorded by ATC as the FDR clock and the ATC clock are not synchronous.
5:30:24	Master caution on	ECAM Message - ENG 1 STALL
5:30:34	Engine 1 TRA was pulled back to idle at AP mode "ALT*" to 8000 ft.	
5:30:37	Level off at 8000 ft	
5:30:39	Master caution on	Triggered by Auto Thrust disengaged
5:30:42	Auto Thrust disengaged.	
5:30:59	While the aircraft was level flying at 8000 ft, TRA 2 was slowly advanced to CLB detent and ENG 1 was still at idle. However the FF2 remained at about 500 kg/hr and no change was observed.	
5:31:16	TRA 1 was advanced to CLB detent but the FF1 remained at about 1000 kg/hr and no change was observed. The aircraft had been slowing down from 288 kts CAS at 8000 ft level off to 245 kts CAS.	
5:31:26	TRA1 was retarded to idle.	
5:31:43	Flight crew initiated "Mayday Call"	This "MayDay Call" time is different from that recorded by ATC as the FDR clock and the ATC clock are not synchronous.
5:32:02	The aircraft slowed down to 220 kts CAS with green dot speed at 212 kts, the aircraft pitch down and commenced descent.	
5:32:16	As the aircraft descent through 7736 ft, TRA 2 was advanced to 25 degrees (CLB detent 45 degrees) and pulled back to idle as no FF or N1 change was observed.	

5:32:21	TRA1 was advanced to CLB detent and FF1 increased from about 1100 kg/hr to 1400 kg/hr and N1 increased from 33% to 37%. The FF1 continued increase slowly.	
5:32:28	Master caution on	ECAM message - ENG 1 STALL (Not recorded in PFR but was read by crew confirmed in CVR) , RR observed engine 1 surge from Engine Gas Path Advisory Report.
5:32:36	Master warning on	AP 2 disengaged
5:32:37	As the aircraft descended through 6956 ft, AP2 was disengaged.	The AP 2 engage parameter was recorded as "Not Engage" after the master warning triggered.
5:32:43	As the aircraft descended through 6784 ft, FD1 and FD2 were disconnected.	
5:32:47	At 6760 ft the vertical speed changed from descent to climb.	
5:32:59	As the aircraft climbed through 6880 ft, TRA 1 was pulled back to idle.	
5:33:22	The aircraft climbed to peak 7164 ft and began the descent. The aircraft speed decayed to 202 kts CAS and the aircraft flew at about green dot speed.	
5:33:48	Between 6880 ft and 6416 ft, TRA 2 was slowly advanced and pulled back to idle twice and there was no response in N1 and FF2.	
5:34:48	Master caution on	ECAM message - NAV GPS 2 FAULT
5:34:23	At 6376 ft TRA 1 was advanced and pulled back to idle. No significant change in EPR was observed.	
5:34:34	TRA 1 was advanced to 19.7 degrees slowly. N1 increased from 43% to 53% at 05:34:55 and stable at 53/54%.	
5:35:12	Master caution on	A Class 1 fault FCMC2 was detected which was caused by the electrical power interrupt.
5:35:39	Master caution on	Recorded in PFR /Fault message - FCMC2(5QM2)

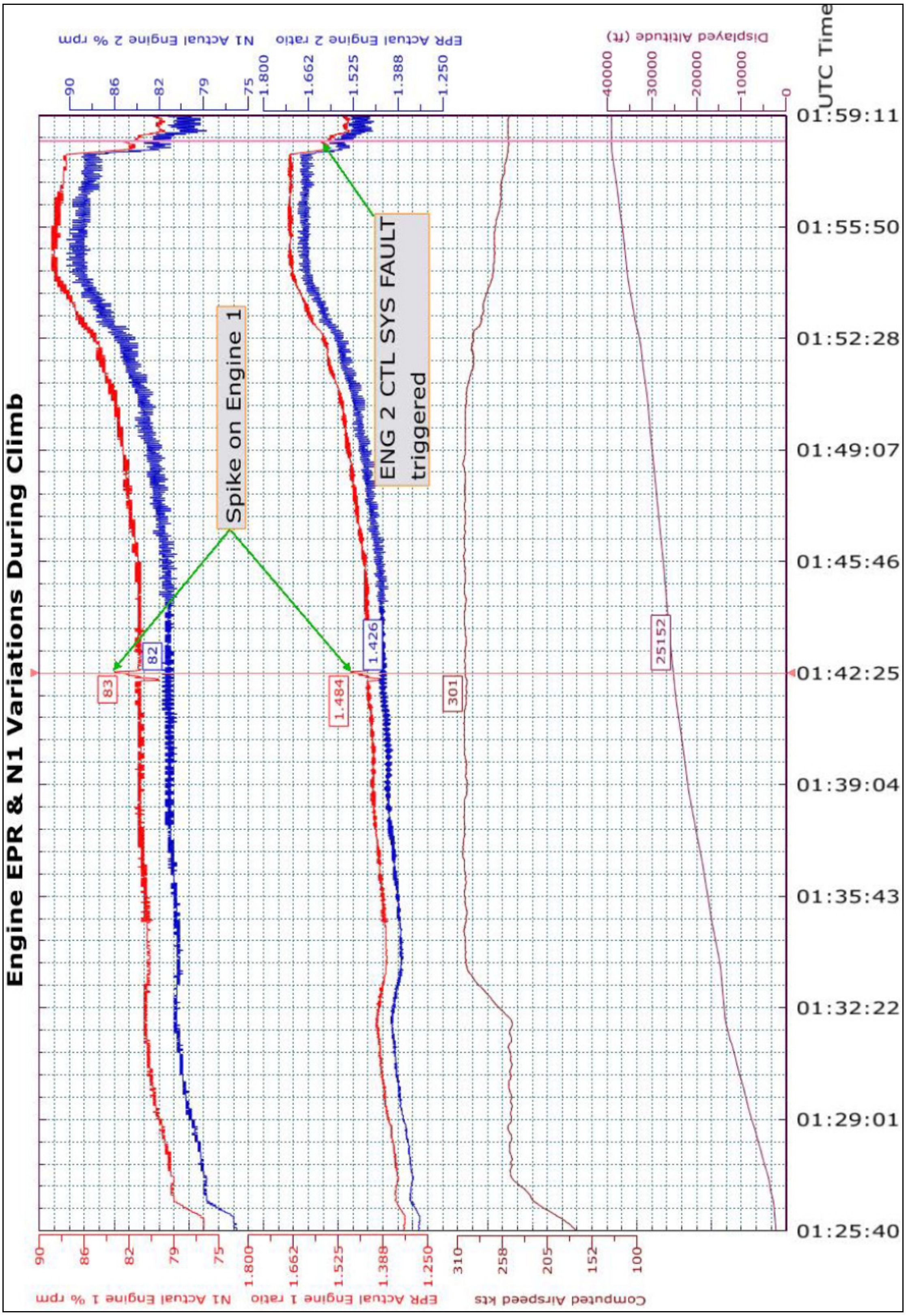
5:35:41	At 5804 ft TRA 1 was advanced to 33.8 degrees and further to 36.6 degrees at 05:35:59. The N1 increased to 64%.	
5:37:15	TRA 1 was further advanced to 42 deg.	
5:37:33	APU bleed valve open	APU on
5:37:48	TRA 1 was advanced to CLB detent and momentary to MCT detent and settled at CLB detent. The EPR stablised at 1.297.	
5:38:02	Master caution on	Recorded in QAR but triggering source is not identified.
5:38:11	Master caution on	Airbus observed an ECAM message (not displayed) ENG 2 HP FUEL VALVE.
5:38:13	LP fuel valve 2 was closed for 9 seconds and re-open. No TRA 2 advance was observed.	ECAM Message - ENG 2 SHUT DOWN
5:38:18	Master caution on	Due to lossing of Green Engine 2 Pump
5:38:36	CONF 1 selected and TRA 1 was pulled to 33.8 deg. EPR 1 decreased from 1.297 to 1.293.	
5:38:44	Master caution on	ECAM Message - ENG 2 START FAULT
5:39:02	Master caution on	ECAM message - ENG 2 STALL (Indicated to crew but not recorded in PFR. Chime was recored in CVR.), Airbus observed ENG 2 STALL from Engine Gas Path Advisory Report.
5:39:28	At 5524 ft TRA 1 was pulled back to idle and EPR decreased to about 1.28.	
5:39:58	At 5204 ft spoilers was extended.	
5:40:10	At 5104 ft gear was selected down.	
5:41:00	Aircraft started turning towards 07L Runway	
5:41:05	Master caution on	Due to unsuccessful engine start
5:41:06	Master warning on	Overspeed was detected. System calculated Vmax 240, actual CAS 244 kts.

5:42		ECAM message - CAB PR SAFETY VALVE OPEN
5:42:21	At 789 ft RA EGPWS Mode 4 "TOO LOW TERRAIN" was triggered and ended at 24 ft RA.	Mode 4 provides alerts for insufficient terrain clearance with respect to flight phase, configuration and speed. Mode 4A was triggered as the flaps were not in landing flap setting.
5:42:28	At 548 ft 233 kts, CONF 2 was selected.	
5:42:31	Master warning on	Overspeed was detected. System calculated Vmax 205, actual CAS 233 kts.
5:42:42	At 214 ft RA EGPWS Mode 2 "Whoop PULL UP" was triggered.	Mode 2 provides alerts to protect the aircraft from impacting the ground when rapidly rising terrain with respect to the aircraft is detected. Mode 2 is based on Radio Altitude closure rate. The aircraft just entered the edge of CLK. At 214 ft RA and closure rate 2100 fpm were just inside the envelope.
05:42:45	At 110 ft RA EGPWS Mode 2 "Terrain" was triggered.	Upon exiting the Mode 2 envelop, terrain clearance continued to decrease, the aural message "Terrain" was triggered.
05:42:49	The aircraft crossed the threshold at about 236 kts with EPR 1 and EPR 2 at 1.22 and 0.938 respectively. The wind was 158/18.	
5:42:56	At 4 ft RA, TRA were moved to max reverse thrust angle for one second and put back to idle immediately.	
5:42:58	Aircraft main gears touched ground. The aircraft pitch was -1.8 degrees and rolled left 2.8 degrees.	
5:42:59	The right gear bounced and spoilers started to deploy at the same time. The aircraft rolled left to 7 degrees and pitch down at -2.5 degrees at second touchdown. The maximum vertical g at second T/D was 1.801g. The maximum delta g was 1.504g.	Left engine pod strike.
5:43		ECAM message - HYD RAT FAULT

5:43:01	Aircraft all gears touched down	
5:43:04	At 211 kts brake pedal deflected at 68 degrees and autobrake disarmed.	Brake pedal operational range 0 - 70 degrees.
5:43:07	As the aircraft decelerated to 184 kts, both L and R TRA were positioned to max reverse thrust angle for 16 sec. The reversers of L Engine unstowed and deployed. The reversers of R engine remained stowed.	The crew pulled max reverse thrust on both L and R engine. The reversers of R engine did not respond to the reverse thrust selection.
5:43:20	Master caution on	ECAM Message - ENG 2 REV FAULT
5:43:23	At 47 kt CAS, both TRA were moved to idle reverse angle and then idle stop. The reversers of L engine remained as unstowed for 19 seconds and stowed after the fuel cut off.	Left engine reversers remained unstowed for unusual long time after reverse thrust cancellation. Left engine reversers stowed after fuel cutoff.
5:43:31	Park brake on	
5:43:33	Master caution on	ECAM Message - ENG 1 REV UNLOCKED
5:43:45	ENG #1 fuel cutoff	
5:43:48	ENG #2 fuel cutoff	

