Air Accident Investigation Unit Ireland

SYNOPTIC REPORT

SERIOUS INCIDENT
Avions de Transport Régional
ATR 72-212A, EI-FCY
Cork Airport

24 August 2016

An Roinn Iompair
Turasóireachta agus Spóirt
Department of Transport,
Tourism and Sport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

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[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI 460 of 2009, the Chief Inspector of Air Accidents on 26 August 2016, appointed Mr Howard Hughes as the Investigator-in-Charge to carry out an Investigation into this Serious Incident and prepare a Report.

Aircraft Type and Registration:	ATR 72-212A, EI-FCY	
No. and Type of Engines:	2 x Pratt & Whitney Canada PW127M	
Aircraft Serial Number:	1129	
Year of Manufacture:	2013	
Date and Time (UTC)[4]:	24 August 2016 @ 08.40 hrs approximately	
Location:	52NM East of Cork Airport (EICK)	
Type of Operation:	Commercial Air Transport, Scheduled - Passenger	
Persons on Board:	Crew - 4	Passengers - 59
Injuries:	Crew - Nil	Passengers - Nil
Nature of Damage:	None	
Commander's Licence:	ATPL[5], issued by the Irish Aviation Authority	
Commander's Age:	39 years	
Commander's Flying Experience:	7,210 hours, of which 6,850 were on type	
Notification Source:	Airport Duty Manager, EICK	
Information Source:	AAIU Field Investigation, AAIU Report Form submitted by the Pilot	

[4] **UTC**: Co-ordinated Universal Time. All times in this Report are quoted in UTC; to obtain Local Time add one hour.
[5] **ATPL**: Airline Transport Pilot Licence

SYNOPSIS

The aircraft was on a scheduled passenger flight from Birmingham Airport (EGBB), United Kingdom, to Cork Airport (EICK), Ireland. The flight was uneventful until just before the aircraft began its descent into Cork, at which point the Flight Crew received a Master Caution, triggered by two electrical faults. This was followed by a Master Warning associated with electrical smoke and by the sight and smell of smoke in the cockpit. The Flight Crew donned their oxygen masks, declared an emergency (Mayday) to Air Traffic Control (ATC), and carried out the SMOKE Checklist memory actions. Non-normal checklists associated with Smoke, Electrical Smoke, and associated electrical failures were also completed, including the Manual Gear Extension checklist. The smoke cleared and the aircraft landed normally. There were no injuries.

1. FACTUAL INFORMATION

1.1 History of the Flight

EI-FCY departed EGBB at 07.35 hrs on a scheduled passenger service to EICK. The flight was uneventful until approximately 52 NM east of EICK, when the Flight Crew received a Master Caution advising them of 'AC Bus 2' and 'Static Inverter 2' faults, followed a few seconds later by a Master Warning for electrical smoke. The Flight Crew then became aware of the smell and visible signs of smoke in the cockpit. On the Commander's instruction the Flight Crew immediately donned their Oxygen Masks and the Co-Pilot transmitted a Mayday message to ATC at EICK. The Flight Crew then commenced the SMOKE Checklist memory actions.

Once the SMOKE memory items were complete, the Commander called for the Quick Reference Handbook (QRH) and the Flight Crew confirmed the memory actions had been completed. The Flight Crew then continued with the SMOKE non-memory items, the first item of which directed them to identify the source of the smoke. As the Engine and Warning Display (EWD) had displayed 'ELEC SMK' (electrical smoke), and both Flight Crew members had seen smoke and identified it as electrical from its smell and location, the Flight Crew continued with the Electrical Smoke checklist. This checklist included instructions to switch off both AC Wild (ACW) generators, to land as soon as possible, and to apply the ACW Total Loss Procedure.

As the Electrical Smoke checklist was being completed, the sight and smell of electrical smoke dissipated, and the ELEC SMK warning was no longer displayed on the EWD. The Flight Crew elected to remove the oxygen masks. At the same time the No. 2 CCM, who was stationed at the front of the passenger cabin, called the cockpit on the aircraft interphone. The No. 2 CCM told the Commander that she had briefly *'got a funny smell'* in the forward cabin area, just aft of the cockpit door. The Commander briefed the No. 2 CCM that the cause of the smoke appeared to be electrical, and that the Flight Crew were completing the relevant checklists. The Commander also informed the No. 2 CCM that the intention was to continue to EICK, and that she (the Commander) would give a more detailed briefing to the No. 1 CCM shortly.

Once the ACW Total Loss checklist had been completed the Commander handed control of the aircraft to the Co-Pilot and informed ATC at EICK regarding the nature of the occurrence, that the smoke had dissipated, and that it was her intention to continue to land at EICK. As both ACW Generators had been switched off in accordance with the Electrical Smoke checklist, neither main hydraulic pump was powered. This resulted in the requirement to perform a manual landing gear extension. The Commander briefed ATC on this, and informed them that an extended final approach would be required.

The Commander called the No. 1 CCM to the cockpit and gave a NITS[6] briefing, outlining that it was her intention to continue to land at EICK, that the smoke had stopped, and for the Cabin Crew to expect a normal landing.

The flight landed at 09.05 hrs and the aircraft taxied onto stand where the passengers disembarked normally.

1.1.1 Interview with Commander

1.1.1.1 General Observations

During an interview with the Commander she noted the following:

- At the same time the EWD indicated 'ELEC SMK' the Commander noticed smoke in the cockpit.
- It had an electrical burning smell, and the Commander saw it coming from the electrical panel behind the Co-Pilot's seat.
- The Co-Pilot informed her that he could see some smoke from the electrical panel behind the Commander's seat.
- As the EWD had displayed ELEC SMK, and both pilots had seen smoke and identified it as electrical from its smell, the Flight Crew continued with the Electrical Smoke checklist.
- As this checklist was being completed, the sight and smell of smoke dissipated, and the ELEC SMK warning was no longer displayed on the EWD so the Commander determined that it was safe to remove the oxygen masks.
- At this time the No. 2 CCM, at the front of the cabin, called the cockpit to inform the Commander that she had briefly got a funny smell at the front of the cabin. The Commander then briefed the No. 2 CCM on the situation, told her that they were in the process of completing checklists, that the flight would be continuing on to Cork, and that she (the Commander) would make contact with the cabin crew shortly.
- The precise source of the smoke could not be determined, especially as the Flight Crew had seen smoke coming from both electrical panels, and the cabin crew had smelled smoke from the forward section of the aircraft.

