الهيئة العامة للطيران المدني
GENERAL CIVIL AVIATION AUTHORITY

United Arab Emirates

Air Accident Investigation Sector

Incident

- Summary Report -

AAIS Case Nº: AIFN/0001/2014

Oxygen System Fire

Operator: Etihad Airways
Make and Model: Airbus A319
Nationality Registration: A6-EID
Place of Occurrence: Abu Dhabi International Airport
State of Occurrence: The United Arab Emirates
Date of Occurrence: 18 January 2014

Investigation Objective

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

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

The use of this Report for any purpose other than that of preventing future accidents may induce to erroneous interpretations and conclusions.

Investigation Process

The occurrence, involving an Airbus A319 Aircraft, registration A6-EID, was notified to the Air Accident Investigation Sector (AAIS) of the United Arab Emirates by phone call to the Duty Investigator (DI) Hotline Number +971 50 641 4667.

The Aircraft manufacturer was notified of the event and also assisted with the Investigation and commented on this Incident Summary Report.

After the Initial/On-Site Investigation phase, the occurrence was classified as 'Incident'.

This Summary Report is adapted from the Final Report format depicted in *Annex 13* in order to suit the purpose of this short investigation. This Summary Report is treated similar to the Final Report *Standard and Recommended Practices* set forth in *Annex 13*.

Notes:

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

- (Aircraft)- the aircraft involved in this incident
- (Operator)- Etihad Airways
- (Investigation)- the investigation into this incident
- (Incident)- the incident that is the subject of this Summary Report.
- (Report)- this investigation Summary Report.

[2] Unless otherwise mentioned, all times in this Report are given in 24-hour clock in

Universal Time Coordinated (UTC), (UAE Local Time minus 4 hours).

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

Factual Information

History of the Event

On 18 January 2014, at approximately 1642 UTC, an Etihad Airways Airbus A319, registration mark A6-EID, operating flight number ETD062, arrived at Abu Dhabi International Airport, the United Arab Emirates, coming from Minsk International Airport, Belarus.

The Aircraft was parked at Bay 402 and was received by the Operator's line maintenance nightshift team. There were no incoming defects and the Aircraft was scheduled for daily and transit-checks in addition to some maintenance actions generated by the Operator's maintenance control center.

After passenger and crew disembarkation, and during the daily-check, the maintenance engineer noticed the DOOR/OXY page in the electronic centralized aircraft monitoring (ECAM) indicating flight crew oxygen System pressure at 1450 psi, whereas as per the daily-check requirement, the minimum pressure for dispatching the Aircraft was 1500 psi. Accordingly, a decision was taken to service the oxygen system prior to dispatch.

While the maintenance engineer was performing in-situ oxygen servicing with the

assistance of a technician, the oxygen pressure regulator transmitter exploded, causing rapid bottle depressurization, a loud bang, and flash of light. The rapid discharge of oxygen caused a minor facial irritation to the maintenance engineer. The technician, who was operating the oxygen trolley, immediately shut off the supply of oxygen and attended to the maintenance engineer.

The Operator's maintenance team leader at Bay 403 heard the explosion and immediately proceeded to the Aircraft. The rapidly discharging crew oxygen bottle was shut off by the maintenance engineer, followed by de-powering of the Aircraft. Emergency services were called and the maintenance engineer was first transported to the airport medical center and then to the hospital for further examination. The engineer was later discharged with minor skin and eye irritation.

Aircraft Information

The Aircraft was relocated from Bay 402 to the maintenance facility and quarantined for further investigation.

All oxygen components related to the Incident were removed and securely stored at the Operator's stores. The oxygen trolley was also placed under quarantine.

The Aircraft was returned to service on the 21 January 2014, at 0848 UTC after addressing all maintenance concerns, including the installation of a new flight crew oxygen bottle, plumbing, and insulation blankets, followed by satisfactory leak checks and functional checks. The avionics bay and surrounding structure (internally and externally) were thoroughly inspected for signs of foreign debris and heat damage.

Figure 1. Oxygen bottle fire damage

For precautionary reasons, the emergency transformer rectifier unit (ETRU) was replaced due to burn marks on the unit's case. The oxygen trolley was checked and re-calibrated and returned to the Operator's line maintenance for use.

Tests and Research

The oxygen cylinder (including the valve body), the pressure regulating transmitter (PRT), and its associated plumbing were dispatched to the manufacturer (Zodiac Aerotechnics), France, for a thorough component investigation and report.