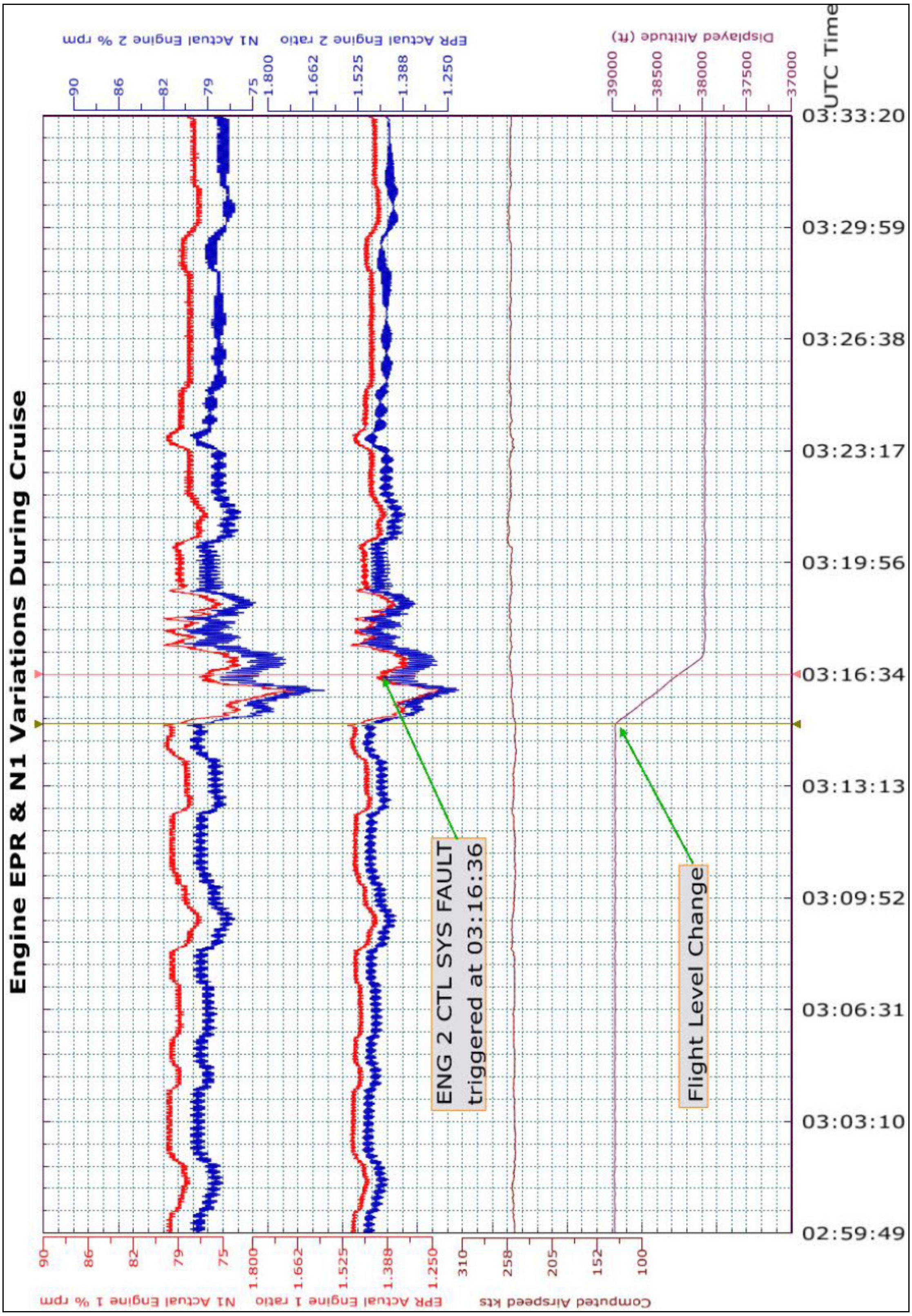
Appendix 5: Engine Performance

A5.1 - Engine Performance during Climb



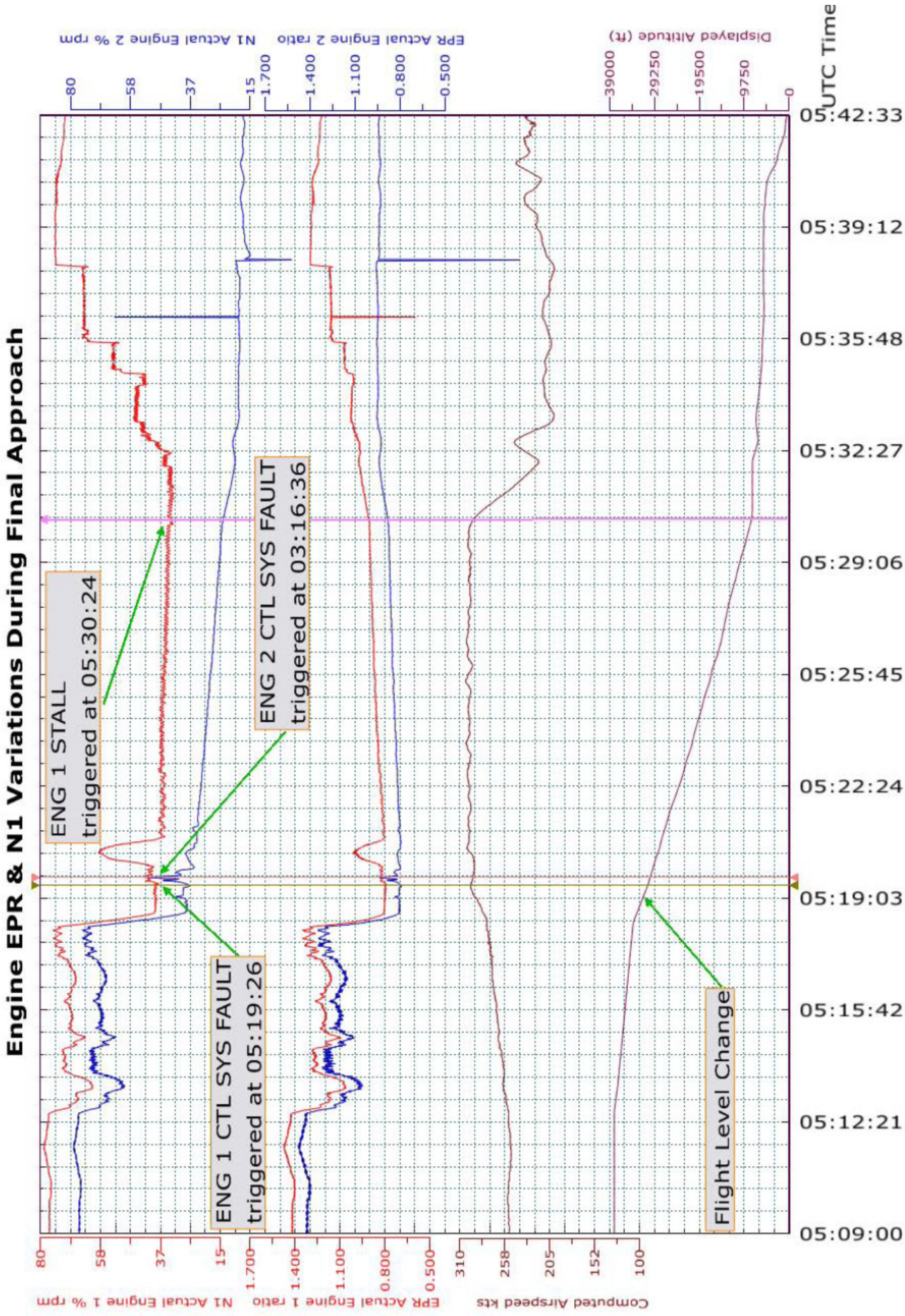
Appendix 5: Engine Performance (Continued)

A5.2 - Engine Performance during Cruise with Flight Level change

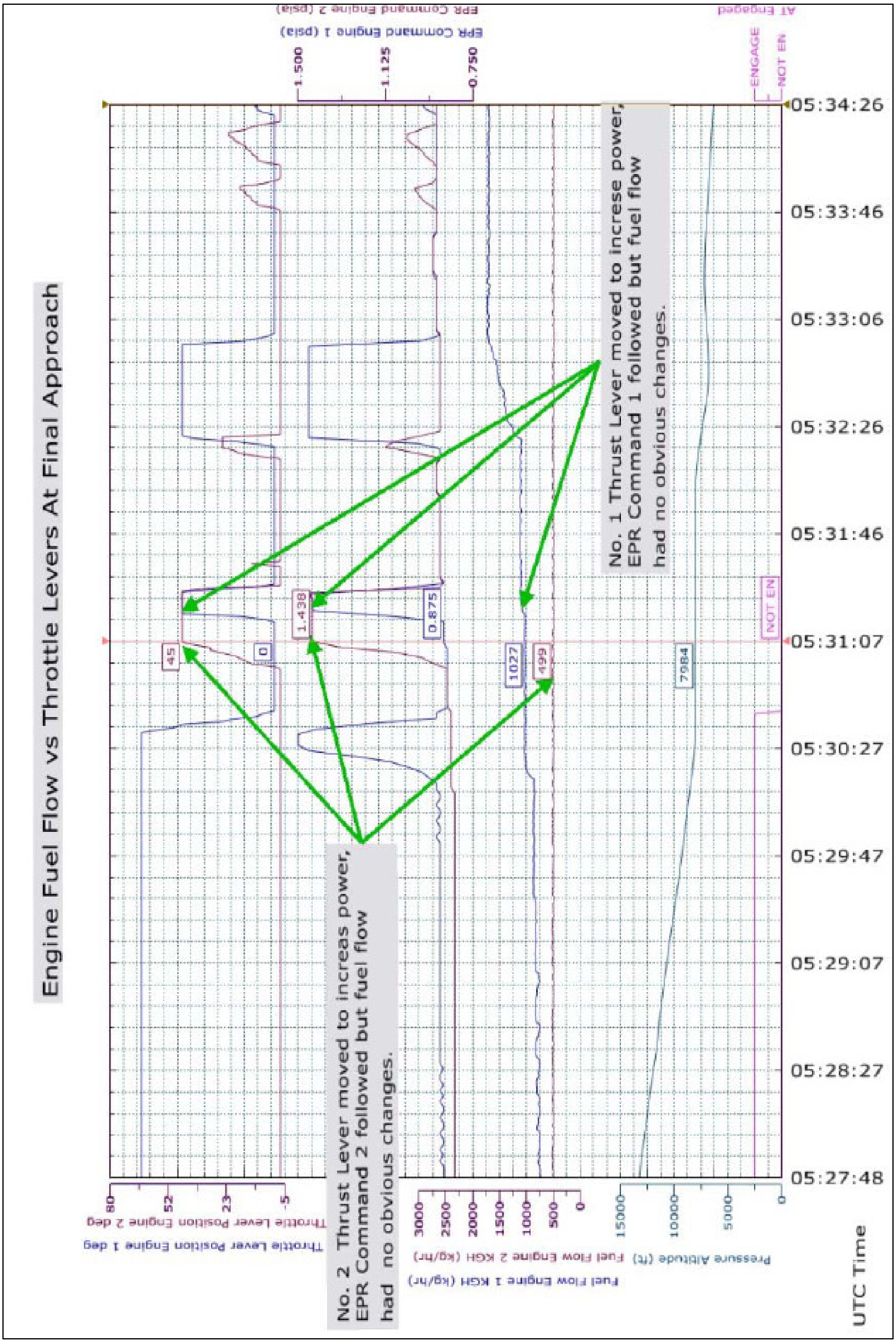


Appendix 5: Engine Performance (Continued)

A5.3 - Engine Performance during Final Approach



Appendix 6: Engine TL position Vs fuel flow when Engines Stall



Appendix 7: Extract of CVR Recording

LEGEND:	
HOT	Crewmember hot microphone voice or sound source
RDO	Radio transmission from accident aircraft
CAM	Cockpit area microphone voice or sound source
PA	Public address system voice or sound source
ATIS	ATIS
TRS	Radio transmission from TRS 128.75 Mhz
TMS	Radio transmission from TMS 126.3 Mhz
APP	Radio transmission from APP 119.1 Mhz
TWR	Radio transmission from TWR 118.2 Mhz
RLR	Radio transmission from Rescue Leader 121.9 Mhz
-1	Voice identified as Captain in LH seat
-2	Voice identified as Co-Pilot in RH seat
-?	Source unidentified
-AC	Aircraft source
-AP	Autopilot source
-ECAM	ECAM source
-EGPWS	EGPWS source
-RADALT	Radio altimeter source
-CCFD	Cabin crew to flight deck call tone
-FDCC	Flight deck to cabin crew call tone
. .	Break in continuity
( )	Questionable insertion
[ ]	Editorial insertion

(All Time in UTC)

hh	mm	ss	From	INTRA-COCKPIT COMMUNICATION	AIR-GROUND COMMUNICATION
				Beginning of CVR Recording	
5	19	58	CAM-ECAM	[chime sound - ECAM warning]	
5	20	1	HOT-1	Okay Engine Two stall.	
5	20	3	HOT-2	Confirmed. I have control. ECAM actions?	
5	20	5	HOT-1	Okay. Thrust Lever number two, confirm?	
5	20	7	HOT-2	Confirm.	
5	20	8	HOT-1	Idle.	
5	20	12	HOT-1	Check. Engine Two parameters checked. We've got fuel flow. We've got EGT. Rotation. You fly.	
5	20	20	CAM	[chime sound]	
5	20	25	HOT-2	Speed VS.	

