SERIOUS INCIDENT

Aircraft Type and Registration:	Airbus A319-131, G-EUPZ
No & Type of Engines:	2 International Aero Engine V2522-A5 turbofan engines
Year of Manufacture:	2001
Date & Time (UTC):	15 March 2009 at 1935 hrs
Location:	London Heathrow Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 87
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage due to overheat in the area behind flight deck panel 123VU
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	34 years
Commander's Flying Experience:	6,929 hours (of which 77 were on type) Last 90 days - 116 hours Last 28 days - 39 hours
Information Source:	AAIB Field Investigation

Synopsis

Following the start of engine No 1, and as generator No 1 came on line, the commander's primary flight display (PFD) and navigation display (ND) blanked and the faults AC BUS 1, FWS FWC 1 and ELEC GEN 1 displayed on the Electronic Centralised Aircraft Monitoring system (ECAM). The crew carried out the ECAM drills and reset generator No 1, after which they heard a loud noise from behind the right circuit breaker (CB) panel, on the flight deck, and noticed a slight smell of electrical burning.

Subsequent investigation revealed evidence of a significant electrical overheat in the area behind the right CB panel. The initiation of the electrical fault and subsequent overheating could not be fully established, but was considered to be most likely due to the presence of a loose article. The presence of dust in the area was also considered to be a contributory factor.

History of the flight

The crew reported for duty at 1810 hrs for a flight from Heathrow Airport to Edinburgh and completed their normal aircraft preparation checks, including a visual check of the flight deck CB panels, with nothing unusual being noted. The aircraft pushed back at 1930 hrs, by which time it was dark.

After the 'before start checks' had been completed the co-pilot successfully started engine No 2 and then commenced the start of engine No 1. At the point that the crew expected generator No 1 to come online, the commander's PFD and ND both blanked, the master caution aural warning sounded, the cockpit overhead lights appeared to dim and the cabin lights also dimmed. The co-pilot checked the engine parameters, which were stable at ground idle and appeared normal.

The ECAM displayed an AC BUS 1 fault message and an associated fault checklist, which the crew actioned; this included placing the avionic cooling blower switch to OVERRIDE. They cleared this fault from the ECAM, revealing a FWS FWC 1 fault message. This required no crew actions so they cleared this fault, to then reveal an ELEC GEN 1 fault and another checklist which instructed them to reset generator No 1. They switched generator No 1 OFF using the switch on the overhead panel, and after a few seconds switched it back ON. On doing so, there was a loud noise that emanated from behind the right CB panel situated behind the co-pilot's seat. The crew then became aware of a notable, but not overbearing, 'electrical' burning smell; they looked for signs of smoke, of which there were none, and the co-pilot used his torch to inspect the area the noise had come from. During this examination the crew did not notice any 'tripped' CBs, but they commented that they did not specifically look at the CBs nor did they inspect those that were hidden from view behind the sliding jump seat.

The commander declared a PAN to ATC, and instructed the ground crew to tow the aircraft back onto stand. The co-pilot shut down both engines, at which point (he later recalled) the flight deck lights returned to their normal level of brightness. The flight crew considered that the problem was transient in nature and in view of the lack of any signs of smoke they did not consider an emergency evacuation was necessary, nor did they consider it was necessary to don their oxygen masks. After the aircraft returned onto the parking stand, the passengers disembarked normally via the air bridge. The crew remained on the aircraft, completed some paperwork and discussed the event with their company engineers.

The crew believed that after resetting generator No 1, they had made no further electrical system selections, other than selecting the avionic cooling fan blower to NORMAL just prior to leaving the aircraft. When the aircraft was back on its parking stand, external electrical power had been connected to the aircraft, but it was not selected and the APU generator was left running throughout.

Electrical system operation (Figure 1)

Alternating current (AC) electrical power on the Airbus A319 is normally provided by two engine-driven integrated drive generators (IDGs); each IDG can produce a 115/200 VAC, 3-phase 400 Hz supply to the electrical network. In addition, the APU has a 90 KVA generator that can produce a 115/200 VAC, 3-phase 400 Hz supply to the network. With the aircraft on the ground there is provision for the electrical power network to be supplied by an external power supply.