Further investigation by the WHA[1] shows that the fire had probably been initiated at the filling valve of the PRT, the heat flow coming from the PRT to the cylinder valve. Then a reverse flow from the cylinder to the PRT was maintained by the oxygen flow during emptying of the cylinder.

The heat flow travelled from the cylinder to the PRT, and that the discontinuity occurred at the threaded connection between the union and the PRT. The Investigation could not determine if a fracture had occurred previously at this threaded connection.

The investigation initial assessment into this Incident revealed an internal component failure of the PRT.

Maintenance procedures and precautions used during the servicing of the oxygen system were found to be in accordance to the appropriate *aircraft maintenance manual* (*AMM*). Airbus was also approached to provide input and they had no recommendations for an inspection plan.

[1] WHA International, Inc., is specialized in fire and explosion investigations, oxygen and hydrogen testing and safety training, accident reconstruction and forensic engineering.

Additional Information

The ground support equipment (GSE) filling equipment was a Newbow Aerospace 4-bottle easy load oxygen supply cart/trolley.

Figure 3. Newbow Aerospace 4- bottle easy load oxygen supply cart

Figure 2. Oxygen bottle rack fire damage

The charging panel consists of an inlet pressure gauge, a manually-loaded self-venting regulator, an outlet pressure gauge, and a quick-acting toggle (QA) charge lever outlet valve.

The following are the instructions for using the GSE filling equipment, as described on the charging panel:

"1. Turn regulator hand-wheel completely off (anticlockwise) making sure outlet pressure gauge reads zero

2. Connect hose to equipment to be charged

3. Open isolation valve on equipment to be charged

4. Set QA valve to "CHARGE" position (see hereunder note)

5. Turn regulator hand-wheel (clockwise) until desired pressure is reached

6. Once equipment is charged, close isolation valve (on equipment)

7. Select STOP position on Q.A. valve, this will vent upstream line

8. Turn regulator hand-wheel completely off (anticlockwise)

9. Check all outlet pressure gauges read zero before disconnecting hose.

Note 1: In case of the QA valve is set to CHARGE position after regulator pressure increase, rapid pressurization (and thus adiabatic compression[2]) in the filling line is possible.

Note 2: Referring to instruction 5, pressure should be increased slowly to avoid adiabatic compression in the filling line."

Analysis

Computed Tomography (CT) Scan[3]

The CT scan of the cylinder valve showed that the stem was partially melted and the outlet filter had disappeared.

[2] In thermodynamics, when an adiabatic compression occurs quickly, heat generated does not have a time to escape.

[3] Computed tomography (CT) is an imaging procedure that uses special x-ray equipment to create detailed pictures, or scans, of areas inside an object.

Pressure Regulator Transmitter (RCF6708)

The parts inside the filling valves had disappeared (O-ring, poppet, spring and screws). The filter and its fixing parts had also disappeared.

The damage on both RCF6708 and cylinder valve

It was observed that the damage was mainly localized on the RCF6708 at the CGA540 coupling level (figures 4 and 5). The cylinder valve was also damaged The stem and the outlet pipe were partially melted.

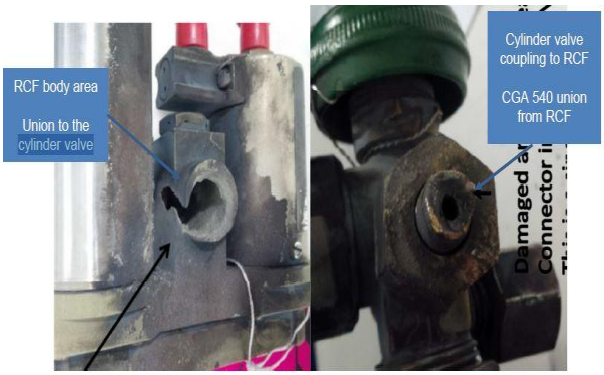

Figure 4. Defective parts

Figure 5. External views of RCF6708 assembly

The event

The following are the main points of the event:

- The position of the QA valve (quick-acting toggle) position at the time of filling was not determined. There was no mention of a QA valve position change from STOP to CHARGE in the sequencing of the event, nor in the O2 Service Trolley Procedure. That there was no pressure rise at the aircraft filling gage seems to indicate that the QA valve was in the STOP position.
- No pressure rise at the filling gage indicates that the flow was blocked upstream the RCF6708 during filling.
- The 'hissing noise' was not heard by the maintenance engineer during filling.

Two scenarios of the event were considered in the Investigation.