5	20	26	HOT-1	Check.	
5	20	30	HOT-1	Okay, Engine Two parameters check.	
5	20	32	HOT-2	Thrust open descent.	
5	20	34	HOT-1	Checked.	
5	20	35	HOT-2	ALT blue Flight level one three zero.	
5	20	37	HOT-1	Yeah, if things look okay apart from the fact obviously that smell.	
5	20	41	HOT-2	That smell, yep.	
5	20	42	HOT-1	It’s obviously stalled and is relightened.	
5	20	43	HOT-2	That’s right. That’s a small vibration the stall	
5	20	46	HOT-1	Yeah. If abnormal Engine Two Master Off. Hmm.	
				From 052053 to 052146: a series of conversation between pilots on handling the following ECAM: - Engine One Control System Fault; - Engine One Slow Response; - Engine Two Slow Response; and the decision of making a PAN call.	
5	21	48	RDO-1		Hong Kong ah Cathay ah seven eight zero PAN PAN, PAN PAN, PAN PAN, we are operating at Engine Two at idle thrust at the moment, but ah operations normal apart from that. And just require, ah, elevated response level of it, thanks.
5	22	5	TMS		Cathay ah seven eight zero roger your PAN.
5	22	9	HOT-2	And we’ve got one three zero, one to go.	
5	22	13	HOT-1	Roger.	
5	22	17	HOT-2	Two five zero for one three zero by MANGO.	
5	22	19	HOT-1	Check.	
5	22	37	HOT-1	Yeah.	
5	22	41	RDO-1		Hong Kong Cathay er seven eight zero PAN if we could just get priority thanks, we would like to track short as much as possible.
5	22	49	TMS		Cathay seven eight zero understood turn left to waypoint LIMES.

5	22	52	RDO-1		Direct LIMES Cathay seven eight zero PAN.
5	22	55	HOT-2	Okay.	
5	22	55	TMS		Cathay seven eight zero PAN do you want to stay at higher level initially?
5	23	0	RDO-1		Cathay seven eight zero, ah, no we are okay with that just the track shortening will be what we would like.
5	23	7	TMS		Cathay seven eight zero PAN roger.
				From 052309 to 052417: a series of conversation between pilots on setting up the FMGS for navigation. During the period, a "cabin crew prepare the cabin for landing" call, and a PA were made	
5	24	19	TMS		Cathay seven eight zero PAN just checking if this both engines at idle thrust or just the one.
5	24	25	RDO-1		Ah, just the one, Engine Two. Ah, Eng One is operations normal, but we have a, we have some severe vibrations and ah a stall but the engine is operating at idle, Engine Two.
5	24	44	RDO-1		Hong Kong Cathay seven eight zero apologies Engine Two is operating at idle thrust, Engine One ops normal.
5	24	51	TMS		[unintelligible] Cathay seven eight zero understood.
				From 052512 to 052555: a series of communications between Commander and ISM about engine indication and control problems, and requested ISM to prepare cabin for landing.	
5	26	14	HOT-1	Engine inoperative go-around, seven right, seven left, alright.	
5	26	29	HOT-1	Okay.	
5	26	38	HOT-1	Well we'll pretty much consider everything ah as being engine-out, right?	
5	26	42	HOT-2	Yep.	
5	26	45	HOT-1	In which case I'll take the landing.	
5	26	47	HOT-2	Understood.	
5	26	47	HOT-1	Alright.	
5	26	48	HOT-2	You have control.	
5	26	48	HOT-1	I have control.	
5	26	49	HOT-1	I'll just ah.	

5	26	50	TMS		Cathay seven eight zero PAN, you'll be landing Runway zero seven left. Do you require any special arrangements?
5	26	55	HOT-2	Negative?	
5	26	55	HOT-1	Negative.	
5	26	56	RDO-2		Landing zero seven left, Cathay seven eight zero, negative.
5	27	0	TMS		Roger.
				From 052822 to 052846: a series of communication between pilots on activating the approach and selecting CONFIG 3 on the FMGS for One-Engine Inoperative approach and go-around.	
5	28	48	TMS		Cathay seven eight zero contact Hong Kong Approach one one niner decimal one.
5	28	52	RDO-2		Approach one one nine one Cathay seven eight zero.
5	28	56	HOT-1	And request high speed thanks, when you can.	
5	28	59	HOT-2	Yep.	
5	29	4	RDO-2		Hong Kong Approach Cathay seven eight zero we're on descent niner thousand received Hotel request high speed below one zero thousand.
5	29	11	APP		Cathay seven eight zero Hong Kong Approach roger can maintain high speed and descend to eight thousand feet.
5	29	17	RDO-2		High speed eight thousand Cathay seven eight zero
5	29	27	HOT-1	Yep, a quick re-brief here the engine-out go-around in case of a go-around, it's climb on track direct SIERA MIKE TANGO VOR, right turn to ROVER, right turn onto a heading of one nine zero or a track of one nine zero, maximum speed is two twenty knots until we are either on the one nine zero or above twenty-five hundred feet.	
5	30	8	HOT-1	Quick recall model. Just got engine operating in idle, number two, got everything sorted away. We've re-briefed. Anything to review or wrap-up that you could think of?	
5	30	19	HOT-2	I don't think so, ah.	
5	30	20	HOT-1	Fuel is good.	

5	30	42	CAM-ECAM	[chime sound - ECAM warning]	
5	30	45	HOT-2	Engine One stall.	
5	30	46	HOT-1	Confirmed. I have control. ECAM actions.	
				From 053049 to 053159: a series of conversation between pilots on handling the ENG 1 STALL ECAM and the decision to escalate the situation from PAN to MAYDAY.	
5	32	0	RDO-2		And ah Approach MAYDAY MAYDAY MAYDAY Cathay seven eight zero had Engine One and Engine Two stall, ah, currently we require a lower descent maintaining eight thousand.
5	32	12	APP		Cathay seven eight zero descend to tree thousand feet.
5	32	14	RDO-2		Three thousand Cathay seven eight zero.
5	32	17	APP		Cathay seven eight zero speed at your discretion.
5	32	19	RDO-2		Cathay seven eight zero
5	32	21	HOT-1	Okay, so that's selected speed, ah, okay, open descent, ALT blue, three thousand, cleared below MSA four thousand three hundred.	
5	32	43	HOT-1	Let's go for the, ah, oh, hang on.	
5	32	46	CAM-ECAM	[chime sound - ECAM warning]	
5	32	49	HOT-2	Okay, Engine One still stall, Engine One lever idle.	
				From 053253 to 053454: a series of conversation between pilots on handling the ENG 1 STALL ECAM and sorting out both engine stall situation. During the period, APU was selected on.	
5	34	46	APP		Cathay seven eight zero your position one five miles south south east of SOKO and ah you can track as desired and advise when you need further assistance.
5	34	57	RDO-1		And Cathay seven eight zero MAYDAY say again?
5	35	0	APP		Cathay seven eight zero your position is one four miles south of SOKO.
5	35	4	RDO-1		Roger, ah, Cathay . .

5	35	6	RDO-1		. . seven eight zero MAYDAY roger at the moment we are heading three three zero on a long base trying to extend our glide as best as possible and we are just trying for re-lights.
5	35	16	APP		Cathay seven eight zero roger advise your in-flight condition.
5	35	19	RDO-1		We are IMC, Cathay seven eight zero MAYDAY.
5	35	23	APP		Cathay seven eight zero MAYDAY roger.
5	35	25	RDO-1		Actually now we are just VMC now Cathay seven eight zero.
5	35	28	APP		Cathay seven eight zero roger, on your present heading . .
5	35	31	APP		. . there will bring you a close base around Lantau Island I'll advise if this is any, if you're too close.
5	35	35	RDO-1		Cathay seven eight zero roger I can't see Lantau for cloud, but we've got the island just to, ah, the southeast of the airfield.
5	35	42	APP		Seven eight zero roger Your present heading is the most efficient to miss the Lantau Island and still make the right base.
5	35	49	RDO-1		Cathay seven eight zero roger.
				From 053551 to053636: Since engine one had some appropriate response to the change of number one thrust lever, the Commander took control of engine one. During the period, engine ignition was selected on. "Cabin crew please be seated for landing" and "Cabin crew to station" calls were made.	
				From 053643 to 053710: a series of conversation between pilots on using the "all engines flamed out fuel remaining checklist". During the period, the Ram Air Turbine (RAT) was selected on.	

5	37	0	APP		Cathay seven eight zero, no need to acknowledge. There has been windshear reported on the south runway. both runways will be made available for your approach. Just let us know when you come in.
5	37	10	RDO-1		Cathay seven eight zero roger.
				From 053712 to 053841: a series of conversation between pilots on continuing the attempt to clear the fault on Engine 2 by setting the Engine Master switch to off then on.	
5	37	18	APP		And the current wind one four zero degrees one seven knots touch down zero seven right. One two zero degrees one four knots touch down zero seven left.
5	38	6	APP		Cathay seven eight zero, no need to acknowledge. Your position abeam SOKO.
5	38	44	HOT-1	Well, Engine One is providing thrust, I'm not going to pull back to idle.	
5	38	49	HOT-1	Okay, Flaps One, thanks mate.	
5	38	51	HOT-2	Okay, speed checked, Flaps One.	
5	38	55	HOT-2	Approach Preparation. Okay, sorry, cabin and cockpit prepared. Cabin secured loose items.	
5	39	4	HOT-2	Okay Cabin crew notified and passengers advised.	
5	39	16	HOT-2	Okay.	
5	39	17	HOT-1	An ladies and gentlemen, this is the Captain speaking. As you no doubt . .	
5	39	20	CAM-?	[chime sound]	

5	39	20	HOT-1	. . may be aware we have a small problem with our engines. Ah you might feel some vibrations and we've given priority to land but I do stress that it's very important that you remain seated with your seatbelts fastened and follow the directions from your cabin crew. We are probably about six or seven minutes from touchdown and we are just manoeuvring now for landing and descending [unintelligible] please remain seated with your seatbelts fastened.	
5	39	40	APP		Cathay seven eight zero your position is one zero miles southeast of the field on base about one one track miles.
5	39	49	RDO-1		Cathay seven eight zero.
5	39	50	HOT-1	Roger, can you give me direct to final zero seven left please. Two five three radial in. Thank you. Go.	
5	40	1	HOT-2	Okay, should be coming up from the right of this cloud ten miles five thousand.	
5	40	7	HOT-1	Thank you.	
5	40	8	HOT-2	We should be making the field now.	
5	40	12	APP		Cathay seven eight zero you descend you can make visual approach as required.
5	40	17	HOT-2	Okay, visual?	
5	40	18	HOT-1	Okay.	
5	40	19	RDO-2		Visual approach as required as required Cathay seven eight zero.
5	40	21	HOT-2	To zero seven left, are you happy with it?	
5	40	22	HOT-1	Yep, yep.	
5	40	23	RDO-2		Ah Cathay seven eight zero will be for zero seven left.
5	40	24	HOT-1	Gear Down.	
5	40	26	HOT-2	Gear Down.	
5	40	26	APP		Cathay seven eight zero
5	40	30	HOT-1	Can you give me zero seven three on the track please.	
5	40	40	HOT-2	Okay, track zero seven three.	
5	40	41	HOT-1	Checked.	
5	40	42	HOT-2	Flaps One. Runway is identified. Landing checklist.	
5	40	48	HOT-2	Cabin is ready. Altimeters?	

5	40	52	HOT-1	QNH one zero one three set.	
5	40	54	HOT-2	QNH one zero one three set.	
5	40	54	APP		Cathay seven eight zero . .
5	40	55	HOT-2	Autobrake?	
5	40	55	APP		. . zero do you have the airfield in sight?
5	40	56	HOT-1	Affirm.	
5	40	57	RDO-2		Cathay seven eight three affirm.
5	40	59	APP		Cathay seven eight zero, standby for landing clearance the wind is currently one two zero degrees one six knots.
5	41	6	RDO-2		Cathay seven eight zero.
5	41	8	HOT-2	Okay, auto, oh, altimeters.	
5	41	11	HOT-1	QNH one zero one three set.	
5	41	13	HOT-2	QNH One zero one three set.	
5	41	15	HOT-2	Autobrake.	
5	41	17	HOT-1	Low.	
5	41	19	HOT-2	Final items, okay, you overshoot the centerline.	
5	41	24	CAM-AC	[overspeed warning starts . . .]	
5	41	25	HOT-1	That’s okay.	
5	41	26	HOT-2	Overspeed.	
5	41	27	HOT-1	Check.	
5	41	29	CAM-AC	[. . . overspeed warning ends]	
5	41	36	HOT-2	Coming up to clear the ECAM here.	
5	41	38	HOT-1	Right. Thanks, mate.	
5	41	43	CAM-RADALT	Two thousand five hundred.	
5	41	45	HOT-2	Okay, Gear Down, Flaps One only this stage.	
5	41	47	HOT-1	Roger.	
5	41	48	HOT-1	Now I’m zigzagging a little bit to lose height here.	
5	41	50	APP		Cathay seven eight zero, the wind one five zero degrees one three knots runway zero seven left cleared to land.
5	41	55	RDO-2		Cleared to land zero seven left Cathay seven eight zero.
5	42	5	APP		Cathay seven eight zero no need to acknowledge four miles from touchdown.
5	42	8	HOT-2	Okay, I’ve got full speedbrake at the moment.	
5	42	9	HOT-1	Yeap.	
5	42	15	HOT-2	Two thirty knots, we are at three miles.	
5	42	18	HOT-1	Checked.	
5	42	19	CAM-RADALT	One thousand.	