The AC electrical power network is split into three parts: network No 1, network No 2 and the Essential network. Each network consists of a series of electrical buses and contactors which distribute the electrical supplies from the various power sources; the AC Bus 1 is the primary bus for network No 1 and AC Bus 2 the primary bus for network No 2. Control of the networks and the generators is by three Generator Control Units (GCU); GCU1 controls IDG1 and network No 1,

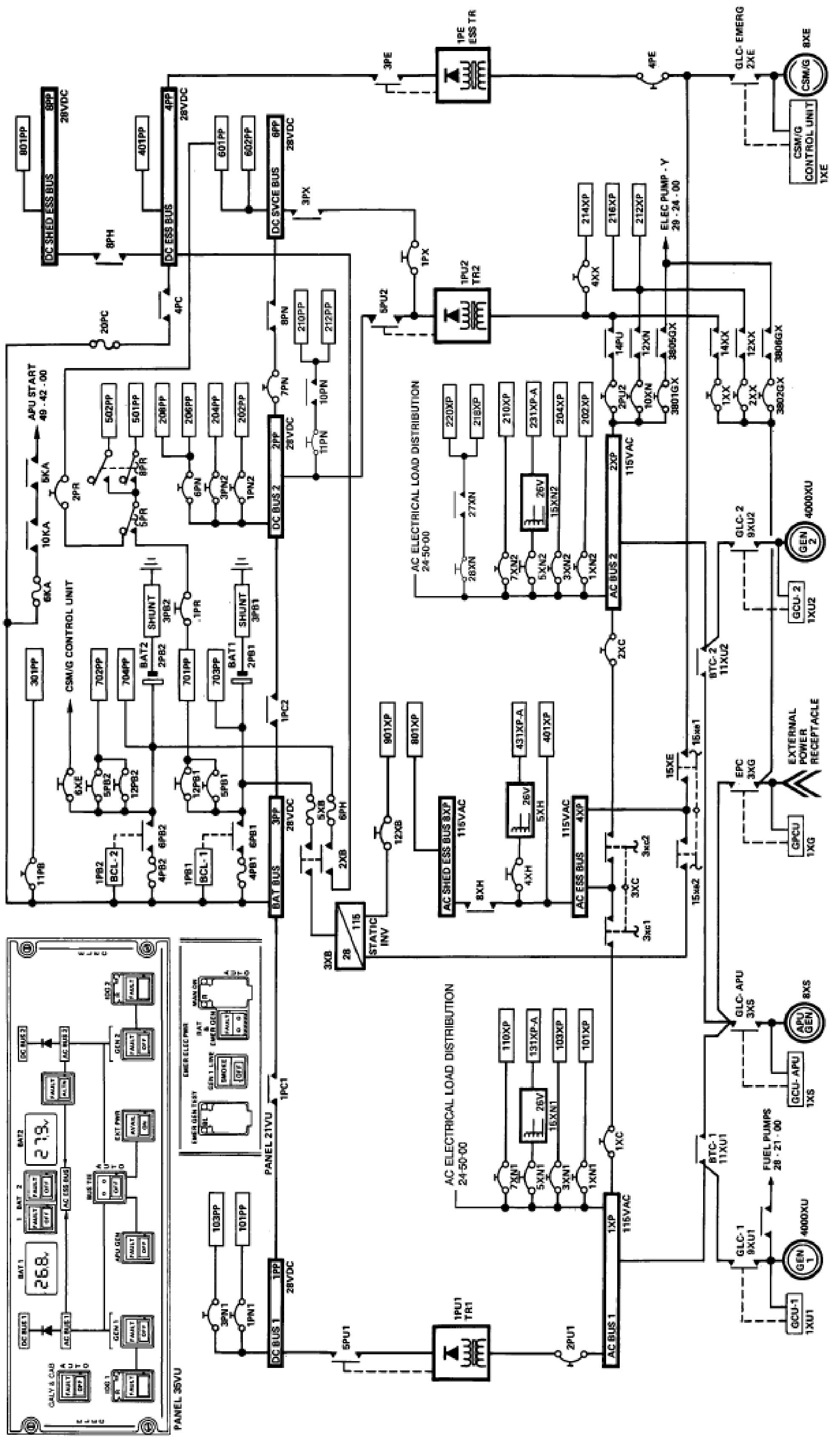

Figure 1

Electrical supply network

GCU2 controls IDG2 and network No 2, and the APU GCU controls the APU generator. Each GCU has four functions: the voltage regulation of the generator, the control and protection of the generator and the network, the control of the electrical system indications and a system test capability.