[6] **NITS Briefing**: Many airlines use an acronym as an aid when briefing cabin crew during non-normal situations to help simplify the communication exchange. One example is the use of a ***NITS brief*** which includes; **N**ature of the problem, **I**ntention (of the Commander), **T**ime available (for the cabin crew to prepare the aircraft for landing), **S**pecial instructions for the Cabin Crew, if required.

- The No. 1 CCM informed the Commander that the smell of smoke had been localised to just the forward area around the No. 2 CCM seat, no passenger had noticed any smoke, and the immediate signs of smoke had dissipated.

1.1.1.2 Specific Concerns

The Commander informed the Investigation that as the Electrical Smoke checklist had directed the Flight Crew to switch off ACW Generators 1 and 2, the Flight Crew now had to apply the ACW Total Loss procedure[7]. This action resulted in the loss of both main hydraulic systems, but the Commander noted that she had expected the Auxiliary Hydraulics to operate normally as the Blue hydraulic system was lost as result of switching the ACW 1 off, and not as a result of loss of hydraulic fluid.

The Commander also informed the Investigation that one consequence of losing both main hydraulic systems, was that the landing gear would require gravity extension. As a result, the Commander said she requested a longer final approach to give time to carry out these additional tasks. ATC facilitated this request. She told the Investigation that once extended by gravity extension, the landing gear could not be retracted. The Commander also noted that following the loss of main hydraulics:

- Aircraft braking would be from emergency brake accumulator pressure only
- Flaps would require Auxiliary Hydraulics for extension
- And that the Auxiliary Hydraulics would only become available following gear extension.

The Commander told the Investigation that a significant portion of the aircraft's Ice and Rain Protection was lost as a result of switching off ACW 1 and 2. But she said that she did not expect this to affect the occurrence flight, given the forecast and actual conditions prevailing that morning.

The Commander noted an additional high workload associated with the performance of the ACW Total Loss checklist and the reduced availability of certain systems.

1.2 Personnel Information

1.2.1 Aircraft Commander

Pilot's Age:	39 years
Licence:	ATPL issued by IAA
Total as Pilot in Command:	4,230 hours
Total on type:	6,850 hours

[7] The Investigation noted that the QRH in use on the date of the event referenced the *'ACW TOTAL LOSS procedure'* as QRH number 2.22. The correct reference number was 2.23. This had no effect on checklist usage by the subject Flight Crew as they referenced the correct QRH item by Title. However this incorrect Reference Number in the QRH was brought to the attention of the Manufacturer by the Operator and an amendment was issued to the QRH.

1.2.2 Co-Pilot

Pilot's Age:	33 years
Licence:	CPL issued by UK CAA
Total as Pilot in Command:	115 hours
Total on type:	1,892 hours

1.3 Aircraft Information

1.3.1 General

The ATR 72 is a twin-engine turboprop short-haul regional airliner. EI-FCY was configured with seating for 72 passengers, and with a complement of two cabin crew members. As was usual practice for this operation, the No. 1 CCM was stationed at the rear of the aircraft cabin and the No. 2 CCM was stationed at the front of the aircraft cabin.

The aircraft has four electric generators, two driven by each engine.

1.3.2 Main Electrical System

Most of the electrical needs of the aircraft are supplied by the two direct current (DC) generators (GEN) – engine 1 drives DC GEN 1 and engine 2 drives DC GEN 2. DC GENs 1 and 2 supply DC Buses 1 and 2 respectively. Each DC Bus also supplies DC current to two static inverters which in turn provide constant frequency alternating current (AC) at 440 Hz to AC Buses 1 and 2.

Each static inverter normally operates at half its rated power so that one static inverter can supply the whole electrical network through a bus-tie contactor in the event that the other static inverter fails.

1.3.3 AC Wild Electrical System

In addition to the Main Electrical System, the ATR 72 has two AC Wild Generators (each driven by its respective engine), that provide variable-frequency alternating electrical power. ACW GEN 1 supplies ACW Bus 1 and ACW GEN 2 supplies ACW Bus 2.

A variable-frequency, or frequency-wild, system is one in which the frequency of its generator voltage output is permitted to vary with the rotational speed of the generator. Although such frequency variations are not suitable for the operation of all types of AC equipment, the output can be applied directly to resistive load circuits such as electrical de-icing systems.

In the case of the subject aircraft, the following systems were powered by the AC Wild electrical system:

ICE & RAIN PROTECTION SYSTEMS[8]:
- Ice Detector
- Commander and Co-Pilot Pitot Probe Heating
- Commander and Co-Pilot Angle of Attack Vane Heating
- Commander and Co-Pilot Total Air Temperature Probe Heating
- Left and Right Windshield Heating
- Anti-Icing of Aileron, Elevator and Rudder Balance Horns
- Anti-Icing of Propellers 1 and 2

HYDRAULIC SYSTEM:
- Main Blue and Green Hydraulic Pumps

ELECTRICAL POWER:
- Transformer Rectifier Unit

LIGHTS:
- Taxi and Take-Off Lights
- Landing Lights (all)
- Strobes Lights (all)
- Flight Compartment – Overhead (Integrated Instrument and Panel)

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All of the above systems are de-powered, and unavailable, when the ACW generators are switched off as part of the Electrical Smoke checklist.

1.3.4 Avionics Smoke Detection

Included in the aircraft's Fire Protection System is the capability to detect smoke in the avionics ventilation circuit. To achieve this, the avionics extract air duct is equipped with a single smoke detection device (ionisation type) located in the duct between the avionics compartment and the avionics air extract fan. The smoke detector is linked to the Fire Warning System, and activates an ELEC SMK red alert on the EWD when smoke is detected. Visual and aural alerts are:

- Master Warning light flashing red
- Aural alert, a Continuous Repetitive Chime
- ELEC SMK red message on the EWD
- ELEC SMK red reverse video message on cabin System Display page.

As the smoke detector is located in the extract duct of the avionics bay, and is monitoring air from the Electric Rack, Electronic Rack and Flight Deck Electrical and Electronic Equipment, smoke detected could be from component(s) in any of these areas. A schematic diagram of the avionics ventilation air circuit is shown in **Figure No. 1**. A note in the QRH cautions flight crew that air conditioning smoke may also trigger an electrical smoke warning.