5	42	25	HOT-2	Okay, we are through ah thousand feet.	
5	42	27	HOT-1	Yeap.	
5	42	28	HOT-2	Still at Flaps One, Spoilers Armed.	
5	42	31	HOT-1	Checked. Now I'm not sure if we are able to get Flaps Two mate.	
5	42	37	HOT-2	Should we just take it out anyway?	
				From 054239 to 054308: a series of EGPWS aural warnings of "Too Low Terrain" and "Pull Up".	
5	42	39	CAM-EGPWS	Too Low Terrain.	
5	42	42	HOT-1	Disregard that.	
5	42	43	HOT-1	Yeah, take it in.	
5	42	44	CAM-EGPWS	Too Low Terrain.	
5	42	45	HOT-2	Speed checked, up rate then Flaps Two.	
5	42	47	HOT-1	Checked.	
5	43	10	CAM-AC	Twenty .. Retard.	
5	43	13	CAM-AC	Ten.	
5	43	17	CAM	[noise of aircraft touching down]	
5	43	22	HOT-2	Full Reverse.	
5	43	28	HOT-2	No Spoilers No REV green No DECEL.	
5	43	38	CAM-?	[chime sound]	
5	43	51	HOT-2	Remain seated, remain seated.	
5	43	51	APP		Cathay seven eight zero when you are able call Tower on one one eight decimal two.
5	43	56	HOT-1	Okay.	
5	43	57	RDO-2		Cathay seven eight zero standby.
5	44	0	HOT-1	Okay, let's shut the engines down.	
5	44	5	RDO-2		Cathay seven eight zero shutting down on the runway.
5	44	8	APP		Cathay seven eight zero approved. Call Tower one one eight two when you can.
5	44	12	RDO-2		Cathay seven eight zero.
5	44	14	HOT-1	Okay standby one.	
5	44	16	HOT-1	Engine shutdown. Park brake is set. We've got pressure. Let's just clear the ECAM.	
5	44	21	HOT-2	Okay Engine One Control System Failure Thrust Lever idle, clear?	
5	44	25	HOT-1	Clear.	

5	44	26	HOT-2	Engine Two Control System Fault Thrust Lever idle, clear?	
5	44	29	HOT-1	Clear.	
5	44	30	HOT-2	High RAT Fault. Uhm, Engine Two Control System Fault clear?	
5	44	34	HOT-1	Clear.	
5	44	35	HOT-2	High RAT fault, clear?	
5	44	36	HOT-1	Clear.	
5	44	37	HOT-2	Engine One Reverse Fault, clear?	
5	44	38	HOT-1	Cleared.	
5	44	38	APP		Cathay seven eight zero there are vehicles attending you, ah, from behind now.
5	44	42	RDO-2		Cathay seven eight zero standby.
5	44	44	HOT-2	Status, clear status?	
5	44	46	HOT-1	Clear.	
5	44	50	HOT-1	Okay, so let's look at the wheel temps. I am just worrying about the evacuation now	
5	44	55	HOT-2	Yep, understood.	
5	44	57	HOT-1	Obviously a possibility of a fire. Melting plugs. Now evacuation the airplane seems to be okay apart from the fire. What?	
5	45	8	HOT-2	Chance of a fire, yep.	
5	45	10	HOT-1	Should we evacuate, or should we take the safer option to stay onboard and just worry that if a fire starts, you know.	
5	45	21	HOT-2	We'll get advice.	
5	45	22	HOT-1	Okay, let me just talk to Tower.	
5	45	28	HOT-1	Ladies and gentlemen the Captain is speaking. We've obviously come to a stop on the runway. Please remain seated and follow your cabin crew's instructions. We are just evaluating the situation now. Please remain seated.	
5	45	43	HOT-1	Right. One one eight seven. One one eight two.	
5	45	46	RDO-1		Tower, Cathay seven eight zero MAYDAY.
5	45	49	TWR		Cathay seven eight zero, go ahead.
5	45	51	RDO-1		Roger, we've got obviously very hot brakes from the landing. Ah if you can please give us any indication of a wheel fire, that would be ah appreciated.

5	46	1	TWR		Cathay seven eight zero, roger your MAYDAY, the err fire vehicle is attending your scene at this moment. We don't see any fire yet.
5	46	11	RDO-1		Roger, Cathay seven eight zero.
5	46	14	HOT-1	Okay, I think maybe the safe option is to stay unless they confirm that the wheels are on fire.	
5	46	20	HOT-2	Something happens.	
5	46	21	HOT-1	What are your thoughts?	
5	46	22	HOT-2	That's good. The only problem is they all start to go, then, which side are we going to get er the people out of. That will be my only consideration there . .	
5	46	33	HOT-1	Yeah . .	
5	46	34	HOT-2	. . they're both approaching a thousand degrees.	
5	46	35	HOT-1	. . they're both going up pretty high aren't they.	
5	46	37	TWR		Cathay seven eight zero, Tower.
5	46	39	RDO-1		Cathay seven eight zero, go ahead.
5	46	40	TWR		Cathay seven eight zero, if you want you can talk to the Fire er Fire Leaders on one two one decimal nine.
5	46	47	RDO-1		One two one nine, Cathay seven eight zero
5	46	49	HOT-2	I'll bring that up COM Two. COM Two up one two one nine.	
5	46	58	HOT-1	So let's just run the Emergency Evacuation Checklist up to the evacuation.	
				From 054702 to 054804, a series of conversation between pilots on running the Emergency Evacuation Checklist. During the period, "cabin crew to stations" call was made, Fire Push button for both engines were pushed.	
5	48	6	RDO-1		Cathay seven eight zero MAYDAY, say again the frequency for Fire Services.
5	48	10	HOT-2	One two one nine?	
5	48	11	TWR		Roger dah Cathay seven eight zero, the frequency is one two one decimal nine and the Rescue Leader wants you idle all engines or shut down all the engines.

5	48	25	RDO-1		Roger, all engines are shut down and I'll speak to him one two one nine.
5	48	29	TWR		Thank you.
5	48	31	RDO-1		Fire Leader Cathay seven eight zero.
5	48	36	RLR		Rescue Leader Pilot over over.
5	48	40	RDO-1		Roger, Rescue Leader this is ah pilot, ah all engines are shut down and ah APU is running and ah we have very hot brakes indicating all, all main gear. Could you please advise if there is any fire indication?
5	48	56	RLR		Pilot, Rescue Leader, the port side and starboard side landing gears are hot brakes [unintelligible].
				End of CVR Recording	

Appendix 8: ATC Recording on 121.9 MHz

(All time in Hong Kong time, i.e., UTC +8 hrs)

TIME (L)	STATION	R/T COMMUNICATION (121.9 MHz)
13:45:21	AFC	CATHAY AIRCRAFT COMMANDER RESCUE LEADER OVER
13:45:31	AFC	TOWER RESCUE LEADER CALLING OVER PLEASE IDLE THE ENGINE FOR INSPECTION OF LANDING GEAR OVER
13:46:03	AFC	TOWER RESCUE LEADER CALLING OVER
13:46:42	AFC	CATHAY PILOT RESCUE LEADER OVER
13:48:11	ASU	ROGER CPA780 THE FREQUENCY IS ONE TWO ONE DECIMAL NINE AND THE RESCUE LEADER WANT YOU TO IDLE ALL ENGINE OR SHUT DOWN ALL THE ENGINE
13:48:28	ASU	THANK YOU
13:48:31	CPA780	FIRE LEADER CPA780
13:48:36	AFC	RESCUE LEADER PILOT OVER CATHAY PILOT OVER
13:48:40	CPA780	ROGER RESCUE LEADER THIS IS PILOT ALL ENGINES ARE SHUT DOWN AND THE APU IS RUNNING AND THE WE HAVE A VERY HOT BRAKE INDICATING ALL ALL MAIN GEAR COULD YOU PLEASE ADVISE IS THERE ANY FIRE INDICATION
13:48:57	AFC	TOWER RESCUE LEADER THE PORTSIDE AND STARBOARD SIDE LANDING GEAR ARE HOT BRAKE WATER SPRAY IS APPLIED TO COOL DOWN THE BRAKING SYSTEM OVER
13:49:17	CPA780	ROGER RESCUE LEADER THIS IS PILOT CONFIRM ARE THE WHEELS ON FIRE CAN YOU SEE SMOKE
13:49:27	AFC	AH SMOKE AND SMALL FIRE I CAN SEE (CROSSED TRANSMISSION BY CPA780 ROGER AH) AND WATER SPRAY IS NOW APPLIED TO THE TO THE BRAKE TO COOL DOWN THE BRAKING SYSTEM OVER
13:49:40	CPA780	.....STILL FIRE AND SMOKE (#)
13:49:44	AFC	PILOT CAN YOU ADVISE THE TEMPERATURE RANGE OF THE LANDING GEAR BRAKE OVER
13:49:50	CPA780	WE ARE INDICATING ONE THOUSAND DEGREES ONE THOUSAND DEGREES
13:49:54	AFC	ONE THOUSAND DEGREES THANK YOU
End of Relevant Communication		

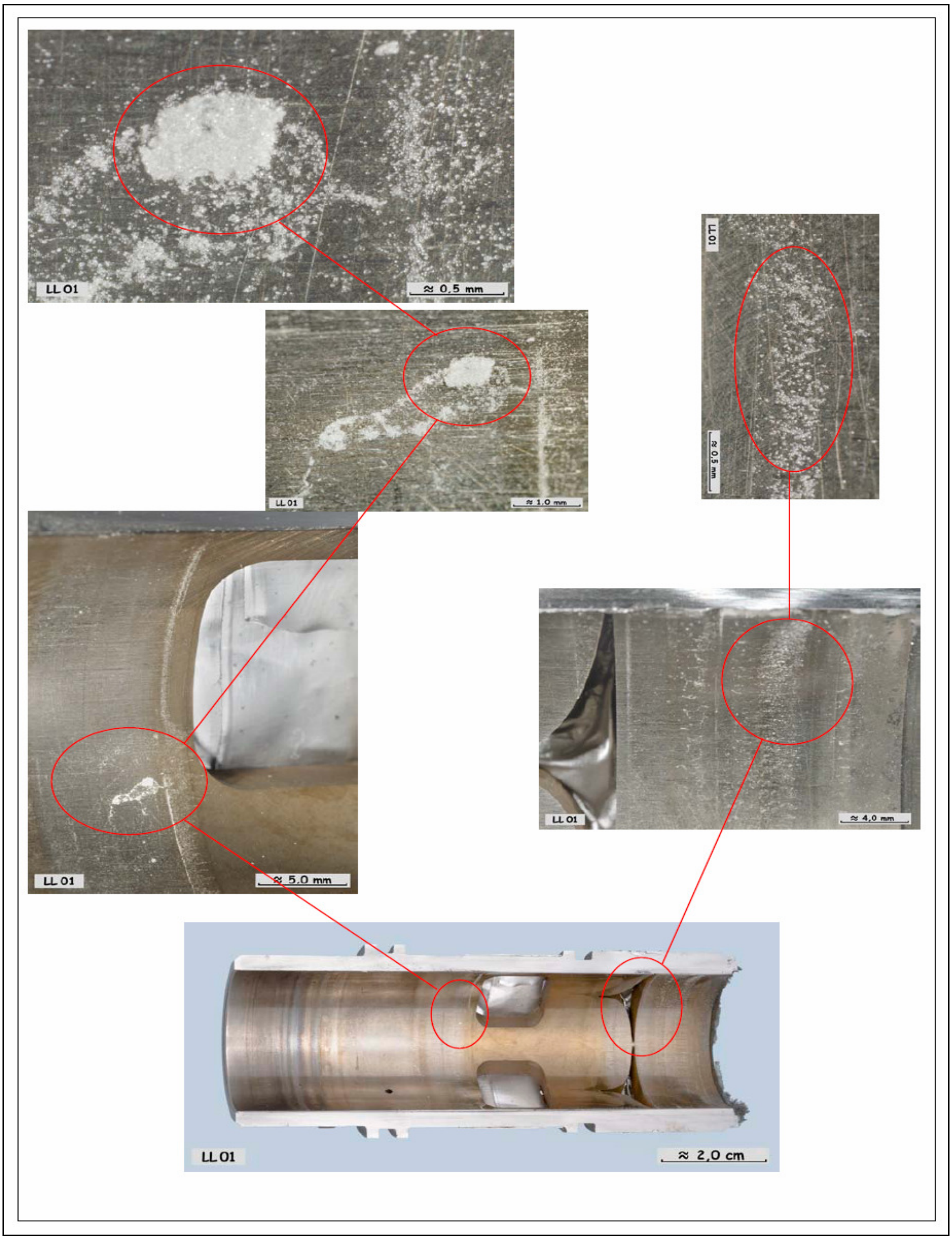
Appendix 9: Engine Events Explanations

Time UTC	Phase	Cockpit Effect	Sources	Fault Message	EXPLANATIONS
0158hr	Cruise	ENG 2 CTL SYS FAULT	PFR	732152 FMU (E2-4071KS)	FMV jammed High curent (above threshold) required to control the FMV
0316hr	Cruise	N/A	PFR	753300 VSV SYSTEM / VSV CONTROL UNIT (E2-4081KS)	VSV jammed. High curent (above threshold) required to control the VSV. Should have been linked to "ENG 2 CTL SYS FAULT"
0519hr	Descent	ENG 1 CTL SYS FAULT	PFR	732152 FMU (E1-4071KS)	FMV jammed High curent (above threshold) required to control the FMV
0519hr	Descent (30218 ft)	ENG 2 STALL	PFR EGPAR TS Data	710000 PROPULSION SYSTEM	Surge detected which was caused by VSV malschedule. VSV malscheduled 25.6 deg closed (VSV commanded 12.8-VSV actual 38.4)
0530hr	Descent (8159 ft)	ENG 1 STALL	PFR EGPAR	710000 PROPULSION SYSTEM	Potential cause: sticking and unresponsive FMU. VSVs within 1.6 degs
0532hr	Descent (7330 ft)	ENG 1 STALL	EGPAR		Potential cause: sticking and unresponsive FMU. VSVs within 2.6 degs
0534hr	Descent	N/A	PFR	240000 POWER SUPPLY INTERRUPT	Based on DFDR data, between 05h34 and 05h35 engine 2 speed dropped down under IDG underspeed threshold (around 52%). As per design, this led to loss of GEN2 and an electrical transient on all bus bars concerned. All subsequent systems were then affected by a normal power supply interrupt.
0535hr	Descent	N/A	PFR	285134 FCMC2 (5QM2)	Set as a result of the ATA24 POWER SUPPLY INTERRUPT which occurred at 05hr34 prior to the FCMC2 being reported as failed by FCMC1. Once electrical power had been restored either by restarting of the engine or via the opposite electrical generator then FCMC2 would have recovered.
0535hr	Descent	ENG 1 EPR LIMITING	TS Data	710000 PROPULSION SYSTEM	EPR command not achieved (EPR commanded 1.25 - EPR Actuel 1.12)