In normal operation, IDG 1 supplies network No 1 and IDG 2 supplies network No 2, with the APU and external power able to supply either network when required. Each generator is connected to its respective network buses via a Generator Load Contactor (GLC). When the generator is not providing power, Bus Tie Contactors (BTC) connect the other engine's generator, APU or external power to the network buses.

Each GCU continually monitors the generator and its electrical network so that, in the event that faults are detected, the system is protected by the isolation of the affected area. Differential Protection (DP) protects the network in the event of a short circuit or an unexpected current draw. The DP uses current transformers (CT) located within the network that monitor the currents flowing at these locations. There is one CT within the IDG, one downstream of the GLC and one downstream of the primary AC Bus supply. There are two DP protection areas, Zone 1 (DP1) which encompasses the generator and its electrical feeder cables, and Zone 2 (DP2) which includes the network between the GLC, BTC and the main AC distribution buses (Figure 2).

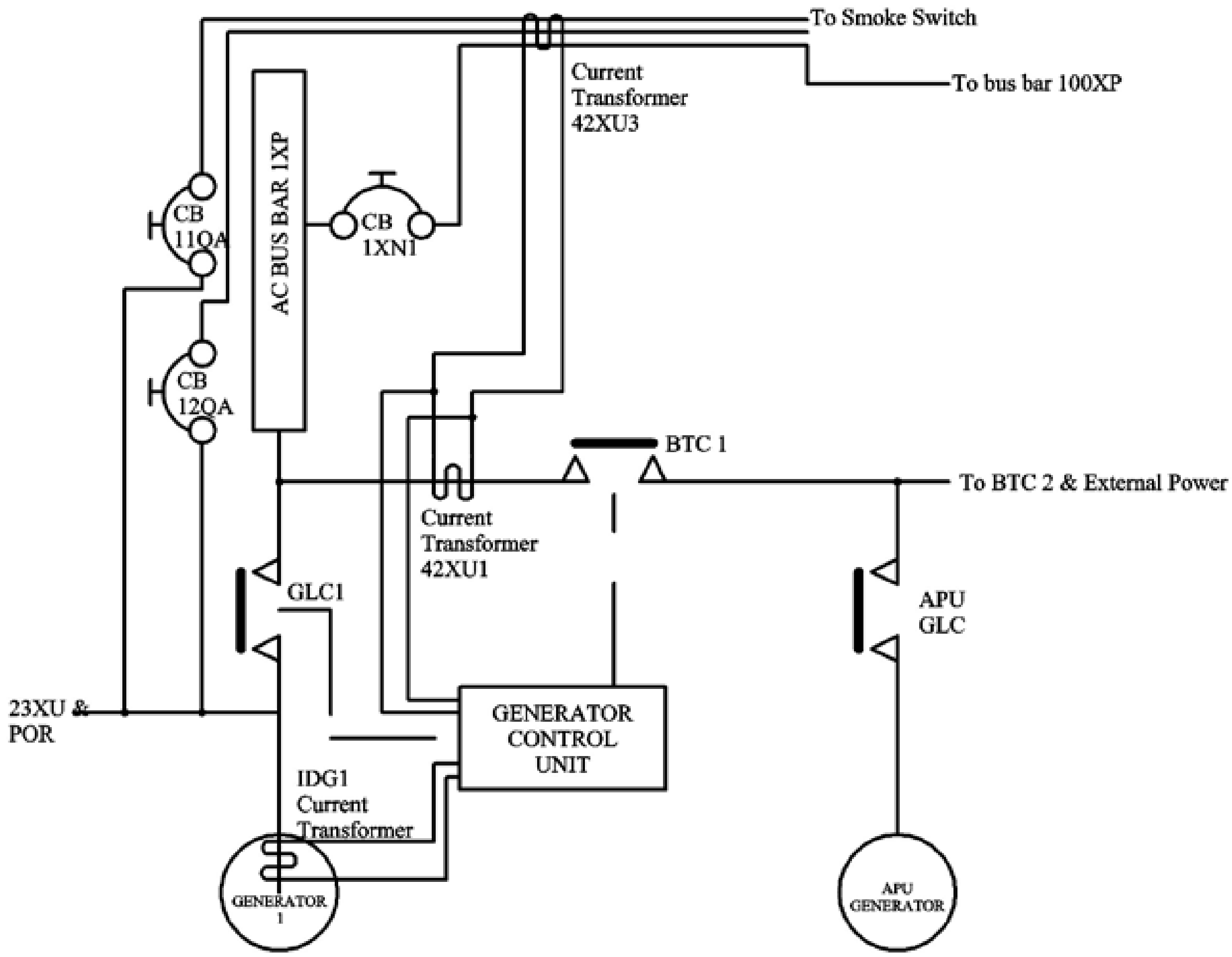

Figure 2

Simplified schematic of network No 1

If the GCU detects a difference in current between CTs of 45 A (+/- 5 A) for more than 37.5 ms (+/- 2.5 ms) then the DP is triggered and both the BTC and GLC controlled by the detecting GCU are opened. After a further 85 ms, the GCU measures the currents at the CTs again and if the difference in current no longer exists then the fault must have been within Zone 2, as the isolation of electrical power to the network has removed the unexpected currents. A DP2 results in the BTC and GLC remaining OPEN and the generator is de-excited. However, if the difference in current at the CTs is still detected, then the fault must have been within Zone 1 as the unexpected current draw must be from the generator. A DP1 results in the GLC remaining OPEN, but the BTC is allowed to CLOSE to connect the affected electrical network to the other engine's generator or the APU generator.

The flight crew can reset a generator fault, such as the GCU DP, by selecting the affected generator switch on the overhead electrical panel to OFF and then selecting it ON again. This reset can only be carried out twice, after which the GCU will prevent any further resets.