[8] Note: The pneumatic de-icing system remained fully operational with regard to de-icing of wings, horizontal stabilisers and engine air intakes.

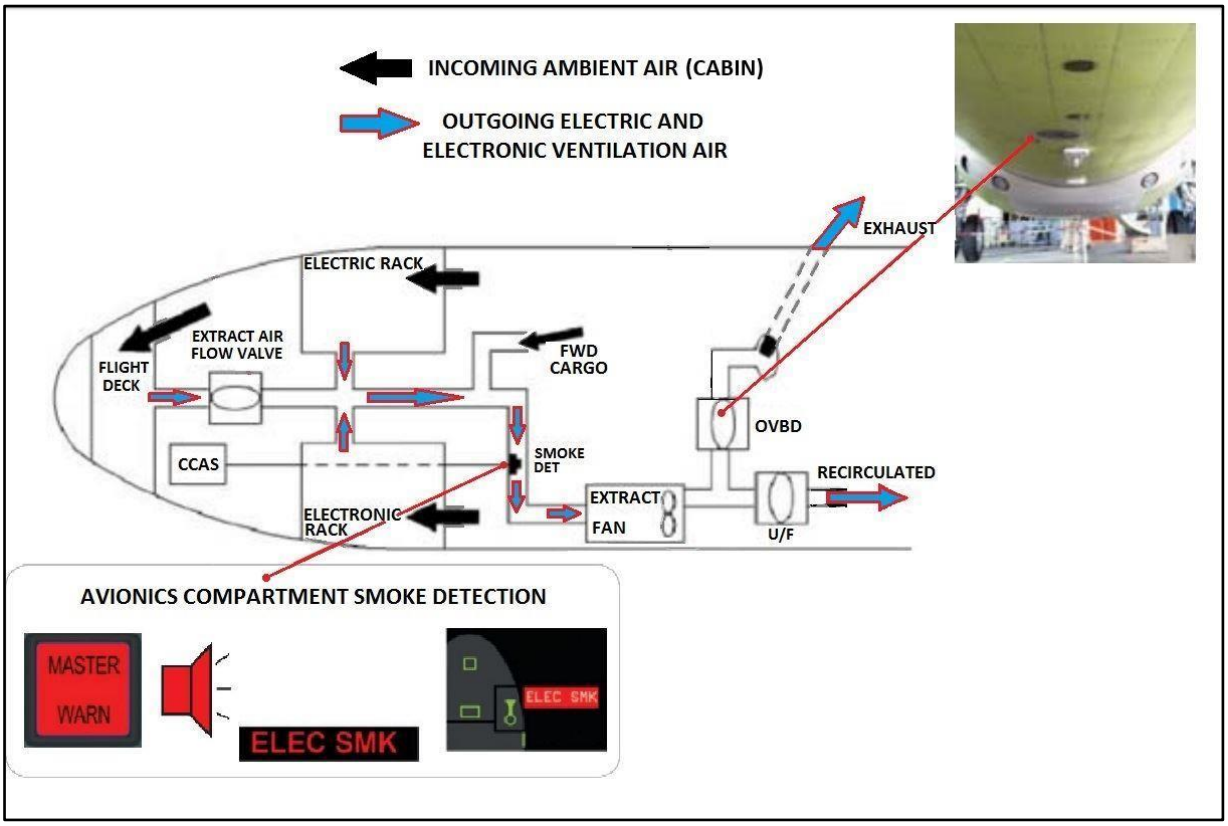

Figure No. 1: Schematic of Avionics Ventilation Air

1.3.5 Hydraulic Systems

The ATR 72 has two hydraulic systems, termed Green and Blue.

The Green system is pressurised by an electric pump powered by the ACW 2 bus bar. It allows the extension and retraction of the landing gear, as well as normal braking.

The Blue system has two electric pumps. During normal operation, the blue system is pressurised by a main electric pump powered by the ACW 1 bus bar. It operates the flaps, ground steering control, emergency brake and the propeller brake.

There is also a Blue Auxiliary hydraulic pump that is electrically powered from DC Bus 2. This pump is used to pressurise the blue hydraulic system in the event of loss of main blue system pressure. It will operate provided that all of the following conditions coexist:

- Its associated push button switch in the cockpit is selected to AUTO
- The blue hydraulic pump pressure is less than 1500 psi
- The propeller brake is released
- The landing gear lever is selected DOWN
- At least one engine is running.

The aircraft's emergency braking system has an accumulator allowing six brake applications in case of loss of the three hydraulic pumps.

1.3.6 Airworthiness Review Certificate (ARC)

EI-FCY was issued with an ARC which was due to expire on 3 April 2017.

1.4 Meteorology

1.4.1 Surface Actual Conditions at EICK

Report Time	09.00
Surface Wind	220 degrees at 4 kts[9]. Varying between 170 and 270 degrees
Visibility	In excess of 10 km
Cloud	FEW Cloud at 2,100 Scattered Cloud at 25,000
Surface Temp / Dew point	15/11
Mean Sea Level Pressure	1022 hPa[10]
Expected change	None expected over the next two hours

1.4.2 Expected Frequency of Icing Conditions

Various articles on the subject of probability of aircraft icing have been published which indicate a high probability of encountering icing conditions in Europe, especially during winter months. During these months the chances of encountering icing conditions may be as high as 45%.

> *'Icing is found most often in places where overcast skies are common* […] *and the clouds have a combination of ideal temperatures within them and at their tops. The locations of the primary SLD[11] maxima are ones where icing clouds with relatively clean source air are expected. These are usually downstream of large fetches of airflow over oceans. Iceland, western Norway, and* [Ireland] *are excellent examples, since their predominant wind directions come off the Atlantic and Arctic Oceans. Such clean source air was found to be conducive to the formation of FZDZ* [freezing drizzle] […].
>
> *Short-range commuter aircraft, in particular, have a good chance of encountering icing and even SLD conditions during flights over Europe. Such aircraft complete many flights per day, and because of their short routes, spend a relatively large percentage of their flight time at altitudes below 20,000 ft where nonconvective icing and SLD are most common[12]'.*

[9] **kts**: Knots (Nautical Miles per Hour)
[10] **hPa**: Hectopascal
[11] **SLD**: Supercooled Large Droplets.
[12] '*An Inferred European Climatology of Icing Conditions, Including Supercooled Large Droplets*' Office of Aviation Research Washington, D.C. 20591. Final Report, June 2005.