1. Mechanical Impact ignition of the PRT fill valve seat O-ring (*or a non-metal contaminant in the vicinity) from chatter of the poppet during filling.
2. Adiabatic compression at the PRT fill valve seat, assuming improper operation of the GSE filling/servicing trolley.

No flow entering in the RCF6708 at the time of the event, as well as no "hissing noise" heard during filling, eliminates the possibility of first scenario.

The second scenario is thus the probable scenario. From design, the filling trolley does not prevent rapid compression, depending on the QA valve opening time. Also, the QA valve position at the time of filling was not clearly established. The fact that the maintenance engineer did not notice any pressure rise during filling can be explained by the QA valve being at the STOP position during filling, and then being placed in the CHARGE position.

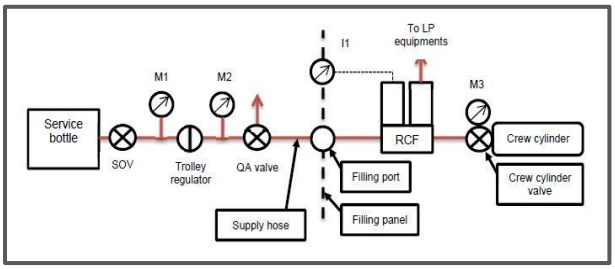

Figure 6. Installation schematic

The Investigation believes that the sequencing of the event, most probably, was as follows:

1. The Service bottle shut-off valve (SOV) was in the closed position. M1=0 psig.
2. The trolley regulator was in the closed position. M2 =0 psig.
3. The crew cylinder valve turned open. M3 =1,450 psig, I1=1,500 psig. Readings were slightly different due to instruments and reading error.
4. QA valve was closed. Purged the supply hose.
5. Supply hose was connected to the filling panel. There was no effect.
6. Service bottle SOV was opened. M1=2,000 psig.
7. The trolley pressure was increased to 1,500 psig. M2=1,500 psig. No filling as QA valve was still closed.
8. Trolley pressure was increased to 1600 psig. No pressure increased at I1 as QA valve was still closed.
9. QA valve opening. This resulted in:
    - Adiabatic compression 0 to 1,600 psig in the filling line
    - Temperature increased to about 800°C at the PRT filling port
    - Fire was initiated at the PRT filling port O-ring level
    - Fire was propagated to the adjacent parts, including the PRT body
    - Fire flow was directed to the cylinder valve
    - The cylinder valve filter was melted/burned
    - Combustion of the PRT body was sufficient to drill it on the thinner area
    - Weakening of the PRT body caused the separation of the PRT and the cylinder valve
    - External fire caused damages to the Aircraft
    - Cylinder emptying was stopped after closing of the cylinder valve.

Once the initial ignition occurred near the PRT fill valve seat, a critical kindling chain was present based on the materials of construction and design of the PRT fill valve and the PRT body that propagated the fire resulting in the observed burn-out of the component. The kindling chain involved the PRT fill valve O-ring (whether or not it was the first material ignited), the fill valve poppet (thin stainless steel), the fill valve spring (thin stainless steel), the fill valve orifice (stainless steel), and then the PRT body (aluminum).

The Investigation believes that the adiabatic compression, most probably, occurred as a result of improper operation of the GSE filling trolley, which was not in accordance with the sequential order of the user instructions. The trolley pressure regulator was used (from 0 to 1500 pisg, then to 1600 psig) before the QA valve was opened, and as mentioned in the user instructions as a note, that rapid pressurization (adiabatic compression) in the filling line is possible for this sequential order, which was the case in this event.

Conclusions

Cause

The Air Accident Investigation Sector determines that the cause of the oxygen system fire was the failure of the oxygen PRT due to adiabatic compression caused by the opening of the quick-acting toggle (QA) valve after pressurization of the servicing trolley regulator, which was not in accordance with sequential order as mentioned in the user's instructions.

Safety Recommendations

Safety Actions Taken

The Operator issued a *Quality Notice* about new dedicated oxygen servicing tool kits entering to service. New maintenance instructions were promulgated to replace crew oxygen bottles as their primary option.

An oxygen training program was approved for maintenance personnel for oxygen servicing and oxygen system maintenance.

The Operator's *maintenance organization exposition (MOE)* was revised to reflect the introduction of the training program. An approved syllabus for oxygen system training has been established.

Summary Report
Safety Recommendations

There are no safety recommendations issued after this Investigation.

This Report is issued by:

The Air Accident Investigation Sector
General Civil Aviation Authority
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