If the GCU detects an abnormal average current of greater than 20A at the time the generator becomes excited, and before the GCU closes the GLC, it will trigger the 'welded GLC' protection. This unexpected current is an indication that the GLC may have welded contacts, as a result the generator is de-excited, leading to the loss of power to the associated AC Bus, and a fault message is displayed on ECAM. The flight crew are not able to reset the generator if the GCU has triggered the 'welded GLC' protection.

On the A320 family of aircraft, power from generator No 1, taken upstream of the GLC1, provides electrical power to the fuel pumps in the event of the crew having to carry out the electrical 'Smoke' procedure. This is to avoid the need to gravity feed fuel while the procedure is being undertaken and thus reduces flight crew workload. Protection of this circuit is by CB 11QA[1] and CB 12QA[2] and in normal operation there is no current flowing through these breakers. However, current will flow if the flight crew select the EMER ELEC GEN 1 LIN switch, on the overhead emergency electrical power panel, to OFF during the 'Smoke' procedure. As the power to CB 11QA and 12QA is supplied upstream of the GLC1, it is available whenever generator No 1 becomes excited and is independent of the GLC1 position.

The electrical power network buses are located in the 120VU cabinet, behind the co-pilot. AC Bus 1 and AC Bus 2 are mounted on panel 123VU (Figure 3), with AC Bus 1 to the left and AC Bus 2 to the right (facing forward). Directly below panel 123VU are the electrical contactors and feeder cables from the various generators. Cooling airflow through panel 123VU, and over the contactors, is achieved by the use of 'blowers' that draw air down through the panel via an orifice in the floor. In the event of a failure of AC Bus 1, the resulting ECAM checklist requires the avionic cooling blowers to be set to OVERRIDE, and as a result the forced airflow through cabinet 120VU ceases.

Recorded Information

Data was recovered from the Flight Data Recorder (FDR), Cockpit Voice Recorder (CVR) and the Quick Access Recorder (QAR). The recordings were combined in order to present a time-history of events during the engine start.