1.5 Aircraft Examination

The aircraft was examined by the Operator's technical staff at EICK subsequent to the event. This identified the source of smoke and fumes to be the number 2 static inverter. The number 2 static inverter was removed and retained for further examination by the Investigation. A replacement unit was installed and the aircraft returned to service.

1.6 Static Inverter Examination

1.6.1 General

The Original Equipment Manufacturer (OEM) of the static inverter used a modification status letter code to denote the level of modification that applied to the unit. The subject static inverter was found to be at MOD LVL "B".

1.6.1.1 Service Bulletin

The OEM had issued a Service Bulletin (SB) in June 2016 upgrading in-service static inverter units to MOD LVL "E". The action required was '*a recommended change'* and stated:

> *'Operators may review their installation records and identify inverters not identified as MOD E or above. Once identified, operators may contact ATR to coordinate return to* [the OEM] *to arrange for the Static Inverter to be upgraded to MOD E'.*

The SB gave three reasons for the change, all of which were regarded as '*Product improvement*', the third of which stated: '*Product improvement of the unit output capacitor, C311 for increased reliability*'. The Classification of Change was stated as '*CLASS II and is a recommended change*'.

1.6.2 Examination of the Static Inverter

The Investigation arranged for the failed static inverter to be sent to the OEM of the unit for examination.

The OEM conducted an engineering examination of the failed static inverter. The OEM produced a Failure Analysis Report which found that the failure of the number two static inverter and associated smoke and odour was caused by a failure of the C602 (1-001-0306-0136) capacitor within the number two static inverter (**Photo No. 1)**.

The OEM report noted that previous occurrences of static inverter failure had been caused by failure of the C311 capacitor. Testing of the C311 capacitor fitted to the subject static inverter determined that it was serviceable.

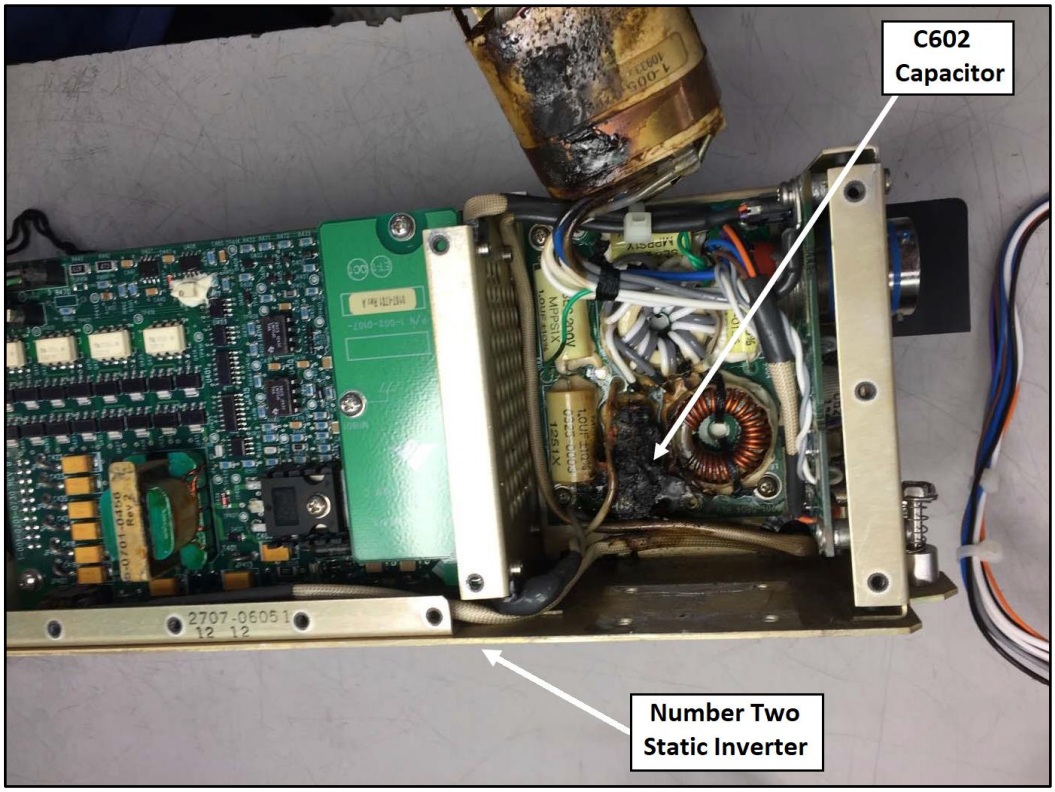

Photo No. 1: Static Inverter showing location of failed capacitor (C602).

1.6.3 Other Static Inverter Failures

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The Aircraft Manufacture was asked for details of other static inverter and electrical failure events resulting in smoke in the cockpit. The Manufacturer informed the Investigation that since 1989 there has been the following reported[13] events which either involved triggering of the ELEC SMK warning and/or detectable smoke in the cockpit:

- 68 events where the ELEC SMK warning triggered (all causes)
- 21 events where the ELEC SMK warning triggered and the root cause was static inverter Failure
- 28 events where smoke was reported in cockpit and the root cause was static inverter Failure.

The Manufacturer noted that there were a total of 49 occurrences for which smoke or smell of smoke was reported (with or without the ELEC SMK warning being triggered) and the root cause was identified as the failure of a static inverter.

The Aircraft Manufacturer informed the Investigation in February 2017 that the smoke event on EI-FCY was the first reported case where a C60X[14] capacitor failure had occurred without any obvious failure of the C311 capacitor. Subsequently, the Investigation has been informed that there have been a number of new cases of smoke due to C60X capacitor failure.

[13] The Manufacturer stated that '*The figures presented come from our technical incident database which is part of ATR continued airworthiness activity and relies on operators event reports*'.
[14] Where 'X' denotes any of the C600 series of capacitors used in the static inverter.

In addition, given the number of static inverter failures with smoke, the Operator asked the Aircraft Manufacturer if this might become the subject of an Airworthiness Directive. In response the Aircraft Manufacturer stated that no AD was planned.