0536hr	Descent	MAINTENANCE STATUS EEC 1A	PFR		See above (05h35) - EPR LIMITING
0536hr	Descent	MAINTENANCE STATUS EEC 1B	PFR		See above (05h35) - EPR LIMITING
0538hr	Descent	N/A. Should have been linked to ENG 2 HP FUEL VALVE	DAR, PFR	732152 FMU (E2-4071KS)SOV POS	Failure of HPSOV to answer to command. HPSOV remains open whereas commanded closed by master lever. Cause: servo command contamination
0538hr	Descent	ENG 2 SHUT DOWN	PFR		Crew set Master lever off in flight
0538hr	Descent		PFR	Maintenance: G ENG 2 PMP DEPRESS VALVE 4000JG1/HSMU (1JG)	Linked to engine shut down: There is a specific logic in the HSMU for A330 A/C equipped with RR engines: The green hydraulic system EDP installed on Engine 1 and 2 (G EDP 1 and G EDP 2) are depressurized to help the in-flight RR Engine restart (less torque requested on engine gear box).
0538hr	Descent	ENG 1 SURGE	EGPAR		Potential cause: sticking and unresponsive FMU. . VSVs within 1.5 degs. Note: the ACMS and FWC uses the same label/bit for surge/stall detection. However the FWC confirmation time is longer hence not recorded/displayed on ECAM
0539hr	Descent	ENG 2 START FAULT	PFR		Start failed as engine could not achieve Idle
0539hr	Descent	ENG 2 STALL.	EGPAR		Engine remained at sub-idle speed
0540hr	Descent	MAINTENANCE STATUS EEC2A	PFR EGPAR		As per design, P0 is frozen during starter assist sequence. As engine did not complete the starting sequence, a discrepancy with ADIRUs was detected
0541hr	Descent	MAINTENANCE STATUS EEC2B	PFR EGPAR	EEC P0 TUBE (E2-4000KS)/ADIRU 1/2 '(1FP1/2)	As per design P0 is frozen during starter assist sequence. As engine did not complete the starting sequence, a discrepancy with ADIRUs was detected
0543hr	Touch down				

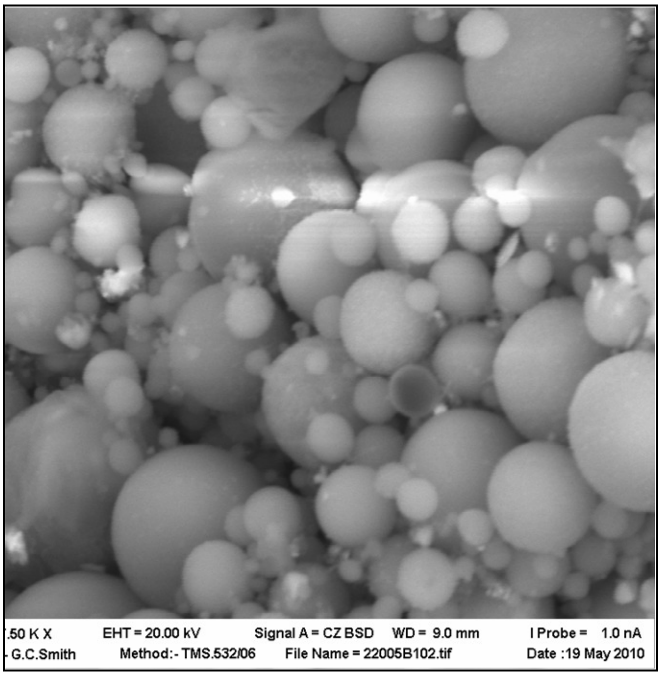
Appendix 10: No. 1 Engine MMV SAP Spheres

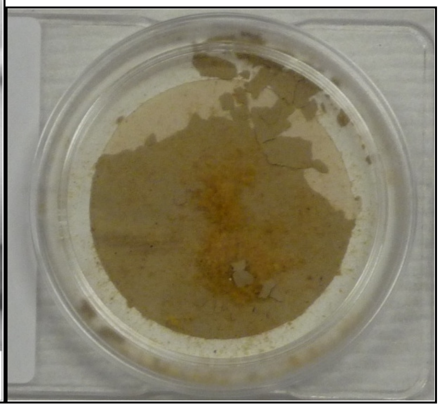
Engine No. 1 MMV cutaway view showing the presence of SAP spheres



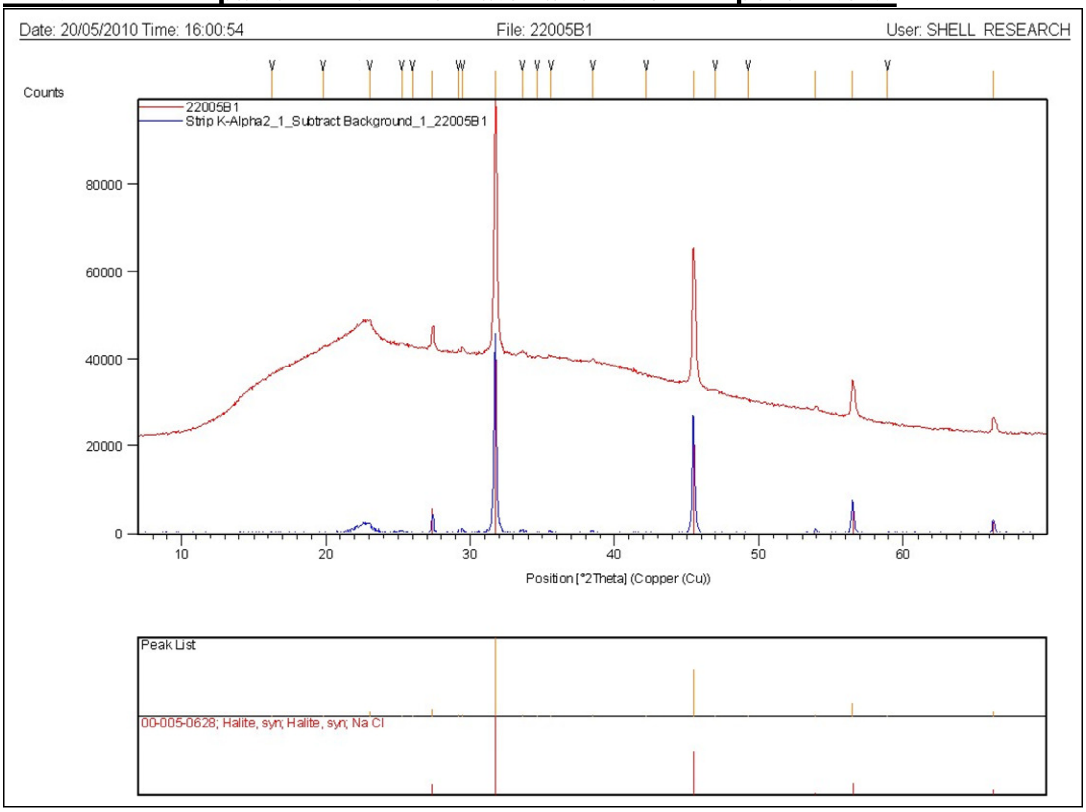
Appendix 11: SAP Spheres Examination and Analysis Results

A11.1 - The Millipore filter containing material extracted from the low pressure fuel filter by Rolls-Royce (right), and the corresponding higher magnification SEM image (left):



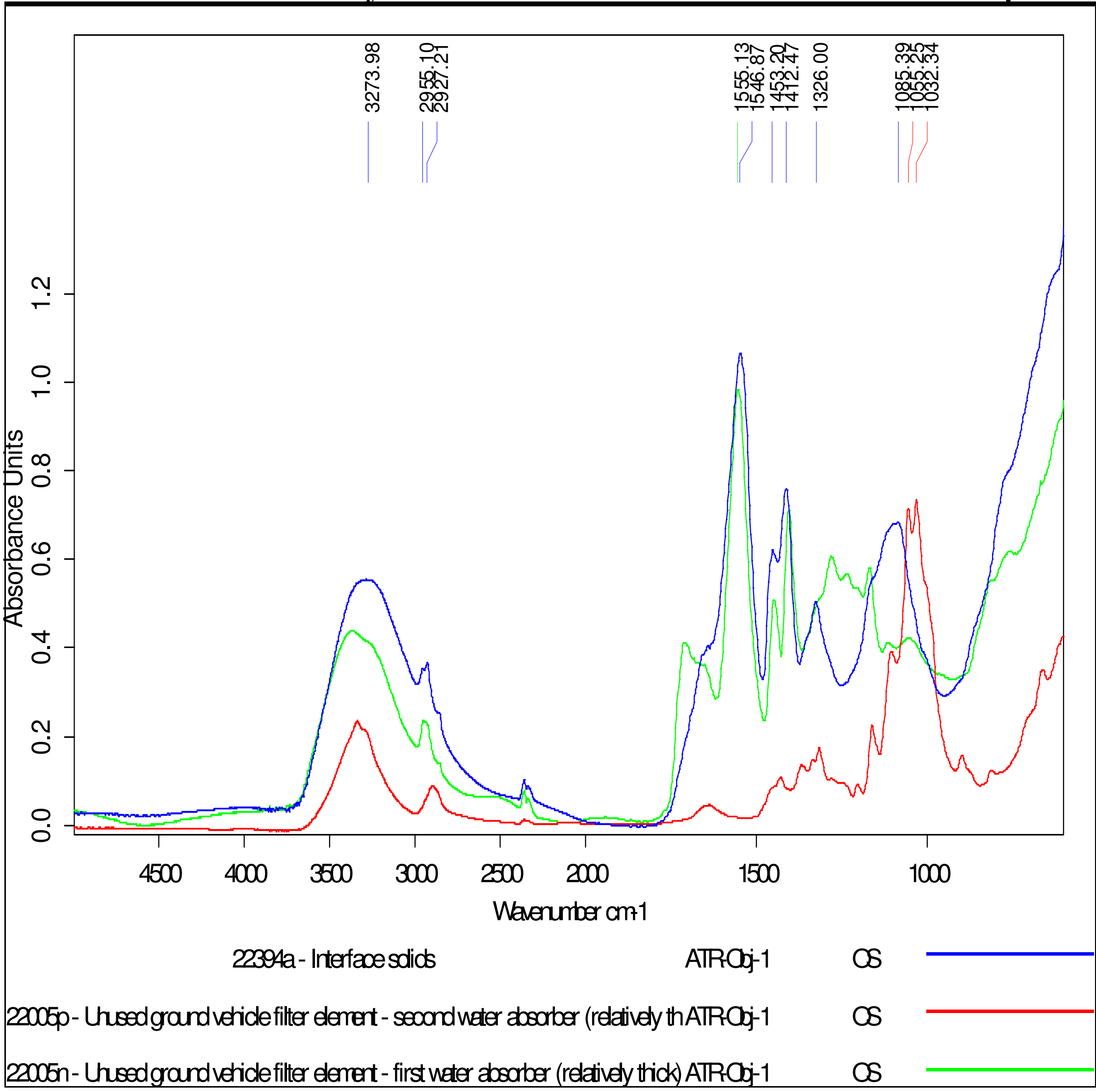


A11.2 – XRD pattern from the material on the Millipore filter:



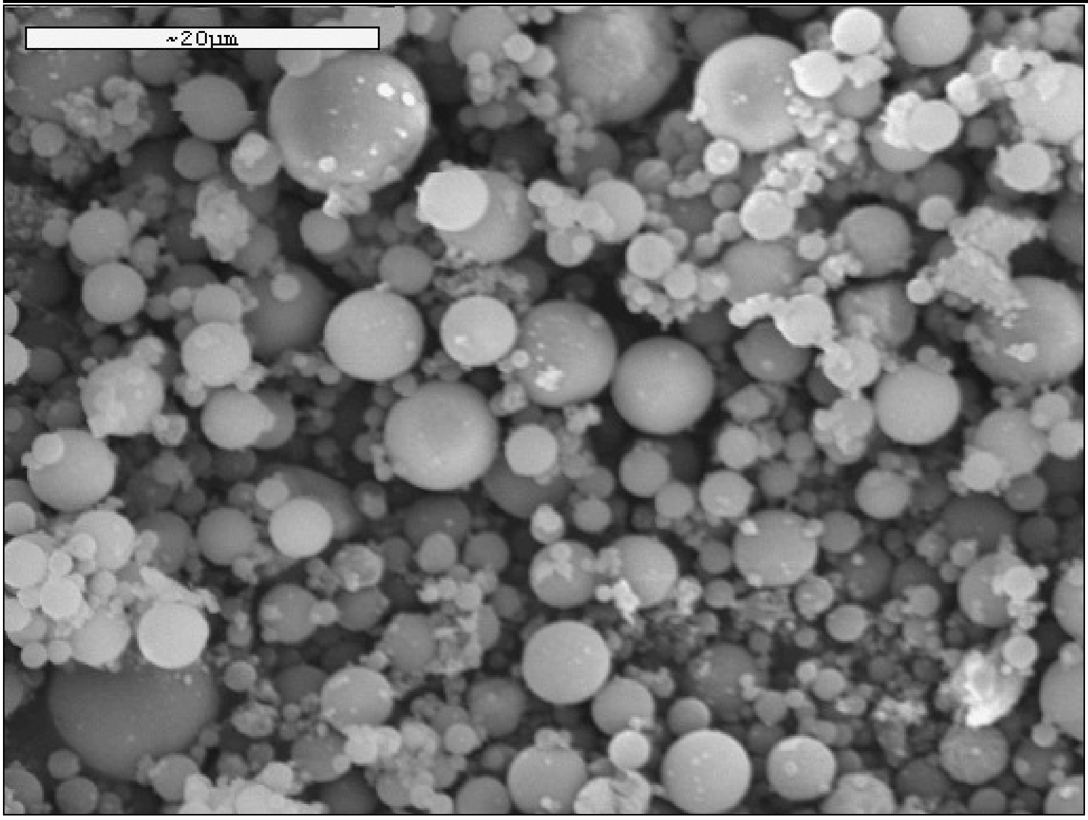
Appendix 11: SAP Spheres Examination and Analysis Results (Continued)

A11.3 – FT-IR ATR spectra from the sphere from the Millipore filter, with the spectra from the water absorber layers of the unused filter monitor shown for comparison:

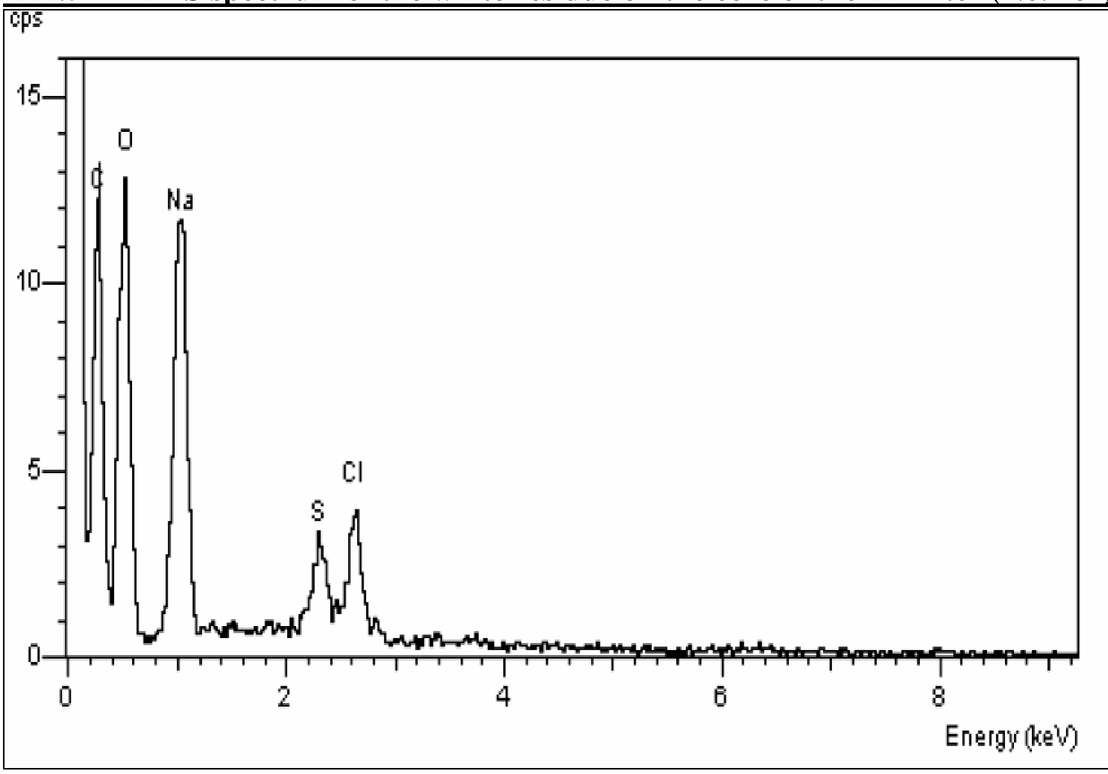


Appendix 11: SAP Spheres Examination and Analysis Results (Continued)

A11.4 – SEM image of the residue found on the core of the LP filter (No.2 engine):

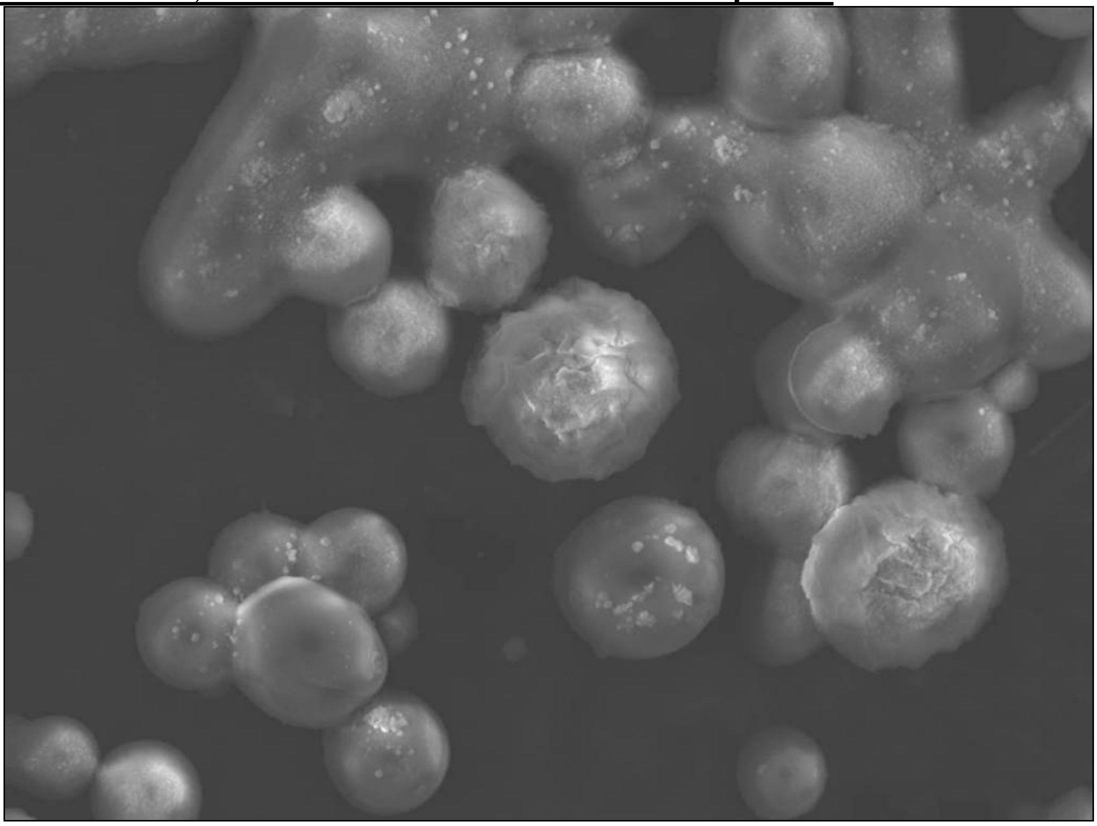


A11.5 – EDS spectrum of the white residue on the core of the LP filter (No.2 engine):



Appendix 11: SAP Spheres Examination and Analysis Results (Continued)

A11.6 – SEM image of spheres with an apparent crystalline white deposit. EDX analysis would suggest that the white crystalline areas appear to be NaCl, but Na (not associated with Cl) is detected over all other areas of the spheres:



Appendix 12: Flow Tests on Filter Monitors

A12.1 - Differential pressure v flow-rate – Table 1

Element identification (Rolls-Royce number bracketed)	New Element	Element 1 (25)	Element 2 (21)	Element 3 (22)	Element 4 (24)	Element 5 (29)	Element 6 (32)	Element 7 (26) (Twisted)	Element 8 (30)
Date of manufacture	Jan 16th 09	April 25th 08	Feb 27th 08	April 25th 08	May 1st 08	April 25th 08	Feb 27th 08	April 25th 08	April 25th 08
Batch No	N/A	1	2	2	1	2	2	2	1
Flow Rate (l/min)									
0	0	0	0	0	145	0	0	0	145
5		145							
10	0.1		3.2	5.0		25.0	3.3	4.5	
20	0.4		7.7	14.5		41.0	8.9	15.7	
30	0.9		17.6	40.0		94.0	22.6	44.0	
40	1.3		37.1	86.0		137.0	38.5	138.0	
50	1.8		73.3	136.0			72.3		
60	2.4		130.6				128		
70	2.9								
80	3.6								
90	4.1								
100	5.0								
113	6.2								

Appendix 12: Flow Tests on Filter Monitors (Continued)

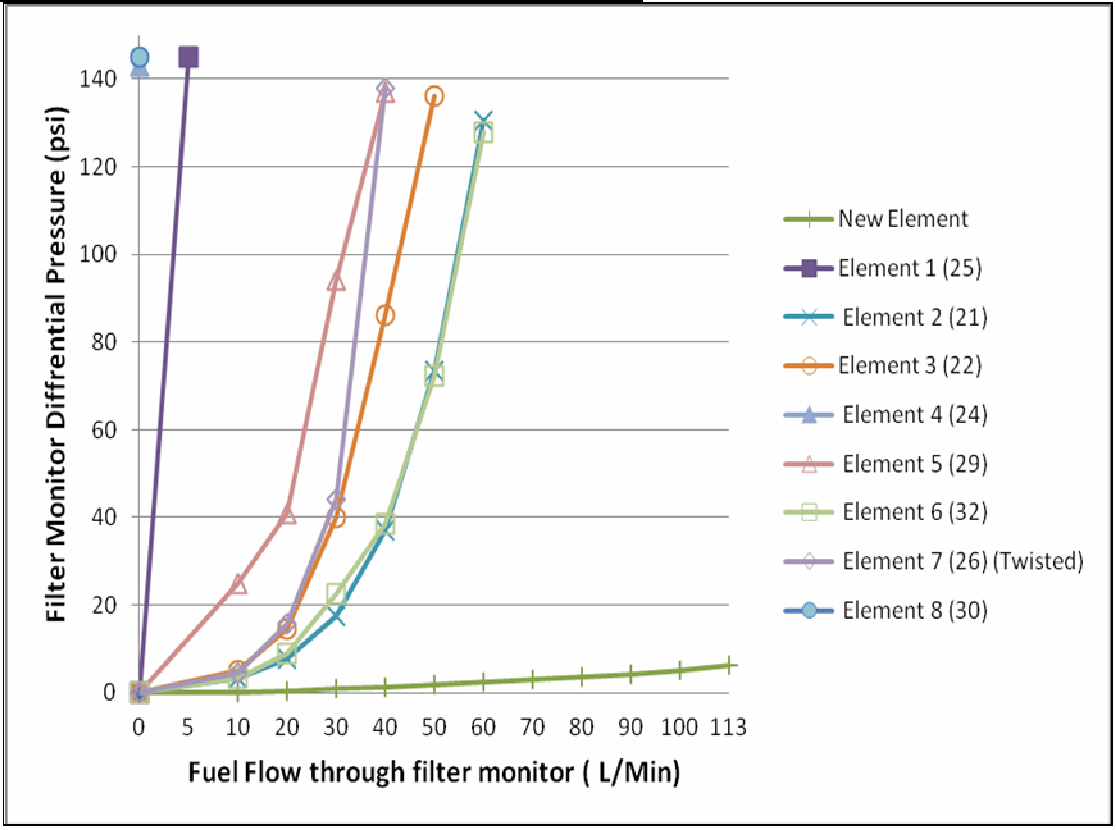
A12.1 - Differential pressure v flow-rate – Table 2