Footnote

1 Panel 123VU position AD12 'L WING PUMP 1 STBY SPLY'.
2 Panel 123VU position AE12 'R WING TK PUMP 1 STBY SPLY'.

The FDR recorded engine No 2 starting first, with its associated GLC 2 closing to allow power from the engine generator into network No 2 of the electrical system. A few seconds later, the engine No 1 master lever was selected to ON and the engine began to start. One minute later the FDR recorded a loss of AC Bus 1, the opening of BTC 1, a number of master cautions and a momentary loss of the AC Essential bus. The GLC 1 remained OPEN and the recorded electrical load for generator No 1 remained at zero.

The flight crew acknowledged the loss of the AC Bus 1 and around 70 seconds later, the generator No 1 reset was performed. This lead to an interruption to the CVR power supply but once it resumed recording, a loud interference noise was recorded on all four channels for two seconds. The AC Bus 1 power supply was then restored by the closing of both the BTCs allowing network No 1 to be supplied by generator No 2. At this stage the crew reported smelling smoke and the aircraft returned to its parking stand.

An attempt was made to download the fault memory from the GCU1, however this was unsuccessful, although a test of the unit was satisfactory. Due to the short time between engine start and shutdown, the CFDIU did not recognise this event as a flight and therefore did not record any data in its memory, nor did it produce a post-flight report.

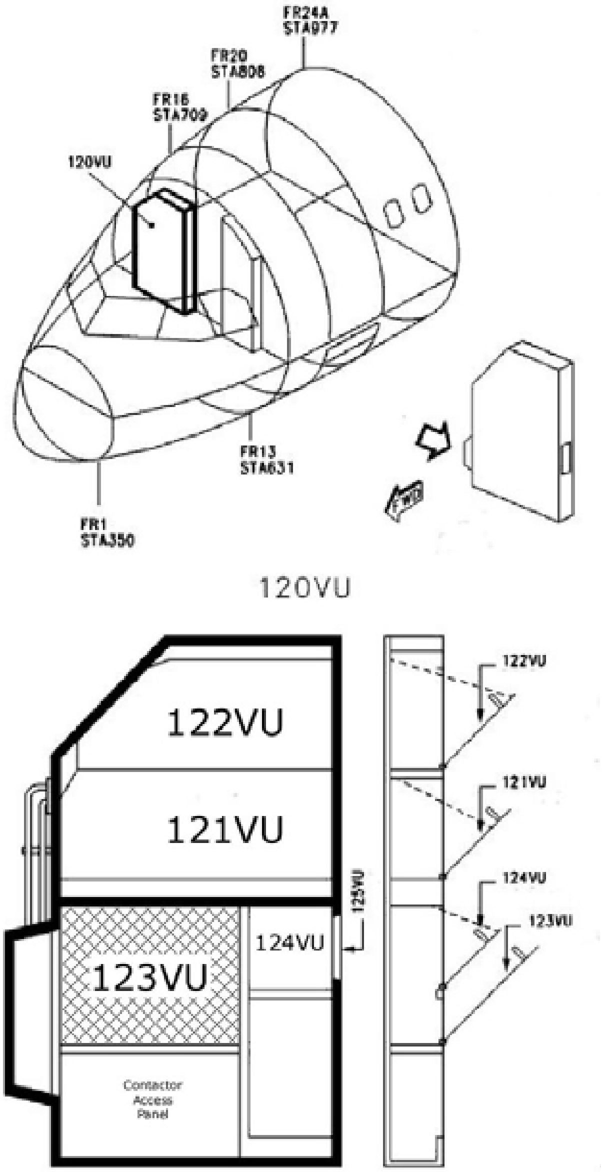

Figure 3

Cabinet 120VU and panel 123VU location

Aircraft examination

A visual inspection of the cockpit and the external faces of the CB panels did not reveal any signs of damage. On the rear right CB panel, 123VU (Figure 3), CB 11QA and 12QA had tripped and on opening the panel there was evidence that significant overheating had occurred, with extensive sooting. The fire damage was centred in the area around CB 11QA with damage to the AC Bus 1 busbar that ran alongside these breakers. (Figures 4 and 5). The busbar had suffered extensive heat damage with areas of melting of the copper terminals.