The Operator further enquired of the Manufacturer if priority might be given to it receiving replacement static inverters with upgraded capacitors. The Manufacturer responded in January 2017 as follows:

> *'*[there are] *5 airlines which have experienced more than 3 smoke/burning smell in cabin over the last twelve months, and* [the Aircraft Manufacturer] *decided to address these airlines prior to other airlines'.*

1.7 Actions Taken by the Aircraft Manufacturer

During the Draft Report comment phase, the Aircraft Manufacturer informed the Investigation that:

> '*Since 2015 there were an increasing number of static inverter failures associated with smoke were reported to* [the Aircraft Manufacturer]*. The subject was* […] *in the process of Continued Airworthiness and Safety. All the events were reported to EASA and regular actions have been taken since to mitigate these events associated with* [Aircraft Manufacturer], *communications to customers through AOMs (All Operators Message), Retrofit letter, TPS (Technical Progress Status) as well as the OEM Service Bulletin publications*. *Actions included an audit of the supplier.*
>
> *In April 2017, the rate of occurrence of "smoke events associated with static inverters" was still compliant with the safety objectives as per the failure classification "Major" i.e. 1x10*$^{-5}$*.*
>
> *In June 2017, in the frame of the continued airworthiness process,* [the Aircraft Manufacturer] *raised an Airworthiness Review Sheet* (ARS) *to EASA to address a potential unsafe condition.* [The Aircraft Manufacturer] *presented the mitigation means that had been already taken and that* [would] *be taken to address the static inverter failure with smoke with which EASA agreed.*
>
> *As of June 2018, all the actions taken by* [the Aircraft Manufacturer] *and the OEM were effective to reduce the rate of occurrence of static inverter failure with smoke and to establish a decreasing trend. As a result, the related Airworthiness Review Sheet was closed in agreement with EASA in June 2018'.*

1.8 EASA Definitions and Classifications

1.8.1 General

The Investigation noted that the Commander felt there was an additional high workload associated with the performance of the ACW Total Loss checklist and the reduced availability of certain systems. Increase in crew workload and probability of failure must be taken into account when examining aircraft system design.

1.8.2 Definition of Unsafe Condition

AMC 21.A.3B (b) [15], which defines when an unsafe condition may exist, notes that: *Although having less severe immediate consequences* […] *the referenced events may reduce the capability of the aircraft or the ability of the crew to cope with adverse operating conditions to the extent that there would be, for example, a significant reduction in safety margins or functional capabilities, a significant increase in crew workload,* […]*'.*

1.8.3 Failure Condition Classifications and Probability Terms

Effect on Flight Crew	No effect on flight crew	Slight increase in workload	Physical discomfort or a significant increase in workload	Physical distress or excessive workload impairs ability to perform tasks	Fatalities or incapacitation
Allowable Qualitative Probability	No Probability Requirement	<--Probable-->	<--Remote--->	<- Extremely-> Remote	Extremely Improbable
Allowable Quantitative Probability: Average Probability per Flight Hour on the Order of:	No Probability Requirement	<----------> $<10^{-3}$	<----------> $<10^{-5}$	<----------> $<10^{-7}$	$<10^{-9}$
Classification of Failure Conditions	No Safety Effect	<----Minor---->	<----Major---->	<-Hazardous->	Catastrophic

Table No. 1: Part of table from EASA Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes, CS-25, Amendment 18, 22 June 2016

EASA informed the investigation that the Aircraft Manufacturer had been in communication with them in respect of smoke from static inverter failure events, and that the Aircraft Manufacturer had issued an Airworthiness Review Sheet (ARS) specific to this issue. The status of this ARS was reviewed at regular intervals by EASA.

EASA informed the Investigation that following *'the ARS review, the safety consequence of a Static Inverter failure including emission of smoke is classified "MAJOR" and the number of events is commensurate with the safety objective. For this reason, per EC regulation 748/2012 – paragraph 21.A.3 - the retrofit is not subject to mandatory corrective (AD) action*'.

[15] **AMC 21.A.3B (b)** of European Aviation Safety Agency document, 'AMC and GM to Part 21' Acceptable Means of Compliance and Guidance Material for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations, Issue 2, 30 October 2012, Annex I to ED Decision 2012/020/R

1.9 Actions Taken by the OEM

The OEM's Failure Analysis Report also noted that '*until recently,* [the OEM] *has not required burn-in*[16] *screening'* [of the capacitors involved in this failure]. The report went on to state that '*specifications for each of these capacitors have subsequently been upgraded to include the burn-in screening process'*. An SB issued in May 2017 stated:

> *'Product improvement to the Static Inverter upgrades the unit from "MOD E" to "MOD F" which replaces capacitors C601 through C605 with new capacitors that have had additional quality screening (i.e. burn-in)'.*

Furthermore, in SB number 1-002-0102-2573-24-44, dated November 2017, the OEM stated that static inverters could be further upgraded. The upgrade involved a change of part number from -2173 to -2573, and included a change to a '*burn-in*' screening of an additional capacitor (C1006). The SB also stated: '*In addition, the replacement capacitor manufacturer has replaced the previous manufacturer on all* [Aircraft Manufacturer] *products'.*

1.9.1 Static Inverter Upgrade

The Aircraft Manufacturer was asked how many static inverter units required upgrading to bring them to a modification standard that incorporated the new capacitors. The Investigation was informed that the '*number of affected units is approximately 1,000*'. The Aircraft Manufacturer informed the Investigation that, in conjunction with the OEM, it had put in place a retrofit capability of 20 units per month until April 2018. This capability was increased, on request of the Aircraft Manufacturer, to 40 units per month from May 2018.

1.9.2 Static Inverter Failure Trend

EASA informed the Investigation that it had monitored the number of static inverter failures, including those with smoke emissions, and that there was a decreasing trend.

1.10 Checklists Associated with the Occurrence

This section should be read in conjunction with **Appendix A**, where the relevant QRH pages are reproduced.

Once the Flight Crew realised that there was smoke in the cockpit the Commander ordered the commencement of the SMOKE checklist (**Appendix A, Figure No. 1**). The first five items of the SMOKE checklist are bounded by a black box, to indicate that these items are to be done from memory.

Once the Flight Crew had completed the initial checklist items, they were then directed to follow the Electrical Smoke checklist '*If source not identified or electrical smoke suspected*'. The Flight Crew had both seen and smelled the presence of electrical smoke and received a Master Warning and EWD displaying ELEC SMK. Thus the Flight Crew continued by carrying out '*ELECTRICAL SMOKE procedure (1.08)…….APPLY*' (boxed in red in **Appendix A, Figure No. 1** for emphasis).