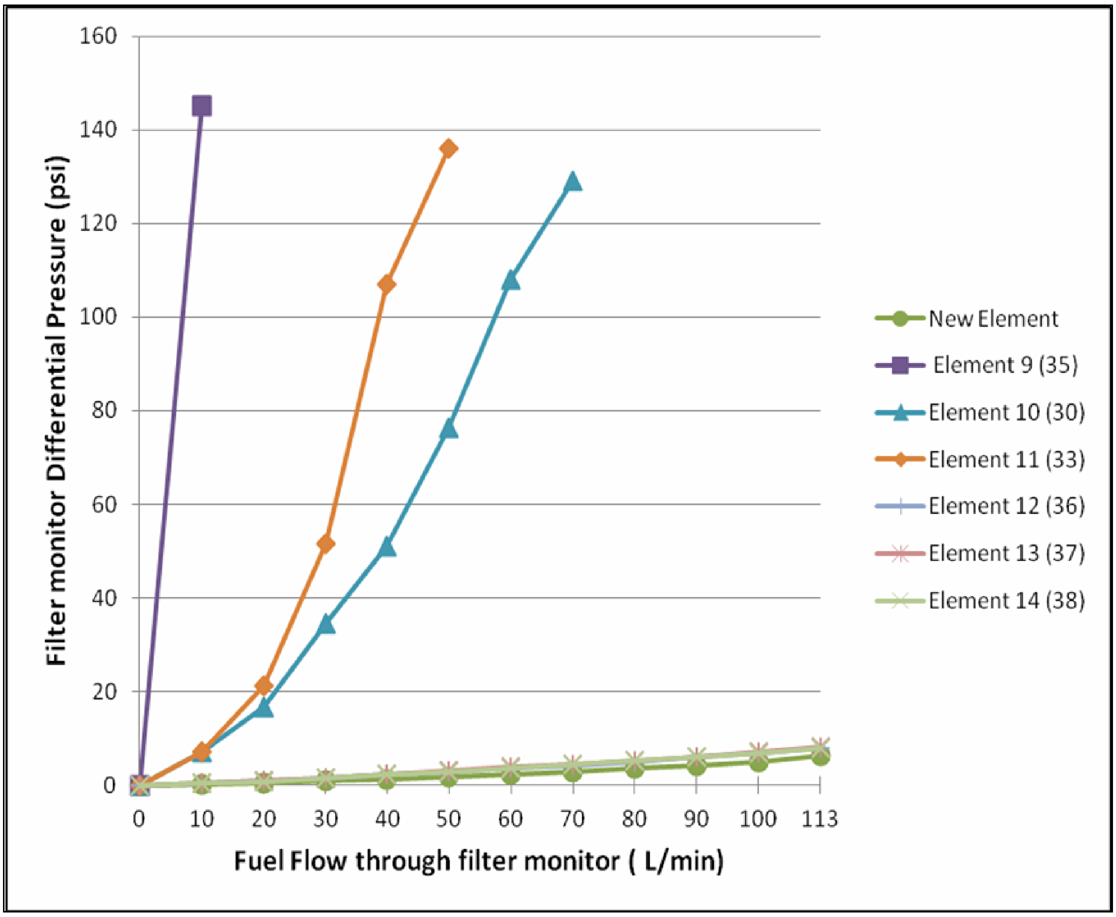
Element identification (Rolls-Royce number bracketed)	New Element	Element 9 (35)	Element 10 (30)	Element 11 (33)	Element 12 (36)	Element 13 (37)	Element 14 (38)
Date of manufacture	Jan 16th 09	Feb 27th 08	N/A	Feb 27th 08	Jan 19th 08	Jan 19th 08	Jan 19th 08
Batch No	N/A	1	1	1	3	3	3
Flow Rate (l/min)	Differential Pressure reading across element (psi)						
0	0	0	0	0	0	0	0
10	0.1	145	7.0	7.0	0.3	0.3	0.3
20	0.4		16.6	21.1	0.9	0.9	0.8
30	0.9		34.5	51.5	1.6	1.6	1.5
40	1.3		51.0	107.0	2.2	2.3	2.2
50	1.8		76.4	136.0	2.8	3.0	2.9
60	2.4		108.0		3.5	3.8	3.6
70	2.9		129.0		4.2	4.5	4.4
80	3.6				5.0	5.2	5.1
90	4.1				6.0	6.1	6.0
100	5.0				6.9	7.0	6.9
113	6.2				7.9	8.2	8.0

Note1: Element 12, 13 & 14 were after the event elements

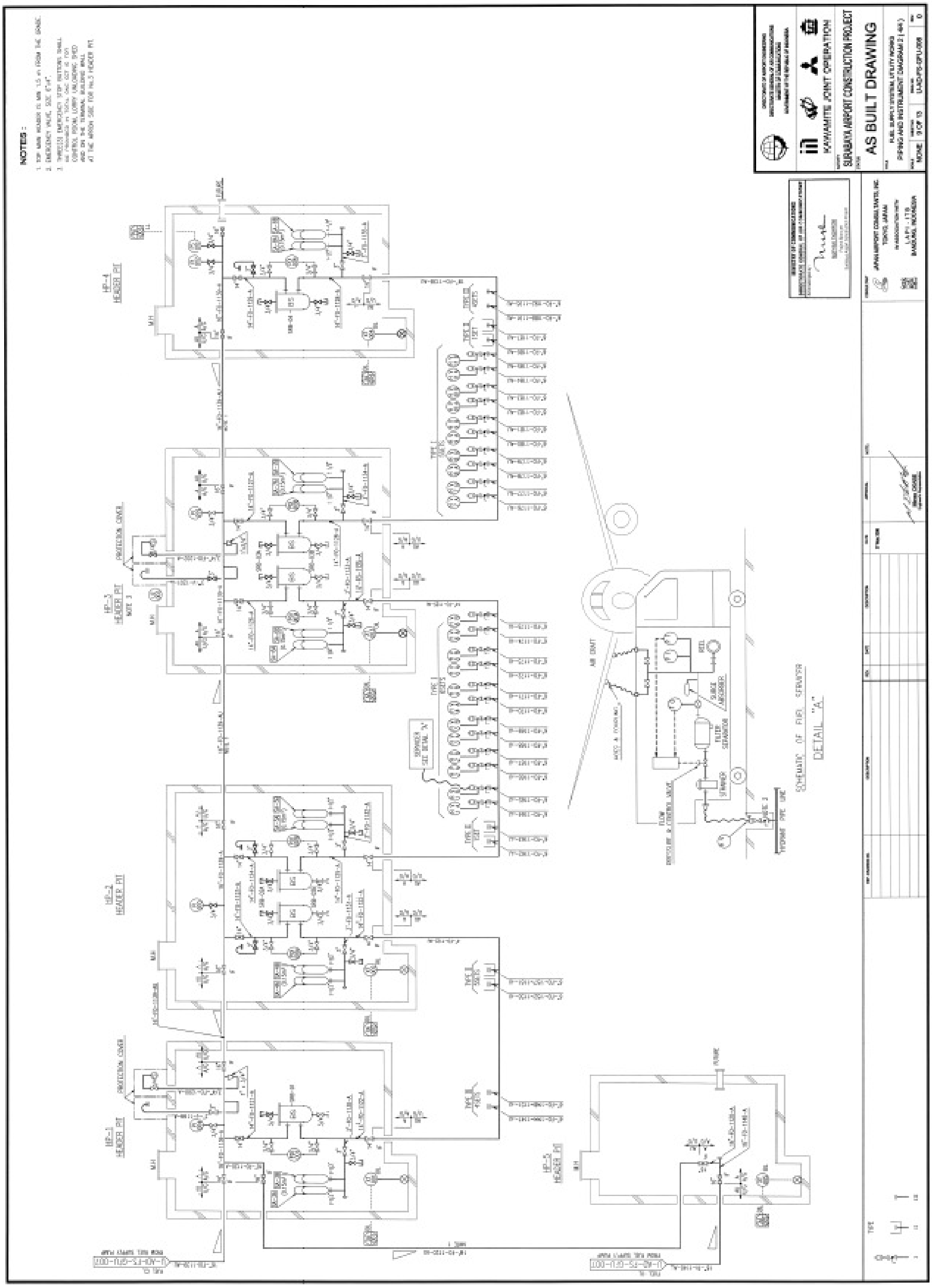
Appendix 12: Flow Tests on Filter Monitors (Continued)

A12.2 - Differential pressure v flow-rate – Graphs:





Appendix 13: WARR Apron Hydrant Refuelling Circuit



Appendix 14: NOTAM on WARR Hydrant Refuelling Operation

```
    GG WARRYOYE
110332ZCZC  WRRRYNYX
(A0296/10 RQNTMR A0272/10
Q) WAAF/QMPHW/IV/M/A/000/999/0722S11247E005
A) WARR
B) 1003110345
C) 1003202359
D) 0000-2359 DLY
E) PARKING STAND 5,6,7,8,9 AND 10 OPERATION BUT CTN ADZ DUE TO WIP
   RMK:EXTENSION AND CLSD PIPE FUEL HYDRANT SYSTEM)
```

Issued on 11/3/2010 for shutdown of hydrant at Stands 5 to10 from 11-20/3/2010

```
NNNNZCZC ZCZC CBA1478 180843
GG WARRYOYE
180842 WRRRYNYX
(A0328/10 NOTAMR A0296/10
Q) WAAF/QMFHW/IV/M/A/000/999/0722S11247E005
A) WARR
B) 1003180800 C) 1006182359
D) MAR 18 0830-2389 AND MAR 19 - JUN 18 0000-2359 DLY
E) PARKING STAND 5,6,7,8,9 AND 10 OPS BUT CTN ADZ DUE TO WIP
RMK: EXTENSION AND CLSD PIPE FUEL HYDRANT SYSTEM)
```

Issued on 18/3/2010 for shutdown of hydrant at Stands 5 to 10 from 0830 of 18/3 - 18/6/2010

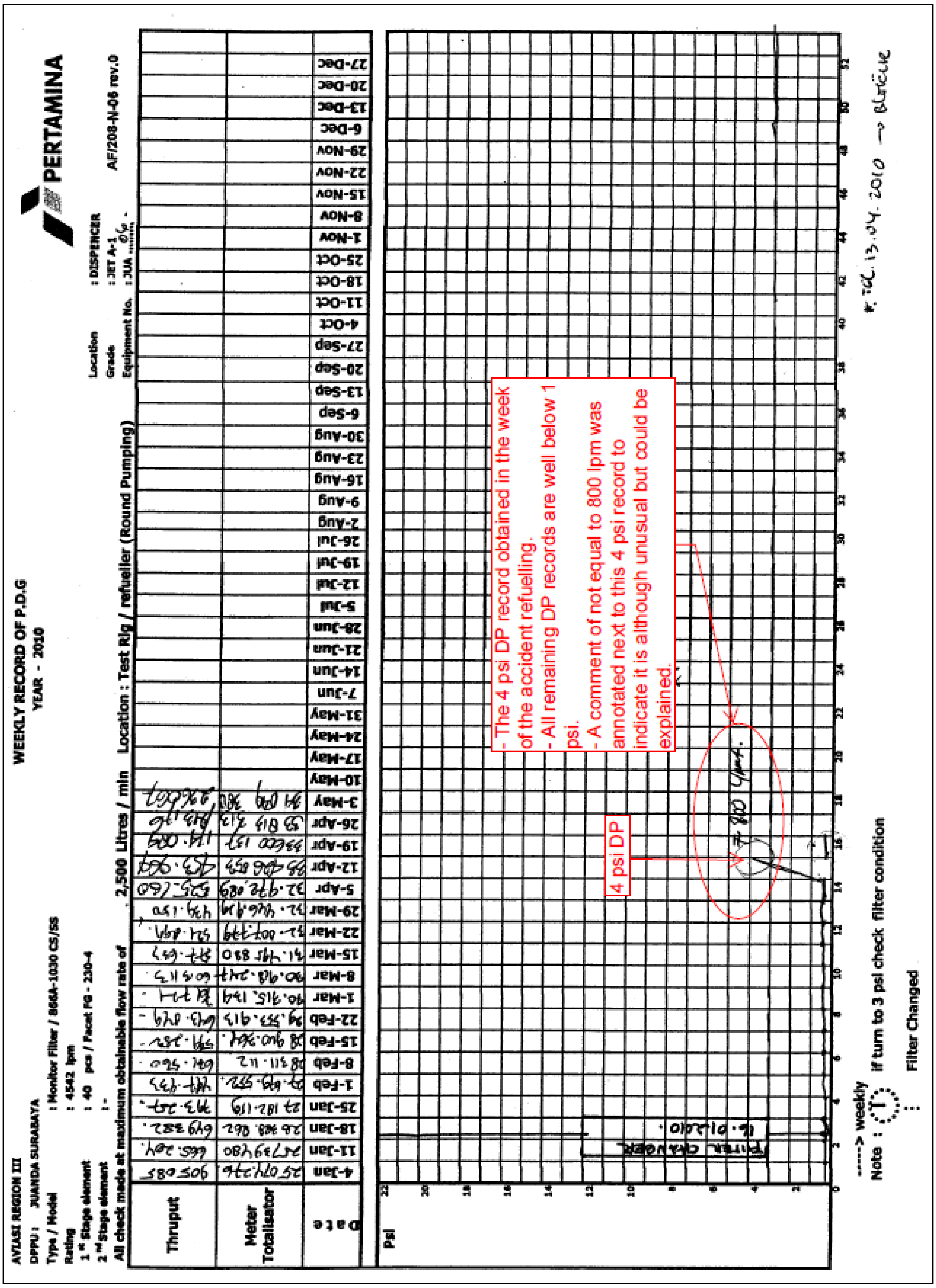
```
NNNNZCZC CBA275 161603
GG WARRYOYE
161601 WRRRYNYX
(A0475/10 NOTAMC A0328/10
Q) WAAF/QMPAK/IV/M/A/000/999/0722S11247E005
A) WARR
B) 1004161000
E) PARKING STAND 5,6,7,8,9 AND 10 RESUMED NML OPS
   RMK/ALL REFUELLING SERVICE VIA HYDRANT PIT)
```