The aluminium structure directly to the left of CB 11QA had melted, creating a 70 mm by 50 mm hole, with a heat-affected zone extending 150 mm by 100 mm (Figure 6). This had resulted in some light sooting in the area behind panel 124VU.

Figure 4

General view of damage to panel 123VU

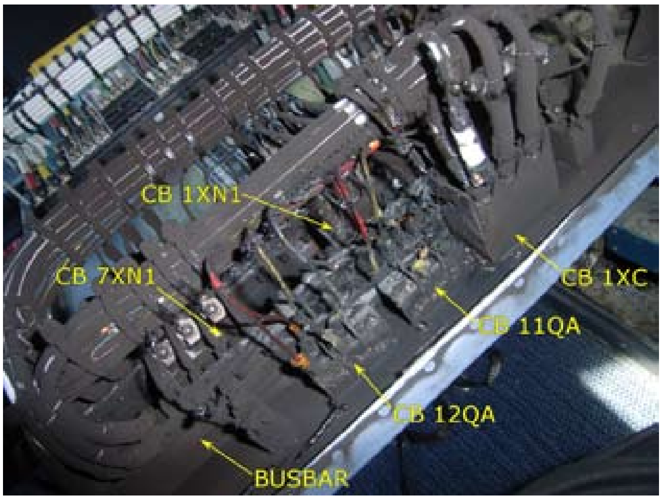

Figure 5

Damage to CB and AC Bus 1 busbar (panel 123VU)

Figure 6

Structural damage outboard of panel 123VU

As a result of the fire, molten debris had dropped down from 123VU and was found in the bottom left corner of the panel and in the area directly below 123VU. The debris had also caused some scorching to the external faces of BTC 1 and GLC 1, which are mounted directly below 123VU.

Detailed aircraft examination

Panel 123VU was removed from the aircraft and taken to a specialist forensic laboratory for a detailed examination under AAIB supervision. The damage to AC Bus 1 was most severe directly behind CB 11QA, with erosion of the busbar terminals and burning and distortion of the busbar insulation material in this area.

There was evidence of damage from arcing and some fibrous deposits between phases on some of the AC Bus 1 exposed connections (Figure 7).

Two exposed terminals on AC Bus 1 had melted and there were 'pin-like' protrusions, which were products of the molten copper (Figure 8). A visual inspection of the unaffected wiring found it to be in a good condition and tests of the wiring did not show signs of degradation that could have caused the electrical faults or the fire. The remaining terminals and connections were found to be correctly installed and the examination did not reveal the presence of foreign objects. All the affected CBs[3] were tested and found to operate within the published specification.

The contactors BTC 1 and GLC 1, their mounting panel and generator No 1, were examined, tested and found to operate satisfactorily.

The soot around the panel consisted of carbon, fluorine, copper and zinc. All of these were consistent with the products of vaporised material and wiring insulation damage from the fire. The debris collected from around and below panel 123VU consisted of molten materials that could be accounted for from the materials used on the panel.

Dust contamination

During the detailed examination of panel 123VU, it became apparent that there was fibrous material, or 'dust', across various exposed busbar terminals. This 'dust' was sampled for its composition and assessed as to whether it could have been a factor in the electrical