[16] **Burn-in**: A process by which components are subjected to known (electrical) loads prior to a system being assembled from those components.

The Electrical Smoke checklist is reproduced as **Appendix A, Figure No. 2**. This checklist directed flight crews, that '*If smoke origin not identified*', then to Land As Soon as Possible (LAND ASAP), and to apply the ACW TOTAL LOSS procedure. The Commander noted that as they had seen smoke emanating from both electrical panels behind the Flight Crew seats, and that the Cabin Crew had smelt smoke in the forward area of the cabin, they were not in a position to identify the origin of the smoke with certainty.

The Operator was asked by the Investigation if any guidance was supplied by the Aircraft Manufacturer to assist flight crew to accurately identify smoke origins upon receipt of an ELECTRICAL SMOKE warning. The Investigation was informed that there was no additional guidance provided by the Aircraft Manufacturer.

The Operator was also asked by the Investigation if any guidance was supplied by the Aircraft Manufacturer to assist flight crew to identify systems to which power could be safely restored following the ELEC SMK checklist item to switch ACW off. The Investigation was informed that there was no additional guidance provided by the Aircraft Manufacturer.

The Flight Crew proceeded to carry out the ACW Total Loss checklist, as directed by the ELEC SMK checklist, which is shown in **Appendix A, Figure No. 3**.

The ACW Total Loss checklist warns the flight crew of the need to avoid icing conditions, to monitor ice accretion and to periodically check airspeed and altitude indications on the primary flight displays with those of the Integrated Electronic Standby Instrument (IESI), which becomes the reference instrument. In addition, the ACW Total Loss checklist also informs flight crew of the systems affected, including normal landing gear extension, and normal braking. In these circumstances, landing gear extension requires the use of the 'Landing Gear Gravity Extension' checklist, which is shown in **Appendix A, Figure No. 4.**

2. ANALYSIS

2.1 General

Following the indication of a fault with the AC Bus 2 and Static Inverter 2, the Flight Crew received a Master Warning for Electrical Smoke. This was accompanied by the sight and smell of electrical smoke from the electrical panels behind each pilot and a report from the No. 2 CCM at the front of the aircraft of a burning smell.

The Flight Crew then donned their oxygen masks and followed the appropriate checklists and procedures associated with:

- Smoke
- Electrical Smoke
- ACW Total Loss
- Landing performance review and calculation
- Landing Gear Gravity Extension
- Loss of normal braking
- Briefing Cabin Crew on nature of emergency.

The Commander noted the high workload associated with the total loss of ACW generators, including the need to continuously cross reference main flight instruments with the standby IESI due to loss of all main electrical anti-icing functions when the ACW generators were switched off as part of the Electrical Smoke checklist.

In addition, the Commander had to consider the commitment to extend the landing gear by gravity extension, as once extended, it could not be retracted. This had implications for aircraft performance, including additional fuel consumption – a particular concern in the event of a diversion. All checklists and associated procedures were carried out and the aircraft landed safely and taxied to the airport ramp, where the passengers deplaned normally.

Information provided to the Investigation by both the Aircraft Manufacturer and the Operator, indicated that there had been a significant number of static inverter failures with emission of smoke on the aircraft type. The number had been increasing since 2015, and all events were reported to EASA.

2.2 Cause of the Smoke

Workshop examination of the number 2 static inverter showed that a C602 capacitor within the unit had failed in a manner that resulted in electrical smoke being emitted from the unit.

This smoke entered the avionics ventilation air flow and was detected by the avionics smoke detector installed in the avionics extract air duct, triggering the associated Master Warnings. The smoke also entered the cockpit and forward cabin, where it was noticed by the Flight Crew and No. 2 CCM.

2.3 Determination of Smoke Source

The Flight Crew were presented with visible smoke in the cockpit which they identified as electrical smoke. Due to the location from where the smoke appeared, coupled with a report from the cabin of an unusual odour, it is understandable that the Flight Crew followed the 'If Smoke Origin Not Identified' section of the Electrical Smoke checklist, which required the Flight Crew to switch off, amongst other things, the ACW generators.

Whilst the Electrical Smoke checklist contains an option for flight crew to '*restore unaffected equipment*', the Investigation was informed that no guidance is available to flight crew on determining '*unaffected equipment*'. Given the incidence of occurrences similar to the subject event and the associated high workload, the Investigation is of the opinion that additional specific guidance material should be made available to flight crew for events involving electrical smoke due to static inverter failure. This might be best achieved by consultation with operators of the aircraft type. The Investigation thus makes the following Safety Recommendation to the Aircraft Manufacturer:

Safety Recommendation

Avions de Transport Régional should consider consulting with operators of the ATR 42/72, as to the possibility of providing specific guidance to flight crew on re-instating electrical supply to unaffected equipment for essential services following use of the Electrical Smoke checklist, subsequent to a Static Inverter failure.
(**IRLD2018011**)

2.4 Actions Taken

The actions taken by the Aircraft Manufacturer and the OEM have been monitored by EASA. The actions taken had successfully reduced the occurrence rate, and the ARS raised by the Aircraft Manufacturer was closed in agreement with EASA.

EASA informed the Investigation that it had taken into consideration the additional workload of flight crews during such an occurrence when determining the failure condition classification. EASA stated it therefore classified static inverter failures with smoke emission as "MAJOR" and that the number of events is commensurate with the safety objective.

EASA have stated it will continue to monitor the subject. Consequently no Safety Recommendation is made in this regard.

3. CONCLUSIONS

(a) Findings

1. Both Flight Crew members were appropriately licensed.

2. The airworthiness certification for the aircraft was valid.

3. Just prior to descent, the Flight Crew received a Master Caution triggered by two electrical faults, an AC Bus 2, and an Inverter 2 fault.

4. This was followed immediately by a Master Warning for Electrical Smoke and the sight and smell of smoke in the cockpit.

5. The Flight Crew donned their oxygen masks and declared a Mayday.

6. The Flight Crew performed the Smoke, Electrical Smoke and Loss of ACW Total Loss checklists.

7. The Flight Crew, informed ATC of the nature of the emergency, and requested landing in Cork.

8. The Commander briefed the Cabin Crew using a NITS briefing format.

9. During the descent the smoke dispersed, and the Flight Crew removed their oxygen masks.

10. The Flight Crew had a significant additional workload associated with switching off both ACW generators as part of the Electrical Smoke Checklist.