Issued on 19/4/2010 for normal hydrant refuelling at Stands 5 to 10 with effective from 16/4/2010

```
NNNNZCZC ZCZC CBA1 211150
GG WARRYOYE
211148 WRRRYNYX
(A0505/10 NOTAMN
Q) WAAF/QMFXX/IV/NBO/A/000/999/0722S11247E005
A) WARR
B) 1004211045 C) 1007211029
D) APR 21 1045-2359, APR 22 - JUL 20 0000-2359, JUL 21 0000-1029
E) ACFT STAND 5,6,7,8,9 AND 10 OPS BUT CTN ADZ DUE TO WIP
RMK: EXTENSION PIPE FUEL HYDRANT SYSTEM U/S)
```

Issued on 21/4/2010 for suspension of hydrant refuelling at Stands 5 to 10 from 1045UTC of 21/4/2010 to 1029 of 21/7/2010.

Appendix 15: Dispenser JUA06 Weekly DP Record Sheet



Appendix 16: Trent 700 Engine Certification Requirement

A16.1 - JAR-E-670:

JAR-E 670 CONTAMINATED FUEL
(See ACJ E 670)

(a) Evidence shall be provided that the complete Engine fuel system is capable of functioning satisfactorily with fuel containing the maximum quantity of liquid/solid contaminating, likely to be encountered in service, for a period sufficient to ensure that Engine malfunctioning as a result of this cause with not occur.

(b) The evidence shall provide assurance that –

(1) The fuel system is not adversely affected by contamination which can pass through any filtration provided, either immediately or during subsequent running, and

(2) It will be possible for the Engine to complete a period equal to at least half the maximum flight duration of the aeroplane in which it is likely to be installed, with the same contaminant level, from the point at which indication of impending filter blockage is first given.

Appendix 16: Trent 700 Engine Certification Requirement (Continued)

A16.2 - ACJ E 670 :

ACJ E 670
Contaminated Fuel Testing
See JAR-E 670

1 *Solid Contaminants*

1.1 The constituents of the contaminant used should be agreed by the Authority. A contaminant with the characteristics detailed in MIL-E-5007C is acceptable.

1.2 A test on the complete fuel system should be carried out either on a running Engine, or on a rig, using fuel continuously contaminated at a rate of 4.5 g of contaminant per 4500 litres.

1.3 The point at which blockage will be indicated to the flight crew should also be established *, and the fuel system should be shown to be capable of continuing to operate without causing Engine malfunction for a further period equal to at least half the maximum flight duration of the aircraft in which it is likely to be installed. (Once this has been established, it is permissible to clean or replace filter(s) as frequently as necessary for the remainder of the test.)

1.4 The test should then be continued at typical running conditions with respect to Rotational Speeds, pressures, fuel flow, etc., for a sufficient time to ensure that the total weight of contaminant passing into the system would be equivalent to 500 hours of normal operation with fuel contaminated to a level of 0.5 g per 4500 litres. At the conclusion of the test, the fuel system should be functioning satisfactorily.

2 *Water Contaminant*

2.1 A test on the fuel system should be carried out, using the fuel contaminated with water, either on a running Engine or on a rig.

2.2 The contaminated fuel should consist of initially saturated with water of a fuel/water temperature of 27C into which a further 0.2 ml of free water per litre of fuel has been evenly dispersed.

2.3 The test should be conducted with the contaminated mixture cooled to the most critical condition for icing likely to be encountered in operation.

2.4 In conducting the tests, such drills on system management as will be issued for use in service should be followed. Where the circumstances of a drill are dependent on receipt of a warning signal, the drill should not be initiated until at least 2 minutes after the warning signal would be indicated to the flight crew.

* If blockage has not occurred by the time the total quantity of contaminant has reached the level specified in 1.4, the objective of 1.3 may be considered to have been met.

Appendix 17: MIL-E-5007E Specification for Contamination Test

(MIL – E – 005007E (AS) or British Equivalent DERD 2153 issue 4)

Contaminant	Particle Size	Quantity
Iron Oxide (Fe_3O_4)	0 – 5 Microns	1.5 Grams/1000 US Gal
Iron Oxide (Fe_2O_3)	0 – 5 Microns	27.0 Grams/1000 US Gal
Iron Oxide (Fe_2O_3)	5 – 10 Microns	1.5 Grams/1000 US Gal
Crushed Quartz	1000 – 1500 Microns	0.25 Grams/1000 US Gal
Crushed Quartz	420 – 1000 Microns	1.75 Grams/1000 US Gal
Sharp Silica Sand	300 – 420 Microns	1.0 Grams/1000 US Gal
Sharp Silica Sand	150 – 300 Microns	1.0 Grams/1000 US Gal
Prepared Dirt conforming to A.C. Spark Plug Co., Part No 1543637 (Coarse Arizona Road Dust)	0 – 5 Microns 12% 5 – 10 Microns 12% 10 – 20 Microns 14% 20 – 40 Microns 23% 40 – 80 Microns 30% 80 – 200 Microns 9%	8.0 Grams/1000 US Gal
Cotton Linters	Staple below 7 (US Department of Agriculture Grading Standards)	0.1 Grams/1000 US Gal
Crude Naphthenic Acid		0.03 % by volume
Salt water, prepared by dissolving salt in distilled water containing not more than 200 parts per million of total solids	4 Parts by weight NaCl 96 Parts by weight H_2O	0.01% by volume entrained

Appendix 18: Airbus QRH 70.07

Airbus QRH 70.07 for Suspected Engine Fuel System Contamination

CATHAY PACIFIC A330/A340 QUICK REFERENCE HAND BOOK	ABNORMAL AND EMERGENCY PROCEDURES	70.07 20 SEP 11

SUSPECTED ENG FUEL SYS CONTAMINATION

This procedure must be applied if one of the two following conditions is encountered. In that case, a fuel contamination can be highly suspected.

- **If ECAM caution** ENG 1(2) CTL SYS FAULT **is triggered with the associated message "**AVOID RAPID THRUST CHANGE**" or "**ENG 1(2) SLOW RESPONSE**", and with rapid and continuous EPR fluctuation indications on both engines:**

  A/THR .... OFF

  - **If EPR fluctuations on both engines stop:**

    ECAM PROC .... APPLY

    A/THR .... KEEP OFF

  - **If EPR fluctuations on both engines continue:**

    ENG FUEL SYS CONTAMINATION PROC .... APPLY

- **If ECAM cautions** ENG 1 CTL SYS FAULT **and** ENG 2 CTL SYS FAULT **are triggered with the associated message "**AVOID RAPID THRUST CHANGE **" or "**ENG 1(2) SLOW RESPONSE**":**

  A/THR .... OFF

  ENG FUEL SYS CONTAMINATION PROC .... APPLY

ENG FUEL SYS CONTAMINATION

This procedure must be applied if a fuel contamination has been confirmed by the application of the *Refer to FCOM/PRO-ABN-70 SUSPECTED ENG FUEL SYS CONTAMINATION* procedure. This fuel contamination may result, in the worst case, in a loss of engine thrust control. This procedure aims at maintaining the thrust on one engine while minimizing the thrust changes on the other, in order to prevent contaminant from blocking the mechanical devices of engine thrust regulation.

In case of ENG 1(2) CTL SYS FAULT on only one engine:
- Set and maintain the thrust on the engine affected by the ECAM caution
- Minimize the thrust changes on the engine not affected by the ECAM caution

In case of ENG 1 and 2 CTL SYS FAULT (both engines affected by the ECAM caution):
- Set and maintain the thrust on the first engine affected by the ECAM caution
- Minimize the thrust changes on the second engine affected by the ECAM caution

WHEN FUEL CONTAMINATION IS CONFIRMED

LAND ASAP

A/THR .... KEEP OFF

MAN THR (ECAM affected or 1st ECAM affected engine) .... SET and MAINTAIN

Set the thrust (N1) on the applicable engine according to the following table. This thrust should be maintained until final approach.

	THRUST SETTING (N1)												
	GROSS WEIGHT (1 000 kg)												
	120	130	140	150	160	170	180	190	200	210	220	230	240
N1 (%)	58.1	58.7	59.4	60.1	60.8	61.6	62.5	63.3	64.1	65.0	65.9	66.8	67.7

- **FOR CRUISE**

  MAN THR (Non ECAM affected or 2nd ECAM affected engine) .... SET AS RQRD

  Minimize thrust changes on the applicable engine.

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ENG FUEL SYS CONTAMINATION (Cont'd)

- **DESCENT**

MAN THR (Non ECAM affected or 2nd ECAM affected engine)..................IDLE
SPD BRK...AS RQRD

Manage the descent using speed brakes as necessary so as to perform a level-off at approximately 3 000 ft AGL and 20 nm from the runway threshold.

ATC...NOTIFY

Notify ATC to ensure runway availability for landing.

- **APPROACH**
  - **At a suitable altitude (approximately 3 000 ft AGL):**

  LEVEL OFF...INITIATE
  AIRCRAFT ....CONFIGURE FOR LDG

  To decelerate the aircraft, manage early gear extension and/or use speed brakes in order to be fully configured when intercepting the final approach path.

FOR LDG...USE FLAP FULL

- **FINAL APPROACH**

TARGET SPD...VAPP

When fully configured, if the speed trend decreases below VAPP, adjust the thrust on the Non affected ECAM or 2nd ECAM affected engine. In case of overspeed adjust the thrust on the ECAM affected or 1st ECAM affected engine.

- **LANDING**

NORMAL OPS...RESUME

Resume normal operations: Retard thrust levers as usual, select reverse thrust and apply brakes as required.

Appendix 19: Safety Action Taken by Pertamina

	Actions Taken		When
1	Revise Pertamina Aviation Procedures	• Incorporate the monitoring and convertion of Filter DP • Devided into 4 books: HSSE & Admin, Quality Control, Refueling Procedures & Maintenance	• January 2011
2	Intensive Training for Quality Control & Refueling procedure with new Training modules by international expert	• Training for trainers • Use the modules as their training modules • In the process of aligning all the modules	• September 2010
3	Conduct Maintenance Training with new Training modules by international expert	• Training for all maintenance personnel • Use the modules as their training modules	• July 2011
4	TSA with Air Total International	• Yearly audit SUB, CGK & DPS • Sharing the Procedures & bulletins • Training	• April 2011
5	Become Associate Member of JIG	• Joint the JIG Managers Meeting & Training • Receive & internalize JIG bulletin, Lesson Learned & procedures	• May 2011
6	Reducing monitor Vessel flow-rate	• Using dummy monitor elements on 1 vehicle • Use 2 new low flow-rate vehicles	• October 2011 • September 2011
7	Improve filter DP (Delta Pressure) monitoring system	• In the trial process of using Filter DP Electronic System • Using new Filter DP monitoring method with daily converted record • Before delivered to hydrant system, install flow-rate indicator for each fixed fliter water separator	• January 2012 • June 2010 • April 2011
8	Improve Audit System	• With INACA (Indonesian National Air Carrier Assotiation) established audit procedure and conduct on major airoports • Using new IFQP Quality & Safety Check List for audit refference	• September 2011 • April 2012