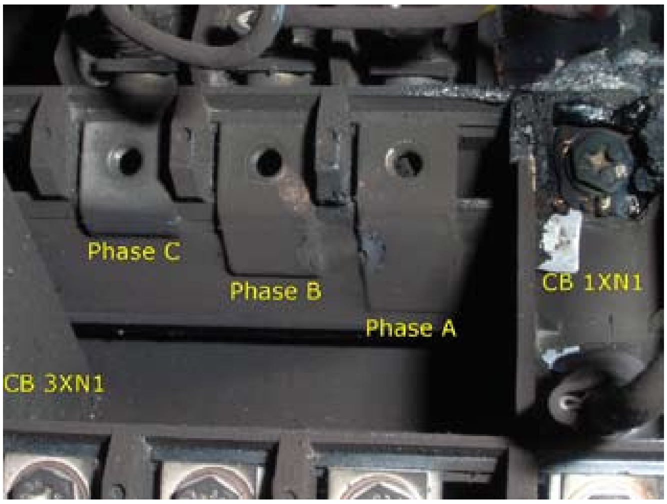

Figure 7

Exposed AC Bus 1 connections

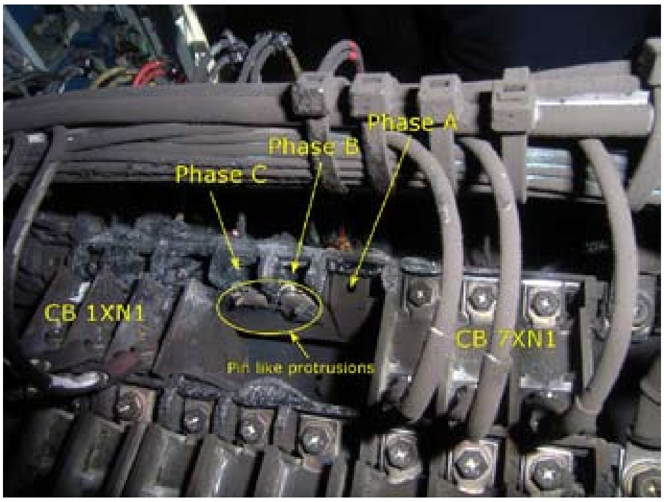

Figure 8

Exposed AC Bus 1 connections – pin-like protrusion

Footnote

3 CBs tested were 11QA, 12QA, 1XC, 1XN1, 23XU1, 7XN1, 3XN1.

faults or the fire. The dust contained fibres, consisting of small mineral fragments and metallic flakes (mainly steel), and organic flakes of skin. Chloride levels in the dust were found to be high, when compared to normal office dust, and the laboratory report commented that this would lead to an increase in its conductivity.

Tracking tests on the dust were carried out[4] in a laboratory. Those tests carried out on 'dry' dust passed, however tests in which a conducting liquid was dropped onto the dust samples, placed on an acrylic sheet, failed with tracking and fire occurring after a few drops. It should be noted that, on examination of G-EUPZ, there was no evidence found of fluid contamination in the area of overheating.

Maintenance history

In January 2009 G-EUPZ underwent a major maintenance input, which included wiring changes and the installation and replacement of CBs in the area of panel 122VU, which is above 123VU. There was also a maintenance record that general cleaning of the wiring looms in the 120VU cabinet had been carried out. Since this maintenance input there were no records of further work or disturbance of the 120VU cabinet.

Electrical Wiring Interconnection Systems (EWIS)[5]

Following the accidents to a Boeing 747-131, N93119, near East Moriches, New York on July 17 1996 and a McDonnell Douglas MD-11, HB-IWF, near Peggy's Cove, Nova Scotia on 2 September 1998, the Federal Aviation Administration commissioned a study ASTRAC[6]) which has led to the Ageing Transport System Program for Electrical Wiring Interconnection Systems (EWIS). As a result the EASA issued changes to Certification Specification (CS) 25, adding Subpart H entitled 'Electrical Wiring Interconnection Systems' in September 2008 and CS 25.1729, which requires instructions for continued airworthiness specifically for EWIS. EASA also issued an 'acceptable means of compliance' document[7] for manufacturers, changes to CS Part M and Part 66 on requirements for personnel and training, and a retrospective requirement for type certificate holders to introduce improved maintenance and zonal inspection programmes of EWIS into the maintenance schedule prior to March 2011.

In May 2007, Airbus introduced changes to their aircraft maintenance planning documents for operators to comply with the EWIS requirements. These recommend the cleaning of the wiring installed in 120VU every 72 months and a general visual inspection of the wiring every 144 months. Aircraft operators are required to introduce these changes into their own approved maintenance schedules by March 2011. The operator of G-EUPZ trained its maintenance staff on the new EWIS maintenance and inspection procedures and introduced the new requirements into their schedule around September 2009.

Analysis

Due to the extent of local fire damage, and the lack of data from the GCU1 and the CFDIU, it was not possible fully to establish the initiating factor for the electrical fire behind panel 123VU. However, based on the available data and the examination of the aircraft, a possible sequence of events has been established, as well as the potential causal and contributory factors.