11. Electrical power was lost to most of the electrical anti-icing equipment due to both ACW generators being switched off as part of the Electrical Smoke Checklist.

12. Switching off both ACW generators also resulted in the loss of both main hydraulic systems, requiring the use of gravity landing gear extension and emergency braking.

13. Once extended under gravity, the landing gear could not be retracted, which had particular implications in the event of a diversion.

14. Switching off of both ACW generators as part of the Electrical Smoke Checklist, results in a significant workload for the Flight Crew, especially during adverse weather conditions.

15. There is no guidance available to flight crew on the reinstating of electrical power in order to regain the use of lost electrical equipment.

16. The OEM has instigated a production change involving a change of capacitor supplier and the 'burn-in' of capacitors used in the assembly of the subject static inverters.

17. The Aircraft Manufacturer has commenced a program for replacement of the subject static inverters on the world fleet of ATR 42/72 aircraft. Currently, this program is not mandatory.

18. EASA has reviewed the occurrence rate of static inverter failure including emission of smoke, its consequences, including additional flight crew workload, and stated that the number of events is commensurate with the safety objective.

(b) Probable Cause

Failure of the C602 (1-001-0306-0136) capacitor within the number two static inverter.

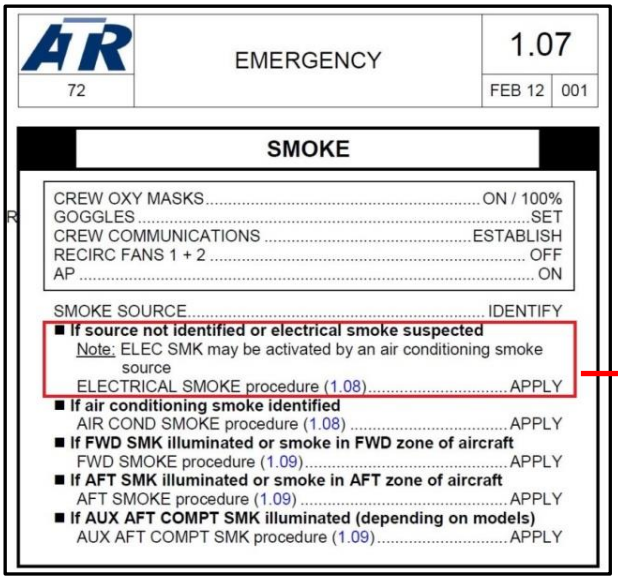
4. SAFETY RECOMMENDATIONS

No.	It is Recommended that:	Recommendation Ref.
1.	Avions de Transport Régional should consider consulting with operators of the ATR 42/72, as to the possibility of providing specific guidance to flight crew on re-instating electrical supply to unaffected equipment for essential services following use of the Electrical Smoke checklist, subsequent to a Static Inverter failure.	IRLD2018011

View Safety Recommendations for Report 2018-020

- END -

Appendix A
Checklists Associated with the Occurrence



ATR 72 | EMERGENCY | 1.07 | FEB 12 | 001

SMOKE

CREW OXY MASKS ..... ON / 100%
GOGGLES ..... SET
CREW COMMUNICATIONS ..... ESTABLISH
RECIRC FANS 1 + 2 ..... OFF
AP ..... ON

SMOKE SOURCE ..... IDENTIFY

■ **If source not identified or electrical smoke suspected**
Note: ELEC SMK may be activated by an air conditioning smoke source
ELECTRICAL SMOKE procedure (1.08) ..... APPLY

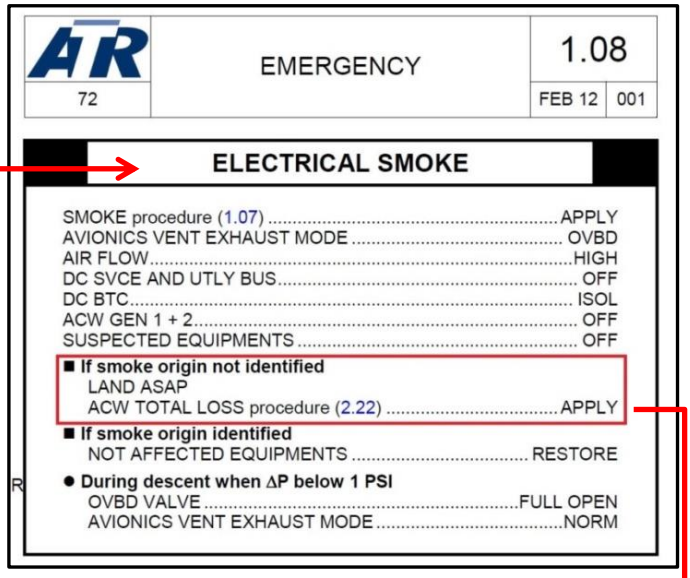
■ **If air conditioning smoke identified**
AIR COND SMOKE procedure (1.08) ..... APPLY

■ **If FWD SMK illuminated or smoke in FWD zone of aircraft**
FWD SMOKE procedure (1.09) ..... APPLY

■ **If AFT SMK illuminated or smoke in AFT zone of aircraft**
AFT SMOKE procedure (1.09) ..... APPLY

■ **If AUX AFT COMPT SMK illuminated (depending on models)**
AUX AFT COMPT SMK procedure (1.09) ..... APPLY