Footnote

4 Conducted generally, and using test equipment for tests, to BS EN 60112:2003.

5 EWIS means any wire, wiring device, or combination of these, including termination devices, installed in any area of the aeroplane for the purpose of transmitting electrical energy. It includes wires, busbars, connectors and cable ties.

6 Ageing Transport Systems Rulemaking Advisory Committee

7 AMC 20-21 'Programme to enhance aeroplane Electrical Wiring Interconnection System (EWIS) maintenance'.

The damage from the fire was centred on CB 11QA and therefore it is most likely that this was the area where the electrical fault and the subsequent fire had initiated. Prior to the start of engine No 1, AC Bus 1 was being supplied by the APU generator though the closed BTC 1, with no reported faults. As engine No 1 started, generator No 1 started to provide electrical power to CB 11QA. This was prior to the closing of GLC1 and it was at this point that GCU1 detected a fault, causing BTC 1 to open and prevented GLC 1 from closing. This led to the loss of AC Bus 1 power and the associated ECAM fault messages and aural warnings. The electrical system response was indicative of a DP, triggered due to the detection of differing current flows in the electrical network. Following this initial event, BTC1, GLC1 were OPEN and the generator remained de-excited indicating that the GCU had detected a fault in Zone 2, and was either a fault somewhere within the electrical network or erroneous current flows in the network for less than 85 ms.

The only change in the electrical network, at the time of the engine No 1 start, was that its generator feeders and CBs 11QA and 12QA had become powered. These CBs are usually dormant and should not have been flowing any current unless there was a short, a fault with the CBs or the crew had operated the EMER ELEC GEN 1 LIN switch on the overhead panel. It is known that the switch was not operated and tests eliminated the possibility of a fault with the CBs, therefore it was possible that current was able to flow through the CB due to a short.

Following the first detected generator No 1 failure, the crew attempted a reset of the generator, as directed by the ECAM checklist, during which they were aware of a loud noise from behind the CB panel and a faint smell of electrical burning. It was also at this stage that the CVR recorded significant interference, all of which were symptoms of electrical arcing. The GCU had reset the generator, which would have not been possible had it triggered the 'welded' GLC protection.

When generator No 1 first became excited a transient short or a short duration arc may have occurred between CB 11QA and AC Bus 1, thereby causing some localised damage to the wiring and the bus bar, leading to unexpected current flows in the network. At the reset of generator No 1, it was re-excited, electrical power was again fed to CB 11QA and BTC1 closed, restoring power to AC Bus 1. The initial damage may have led to further arcing as the electrical power was restored to the network.

The crew had already completed the ECAM checklist so the avionic cooling blower fan was now in OVERRIDE thereby removing the forced airflow through the 120VU cabinet. The arcing led to a highly ionised atmosphere behind 123VU, which was not dissipated by the airflow and would have contributed to further arcing. Dust was prevalent in the area behind the panel and on exposed phases on the AC bus bars. This would have contributed to the propagation of the fire by providing a combustible material and may also have contributed to the arcing as the 'creepage' distance between terminals was reduced by the contaminant.

From the recorded data it was concluded that the GCU 1 again triggered the DP and as the erroneous currents were still present after the initial 85 ms, evidenced by interference on the CVR for 2 seconds, the fault was probably detected as being in Zone 1. As a Zone 1 fault indicates a fault with the generator or its electrical feeders, the GLC1 remained OPEN, generator No 1 was de-excited, and BTC 1 CLOSED connecting AC Bus 1 to network No 2. Power then remained on AC Bus 1 with no further indication of arcing or fire, so the electrical arcing and the associated fire was short-lived, but it had been very intense with temperatures in excess of 1084°C.

As no other physical reason for the electrical fault could be identified, it was possible that a conducting loose article had caused a short at the time that generator No 1 first came online. No loose article was found in the panel, however, it could have come from a number of sources and it is likely that it vaporised during the initial stages due of the fire. As a result it has not been possible to determine how or when a loose article entered the affected area.

Safety actions

The introduction of the new EWIS requirements, and the associated training, already highlights the need for good housekeeping and cleanliness of electrical connection systems in aircraft; its introduction into scheduled maintenance should reduce recurrence of electrical faults from foreign objects and debris.