Figure No. 1: QRH SMOKE Checklist



ATR 72 | EMERGENCY | 1.08 | FEB 12 | 001

ELECTRICAL SMOKE

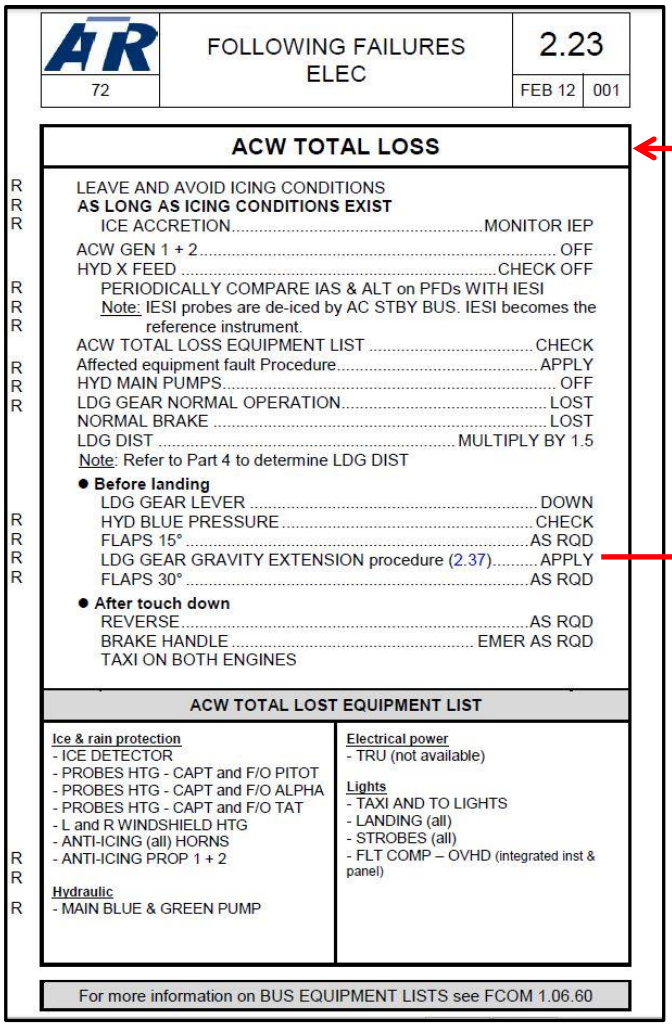
SMOKE procedure (1.07) ..... APPLY
AVIONICS VENT EXHAUST MODE ..... OVBD
AIR FLOW ..... HIGH
DC SVCE AND UTLY BUS ..... OFF
DC BTC ..... ISOL
ACW GEN 1 + 2 ..... OFF
SUSPECTED EQUIPMENTS ..... OFF

■ **If smoke origin not identified**
LAND ASAP
ACW TOTAL LOSS procedure (2.22) ..... APPLY

■ **If smoke origin identified**
NOT AFFECTED EQUIPMENTS ..... RESTORE

● **During descent when ΔP below 1 PSI**
OVBD VALVE ..... FULL OPEN
AVIONICS VENT EXHAUST MODE ..... NORM

Figure No. 2: QRH ELECRICAL SMOKE checklist



ATR 72 | FOLLOWING FAILURES ELEC | 2.23 | FEB 12 | 001

ACW TOTAL LOSS

LEAVE AND AVOID ICING CONDITIONS
AS LONG AS ICING CONDITIONS EXIST
ICE ACCRETION ..... MONITOR IEP
ACW GEN 1 + 2 ..... OFF
HYD X FEED ..... CHECK OFF
PERIODICALLY COMPARE IAS & ALT on PFDs WITH IESI
Note: IESI probes are de-iced by AC STBY BUS. IESI becomes the reference instrument.
ACW TOTAL LOSS EQUIPMENT LIST ..... CHECK
Affected equipment fault Procedure ..... APPLY
HYD MAIN PUMPS ..... OFF
LDG GEAR NORMAL OPERATION ..... LOST
NORMAL BRAKE ..... LOST
LDG DIST ..... MULTIPLY BY 1.5
Note: Refer to Part 4 to determine LDG DIST

● **Before landing**
LDG GEAR LEVER ..... DOWN
HYD BLUE PRESSURE ..... CHECK
FLAPS 15° ..... AS RQD
LDG GEAR GRAVITY EXTENSION procedure (2.37) ..... APPLY
FLAPS 30° ..... AS RQD

● **After touch down**
REVERSE ..... AS RQD
BRAKE HANDLE ..... EMER AS RQD
TAXI ON BOTH ENGINES

ACW TOTAL LOST EQUIPMENT LIST

Ice & rain protection
- ICE DETECTOR
- PROBES HTG - CAPT and F/O PITOT
- PROBES HTG - CAPT and F/O ALPHA
- PROBES HTG - CAPT and F/O TAT
- L and R WINDSHIELD HTG
- ANTI-ICING (all) HORNS
- ANTI-ICING PROP 1 + 2

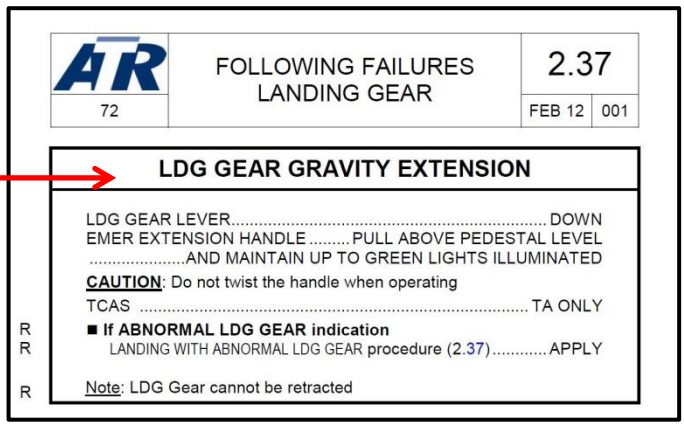
Hydraulic
- MAIN BLUE & GREEN PUMP

Electrical power
- TRU (not available)

Lights
- TAXI AND TO LIGHTS
- LANDING (all)
- STROBES (all)
- FLT COMP – OVHD (integrated inst & panel)

For more information on BUS EQUIPMENT LISTS see FCOM 1.06.60

Figure No. 3: QRH ACW Total Loss checklist



ATR 72 | FOLLOWING FAILURES LANDING GEAR | 2.37 | FEB 12 | 001

LDG GEAR GRAVITY EXTENSION

LDG GEAR LEVER ..... DOWN
EMER EXTENSION HANDLE ..... PULL ABOVE PEDESTAL LEVEL
..... AND MAINTAIN UP TO GREEN LIGHTS ILLUMINATED
CAUTION: Do not twist the handle when operating
TCAS ..... TA ONLY

■ **If ABNORMAL LDG GEAR indication**
LANDING WITH ABNORMAL LDG GEAR procedure (2.37) ..... APPLY

Note: LDG Gear cannot be retracted

Figure No. 4: QRH LDG GEAR GRAVITY EXTENSION checklist

Note: A red box has been added by the Investigation to **Figures 1 and 2** to highlight pertinent sections of the text.

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

Produced by the Air Accident Investigation Unit

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